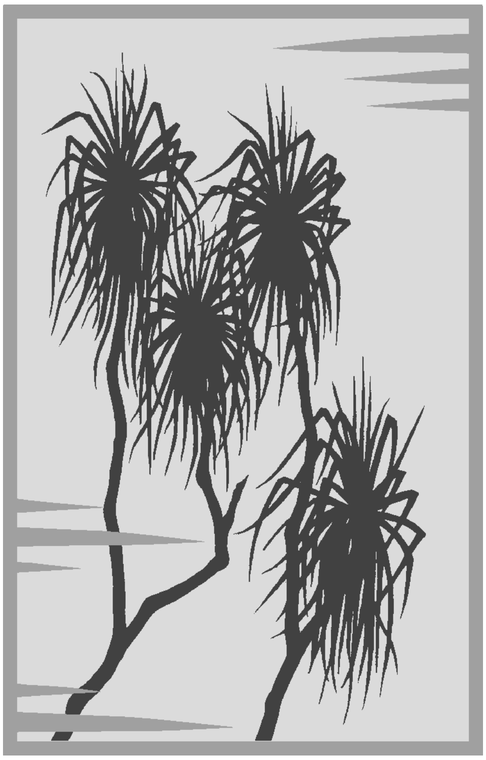
Australian Government

Department of the Environment and Heritage

SUPERVISING SCIENTIST



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2005-2006

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Australian Government

Department of the Environment and Heritage

Supervising Scientist

Hon Greg Hunt MP
Parliamentary Secretary to the Minister for the Environment and Heritage
Parliament House
CANBERRA ACT 2600

16 October 2006

Dear Parliamentary Secretary

In accordance with subsection 36(1) of the *Environment Protection (Alligator Rivers Region) Act 1978* (the Act), I submit to you the twenty-eighth Annual Report of the Supervising Scientist on the operation of the Act during the period of 1 July 2005 to 30 June 2006.

Yours sincerely

Alan Hughes
Supervising Scientist

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Involving local Aboriginal people is an important aspect of the work of the Supervising Scientist. Photos (top): consultation with Mirarr traditional owners at Mula in Kakadu National Park; (middle & bottom) local Aboriginal people and members of the Junior Ranger Programme help SSD staff sort live macroinvertebrates at Georgetown (middle) and Anbangbang (bottom) Billabongs in Kakadu National Park.

CONTENTS

Tables

Figures

FOREWORD

Subsection 36(1) of the *Environment Protection (Alligator Rivers Region) Act 1978* requires the Supervising Scientist to provide an Annual Report to Parliament on the operation of the Act and on certain related matters. The Act requires the following information to be reported:

- all directions given to the Supervising Scientist by the Minister for the Environment and Heritage;
- information on the collection and assessment of scientific data relating to the environmental effects of mining in the Alligator Rivers Region;
- standards, practices and procedures in relation to mining operations adopted or changed during the year, and the environmental effects of those changes;
- measures taken to protect the environment, or restore it from the effects of mining in the region;
- requirements under prescribed instruments that were enacted, made, adopted or issued and that relate to mining operations in the Alligator Rivers Region and the environment;
- implementation of the above requirements; and
- a statement of the cost of operations of the Supervising Scientist.

SUPERVISING SCIENTIST'S OVERVIEW

I would like to start this overview by paying tribute to my predecessor, Dr Arthur Johnston, who retired in October 2005. Dr Johnston had been Supervising Scientist since June 1999, and had been Director of the Environmental Research Institute of the Supervising Scientist (***eriss***) between 1989 and 1999. He started working at ***eriss*** as Senior Research Scientist in 1982. Dr Johnston's contribution to environmental protection in the Alligator Rivers Region in these various roles cannot be overstated and his extensive knowledge of the work undertaken in the area is to be envied.

Dr Johnston's expertise in health physics and environmental protection continues to be recognised and utilised. Since retiring from the Division he has been appointed to the Prime Minister's Uranium Mining, Processing and Nuclear Energy Review (UMPNER) Taskforce, and he remains a member of the Australian Radiation Health and Safety Advisory Council and of the Environment Committee of the International Commission on Radiological Protection (ICRP).

The Supervising Scientist plays an important role in the protection of the environment of the Alligator Rivers Region through the supervision, monitoring and audit of uranium mines in the Region, as well as research into the possible impact of uranium mining on the environment of the Region.

Ranger is currently the only operational uranium mine in the Region, and is owned and operated by Energy Resources of Australia Ltd (ERA). Production commenced at Ranger in August 1981, and current plans will see mining in Pit 3 cease in 2008 with milling of ore expected to continue through until 2014.

As the time of mine closure and rehabilitation draws closer, the work of the Supervising Scientist has included a growing focus on these themes. Staff have been engaged with a broad range of stakeholders in discussions and research activities associated with rehabilitation and closure.

Apart from rehabilitation and mine closure planning, staff of the Division remained active in ongoing supervision, inspection and audit, radiological, biological and chemical monitoring, and research activities in relation to both present and past uranium mining activities in the Region.

The Jabiluka project remains on long-term care and maintenance, and the next stage of the project is a matter for discussion between ERA and the area's traditional Aboriginal owners.

The Nabarlek mine in western Arnhem Land was decommissioned in 1995 and the adequacy of the rehabilitation of this site remains under ongoing assessment. Tropical Cyclone Monica passed very close to the Nabarlek site on the evening of 24 April 2006 and assessments of the site since then have indicated extensive damage to vegetation as well as to residual mine infrastructure.

Tropical Cyclone Monica also passed close to the Ranger mine site and the Jabiru township. Jabiru experienced widespread damage to trees and infrastructure, with some minor damage inflicted on the Division's Jabiru Field Station near the mine site and a number of staff houses in the township. Thankfully, there were no injuries.

Details on research outcomes of the Environmental Research Institute of the Supervising Scientist (***eriss***) are published in journal and conference papers and in the Supervising Scientist and Internal Report series. Some important programs have been highlighted in this annual report.

In particular, the water quality monitoring programme has been considerably enhanced with the installation of continuous monitoring equipment for pH, electrical conductivity and turbidity in Magela Creek upstream and downstream of Ranger mine during the past wet season. This programme will continue in parallel with the normal water quality monitoring programme for a number of seasons to provide baseline information prior to a review of monitoring programmes.

An extended report has been provided of the outcomes of a benchmark landscape environmental risk assessment of threats and pressures to the Magela floodplain. This assessment is the final part of the 'Landscape-scale analysis of impacts' programme, established in 2002 following the report of the International Science Panel into the potential impacts of uranium mining at Jabiluka and Ranger on the World Heritage values of Kakadu National Park. The objective of this work was to help to clearly differentiate the relative risks posed by mining and non-mining impacts, whilst contributing to a broader assessment of the World Heritage values of the Park.

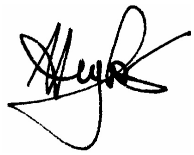
A major programme of research on characterisation of northern tropical rivers, and assessment of risk from actual and potential threats is being carried out under the framework of the Tropical Rivers Inventory and Assessment Project (TRIAP). The work is funded by Land and Water Australia and the Natural Heritage Trust and is a collaborative effort between ***eriss***, James Cook University and the University of Western Australia, with additional involvement of the University of Wageningen in the Netherlands. This programme will continue during 2006–07.

In May 2006 the Australian Government announced funding of $7.3 million over four years to undertake rehabilitation of former uranium mining sites in the South Alligator River Valley in the southern part of Kakadu National Park. The Supervising Scientist Division has provided advice and assistance to the Director of National Parks on management of these sites for a number of years, and we will continue to provide scientific and technical advice and assistance as the rehabilitation works move into the next phase.

The Alligator Rivers Region Technical Committee (ARRTC) continues to play a vital role in assessing the science used in making judgements about the protection of the environment from the impacts of uranium mining. Professor Barry Hart, who chaired ARRTC since 2001, retired from the role in September 2005. During his tenure, Professor Hart made a significant contribution to the work of ARRTC and my sincere thanks are extended to him.

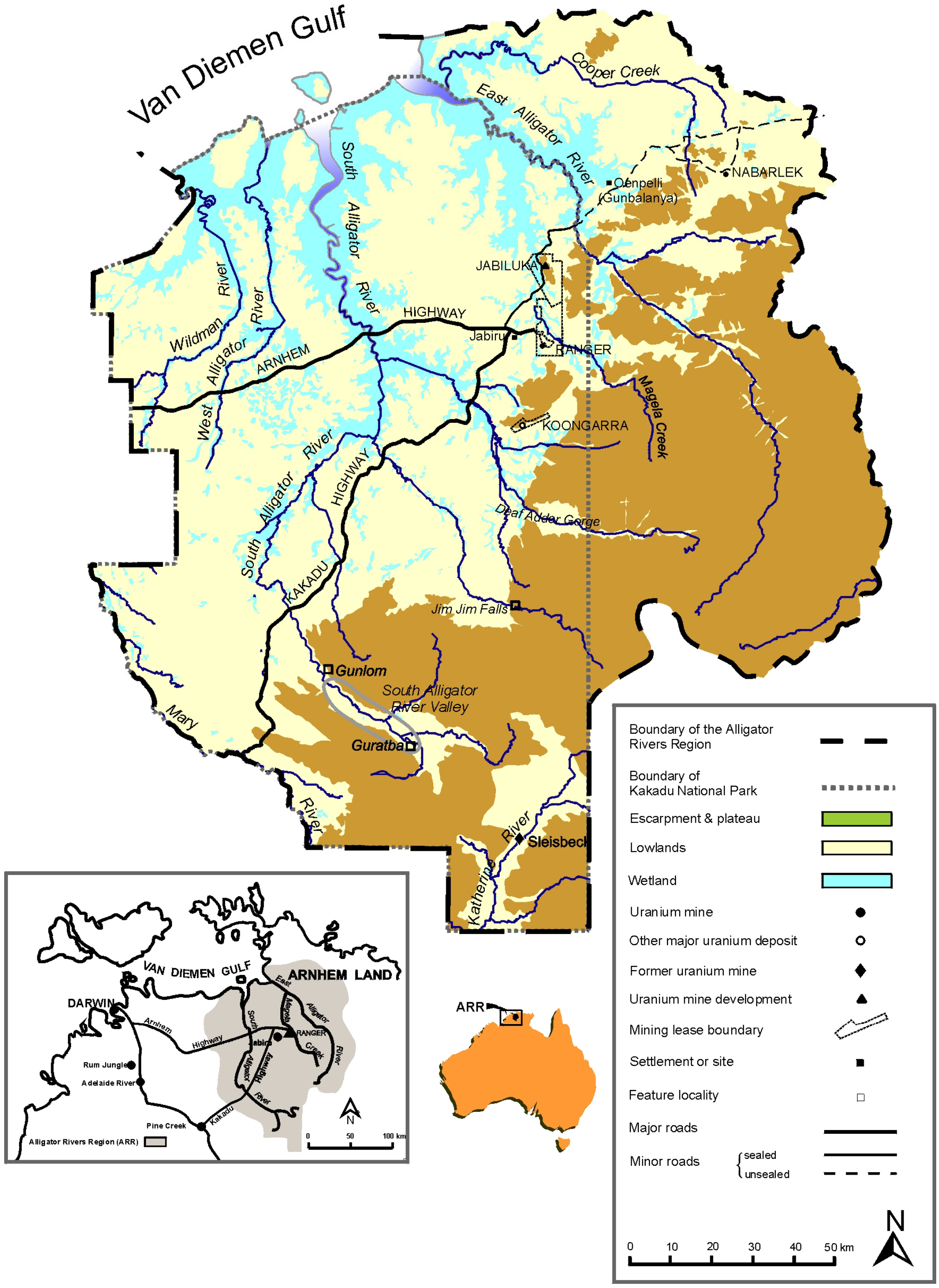
The Hon Greg Hunt MP, Parliamentary Secretary to the Minister for the Environment and Heritage, subsequently appointed Mr Ray Evans as the new chair. Mr Evans has been a member of the committee since 2001 and has an extensive knowledge of the activities of the committee and of the Alligator Rivers Region.

Finally, I would like to offer my personal thanks to all the staff of the Supervising Scientist Division for their efforts during the year. The commitment and professionalism of all the Division's staff has been a vital factor in the Division being able to fulfil its role in ensuring that the environment of the Alligator Rivers Region remains protected.

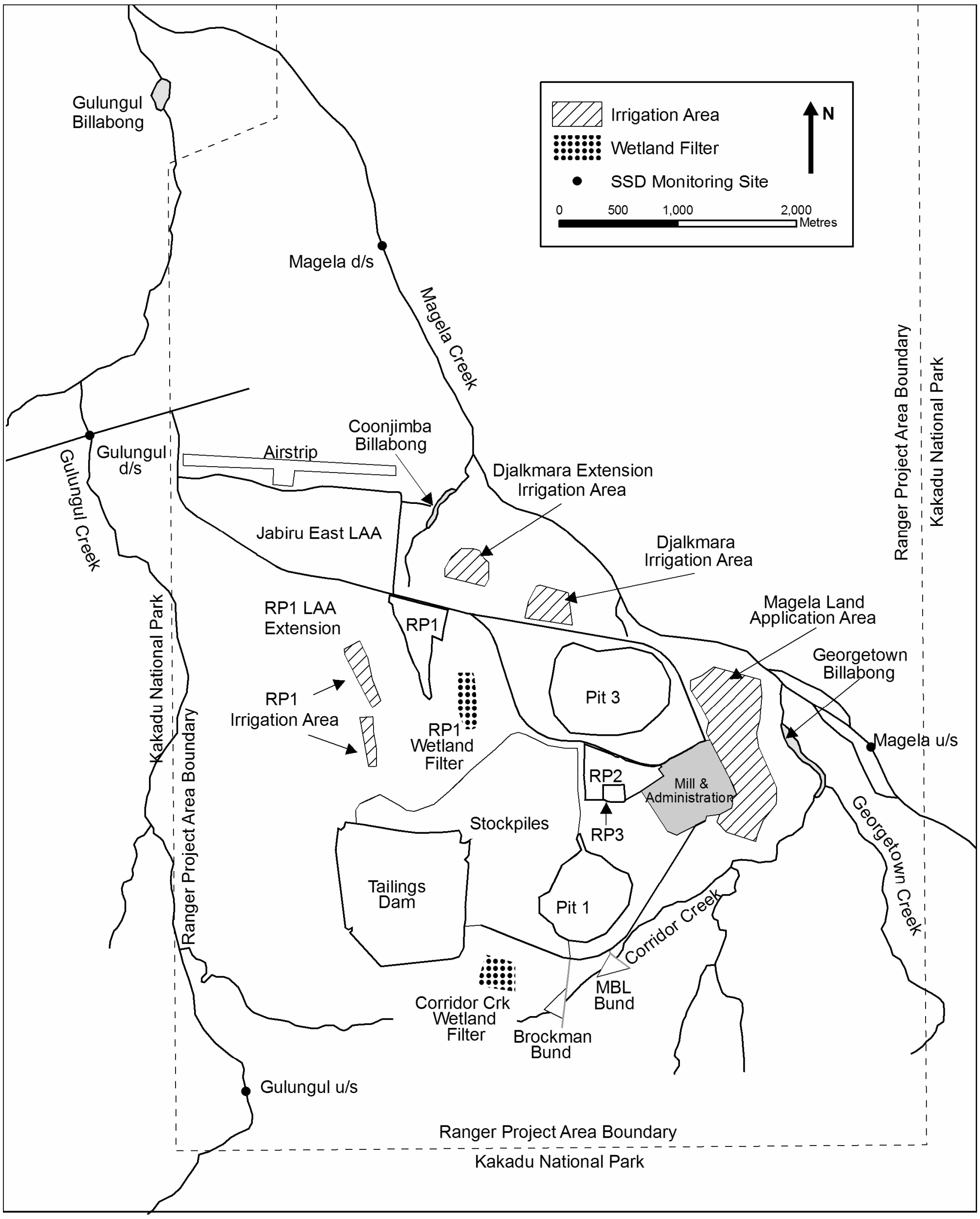


Alan Hughes

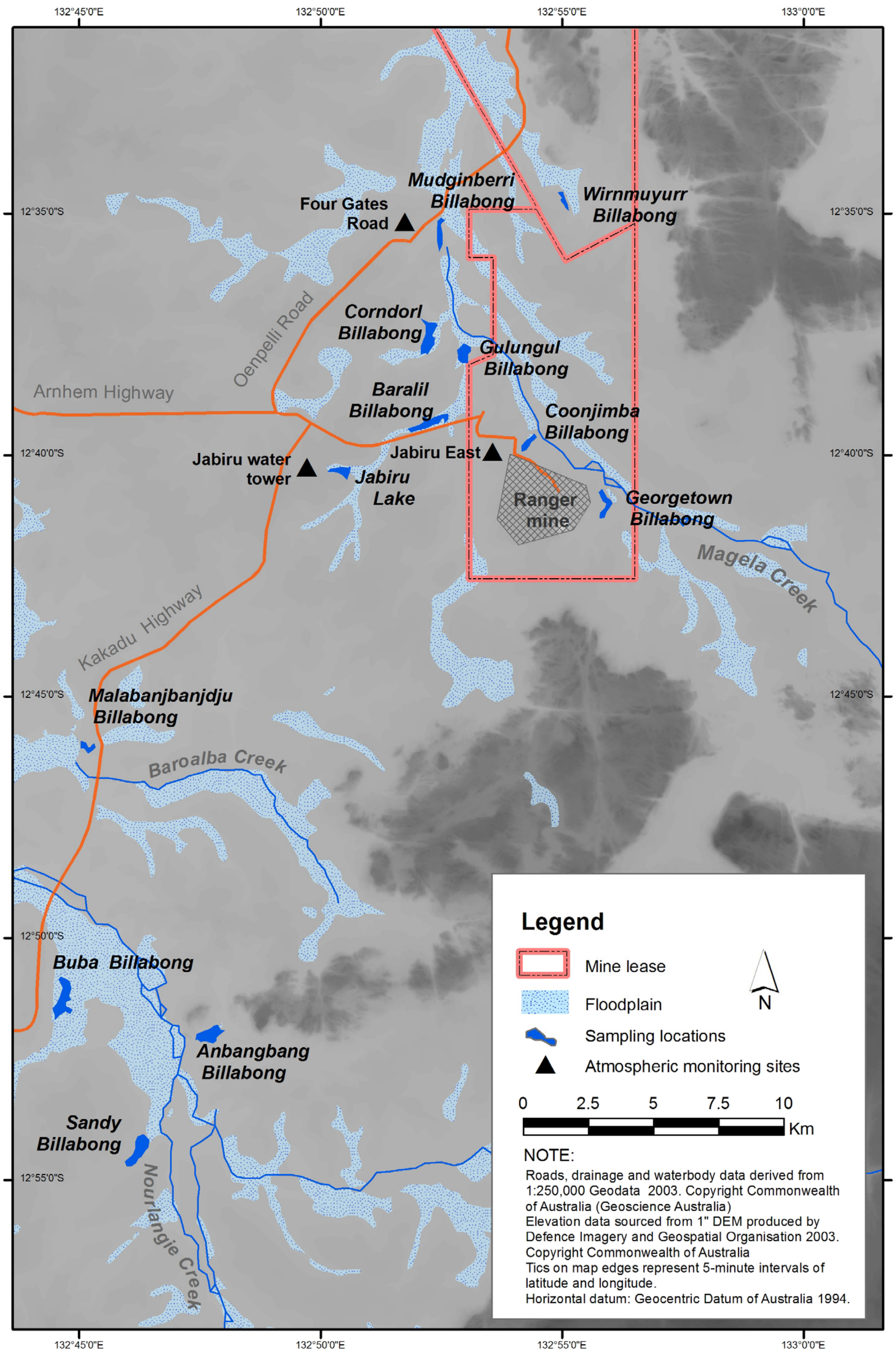
Supervising Scientist



Map 1 Alligator Rivers Region



Map 2 Ranger mine site



Map 3 Sampling locations used in SSD's research and monitoring programmes

ABBREVIATIONS & GLOSSARY

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ARR	Alligator Rivers Region
ARRAC	Alligator Rivers Region Advisory Committee
ARRTC	Alligator Rivers Region Technical Committee
DEH	Department of the Environment and Heritage
DITR	Department of Industry, Tourism and Resources
DPIFM	Department of Primary Industry, Fisheries and Mines
EMS	Environment Management System
EPARR Act	*Environment Protection (Alligator Rivers Region) Act 1978*
ERA	Energy Resources of Australia Ltd
eriss	Environmental Research Institute of the Supervising Scientist
ERs	Environmental Requirements
ESD	Ecologically Sustainable Development
EWLS	EWL Sciences Pty Ltd
G8210009	Magela Creek d/s (downstream) gauging station
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISP	Independent Science Panel
KKN	Key Knowledge Needs
MCUS	Magela Creek u/s (upstream) site
MMP	Mining Management Plan
MTC	Minesite Technical Committee
nctwr	National Centre for Tropical Wetland Research
NLC	Northern Land Council
NRETA	NT Department of Natural Resources, Environment and the Arts
oss	Office of the Supervising Scientist
PAN	Parks Australia North
RL	Reduced Level – the number after RL denotes metres above or below a chosen datum
RPI	Routine Periodic Inspection
SSD	Supervising Scientist Division
TBL	Triple Bottom Line
TRIAP	Tropical Rivers Inventory and Assessment Project
WTP	Water Treatment Plant

1 INTRODUCTION

1.1 Role and function of the Supervising Scientist

The Supervising Scientist is a statutory office under the *Environment Protection (Alligator Rivers Region) Act 1978* and the occupant of the office is the head of the Supervising Scientist Division (SSD) within the Department of the Environment and Heritage.

The Supervising Scientist Division consists of the Environmental Research Institute of the Supervising Scientist (***eriss***) and the Office of the Supervising Scientist (***oss***).

eriss conducts environmental monitoring and research into the impact of uranium mining on the environment and people of the Alligator Rivers Region of the Northern Territory. ***eriss*** also conducts research on the sustainable use and environmental protection of tropical rivers and their associated wetlands, and is a partner in the National Centre for Tropical Wetland Research (***nctwr***).

oss carries out supervision, audit and policy functions in relation to uranium mining in the Alligator Rivers Region and provides support and administrative services to the Division.

In summary, the functions of the Supervising Scientist, as specified in the EPARR Act, are to:

- develop, coordinate and manage programmes of research into the effects on the environment of uranium mining within the Alligator Rivers Region;
- develop standards, practices and procedures that will protect the environment and people from the effects of uranium mining within the Alligator Rivers Region;
- develop measures for the protection and restoration of the environment;
- coordinate and supervise the implementation of requirements made under laws applicable to environmental aspects of uranium mining in the Alligator Rivers Region;
- provide the Minister for the Environment and Heritage with scientific and technical advice on mining in the Alligator Rivers Region; and
- on request, provide the Minister for the Environment and Heritage with scientific and technical advice on environmental matters elsewhere in Australia.

1.2 Performance summary

SSD is a Division of the Department of the Environment and Heritage and, as such, is funded as part of the Environment and Heritage Portfolio Budget Statements (PBS). The Department of Environment and Heritage's own annual report reports against the PBS.

The activities of the Supervising Scientist fall within PBS Outcome 1, which is:

> The environment, especially those aspects that are matters of national environmental significance, is protected and conserved.

Outcome 1 is divided into five individual *Outputs*. The Supervising Scientist is included in Output 1.2 *Conservation of the land and inland waters* and Output 1.5 *Response to the impacts of human settlements.* Output 1.2 includes Sub-output 1.2.5 *Tropical wetlands research* and Output 1.5 includes Sub-output 1.5.3 *Supervision of uranium mines*.

The Supervising Scientist's responsibilities in relation to Sub-output 1.2.5 are included in Chapters 3 and 5 of this annual report.

Sub-output 1.5.3 encompasses a range of research, monitoring and supervising tasks. These are described in Chapters 2 and 3 and contribute towards the protection of the Alligator Rivers Region environment from the impacts of uranium mining.

Communicating the outcomes of research, monitoring and supervision activities to stakeholders and the broader scientific community is also an important part of the work of the Supervising Scientist. Communication and liaison with the Aboriginal people of the Alligator Rivers Region is of particular importance. Further information on communications activities is provided in Chapter 5.

1.3 The Alligator Rivers Region and its uranium deposits

The Alligator Rivers Region is approximately 220 km east of Darwin (see Map 1). Encompassing an area of about 28 000 km^2, it includes the catchments of the West Alligator, South Alligator and East Alligator Rivers, extending into west Arnhem Land. The World Heritage listed Kakadu National Park lies entirely within the Alligator Rivers Region.

Mineral titles over the Ranger, Jabiluka and Koongarra uranium deposits within the Alligator Rivers Region pre-dated the proclamation of Kakadu National Park. The Ranger Project Area and the Jabiluka and Koongarra leases that were in existence at the time of proclamation of the Park were excluded from the area of the Park and are not now, nor have ever been, a part of Kakadu National Park. Nabarlek is situated to the east of Kakadu National Park within Arnhem Land.

Ranger is currently the only operational uranium mine in the Region. Development work at Jabiluka ceased in 1999 and the site was placed in long-term care and maintenance in 2003–04.

The Koongarra uranium deposit is a significant uranium resource but grant of an exploration licence, which is a prerequisite to the operator seeking a mining title, is under veto by traditional Aboriginal owners under the provisions of the *Aboriginal Land Rights (Northern Territory) Act 1976*. Discussions between the traditional Aboriginal owners and the mining company recommenced in 2005.

Nabarlek was operational in the 1970s and 1980s but has now been decommissioned and rehabilitation and revegetation work is continuing.

There are also a number of former uranium mines in the South Alligator River Valley that date back to mining and milling activities in the 1950s and 1960s.

1.3.1 Nabarlek

Nabarlek is located approximately 280 km east of Darwin. Queensland Mines Ltd undertook mining at Nabarlek during the dry season of 1979, and milling of the ore continued until 1988. Some 10 857 t of uranium concentrate (U_3O_8) was produced whilst the mill was operational.

The mine was decommissioned in 1995–96 and the performance of the rehabilitation and revegetation programme continues to be monitored prior to final close-out.

1.3.2 Ranger

Energy Resources of Australia Ltd (ERA) operates the Ranger mine, which is 8 km east of the township of Jabiru. The mine lies within the 78 km^2 Ranger Project Area and is adjacent to Magela Creek, a tributary of the East Alligator River. The Ranger Project Area is surrounded by, but does not form part of, Kakadu National Park.

Ranger is an open cut mine and commercial production of uranium concentrate (U_3O_8) has been under way since 1981. Orebody No. 1 was exhausted in December 1994 and excavation of Orebody No. 3 began in May 1997.

Current ERA planning is for mining to cease in 2008 with processing of stockpiled ore to continue until 2014. Planning has commenced for the eventual decommissioning and rehabilitation of the site.

1.3.3 Jabiluka

The Jabiluka mineral lease abuts the northern boundary of the Ranger Project Area, with the Jabiluka site situated some 20 km north of the Ranger mine site. It is also owned by Energy Resources of Australia Ltd.

Unlike the Ranger and Nabarlek deposits, the Jabiluka orebody lies beneath a cover of cliff-forming sandstone. It is in the catchment of the East Alligator River, adjacent to Ngarradj (Swift Creek), which drains north to the Magela floodplain. The Commonwealth Government completed its assessment of ERA's Environmental Impact Statement, which provided for milling of Jabiluka ore at Ranger, on 22 August 1997.

Development work at Jabiluka took place in the late 1990s but ceased in September 1999 and the site was then placed in an environmental management and standby phase that lasted until 2003–04.

Following discussions between ERA, the Commonwealth and Northern Territory Governments, the Northern Land Council (NLC) and the Gundjeihmi Aboriginal Corporation (GAC – representing the area's traditional Aboriginal owners, the Mirarr people) during 2002–03, agreement was reached and Jabiluka was subsequently placed in long-term care and maintenance. This agreement includes an ERA undertaking not to engage in mining activities at Jabiluka without the consent of the Mirarr people. The agreement was endorsed by the NLC in April 2004 and was approved by the Minister for Immigration and Multicultural and Indigenous Affairs in 2004–05.

1.3.4 Koongarra

The Koongarra deposit is about 25 km south-west of Ranger, in the South Alligator River catchment. An Act (the *Koongarra Project Area Act 1981*) providing for a change of the boundaries of the project (and thus the area of excision from Kakadu National Park) was passed in 1981 but has not been proclaimed. The Koongarra deposit is owned by Koongarra Pty Ltd, a subsidiary of French company Areva. Plans to develop Koongarra were not approved by traditional Aboriginal owners in April 2000, and the proposal was then subject to a five year period under the *Aboriginal Land Rights (Northern Territory) Act 1976* during which time no further discussions could occur between traditional Aboriginal owners and Koongarra Pty Ltd.

Koongarra Pty Ltd wrote to the Northern Land Council in May 2005 seeking to recommence discussions with traditional Aboriginal owners.

1.3.5 South Alligator Valley mines

Several small uranium mining and milling operations occurred during the 1950s and 1960s in the South Alligator River Valley, in the southern part of the Alligator Rivers Region. Mining occurred at several locations in the valley, principally at El Sherana, El Sherana West, Rockhole Creek and Coronation Hill (Guratba). Milling occurred at Rockhole Creek within the South Alligator Valley as well as at nearby Moline, which lies outside the Alligator Rivers Region.

Output from these mines was relatively small. It is estimated that less than 1000 t of uranium concentrate was produced at the Rockhole Creek and Moline mills from the ore mined in the South Alligator Valley during the 1950s and 1960s.

These sites, excluding Moline, are the responsibility of the Commonwealth Director of National Parks through Parks Australia North. On 9 May 2006 the Hon Greg Hunt MP, Parliamentary Secretary to the Minister for the Environment and Heritage, announced funding of $7.3 million over four years to conduct rehabilitation activities at abandoned uranium mining sites in the valley.

The Supervising Scientist Division continues to be involved in a number of projects assisting Parks Australia North with rehabilitation.

This work is further described in Sections 2.5.1 and 2.5.2 of this Annual Report.

2 ENVIRONMENTAL ASSESSMENTS OF URANIUM MINES

2.1 Supervision process

The processes used by the Supervising Scientist to supervise uranium mining operations in the Alligator Rivers Region may be broadly categorised as participating in Northern Territory regulatory processes and audit and inspection. The outcomes of these activities are considered by the Supervising Scientist together with environmental monitoring data and other information to draw conclusions regarding the effectiveness of environmental management at uranium mining sites.

2.1.1 Minesite Technical Committees

Minesite Technical Committees (MTCs) have been established for Ranger, Jabiluka and Nabarlek. The MTC meetings provide an effective forum for stakeholders, including the Supervising Scientist, to discuss technical environmental management issues, especially in connection with the assessment of applications and reports submitted by mining companies for approval under Northern Territory legislation. Each MTC is made up of representatives from the Northern Territory Department of Primary Industry, Fisheries and Mines (DPIFM) which provides the Chair, the Office of the Supervising Scientist (***oss***), the Northern Land Council (NLC) and the relevant mining company. A representative from the Gundjeihmi Aboriginal Corporation is invited to attend each meting. Other organisations or experts may be co-opted from time to time as required to assist MTC members. The summary record of each MTC meeting held in 2005–06 was provided to the Environment Centre of the Northern Territory for information.

2.1.2 Audits and inspections

The Supervising Scientist, in consultation with the applicable MTCs, has developed and implemented a programme of inspections and environmental audits at Ranger Mine, Jabiluka Project Area and Nabarlek Mine.

The Routine Periodic Inspections (RPI) take place monthly at Ranger, being the only operating minesite in the region, and quarterly at Jabiluka, currently in long-term care and maintenance. The RPIs are intended to provide a snapshot of environmental management as well as an opportunity for the inspection team to discuss environmental management issues with staff on site. These discussions may include any unplanned events or reportable incidents and any associated follow-up actions. The inspection team is made up of representatives from ***oss***, DPIFM and the NLC.

The abandoned minesites at South Alligator Valley are also routinely inspected twice a year.

The environmental audits are conducted by a team of qualified audit staff from ***oss***, DPIFM and the NLC and are undertaken in general accordance with ISO Standard 19011:2003

(*Guidelines for quality and/or environmental management systems auditing*) and are consistent with current best practice in environmental assessments.

The annual environmental audit of Ranger and Jabiluka occurs in April or May to assess each site under end-of-wet season conditions. The final audit report is tabled at the following meeting of the Alligator Rivers Region Advisory Committee (ARRAC). A follow-up review of the audits is undertaken in November each year. The Nabarlek programme is slightly different in that an inspection is carried out early in the dry season and the annual environmental audit is conducted in November.

The audit outcomes are described later in this Annual Report.

2.1.3 Assessment of reports, plans and applications

The general Authorisations for the Ranger mine and the Jabiluka project are issued under the Northern Territory *Mining Management Act 2001* and are essentially the same as those operating under the previous *Uranium Mining (Environment Control) Act 1979.* The Act provides for alterations to the Authorisation to be issued by the Northern Territory Government. The Authorisations require that ERA seeks approval for certain activities from the Northern Territory regulatory authority, through DPIFM, who then grants approval or not after ***oss*** and the NLC have assessed the proposal and provided comment. This is the primary mechanism whereby the Supervising Scientist participates in the regulatory processes of the Northern Territory Government.

The main reports and plans assessed by the Supervising Scientist during 2005–06 included:

- Ranger Amended Plan of Rehabilitation No. 31;
- Ranger Mine Water Management System Operation Manual;
- Ranger Mine and Jabiluka Project Annual Environmental Reports;
- Ranger Mine and Jabiluka Project Wet Season Reports
- Ranger Mine Annual Tailings Dam Inspection Report;
- Ranger Mine and Jabiluka Radiation Protection Monitoring Programme Quarterly and Annual Reports;
- Jabiluka Mine Development Project Plan of Rehabilitation No. 9;
- ERA monthly environmental monitoring data and quarterly reports submitted in accordance with the Authorisations;
- Applications by the mining companies for amendments to their Authorisations;
- Ranger Mine – Draft Closure Model First Pass

2.2 Ranger

2.2.1 Developments

Mining and milling of uranium ore at Ranger continued throughout 2005–06, with further development of the orebody in Pit 3.

The Ranger mill produced 5184 t of uranium oxide (U_3O_8) during 2005–06 from 1 960 000 t of treated ore (Table 2.1). Production statistics for the milling of ore and the production of U_3O_8 at Ranger for the years 2001–2002 to 2005–06 are shown in Table 2.2.

TABLE 2.1 RANGER PRODUCTION ACTIVITY FOR 2005–2006 BY QUARTER

	1/07/2005 to 30/09/2005	1/10/2005 to 31/12/2005	1/01/2006 to 31/03/2006	1/04/2006 to 30/06/2006	Total
Production (drummed tonnes of U_3O_8)	1 590	1 606	1 392	596	5 184
Ore treated ('000 tonnes)	567	508	555	330	1 960

TABLE 2.2 RANGER PRODUCTION ACTIVITY FOR 2001–2002 TO 2005–2006

	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006
Production (drummed tonnes of U_3O_8)	3 815	5 312	4 666	5 544	5 184
Ore treated ('000 tonnes)	1 429	2 153	1 880	2 231	1 960

On-site activities

Exploration

ERA is continuing to conduct exploration drilling near the eastern edge of Pit 3, and in other areas within the Ranger Project Area following interpretation of the results of airborne geophysical surveys conducted during 2005.

Water Treatment Plant

Construction of a Water Treatment Plant (WTP) began in April 2005 (Figure 2.1) and was completed in November 2005. The Water Treatment Plant was identified as the preferred treatment option during ERA's investigations into reducing the water inventory, which has increased over the last few years. It is designed to treat both process and pond water prior to their release from site. Commissioning of pond water treatment was undertaken in December 2005 and 758.83 ML of pond water permeate has been released to Corridor Creek Wetland Filter up to the end of this reporting period. Commissioning of the process water circuit had not yet commenced at the time of writing and therefore no process water has been released during this reporting period. The commissioning of the WTP has been significantly behind schedule resulting in the pond and process water inventory not being reduced as much as planned. Site water management is discussed in more detail in Section 2.2.2.

Figure 2.1 Water Treatment Plant

Seepage barrier in Pit 1

The construction of a seepage limiting barrier in Pit 1 is now complete. ERA continues to monitor groundwater around the seepage barrier and within adjacent aquifers. This is a statutory requirement and reports are provided to stakeholders for comment and are discussed during RPIs and MTC meetings.

ERA is currently authorised to store tailings in Pit 1 to RL12 as an interim operational strategy. If the interim strategy is not proven to meet the requirements of the MTC for final containment, the Supervising Scientist has advised that tailings should be removed from Pit 1 to a scientifically justifiable level approved by the Supervising Authorities. It is expected that tailings will reach RL12 in Pit 1 during 2008. Tailings and waste management are discussed in more detail in Section 2.2.2.

Tailings Dam Lift

The approvals process for a lift of the walls of the Ranger Tailings Dam from RL43.5 to RL51.0 began in June 2006, with work commencing in July 2006.

2.2.2 On-site environmental management

Water management

Water management continues to be a critical component of environmental protection as well as being of importance to the smooth operations of the mine. During the 2005–06 wet season a number of operational issues, and 'wetter than usual' seasonal conditions (Figure 2.2) have resulted in the pond and process water inventory being significantly greater than forecast.

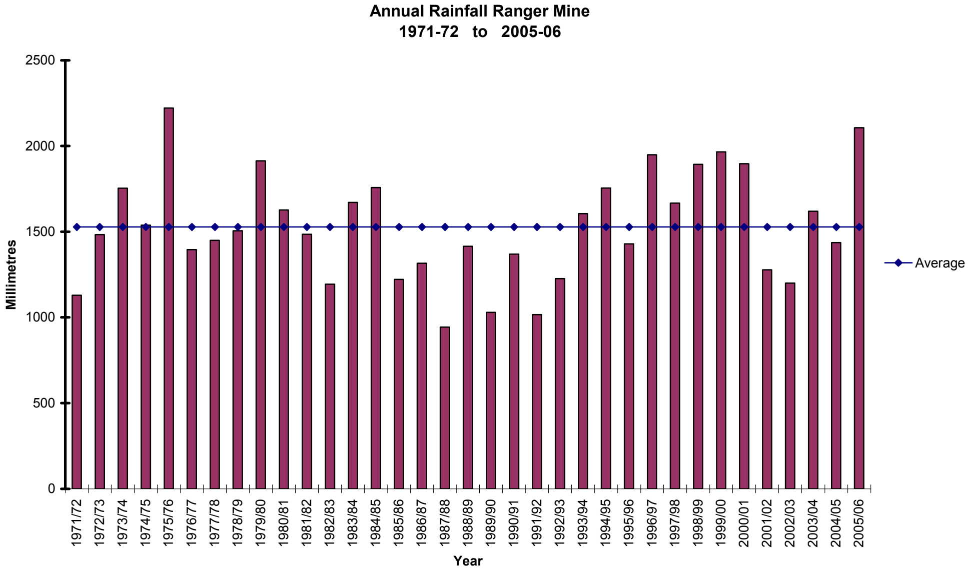


Figure 2.2 Annual rainfall Ranger mine 1971–72 to 2005–06

The major factors identified as contributing to the excess inventory include:

- the expansion of Pit 3 in 2004, resulting in larger catchment for rainfall and surface runoff,
- higher than expected seepage into Pit 3 which is thought to have expressed through the upper reaches of the North Wall in line with where Djalkmara Billabong used to be located,
- a delay in the commissioning of the Water Treatment Plant, and subsequent operational issues resulting in reduced treatment volumes during the second half of the wet season,
- a 'wetter than usual' wet season – approximating to a 1 in 33 year event, and
- the passing of Tropical Cyclone Monica over Jabiru in the early hours of 25 April 2006 resulting an intense rainfall event (≈ 100 mm in less than six hours) falling across the catchment late in the wet season.

Subsequently ERA has proposed a number of additional water management strategies in an effort to reduce the inventory prior to the 2006–07 wet season.

Under normal circumstances ERA disposes of excess water by:

- direct land application or land application following polishing through wetland filters,
- dust suppression on haul roads,
- passive evaporation from ponds, and
- utilisation within the process plant.

In order to increase the rate of disposal, ERA proposed a suite of management strategies including:

- ponding of Retention Pond 2 water on the Southern 2s stockpile surface to enhance evaporation of Retention Pond 2 water,
- an increased capacity of water carts for use in dust suppression,
- an increase in Retention Pond 2 Maximum Operating Level (MOL), and
- new Land Application Areas for irrigation of polished and unpolished pond water.

Process water system

Under the Commonwealth Environmental Requirements, water that is in direct contact with uranium ore during processing (process water) must be maintained within a closed system. It may only be released by evaporation or after treatment in a manner and to a quality approved by the Supervising Scientist. There were no releases of process water from the circuit during the reporting period.

Pond water system

The pond water system contains water that has been in contact with stockpiled mineralised material and operational areas of the site other than those contained within the process water system. This also includes water from Pit 3. The water is managed in accordance with the Water Management Systems Operation Manual. The manual describes a system whereby water is managed according to source and quality. The pond water system consists of Retention Pond 2, Retention Pond 3 and Pit 3. Water from Retention Pond 2 or Pit 3 may not be released without prior treatment through wetland filtration and/or irrigation. In recent years, management of the pond water system has changed from a proscribed regime based on catchment type to one in which water is managed according to water quality. As mentioned previously the pond water inventory is higher this year due to a number of factors and at the end of the reporting period was 2854 ML.

Methods of disposal of pond water

Ponding of Retention Pond 2 water on the Southern 2s stockpiles

Temporary pond water storage bunds were specially constructed on the Southern 2s stockpile to take advantage of enhanced evaporation and infiltration over the duration of the 2006 dry season (Figure 2.3).

The design of the system comprises bunds constructed from low grade material. These bunds are approximately 1 m in height and 5 m in width and extend the breadth (E–W) of the stockpile perpendicular to the slope. The bunds are spaced at approximately 1 m contour intervals and form a series of levees creating a network of terraced ponds. The geotechnical integrity of the stockpile is maintained by ensuring that the boundaries are at least 40 m from the edge in any direction.

Pond water is pumped directly from Retention Pond 2 and enters the stockpile upgradient of the most northerly bund. It then pools and cascades downslope over rock-lined spillways. The maximum depth of water can be 1 m (immediately behind the bund) and therefore the average water depth can be up to 0.5 m. Pumping stops when pond water is observed to first enter the lowest ponding area to avoid overtopping.

At the end of the dry season, and before the first 100 mm of rainfall of the wet season, the surface of the stockpiles will be reinstated to shed surface runoff via the drop-down structure at the southern end.

Figure 2.3 Ponding on 2s stockpile

Passive release water

Rainfall runoff water discharges from the Ranger site during the wet season via Gulungul Creek, Corridor Creek and Coonjimba Creek with minor overland flow direct to Magela Creek. Retention Pond 1 (RP1) and the Corridor Creek wetlands act as sediment traps prior to outflow from the site. The Corridor Creek wetland filter receives runoff from specially prepared sheeted areas of low grade and waste rock stockpiles to minimise infiltration and excess water contribution to the Pond Water system. RP1 also receives some sheeted runoff from stockpiles and overflows via a constructed weir into Coonjimba Creek every wet season. Discharge over the RP1 weir occurred between 18 January 2006 and 29 May 2006.

Increase in RP2 Maximum Operating Levels

The dry season and wet season Maximum Operating Levels for Retention Pond 2 have been increased from RL19.25 m to RL19.80 m, and from RL18.75 m to RL19.00 m respectively to allow for additional storage capacity. In order to apply the new levels, ERA intends to construct a spillway on the northern wall of Retention Pond 2 which will provide suitable relief capacity for storm events so that overtopping of the dam does not occur and the integrity of the dam wall is maintained. The construction of the spillway will take approximately one month and will require water levels within Retention Pond 2 to be lower than the construction site. ERA determined that it was not practical to do this work in the short term as it would require the removal of water from Retention Pond 2 into Pit 3 impacting on the mining activities within Pit 3. Therefore as an interim measure, to take advantage of the additional storage immediately, a contingency is in place that makes use of an existing channel entering Retention Pond 2 from behind the workshop at the eastern end of Retention Pond 2. In the event of any unseasonal rain raising the water level within the pond to unacceptable levels above the Maximum Operating Level, ERA will cut a temporary spillway from this channel to Djalkmara sump through the old access road bund. Water would then flow through this temporary spillway to the Djalkmara sump and then into Pit 3, providing sufficient relief capacity to ensure the integrity of Retention Pond 2 is maintained.

Commissioning of new land application areas for application of pond water

ERA has been granted approval for the commissioning and operation of two new Land Application Areas to dispose of pond water during the 2006 dry season only. The larger of the two areas is situated on the former Jabiru East township and occupies approximately 52 ha (Jabiru East Land Application Area). The second site is an extension to the existing RP1LAA and is 24 ha (RP1LAAext). Both areas will be irrigated with unpolished Retention Pond 2 water under the same arrangements as the current Magela Land Application Area.

Stockpile sheeting

During the 2006 dry season the bunding to divert the first 200 mm of runoff from the Corridor Creek wetland filter into the pond water system was reinstated due to the use of the stockpiles in disposing of Retention Pond 2 water (as described above).

Wetland filters and land application areas

Two wetland filter systems operated during 2005–06. The Corridor Creek system and the Retention Pond 1 constructed wetland filter in the Retention Pond 1 catchment.

The Retention Pond 1 constructed wetland filter (RP1CWF) operated successfully throughout the 2006 dry season commencing on 23 May 2006 providing polished water for land application on the Retention Pond 1 and Djalkmara Land Application Areas. In addition RP1CWF supplied water for the suppression of dust on the temporary road constructed to haul laterite gravel material to the tailings dam.

Treated pond water from the Water Treatment Plant reports to the Corridor Creek Wetland Filter.

Land application commenced on 20 June 2005 for all application areas apart from the Magela Land Application Area which commenced the day after cease to flow was declared for Magela Creek. Land application continued until 17 November 2005. Both Djalkmara irrigation areas and the Retention Pond 1 irrigation area operated in rotating shifts of 8 hours over a 24-hour period. Supply to these areas is regulated by pumping from Cell 9 of the Retention Pond 1 wetland filter. Retention Pond 2 is irrigated directly on the Magela Land Application Area.

Tailings and waste management

Tailings

Since August 1996, no process residue from the milling of ore has been deposited into the tailings dam with Pit 1 now the sole receptor. Over this time a total of 20 million tonnes of tailings have been deposited in Pit 1, which apart from 1.8 million tonnes of tailings dredged from the tailings dam, is derived directly from ore processing. Transfer of tailings into Pit 1 from the milling and processing of ore is currently by central sub-aqueous deposition.

The average density of process residue in Pit 1 at 30 June 2006 was 1.37 t/m^3, which meets the minimum target density of 1.2 t/m^3.

It is a condition of the Commonwealth Environmental Requirements that all tailings be returned to the pits prior to mine closure. The current approval for tailings above RL0 in Pit 1 is an interim operational strategy and ERA will have to undertake further research and investigative work to provide a final tailings containment solution to the Supervising Authorities for approval. If the interim strategy is not proven to meet the requirements of the MTC for final containment, the Supervising Scientist has advised that tailings should be removed from Pit 1 to a scientifically justifiable level approved by the Supervising Authorities. It is expected that tailings will reach RL12 in Pit 1 during 2008.

In March 2006 ERA lodged a draft application with the MTC for the storage of tailings in Pit 3. Comments on the draft were provided by stakeholders to ERA and follow up discussions were held during a workshop on 16 June 2006. ERA intends to address these comments and submit a final application in the near future.

Audit outcomes

2006 Environmental Audit

The Annual Environmental Audit on behalf of external stakeholders of Ranger Mine was undertaken from 16 May to 19 May 2006. The audit team was made up of personnel from the Office of the Supervising Scientist, the Department of Primary Industry, Fisheries and Mines, and the Northern Land Council. The subject of the audit was compliance with the Ranger Authorisation 0108-03.

The audit team were generally satisfied that Ranger Mine complied with the major components of the Authorisation. Of the 63 criteria assessed the audit findings are as follows:

- 1 requires urgent action;
- 3 require action in the form of a firm deadline;
- 3 were satisfactory but improvement is recommended; and
- 56 were satisfactory.

A new ranking system that better reflects the style of audit undertaken has been developed by ***oss*** and was in use this year for the first time. The system is similar to the system used in the past with respect to the scale of the aspect and action required. The difference is that the new system is based on encouraging continuous improvement in that recommendations for the level of action and action required are made, which gives the auditee direction in remediating a deficiency prior to the follow-up audit.

Minesite Technical Committee

The Ranger Minesite Technical Committee (MTC) met six times during 2005–06. Dates of meetings and significant issues discussed are shown in Table 2.3.

TABLE 2.3 RANGER MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant additional agenda items
29 August	Pond and process water treatment programme update, RL0 application update, Stockpile runoff proposal, Review of Ranger Authorisation, Gulungul monitoring site location, Northern Stockpile extension, Vegetation surveys of irrigation areas, Review of the Retention Pond 1 wetland filter, Temporary ADU storage, Laterite processing.
07 October	As above plus Pit 1 update, The role of the MTC in Ranger closure planning and approvals.
18 November	Pond and process water treatment programme update, Pit 1 update, Status of the Mine Management Plan and approvals, Vegetation surveys of irrigation areas, Temporary ADU storage, Review of Ranger Authorisation, Geochemical properties of waste stockpiles, Mine Closure, Review of Ranger reserves and proposal for additional exploration drilling, Closeout recommendations from SSR184 and 185.
20 January	Pond and process water treatment programme update, Pit 1 update, Status of the Mining Management Plan and approval(s), Mine closure, Review of Ranger reserves and proposal for additional exploration drilling, Power line clearing to Magela Bore field
27 March	As above plus: Ranger Mine Draft Closure Model, Acid plant and EPBC Act referral, Laterite Plant, Pit 3 Tailings Deposition, Uranium Industry Framework update,
30 May	Pond and process water management, mine closure, exploration drilling, draft application for tailings deposition in Pit 3

Authorisations and Approvals

There were four applications assessed by ***oss*** during 2005–06 (see Table 2.4). All were approved by DPIFM after concerns raised by stakeholders were addressed. Changes to the Authorisation that required input from ***oss*** are listed in Table 2.4.

TABLE 2.4 RANGER AUTHORISATION CHANGES/APPROVALS

Date received	Issue
18 August 2005	Approval to change the programme of inspection of vegetation in irrigation areas
16 May 2006	Approval to use the southern 2s stockpile surface for storage of Retention Pond 2 water
23 May 2006	Approval for the extraction of gravel for the tailings dam wall lift
20 June 2006	Approval for the increase in Maximum Operating Level of Ranger's Retention Pond 2

Incidents

Background to incident investigation

Since 2000 ERA has undertaken to provide stakeholders with a comprehensive list of environmental incidents reported at its Ranger and Jabiluka operations on a regular basis. The regular monthly environmental incident report is additional to reports made to meet the statutory requirements for incident reporting. This regime of reporting all recorded environmental incidents is undertaken voluntarily by ERA in response to concerns expressed by stakeholders about the establishment of suitable thresholds of incident severity for reporting.

Immediately upon receipt of notification of such incidents, ***oss*** assesses the circumstances of the situation and a senior officer makes a decision on the appropriate level of response. Dependent on the assessment, this response will range from implementation of an immediate independent investigation such as occurred in March 2004 following a potable water contamination incident, through seeking further information from the mine operator before making such a decision. In those cases where immediate action is not considered to be required the situation is again reviewed on receipt of a formal incident investigation report from the operator.

Prior to each Routine Periodic Inspection (see Section 2.1.2) the inspection team reviews the previous month's incident reports and any open issues. Where incidents are considered to have any potential environmental significance or represent repetitions of a class of occurrences an onsite review is scheduled as a part of the routine inspection protocol.

oss determined that no incidents that occurred during the reporting period were of a serious enough nature to warrant a separate independent investigation, however, the following incidents were followed up as part of the routine periodic inspections.

ADU spray in Precipitation Building

On 14 October 2005, ***oss*** was notified that an incident had occurred in the Precipitation Building involving an operator being sprayed with ammonium diuranate (ADU). During the night the operator observed that a short section of the ADU line near the pump that pumps ADU from the product thickener to the calciner was bulging, indicating a blockage in the line. The operator went to shut the pump down, however, the line failed before he could complete the process resulting in him being sprayed with ADU. The operator took the appropriate action to wash himself off. ADU was also sprayed within the Precipitation Building.

The Precipitation Building was promptly cleaned up and the operator underwent 24 hour urine testing. On the basis of the urine monitoring results and the biokinetic model for uranium published by the International Commission on Radiation Protection, the committed effective dose to the operator as a result of ingestion of uranium was approximately 0.1 microSieverts (µSv). This dose is low compared with the typical 1500 to 2000 µSv that humans receive each year from natural background.

Tailings pipe rupture

On 11 November 2005 at approximately 10.00 am there was a failure of the tailings pipe adjacent to the tailings pumping station. The failure resulted in approximately 1 m^3 of tailings being sprayed onto and across the Corridor Road and into the adjacent bush. This area of bush is part of the clean catchment of Corridor Creek.

The incident was noticed immediately and the tailings circuit was shut down until repairs and clean up could be undertaken. The tailings were removed from the Corridor Road along with the approximately 600 m^2 of bush. The material was placed in the tailings repository.

Accidental irrigation of Magela Land Application Area

To manage the water level in Retention Pond 2, pumping from Retention Pond 2 to Pit 3 (using a pontoon pump) commenced at 8.00 pm on 21 January 2006. The water management system is designed to allow water to be transferred from Retention Pond 2 to Pit 3 and/or the Magela Land Application Area (MLAA). In this instance the valves were set in the appropriate position to send water only to Pit 3 and water was observed exiting the pipe into Pit 3 as expected.

The following day during a routine daily check at approximately 12:15 pm, a flow meter in the line that feeds the MLAA was observed to be turning. The valve that should have prevented flow in that line was observed to be closed as appropriate indicating that the valve had likely failed. At 12:30 pm a valve downstream of the failed valve was closed stopping flow to the MLAA. ERA management and stakeholders were notified immediately.

Meter readings indicated that 1531 cubic metres had been sent to the MLAA between 8.00 pm on 21 January 2006 and 12:30 pm on 22 January 2006. This equates to an irrigation rate of 0.026 m^3/s. Four zones (of approximately 20) in the MLAA received the water.

At the time of the release, Magela Creek was flowing at more than 169 m^3/s. Conservatively if that water discharged directly into Magela Creek, the dilution expected would be around 1 in 6500. Following the incident, water samples were taken from Retention Pond 2 and analysed indicating a uranium concentration of approximately 4400 µg/L. If this water had been directly discharged into Magela Creek it would result in a worst case concentration of approximately 0.7 µg/L assuming full mixing. This is well below the ecotoxicological limit of 6 µg/L for uranium concentrations in Magela Creek.

Both ERA and SSD sampled Magela Creek in the days following the incident and observed no unusual results, ie the results were within the range seen in previous years at that time of the year.

ERA undertook a formal investigation and provided stakeholders with a report outlining the root cause of the incident and proposed actions to prevent a similar incident in future.

Potential ingestion of contaminated dust in product packing room

On 27 February 2006, ***OSS*** was notified by ERA that an employee maintaining the hoppers in the product packing room noticed a metallic taste in his mouth and a 'cloud' around the room at approximately 10.30 am that day. The employee was wearing full Personal Protective Equipment, including an airstream helmet. As a precaution, a 24 hour urine sample was collected and analysed for uranium content. The result of the analysis of the 24 hour urine sample (first 24 hours) indicated that the urine contained 0.38 µg of uranium. Assuming that all of this came from an acute intake via inhalation on the 27th of February, the worker received a dose of approximately 80 microSieverts or 0.4% of the average annual dose received by the general public.

Investigations into the incident indicated that it was unlikely that the airstream helmet had failed. If an airstream helmet is not operating whilst being worn it quickly fogs up. The employee indicated that this had not occurred. The results of the urine analysis are also indicative of the levels of uranium expected from drinking potable water from the Brockman bore field.

2.2.3 Off-site environmental protection

Surface water quality

Under the Authorisation, ERA is required to monitor and report on water quality in Magela and Gulungul Creeks adjacent to the mine. Specific water quality objectives must be achieved in Magela Creek. These objectives were recently reviewed and updated by the ***oss***.

The Authorisation specifies the sites, the frequency of sampling and the analytes to be reported. Each week during the wet season, ERA reports the water quality at key sites at Ranger, including Magela and Gulungul Creeks, to the major stakeholders (the Supervising Scientist, DPIFM and NLC). A detailed interpretation of water quality across the site is provided at the end of each wet season in the ERA Ranger Annual Wet-season Report.

In addition to ERA's monitoring programme, the Supervising Scientist conducts an independent surface water monitoring programme that includes chemical and physical monitoring in Magela and Gulungul Creeks and biological monitoring of numerous water bodies in the region. Key results (including time-series charts of key variables of water quality) are reported on the Internet at www.deh.gov.au/ssd/monitoring/index.html. The highlights of the monitoring results are summarised below.

Chemical and physical monitoring of Magela Creek

The first water chemistry samples for the Supervising Scientist's surface water monitoring programme for the 2005–06 wet season were collected from Magela Creek on 6 December 2005, one day after flow was observed at the downstream statutory compliance point. Weekly sampling was conducted throughout the wet season, and continued until the creek ceased to flow, with the following exceptions: (i) following an accidental irrigation of the Magela Land Application Area with pond water on 21–22 January 2006, additional sampling of Magela Creek was undertaken on 23 January 2006; and (ii) in the last week of April 2006, sampling did not occur after Tropical Cyclone Monica passed over Jabiru on 25 April 2006 because sites were inaccessible. SSD collected its last sample on 24 August 2006 shortly before Magela Creek ceased flowing.

The values of all available indicators for the wet season, including the period immediately following the irrigation incident, have been within limits/guidelines[1] set by the Supervising

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1 Iles M 2004. Water quality objectives for Magela Creek – revised November 2004. Internal Report 489, December, Supervising Scientist, Darwin. Unpublished paper.

Scientist for the protection of the aquatic environment and are within the range seen in previous years.

The upstream and downstream key water quality data from both the SSD and ERA programmes are summarised in Table 2.5 while uranium concentrations from both the SSD and ERA routine and investigative monitoring (following the irrigation incident) are shown in Figure 2.4. There is good agreement between the datasets of both organisations.

Uranium, manganese, magnesium and sulfate median values from both datasets were higher downstream of the mine but the concentrations were very low and not of environmental concern. Uranium concentrations remained well below (<3% of) the limit (Figure 2.4). The low values are indicative of the pattern of improved water quality seen in the past four wet seasons, demonstrated in the uranium results of Figure 2.5.

Electrical conductivity (EC), whose guideline value provides a management tool for the control of magnesium and sulfate concentrations, was also slightly higher downstream but compared to the guideline value the difference was small. The manganese, pH, and turbidity medians are similar at both sites for each dataset.

The water quality objectives set to protect the aquatic ecosystems downstream of the mine were achieved during the 2004–05 wet season. Available biological monitoring data (described later in this section) also indicate that the environment remained protected throughout the season.

TABLE 2.5 SUMMARY OF MAGELA CREEK 2005–06 WET SEASON# WATER QUALITY UPSTREAM AND DOWNSTREAM OF RANGER

Parameter	Guideline or Limit*	Organisation	Median		Range	
			Upstream	Downstream	Upstream	Downstream
pH	5.0 – 6.9	SSD	6.4	6.4	5.6 – 6.8	5.9 – 6.8
		ERA	6.3	6.4	5.5 – 6.7	5.8 – 6.7
EC (μS/cm)	43	SSD	14	17	7.9 – 20	8.5 – 23
		ERA	12	15	4.8 – 20	6.9 – 23
Turbidity (NTU)	26	SSD	2.0	2.2	0.9 – 14	0.8 – 18
		ERA	2.	2.	1 – 11	1 – 14
Sulfate‡ (mg/L)	Limited by EC	SSD	0.2	0.7	0.1 – 0.4	0.3 – 3.4
		ERA	0.2	0.8	0.1 – 0.6	0.3 – 3.8
Magnesium‡ (mg/L)	Limited by EC	SSD	0.6	0.9	0.2 – 1.1	0.3 – 1.4
		ERA	0.5	0.8	0.1 – 0.9	0.2 – 1.2
Manganese‡ (μg/L)	26	SSD	4.4	4.9	2.2 – 13	2.1 – 16
		ERA	3.9	4.1	1.9 – 10	3.2 – 16
Uranium‡ (μg/L)	6	SSD	0.014	0.048	0.003 – 0.044	0.014 – 0.153
		ERA	0.018	0.064	0.006 – 0.060	0.014 – 0.145

ERA data taken from the ERA Weekly Water Quality Report 18 August 2006; ‡ dissolved (<0.45 μm); # SSD results from the last sampling event, 24 August, outstanding at time of report writing; * A compliance limit applies to uranium, management guidelines apply to all other parameters shown.

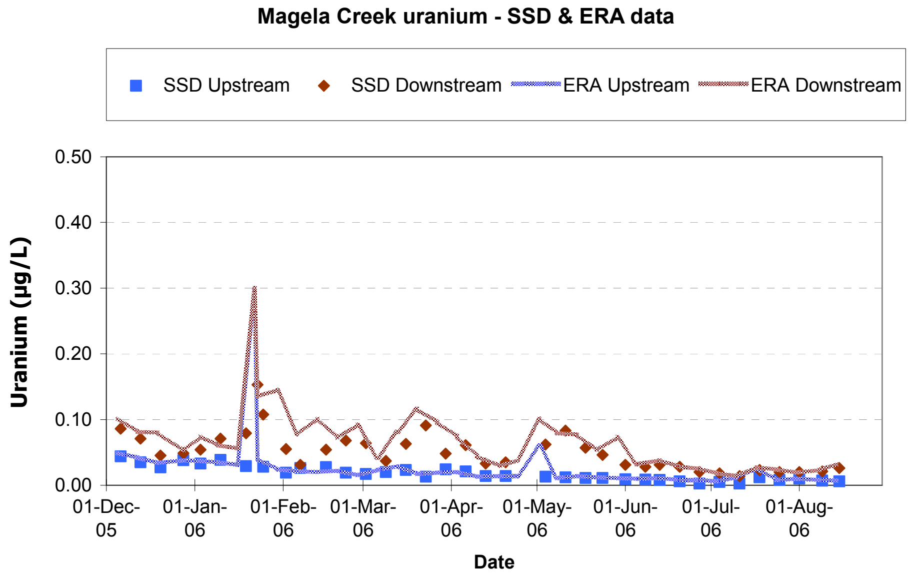


Figure 2.4 Uranium concentrations measured in Magela Creek by SSD and ERA during the 2005–06 wet season

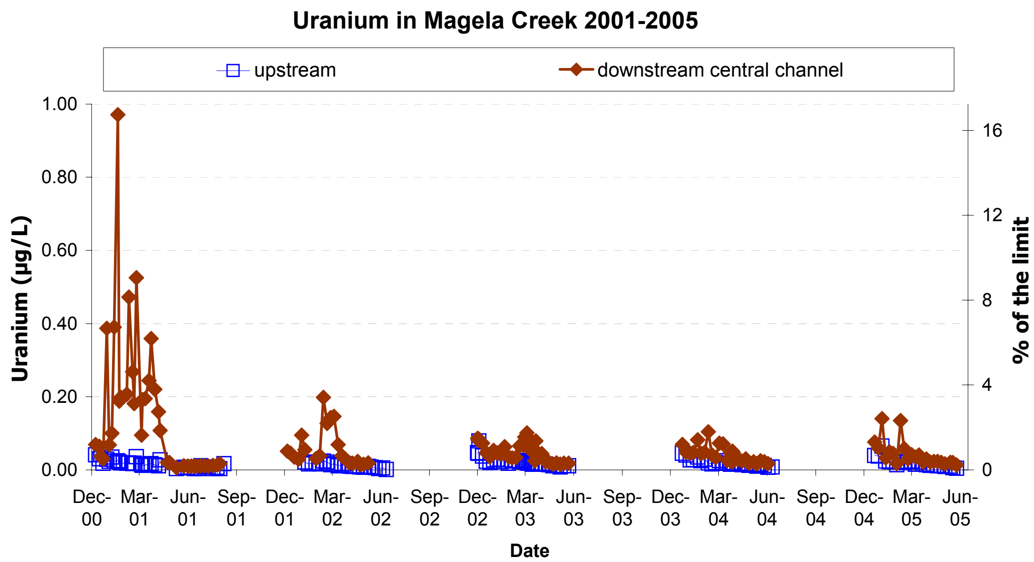


Figure 2.5 Uranium concentrations in Magela Creek since the 2000–01 wet season (SSD data)

Chemical and physical monitoring of Gulungul Creek

The first water chemistry samples for the Supervising Scientist's surface water monitoring programme for the 2005–06 wet season were collected from Gulungul Creek on 29 November 2005, the first week after flow commenced in the creek. Weekly sampling was conducted throughout the wet season, and continued while the creek was flowing, except for the last week of April 2006 when sites became inaccessible after Tropical Cyclone Monica passed over Jabiru (on 25 April 2006). SSD collected its last sample on 15 August 2006 shortly before Gulungul Creek ceased to flow.

The upstream and downstream water quality data from both the SSD and ERA programmes are summarised in Table 2.6 with uranium concentrations shown in Figure 2.6. There is good agreement between the datasets of both organisations and the overall water quality and seasonal trends for the 2005–06 wet season are comparable to those seen in previous years (Figure 2.7).

Although median values for most of the key variables were slightly higher downstream of the mine (Table 2.6), the concentrations were very low and not of environmental concern.

ERA measured elevated uranium on the first day of flow (Figure 2.6) when it sampled within hours of flow first occurring. Uranium concentrations were below the limit and the concentration at the upstream site was higher than that at the downstream site. In mid-January 2006, SSD measured a higher than usual uranium concentration of 0.393 µg/L (less than 7% of the 6 µg/L limit determined for Magela Creek). None of these excursions is considered to be environmentally significant: values this high experienced previously and for longer periods did not impact on the biodiversity. Available biological monitoring data (described later in this section) also indicate that the environment remained protected throughout the season.

TABLE 2.6 SUMMARY OF GULUNGUL CREEK 2005–06 WET SEASON WATER QUALITY UPSTREAM AND DOWNSTREAM OF RANGER

Parameter	Company	Median		Range	
		Upstream	Downstream	Upstream	Downstream
pH	SSD	6.3	6.5	5.4 – 6.7	5.7 – 6.7
	ERA	6.3	6.4	5.1 – 6.7	5.4 – 6.6
EC (µS/cm)	SSD	16	19	10 – 21	11 – 29
	ERA	13	15	8.7 – 24	8.4 – 26
Turbidity (NTU)	SSD	1.0	1.4	0.4 – 5.4	0.7 – 7.7
	ERA	1.	1.	<1 – 8.	<1 – 5.
Sulfate‡ (mg/L)	SSD	0.2	0.4	0.1 – 0.7	0.1 – 2.3
	ERA	0.2	0.5	0.1 – 1.2	0.1 – 1.8
Magnesium‡ (mg/L)	SSD	0.9	0.9	0.5 – 1.8	0.5 – 1.8
	ERA	0.8	0.8	0.3 – 1.6	0.4 – 1.3
Manganese‡ (µg/L)	SSD	2.1	3.6	1.2 – 8.5	2.0 – 18
	ERA	2.0	3.2	1.2 – 11	1.8 – 18
Uranium‡ * (µg/L)	SSD	0.054	0.095	0.030 – 0.169	0.058 – 0.393
	ERA	0.060	0.102	0.032 – 1.64	0.053 – 1.05

‡ dissolved (<0.45 µm), * limit = 6 µg/L

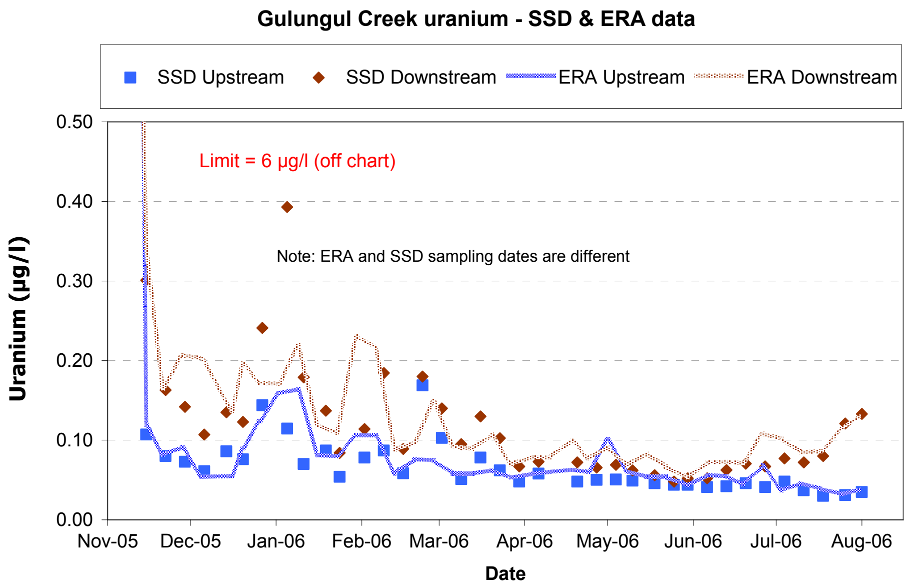


Figure 2.6 Uranium concentrations measured in Gulungul Creek by SSD and ERA during the 2005–06 wet season

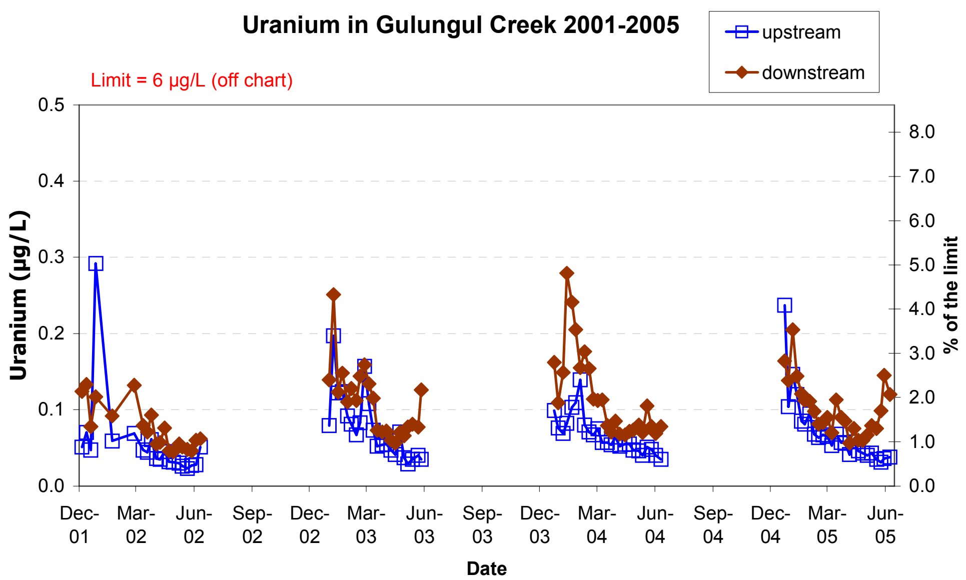


Figure 2.7 Uranium concentrations in Gulungul Creek between 2000 and 2005 (SSD data)

Biological monitoring in Magela Creek

Based on ***eriss*** research since 1987, biological monitoring techniques have been developed that can be used to assess the environmental impact of uranium mining on aquatic ecosystems downstream of the Ranger mine. Two broad approaches are used: early detection studies and assessment of overall ecosystem-level responses.

Creekside monitoring is used for *early detection* of effects in Magela Creek arising from any dispersion of mine waters during the wet season. For *ecosystem-level responses*, benthic macroinvertebrate and fish communities from Magela and Gulungul Creek sites are compared with historical data and data from control streams. Results of creekside monitoring and fish community studies conducted during the 2005–06 wet and early dry seasons are summarised here. (Macroinvertebrate samples collected from stream sites in May 2006 had not been processed at the time this report was being prepared. Associated and additional data and results will be more fully reported in a Supervising Scientist Report to be compiled later in 2006.)

Creekside monitoring

In this form of monitoring, effects of Ranger mine wastewater dispersion are evaluated using responses of aquatic animals held in tanks on the creek side. The responses of two test species are measured over a four-day period:

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

Animals are exposed to a continuous flow of water pumped from upstream of the mine site (control site) and from the creek just below gauging station G8210009, some 5 km downstream of the mine (Map 2, Magela d/s). Tests usually commence in December and cease in early April each year, the period of significant creek flow in Magela Creek.

Seven creekside tests were conducted in the 2005–06 wet season. Significant pump failure occurred during the fourth test at the upstream site, to the extent that the test did not meet acceptance and validity criteria. While the data for this test are displayed in the accompanying figures, they are not used in formal statistical analysis to detect and assess potential mining impact. (By convention, the upstream-downstream ‘difference’ value is omitted from the graphs of test organism responses to signify an invalid test.)

Amongst the snail tests, egg production at upstream and downstream sites was similar across all tests conducted for the wet season (Figure 2.8). The results also resemble the pattern of egg production observed in previous wet seasons with the possible exception of the relatively low egg production observed at the downstream site in the fifth test. This value was a consequence of significantly lower ($P<0.05$) egg production observed in the duplicate water drawn from the west bank of the creek at the downstream site (mean of 54 eggs per snail vial), relative to the corresponding duplicate water drawn from the east bank at this site (107 eggs per snail vial) and from the two duplicate waters drawn from the upstream site (117 and 123 eggs per snail vial). Corresponding spot water chemistry data collected during this test as part of the SSD’s routine monitoring programme do not indicate any significant elevation of analytes at this site. Additional water chemistry data, together with continuous datasonde records for key parameters including conductivity and pH, were also collected during this creekside test and results, similarly, do not show any major discrepancies in water quality. Thus the reduced snail egg production observed at the downstream west bank site during the fifth test does not appear to be mine-related.

Using the snail egg production data shown in Figure 2.8, 'difference' values for 2005–06 were compared with those from previous years. No significant difference was found (P>0.05).

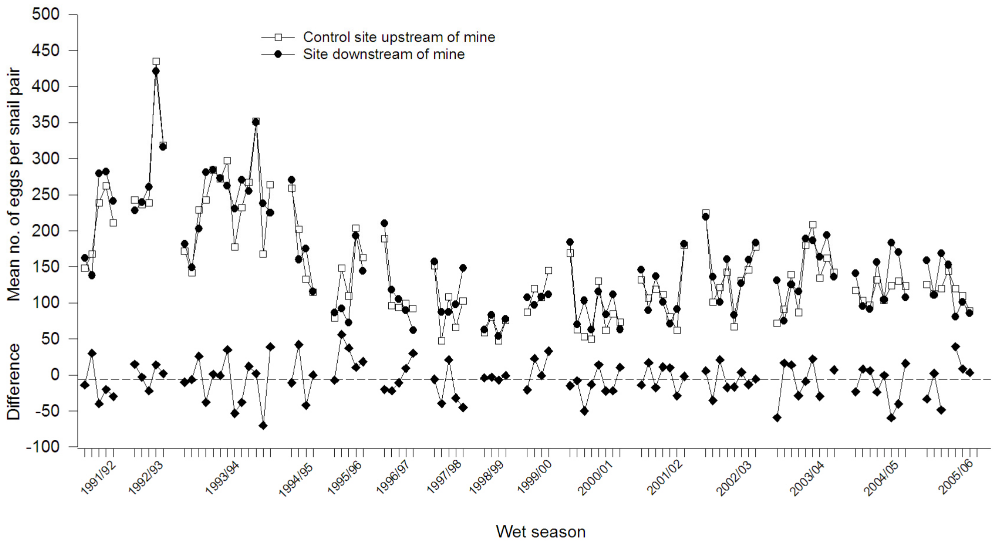


Figure 2.8 Creekside monitoring results for freshwater snail egg production for wet seasons between 1992 and 2006. (Snail egg production data for the first three tests of 1995/96, all tests for 1997/98, 1998/99 and 1999/00, and the last four tests in 2000/01, were provided by ERA.)

Across all fish tests, larval fish survival at upstream and downstream sites was consistent with the same relative survival rates observed in previous wet seasons with, typically, reduced survival at the upstream site relative to the downstream site (Figure 2.9). (Possible causes were discussed in the Supervising Scientist Annual Report for 2002–03.)

From the collective creekside results, it was concluded that there were no adverse effects of dispersed Ranger mine wastewaters to Magela Creek on either of the creekside test species over the 2005–06 wet season.

Monitoring using macroinvertebrate community structure

Macroinvertebrate sampling is conducted in May each year. Results of the studies conducted in 2005 and previous years were reported in the 2004–05 Supervising Scientist Annual Report. The samples collected in May 2006 were still undergoing analysis and interpretation at the time of report writing.

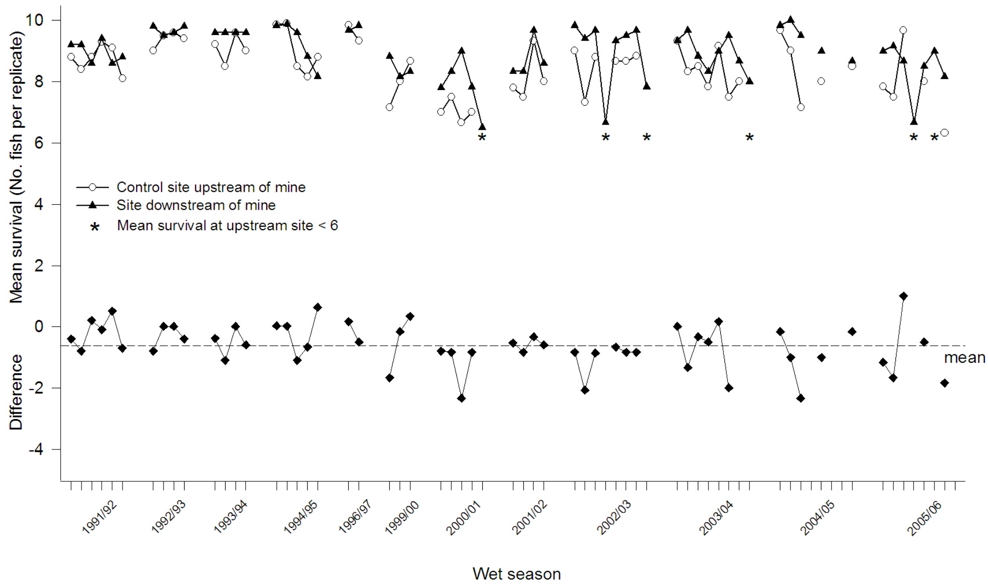


Figure 2.9 Creekside monitoring results for larval black-banded rainbowfish survival, for wet seasons between 1992 and 2006. (Larval fish survival data for the second test in 1999/00 were provided by ERA.)

Monitoring using fish community structure

Sampling of fish communities in billabongs is conducted in late April to the end of June of each year. Data are gathered, using non-destructive sampling methods, from 'exposed' and 'control' sites in deep channel billabongs and shallow weedy lowland billabongs. Details of the sampling methods and sites were provided in the 2003–04 Supervising Scientist Annual Report.

For both deep channel and shallow lowland billabongs comparisons can be made between: (i) directly exposed billabong versus control billabong from independent catchments (Nourlangie Creek, East Alligator River, Wirnmuyurr Creek); and/or (ii) directly exposed versus indirectly exposed billabongs in Magela Creek, recognising that this second approach is confounded by possible movement of fish between the two lowland billabong types in the same stream system.

Channel billabongs

The similarity of fish communities in Mudginberri Billabong (directly exposed site downstream of Ranger) and Sandy Billabong (control site in the Nourlangie catchment) was determined using multivariate dissimilarity indices. Calculated for each annual sampling occasion, the dissimilarity index is a measure of the extent to which fish communities of the two sites differ from one another. A value of 'zero' indicates identical fish communities while a value of 100% indicates totally dissimilar communities, sharing no common species. A significant change or trend in the dissimilarity values over time could imply mining impact. A plot of the dissimilarity values from 1994 to the present is shown in Figure 2.10.

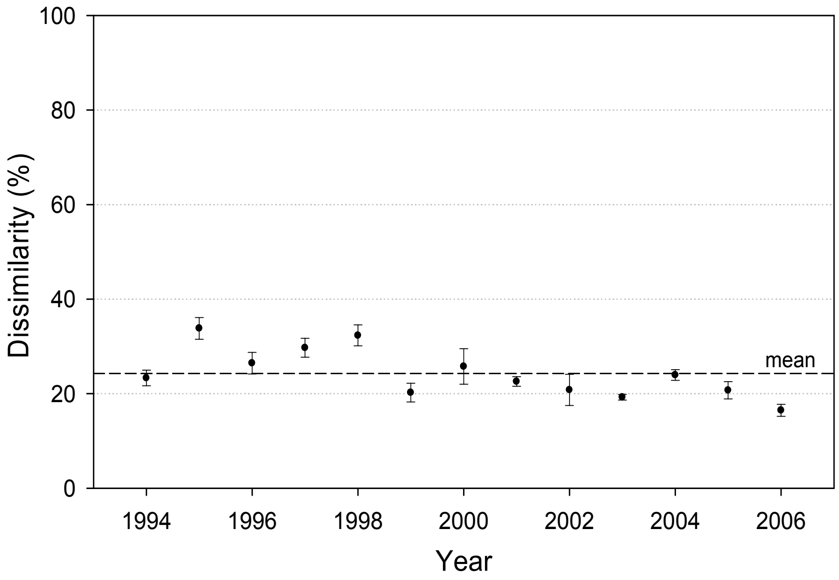


Figure 2.10 Paired control-exposed dissimilarity values (using the Bray-Curtis measure) calculated for community structure of fish in Mudginberri ('exposed') and Sandy ('control') billabongs in the vicinity of the Ranger uranium mine over time. Values are means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of transect data between the two billabongs. There has been a significant decline in paired-site dissimilarity over time but there is no evidence that this decline is mine-related (see text for further explanation).

In the Supervising Scientist Annual Report for 2003–2004, a significant decline was noted in the paired-site dissimilarity measures over time. This decline has continued (Pearson's correlation $R = -0.70$, $P<0.05$) with the value reported in 2006 the lowest yet recorded (Figure 2.10). The decline is primarily attributed to the particularly high abundances of chequered rainbowfish (*Melanotaenia splendida inornata*) and to a lesser extent glassfish (*Ambassis* spp) in Mudginberri Billabong in the early years of the study, relative to Sandy Billabong. Chequered rainbowfish have declined in Mudginberri Billabong since sampling commenced in 1989. The decline in rainbowfish numbers, and by association, the paired billabong dissimilarity value, is not related to any change in water quality over time as a consequence of water management practices at Ranger. This issue was examined in more detail in the Supervising Scientist's 2004–05 Annual Report where the environmental correlates (1) wet season stream discharge, (2) natural, wet season stream solute concentration, (3) length of previous dry season, and (4) habitat conditions on Magela Creek floodplain, were identified as possible causes of the decline in rainbowfish.

Further work is required to elucidate the cause of the decreasing dissimilarity of fish communities between Sandy and Mudginberri billabongs. The continued decline has been less influenced by chequered rainbowfish and glassfish in the latter years, suggesting more subtle changes in community structure are also occurring.

Shallow lowland billabongs

Fish in shallow billabongs were not sampled in 2006. While the current baseline of fish community data (pre-closure) from these sites is reasonably extensive, this is not the case for macroinvertebrate communities. Biological data in association with water chemistry data are being used to develop mine site closure criteria for the shallow water bodies around Ranger mine. To this end, resources during 2006 were diverted to the collection of macroinvertebrate samples from the shallow lowland billabongs to redress data deficiencies required for developing closure criteria for these sites. Currently macroinvertebrate samples collected in May are being sorted and identified. Interim closure criteria will be available in December 2006 following sample processing and data analysis. Sampling of fish communities in shallow billabongs will be reviewed, along with the broader biological monitoring programme, in October 2006.

2.2.4 Outcome of investigations into incidents at Ranger in 2003–04

The Supervising Scientist's reports on the incidents, *Investigation of the potable water contamination incident at Ranger mine March 2004* (Supervising Scientist Report 184) and *Investigation of radiation clearance procedures for vehicles leaving the Ranger mine* (Supervising Scientist Report 185), were tabled in Parliament on 30 August 2004 and subsequently made available to all major stakeholders in hard copy format and through the Supervising Scientist's web site.

Following consideration of issues raised in the reports, the Minister for Industry, Tourism and Resources, the Hon Ian Macfarlane MP, wrote to ERA requiring the company to comply with a series of conditions under the *Atomic Energy Act 1953*. These conditions were based on the recommendations in the Supervising Scientist's two reports. Minister Macfarlane required that the conditions be met in accordance with a timeframe involving deadlines of 10 September 2004, 31 October 2004 and 31 December 2004.

The final of the conditions, involving the implementation of workplace safety standard AS4801/2001 (*Occupational health and safety management systems – Specification with guidance for use*) by 30 September 2005, was met by the required date.

The Ranger Minesite Technical Committee has, at each of its meetings, reviewed the status of compliance by ERA against the Supervising Scientist's full set of recommendations. In July 2005 the Supervising Scientist engaged ARPANSA to conduct an additional detailed audit of the Radiation Safety Practices at the Ranger mine. The purpose of this audit was to examine the steps that ERA has taken to upgrade its radiation management system and, as a result, to address concerns about the radiation protection culture at Ranger. The audit concluded that the Radiation Safety Management System was a comprehensive system that if implemented would ensure radiation safety at the Ranger site.

2.3 Jabiluka

2.3.1 Developments

No developments occurred at the Jabiluka site during the reporting period. The site is maintained as a passive discharge site under the long-term care and maintenance regime of management.

Decommissioning of Djarr Djarr camp commenced in September 2005, with core from the sheds being transported to storage sheds at Ranger Mine. The removal of the infrastructure was completed in October 2005 and rehabilitation works are in progress.

2.3.2 On-site environmental management

Water management

The site is continuing to be maintained as a passive discharge site.

Figure 2.11 Jabiluka Project Area during the 2005–06 wet season

Audit outcomes

The Annual Environmental Audit on behalf of external stakeholders of the Jabiluka Project Area was undertaken on 18–19 May 2006. The audit team was made up of personnel from the Office of the Supervising Scientist, the Department of Primary Industry, Fisheries and Mines, and the Northern Land Council. The subject of the audit was compliance with the Jabiluka Authorisation 0140-03.

The audit team were generally satisfied that the Jabiluka Project Area complied with the major components of the Authorisation.

Minesite Technical Committee

The Jabiluka Minesite Technical Committee (MTC) met six times during 2005–06. Dates of meetings and significant issues discussed are shown in Table 2.7.

TABLE 2.7 JABILUKA MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant additional agenda items
29 August 2005	Mining Management Plan, Decommissioning and rehabilitation of Djarr Djarr, Updated progress against environmental conditions of the Jabiluka Environmental Impact Statement (EIS) and Public Environment Report (PER), Jabiluka surface and groundwater monitoring programme.
7 October 2005	No new items
18 November 2005	No new items
20 January 2006	Mining Management Plan; Decommissioning and rehabilitation of Djarr Djarr; Updated progress against environmental conditions of the Jabiluka EIS and PER; Jabiluka surface and groundwater monitoring programme; Anomalous results from eriss sampling programme; Mine Valley access.
27 March 2006	As above plus: Submission date for Jabiluka Annual Plan of Rehabilitation.
30 May 2006	Mining Management Plan; Updated progress against environmental conditions of the Jabiluka EIS and PER; Mine Valley access; Access to monitoring sites following Cyclone Monica.

Authorisations and Approvals

Changes to, and approvals under, the Authorisation during 2005–06 are listed in Table 2.8.

TABLE 2.8 JABILUKA AUTHORISATION CHANGES/APPROVALS

Date	Issue
27 September 2005	Approval to modify the water monitoring programme to align with the current low environmental risk of the site (the site being in long-term care and maintenance).

Incidents

There were no reportable incidents at Jabiluka during the year.

2.3.3 Off-site environmental protection

Surface water quality

In accordance with the Jabiluka Authorisation, ERA is required to monitor a range of surface and ground waters on the lease and to demonstrate that the environment remains protected. Specific water quality objectives (criteria thresholds were described in Supervising Scientist Annual Report 2003–04) must be achieved. Each month during the wet season, ERA reports the water quality in Ngarradj (Swift Creek) to the major stakeholders (SSD, DPIFM and NLC). A detailed interpretation of water quality across the site is provided at the end of each wet season in the ERA Jabiluka Annual Wet-season Report.

In addition to the ERA programme, SSD conducts monthly chemical and physical monitoring in Ngarradj (Swift Creek). Key water quality data from SSD and ERA routine monitoring of Ngarradj are reported at www.deh.gov.au/ssd/monitoring/ngarradj-chem.html.

A summary of the data collected is provided below.

Chemical and physical monitoring of Ngarradj (Swift Creek)

Toward the end of 2003 Jabiluka entered a long-term care and maintenance phase. Since the site poses a very low risk to the environment, SSD's water chemistry monitoring programme at Ngarradj was reduced to monthly sampling for the 2004–05 wet season, augmented by automatic recordings of turbidity and hydrological data at six-minute intervals. DPIFM resumed the role of performing check monitoring at Ngarradj, also on a monthly basis, but offset by two weeks from the SSD programme. These independent programmes complemented each other, providing an approximately fortnightly frequency of water sampling and a combined dataset to assess the water quality at Ngarradj. ERA continued to carry out monitoring on a weekly basis.

The first water chemistry samples for SSD's 2005–06 wet season surface water monitoring programme were collected from Ngarradj on 10 January 2006 and ERA collected samples from Ngarradj on 29 December 2005 from the downstream site only (the upstream site was not yet flowing). SSD collected samples monthly until June. ERA and DPIFM have also sampled monthly but to a different schedule. ERA collected samples up to July shortly before the creek stopped flowing.

The upstream and downstream water quality data from both the SSD and ERA programmes are summarised in Table 2.9. ERA and SSD data are in good agreement with values and trends similar to those seen in previous years measured again this season. Uranium concentrations measured by ERA and SSD during the 2005–06 wet season are shown in Figure 2.12. Uranium concentrations are only marginally higher at the downstream site and are less than 0.5% of the limit. These trends have been observed since data collection began in 1998 (Figure 2.13.

The water quality objectives set to protect the aquatic ecosystems downstream of Jabiluka were achieved, providing assurance that the environment remained protected throughout the wet season.

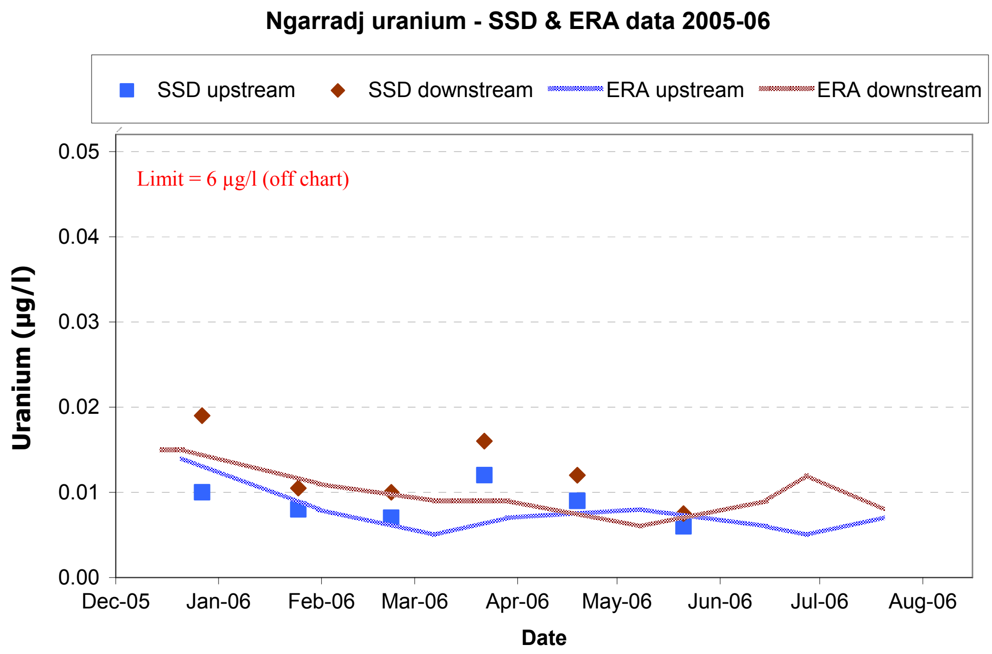


Figure 2.12 Uranium concentrations measured in Ngarradj by SSD and ERA in the 2005–06 wet season

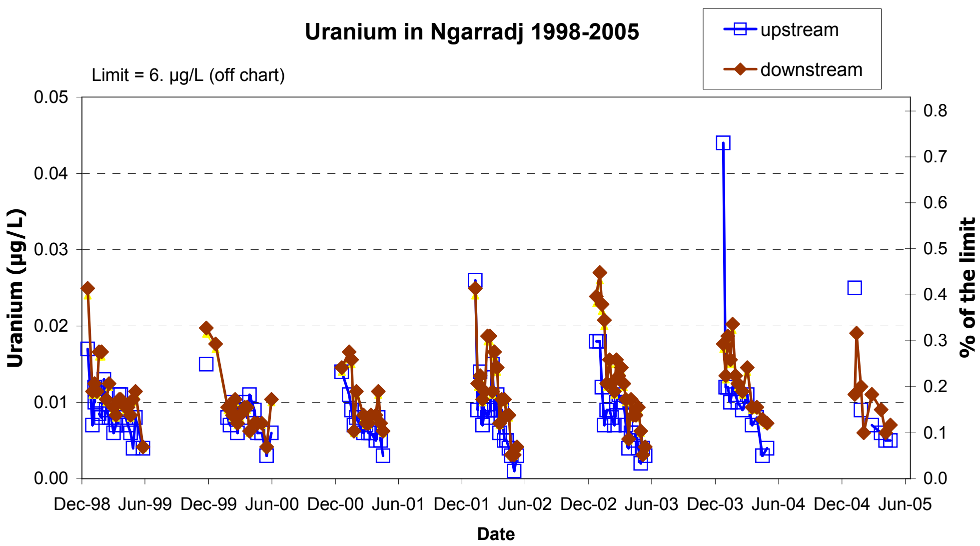


Figure 2.13 Uranium concentrations in Ngarradj since the 1998–99 wet season (SSD data 1998–99 to 2003–04, SSD & ERA data 2004–05)

TABLE 2.9 SUMMARY OF NGARRADJ (SWIFT CREEK) 2005–06 WET SEASON WATER QUALITY UPSTREAM AND DOWNSTREAM OF JABILUKA

Parameter	Guideline or Limit	Organisation	Median		Range	
			Upstream	Downstream	Upstream	Downstream
PH (field data)	3.9–6.0	SSD	5.1	5.5	4.6 – 5.4	4.8 – 5.8
		ERA	5.2	5.6	4.7 – 5.4	4.8 – 5.8
EC (μS/cm) (field data)	21	SSD	15	13	10 – 18	9.3 – 15
		ERA	11	12	10 – 14	8.7 – 13
Turbidity (NTU)	–	SSD	0.6	1.1	0.4 – 1.8	0.6– 3.2
		ERA	1.	1.	<1 – 1.	<1 – 2.
NO_3 (as NO_3) (mg/L)	1.26	SSD	ND	ND	ND	ND
		ERA	<0.02	0.04	<0.02 – 0.11	<0.02 – 0.06
Sulfate‡ (mg/L)	1.5	SSD	0.4	0.3	0.3 – 0.8	0.2 – 0.6
		ERA	0.3	0.2	0.2 – 0.9	0.1 – 0.7
Magnesium‡ (mg/L)	0.76	SSD	0.3	0.3	0.1 – 0.3	0.1 – 0.4
		ERA	0.2	0.4	0.2 – 0.4	0.2 – 0.6
Uranium‡ (μg/L)	6.	SSD	0.009	0.011	0.006 – 0.012	0.008 – 0.019
		ERA	0.007	0.009	0.005 – 0.014	0.006 – 0.015

ERA data taken from the ERA Weekly Water Quality Report 11 August 2006; * SSD data laboratory data; pH & EC based on field data – the common measurement to all organisations; ‡ dissolved (<0.45 μm); A compliance limit applies to uranium, management guidelines apply all other parameters shown. ND = no data.

Biological monitoring in Ngarradj (Swift Creek)

The biological monitoring programme for Jabiluka has ceased, commensurate with the low risk posed while the site is in long-term care and maintenance mode. The last sampling event took place in the 2004 dry season. Results from six-years (1999–2004) of fish community structure studies were reported in the 2003–04 Supervising Scientist Annual Report along with available results for macroinvertebrate community structures.

2.4 Nabarlek

2.4.1 Developments

The impact of Tropical Cyclone Monica (which passed directly over Nabarlek in the early hours of 25 April 2006) in addition to a number of fires caused considerable damage to the site, hampering rehabilitation. Discussions are underway between Hanson (the Nabarlek leaseholder) and the Northern Land Council (on behalf of the traditional Aboriginal owners) on issues related to the repair and clean up of Nabarlek.

Nabarlek Rehabilitation Bond

Stakeholders continue to work on identifying suitable closure criteria for the site. A revised revegetation plan is required to update the Nabarlek Mining Management Plan upon which the rehabilitation security is based. The current Mining Management Plan and level of security applies until a new Mining Management Plan is approved.

Minesite Technical Committee

The Nabarlek Minesite Technical Committee met twice during the year. Table 2.10 provides information on the meeting and the major points of discussion.

TABLE 2.10 NABARLEK MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant agenda items
5 December 2005	Radiologically anomalous area, Rehabilitation status issues paper update, Environmental monitoring, Mining management plan and security, Closure criteria,
3 April 2006	Radiologically anomalous area, Rehabilitation status issues paper update, Environmental monitoring, Mining management plan and security, Closure criteria, Cameco survey, and Community water grant

Authorisations and Approvals

There were no changes to the Authorisation during the reporting period.

Incidents

There were no reportable incidents at Nabarlek during the year.

2.4.2 On-site conditions

Staff from ***eriss*** continue to undertake research programs at Nabarlek and the site is subject to at least two formal visits from ***oss*** staff during the year. In addition, ***oss*** often carries out opportunistic site inspections if in the area on other business (eg exploration inspections).

The formal site inspections carried out at Nabarlek each year are:

- The post-wet season inspection – the intent of this inspection is to check site stability and erosion following the wet season and to plan works for the coming dry season.
- The annual audit (in November) of compliance with the Mining Management Plan. The Audit report is tabled under a separate agenda item.

Tropical Cyclone Monica passed directly over Nabarlek during the early hours of 25 April 2006. The site was further damaged by a large fire in early May 2006. The post-wet season inspection, conducted on 30 June 2006 by representatives from SSD, DPIFM, NLC and Hanson Pty Ltd, focused on recording the damage caused by these two events.

Audit outcomes

A compliance audit of the Nabarlek Mining Management Plan February 2003 (the currently authorised document) was undertaken by a team of auditors from NLC, DPIFM and ***oss***. The aim was to assess the effectiveness of management systems and to provide feedback to Hanson (the audited company) on establishment and status of these systems. The audit outcomes were:

- Conditional – The audit team identified one Conditional issue, which related to the radiologically anomalous area. A decision on management of the radioactive material from the area is pending.
- Not Verified – No items were considered as not verified.
- Acceptable – 13 of the 14 issues audited were considered acceptable.

NB: This audit was undertaken prior to the new ranking system being introduced.

Radiologically Anomalous Area

The radiologically anomalous area is an area of approximately 0.4 ha lying to the southwest of the former pit area. The area has elevated levels of radioactivity and has been identified to contribute about one quarter of the total radon flux from the rehabilitated mine site and three quarters of the radionuclide flux from the site via the erosion pathway (greater detail is provided in the Supervising Scientist's 2004–05 Annual Report).

The issue remains a standing item on the Nabarlek MTC agenda. A proposal to remediate the area will be included in the next Mining Management Plan.

2.4.3 Off-site environmental protection

Statutory monitoring of the site continues to be undertaken by DPIFM and the lease holder, Hanson. DPIFM carries out all surface and groundwater monitoring on and off-site, including surface water monitoring downstream of the mine in Kadjirrikamarnda and Cooper Creeks. DPIFM reports the results of this monitoring in the six-monthly Northern Territory Supervising Authorities Environmental Surveillance Monitoring in the Alligator Rivers Region reports. These creeks are reported to have low electrical conductivities (<24 µS/cm) and low concentrations of the key mining indicators, sulfate (< 1 mg/L) and uranium (< 0.1 µg/L).

SSD continues to undertake research programmes at Nabarlek including radiation assessments, revegetation success and monitoring techniques, and erosion and contaminant transport. The research is aimed at enabling an overall assessment of rehabilitation success at Nabarlek. Progress on these programmes is reported in Supervising Scientist Annual Reports and in the Internal Report series.

2.5 Other activities in the Alligator Rivers Region

2.5.1 Rehabilitation of the South Alligator Valley uranium mines

Staff of SSD continue to liaise with Parks Australia regarding the rehabilitation of former mine and mill sites in the South Alligator Valley. In May 2006, the Hon Greg Hunt MP, Parliamentary Secretary to the Minister for the Environment and Heritage, announced funding of $7.3 million over a four year period for rehabilitation of abandoned uranium mine sites in the South Alligator Valley. SSD is represented on the Project Steering

Committee which was established to provide advice to Parks Australia, ensure that communication is effective, and resolve issues related to the rehabilitation and incorporation of the mineral leases into Kakadu National Park.

The Steering Committee, Parks Australia staff and some of the traditional Aboriginal owners and representatives of the Werenbun Aboriginal Corporation met for two days in the South Alligator Valley to discuss the way forward and visit sites of interest. During that visit SSD staff carried out the routine inspection of the radioactive material containment sites and collected water from Rockhole Mine Creek as part of an investigation into the behaviour of the acid drainage affecting the creek.

The triennial radiometric survey of the containment sites that ***oss*** conducts to meet ARPANSA licence requirements is planned for late in the 2006 dry season. The Environmental Radioactivity section of ***eriss*** will be involved in characterising the wastes at Sleisbeck and other South Alligator Valley sites and in establishing preferred sites for long-term waste containment.

2.5.2 Exploration

oss undertakes a programme of site inspections at exploration sites in west Arnhem Land where Cameco Australia Pty Ltd is exploring for uranium. This entails two inspections, one of Myra Falls Camp and associated exploration activities and the other of King River Camp and associated exploration activities. The inspections are scheduled to take place when the camps are operating and exploration is being actively undertaken, which is during the dry season.

On 22 August 2005, representatives from ***oss***, NLC and DPIFM conducted the second dry season inspection of Cameco's exploration sites, the first being undertaken at the end of the 04–05 reporting period. The inspection entailed a visit to the heli-drilling programme operating out of Myra Falls Camp and the camp itself. There were no issues identified with the heli-drilling operations or the operations at the Myra Falls Camp.

The inspection of King River Camp was undertaken outside of this reporting period and will be reported in the 06–07 Annual Report.

2.6 Radiological issues

2.6.1 Background

Applicable standards

The radiation dose limit for workers recommended by the International Commission on Radiological Protection (ICRP) and adopted in Australia by the National Health and Medical Research Council (NHMRC) is 100 milliSieverts (mSv) in a five-year period with a maximum of 50 mSv in any one year. The *Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores (1987)* has now been replaced by the *Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)*. The Code of Practice recommends separating radiation workers into designated and non-designated, where designated workers are those who may be expected to receive an occupational radiation dose exceeding 5 mSv in one year. These workers are monitored more intensely than the non-designated workers. The radiation dose limit to the public from a practice such as uranium mining recommended by the ICRP is 1 mSv per year.

Consequently, there are three levels of radiation dose limits to distinguish, which specify the maximum allowable annual radiation dose from other-than-natural sources:

- the public (1 mSv)
- non-designated workers (5 mSv)
- designated workers (20 mSv).

Monitoring and research programs

ERA conducts statutory and operational monitoring of external gamma exposure to employees through the use of dose badges, radon decay products and long lived alpha activity (dust) in the air, and surface contamination levels. The statutory aspects of the programme are prescribed in Annex B of the Ranger Authorisation (0108-04) with results reported to the MTC members on a quarterly basis.

The ERA Radiation Monitoring Programme is undergoing review with input from the MTC Radiation Working Group. The Alligator Rivers Region Technical Committee has expressed support for the overall approach used in radiation monitoring and protection.

The Supervising Scientist conducts routine monitoring of the atmospheric pathways of radiation dispersion from Ranger and a number of radiation research projects for human and environmental protection.

2.6.2 Radiation at and from Ranger

Radiological exposure of employees

The three primary radiation exposure pathways to workers at Ranger are:

- Inhalation of radioactive dust
- Exposure to external gamma radiation
- Inhalation of radon decay products (RDP).

Mill maintenance workers and electricians receive approximately half of their dose from inhalation of radioactivity trapped in or on dust. The majority of the radiation dose received by employees in the mine and mill production is from external gamma radiation.

Table 2.11 shows the annual doses received by designated and non-designated workers in 2005, and a comparison with the average doses from the year before as reported by ERA. The average and maximum radiation doses received in 2005 were approximately 5% and 24% respectively of the recommended ICRP 60 annual dose limits.

TABLE 2.11 ANNUAL RADIATION DOSES RECEIVED BY WORKERS AT RANGER URANIUM MINE

	Annual dose in 2004		Annual dose in 2005	
	Average mSv	Maximum mSv	Average mSv	Maximum mSv
Non-designated worker	Not calculated[1]	0.7	Not calculated	1.1
Designated worker	1.0	4.6	1.0	4.8

1 A hypothetical maximum radiation dose to non-designated employees is calculated using the gamma exposure results of employees of the Emergency Services Group, and dust and radon results measured at the Acid Plant. Consequently, the dose is conservative and would exceed actual doses received by non-designated employees, and are hence considered maximum doses.

Radiological exposure of the public

The ICRP recommends that the annual dose received from a practice such as uranium mining and milling should not exceed 1 milliSievert (mSv) per year. This dose is on top of the radiation dose received naturally, which averages approximately 2 mSv per year in Australia, but typically varies between 1–10 mSv per year. Furthermore the dose limit applies to the sum of all pathways and practices, and the ICRP (1997) states in paragraph 6.2.1 that:

> to allow for exposures to multiple sources, the maximum value of the constraint used in the optimisation of protection for a single source should be less than 1 mSv in a year. A value of no more than about 0.3 mSv in a year would be appropriate.

There are two main pathways of potential exposure to the public during the operational phase of a uranium mine and Ranger is the main potential source of additional (to natural levels) radiation exposure to the community in the Alligator Rivers Region. The two pathways are the inhalation pathway, which is a result of dispersion of radionuclides from the mine site into the air, and the ingestion pathway, which is caused by the uptake of radionuclides into bushfoods from the Magela Creek system downstream of Ranger.

Inhalation pathway

Both ERA and SSD monitor the two airborne pathways:

- Radioactivity trapped in or on dust (or long lived alpha activity, LLAA)
- Radon decay products (RDP).

The main areas of habitation in the vicinity of Ranger and Jabiluka are Jabiru, Mudginberri and Jabiru East, consequently the SSD monitoring focuses on those three population centres in the region (see Map 3). Airborne RDP and LLAA concentrations are measured monthly and the results compared with ERA's quarterly atmospheric monitoring results from Jabiru and Jabiru East. Of the two airborne pathways RDP accounts for most of the dose received.

In 2005, Ranger calculated an average background RDP concentration of 0.081 µJ per m^3 and a mine derived concentration on top of the background of 0.03 µJ per m^3. Multiplied with the hours when the wind was blowing from the mine and background areas, respectively, one can calculate that approximately 0.78 mSv are received from the inhalation of natural background and 0.037 mSv (approximately 5% of the total) from mine derived radon.

Figure 2.14 shows Jabiru and Jabiru East RDP data and a comparison with ERA data from June 2003 up to June 2006. Both, RDP and LLAA concentrations measured by SSD and ERA show the expected seasonal trend with higher values during the dry and lower values during the wet season. Differences in sampling time and location may be the cause of the slight differences in RDP concentrations observed at Jabiru, with ERA's values being higher than values measured by SSD.

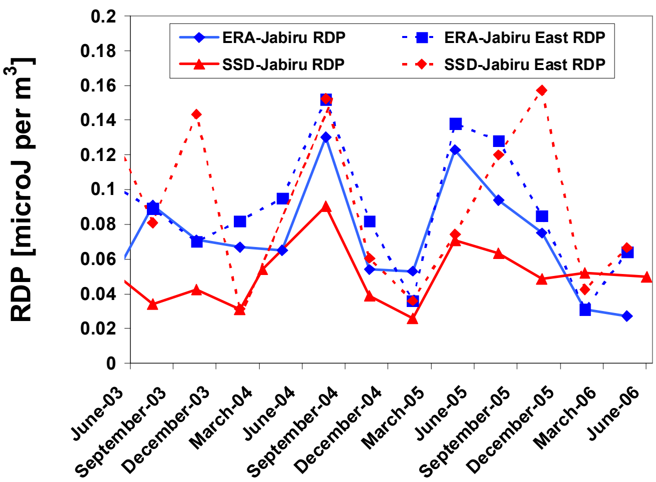


Figure 2.14 Radon decay product concentration measured by SSD and ERA in Jabiru and Jabiru East from June 2003 to June 2006

Table 2.12 shows the average annual doses received from the inhalation of radon decay products in the air, as calculated from the RDP concentration data from ERA and SSD (in brackets) at Jabiru. This is assuming an occupancy of 8760 hrs (one year) and a dose conversion factor for the public of 0.0011mSv per µJ·h/m³. Mine derived annual doses from the inhalation of radon progeny are shown, as calculated by ERA using a wind correlation model developed by ***eriss***, which correlates wind direction with airborne radon decay product concentration.

TABLE 2.12 RADON DECAY PRODUCT CONCENTRATIONS AT JABIRU AND JABIRU EAST, AND TOTAL AND MINE DERIVED ANNUAL DOSES RECEIVED AT JABIRU IN 2003–2005

		2003	2004	2005
RDP concentration [µJ/m³]	Jabiru East	0.075 (0.101)	0.103 (0.095)	0.097 (0.097)
	Jabiru	0.065 (0.043)	0.079 (0.063)	0.088 (0.052)
Total annual dose [mSv] Jabiru		0.63 (0.41)	0.76 (0.61)	0.85 (0.50)
Mine derived dose [mSv] at Jabiru		0.011	0.014	0.037

Ingestion pathway

Radium in Magela Creek waters is routinely monitored by both ERA and SSD and the limit for radium in Magela Creek is based on dietary uptake of the Aboriginal people downstream of the mine. Local Aboriginal people have expressed concerns about the radionuclide concentration in mussels from Mudginberri Billabong. Consequently, SSD routinely monitors the aquatic aspects of the ingestion pathway and bioacumulation monitoring samples have been collected each year and analysed for both radionuclides and heavy metals. The collections include yearly collections of mussels at Mudginberri (the potentially contaminated site) and Sandy Billabongs (control site) and fish being collected from these billabongs every two years.

^{226}Ra activity concentrations in mussel flesh from Mudginberri Billabong is higher than at the control site and the committed effective dose from the ingestion of 2 kg of mussels from Mudginberri Billabong is about four times the committed effective dose from the ingestion of the same amount of Sandy Billabong mussels. However, historical data show, that there is no indication of an increase of ^{226}Ra activity concentrations in mussel flesh in Mudginberri Billabong over time and thus the difference is unlikely to be mine-related. Reasons for the higher ^{226}Ra activity concentrations measured may include the mineralised nature of the Magela Creek catchment area and the associated naturally higher ^{226}Ra content in Mudginberri Billabong sediments and water as compared to Sandy Billabong, or differences in sediment particle size distribution. Furthermore, it has been shown that calcium levels influence radium uptake in mussels, and the higher calcium concentrations in Sandy Billabong water may decrease radium uptake in those mussels.

With the rehabilitation of Ranger there will be radiological protection issues associated with the land use by local Aboriginal people and a shift towards terrestrial food sources. These foodstuffs include both terrestrial animals and plants. Over the last 25 years, SSD has gathered radiological concentration data on bush foods throughout the Alligator Rivers Region in the Northern Territory. These data have been used to replace IAEA default radionuclide concentration factors with locally derived values, providing a more reliable estimate of ingestion doses.

2.6.3 Jabiluka

Radiological exposure of employees

The Jabiluka Authorisation was revised in July 2003 and the statutory requirement of quarterly reporting of radiological monitoring data for Jabiluka was removed. The current Authorisation requires reporting of radiation monitoring data only if any ground disturbing activities involving radioactive mineralisation occur on site. No ground disturbing activities took place during this reporting period.

Radiological exposure of the public

Although there were no activities reported at the Jabiluka mine site, the population group that may, in theory, receive a radiation dose due to future activities at Jabiluka is a small community approximately 10 km south of Jabiluka at Mudginberri, comprising around 60 individuals.

The Supervising Scientist has a permanent atmospheric research and monitoring station at Four Gates Rd radon station a few kilometres west of Mudginberri (see Map 3). Radon decay product (RDP) and long-lived alpha activity (LLAA) concentrations are measured there on a monthly basis. In addition, radon gas is continuously measured at the station with radon data being recorded every 30 minutes.

Figure 2.15 shows the quarterly averages of radon decay product and long-lived alpha activity concentrations measured at Four Gates Rd radon station by SSD up to June 2006. Radon decay product and long lived alpha activity concentrations are small and comparable with natural background levels. The average airborne radionuclide concentrations measured in 2005 would translate into an annual total effective dose, including natural background, of 0.52 mSv from RDP and less than 0.01 mSv from LLAA. Only a small fraction of these doses would be due to mine-derived radionuclides.

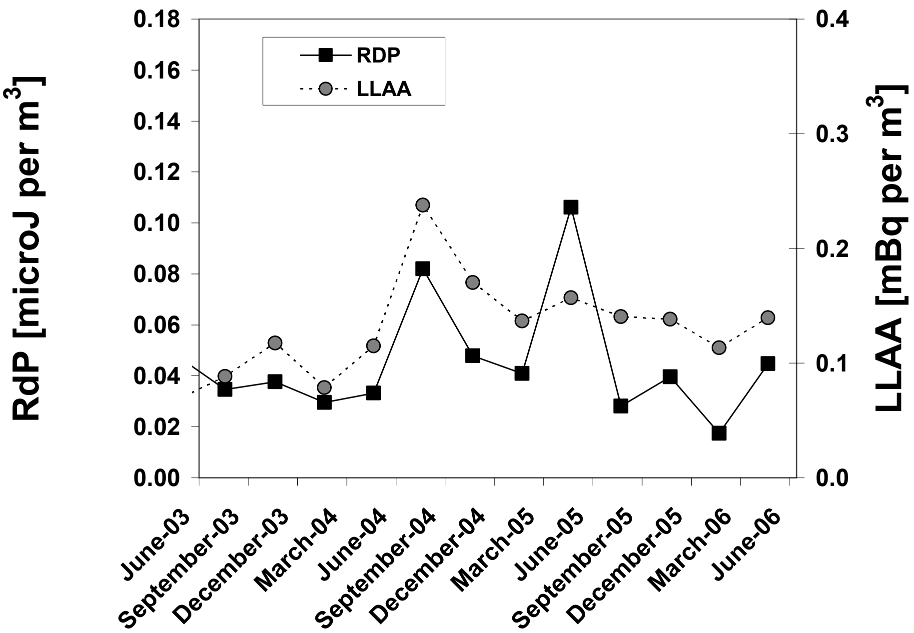


Figure 2.15 Radon decay product (RDP) and long-lived alpha activity (LLAA) concentrations measured at SSD's Mudginberri Four Gates Rd radon station

3 ENVIRONMENTAL RESEARCH AND MONITORING

The *Environment Protection (Alligator Rivers Region) Act 1978* established the Alligator Rivers Region Research Institute (ARRRI) to undertake research into the environmental effects of uranium mining in the Alligator Rivers Region. The scope of the research programme was widened in 1994 following amendments to the Act. ARRRI was subsequently renamed the Environmental Research Institute of the Supervising Scientist (***eriss***).

The work of ***eriss*** consists of two main areas:

- monitoring and research for the protection of people and the environment, focusing on the effects of uranium mining in the Alligator Rivers Region;
- research on the sustainable use and environmental protection of tropical rivers and their associated wetlands.

Six thematic areas (based primarily on geographic provenance) have been identified by the Alligator Rivers Region Technical Committee (ARRTC) as being the Key Knowledge Needs to ensure the current and future protection from uranium mining of the environment of the Alligator Rivers Region. The Key Knowledge Needs appear at Appendix 1.

For each of the thematic areas the key research needs relating to monitoring, closure and rehabilitation for current (Ranger and Jabiluka), rehabilitated (Nabarlek) and legacy (South Alligator River Valley) sites were identified and prioritised. These research topics provide the basis for defining the core ***eriss*** project activities to be carried out from year to year. The content and outcomes of the research programme are assessed annually by ARRTC, whose charter and activities are described in detail in Chapter 4 of this Annual Report.

eriss contributes to the addressing of each of the Key Knowledge Needs by applying a broad range of scientific expertise across the research fields of:

- Ecotoxicology;
- Environmental radioactivity;
- Hydrological and geomorphic processes;
- Monitoring and ecosystem protection;
- Biophysical pathways and ecological risk assessment.

A selection of highlights from each of these fields of endeavour is presented here.

In particular, the water quality monitoring programme has been considerably enhanced with the installation of continuous monitoring equipment for pH, electrical conductivity and turbidity in Magela Creek upstream and downstream of the mine site. Continuous, time-series water quality data will offer a more complete description of the fluctuations in quality that are missed by weekly grab sampling, such as effects caused by variation in flow.

An extended report has been provided of the outcomes of a benchmark landscape environmental risk assessment of threats and pressures to the Magela floodplain. This assessment is the final part of the 'Landscape-scale analysis of impacts' programme, established in 2002 following the report of the International Science Panel into the potential impacts of uranium mining at Jabiluka and Ranger on the World Heritage values of Kakadu National Park. The objective of this work was to help to clearly differentiate the relative risks posed by mining and non-mining impacts, whilst contributing to a broader assessment of the World Heritage values of the Park.

A major programme of research on characterisation of northern tropical rivers, and assessment of risk from actual and potential threats, is being carried out under the framework of the Tropical Rivers Inventory and Assessment Project (TRIAP). The work is funded by Land and Water Australia and the Natural Heritage Trust and is a collaborative effort between ***eriss***, James Cook University and the University of Western Australia, with additional involvement of the University of Wageningen in the Netherlands. The scope and current status of this project are described below.

Further details on research outcomes are published in journal and conference papers and in the Supervising Scientist and Internal Report series. Publications by Supervising Scientist Division staff in 2005–06 are listed in Appendix 2. More information on the Division's publications, including the full list of staff publications from 1978 to the end of June 2006, is available at www.deh.gov.au/ssd/publications.

3.1 Toxicity of treated pond water from Ranger uranium mine to five local freshwater species

Several factors, including a number of above average wet seasons, the need to keep the base of Pit 3 dry for mining and the removal of Djalkmara Billabong (a wetland previously used to hold and polish run-off from the minesite prior to controlled release into Magela Creek), prompted Energy Resources of Australia Ltd (ERA) to consider alternative methods for the reduction of onsite (pond) waters at the Ranger mine. Proposals for the treatment of pond water were discussed with stakeholders throughout 2004–05. Whilst a pilot plant and laboratory experiments demonstrated through water chemistry analysis that the quality of the treated pond water would likely be suitable for release, it was agreed that for additional assurance, SSD would undertake ecotoxicological testing on treated pond water (permeate) from the newly commissioned plant prior to release into the Corridor Creek wetlands.

ERA completed commissioning the pond water treatment plant in December 2005 and provided SSD with assurance that the permeate being produced at the time was representative of future outputs, and thus, ready for ecotoxicological testing. SSD staff from the Jabiru Field Station sampled the permeate on 12 December 2005 and ERA staff delivered the sealed sample bottles to the SSD Darwin laboratories for testing the same day.

Five local organisms, a unicellular alga (*Chlorella* sp.), macrophyte (duckweed; *Lemna aequinoctialis*), cnidarian (*Hydra viridissima*), crustacean (water flea; *Moinodaphnia macleayi*) and a fish species (*Mogurnda mogurnda*), were exposed to concentrations of

30%, 44%, 67% and 100% treated pond water permeate and a Magela Creek water control. All dilutions of the permeate were undertaken using freshly collected Magela Creek water.

Exposure to the treated pond water permeate had no effect on the growth of the two plant species and the hydra, nor on the survival of the fish. The water flea (*M. macleayi*), however, was shown to produce significantly less offspring when exposed to the two highest concentrations of permeate (67% and 100%) (Figure 3.1). Thus, the Lowest-Observed-Effect-Concentration (LOEC) and No-Observed-Effect-Concentration (NOEC) were 67% and 44% permeate, respectively.

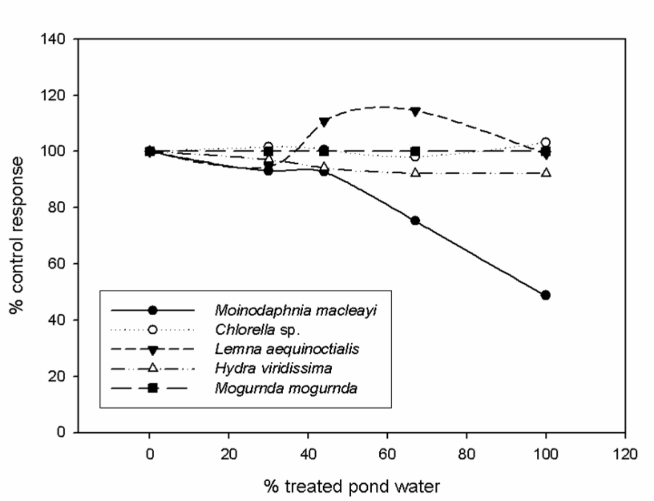


Figure 3.1 Response of five local species to treated pond water permeate. Note that the elevated response observed in the *L.aequinoctialis* test was found to be not significantly different from the control.

Chemical analysis of the treated pond water found that all metals, other than uranium, were below or around the limits of detection and hence unlikely to be contributing to the observed toxicity. The 4 µg/L of uranium in the treated pond water was less than what has been shown to cause toxicity to *M. macleayi* in Magela Creek water.

However, natural Magela Creek water typically contains 2–8 mg/L dissolved organic carbon, which has been shown to ameliorate uranium toxicity. A notable characteristic of the permeate was that dissolved organic carbon was below the detection limit (<1 mg/L). The absence of dissolved organic carbon in the permeate may therefore result in greater uranium toxicity to *M. macleayi*. An alternative hypothesis is that the absence of dissolved organic carbon and possibly other essential ions from the permeate may result in a reduction in reproduction and survival of *M. macleayi* as a result of nutrient/ion deficiencies.

It is planned to test the above hypotheses by measuring the toxicity of uranium in a 'synthetic' Magela Creek water that simulates the inorganic composition of the water but contains no dissolved organic carbon, and to compare the results to experiments conducted in natural Magela Creek water.

Regardless of the outcome of this planned testwork, the response of *M. macleayi* to the treated pond water was only mild to moderate, and any potential for an effect on downstream biota could be avoided by diluting the permeate as it is released off-site. An acceptable dilution factor of one part permeate to 23 parts Magela Creek water (that is, 4.4% permeate) was calculated using the 'safety factor' approach outlined in the ANZECC/ARMCANZ (2000) Water Quality Guidelines. The preferred distribution-fitting method for deriving acceptable concentrations/dilutions was inappropriate in this case because only one of the five species tested responded to the permeate.

The one in 23 dilution factor has been adopted by ERA as one of the primary criteria for the release of treated pond water to Magela Creek, and should be easily achievable through the wet season period.

An analogous approach to the testing of treated mine process water is expected to take place once the plant has been commissioned for this grade of water in late 2006.

3.2 Toxicity of uranium to two local freshwater species

Historically, uranium has been the primary toxicant of concern for the aquatic ecosystems downstream of the Ranger mine. Consequently, many ecotoxicological studies have been undertaken to assess the toxicity of uranium and the influence of various environmental variables (for example, pH, alkalinity, water hardness, and dissolved organic carbon) on the toxicity of uranium to local aquatic species. In total, nearly 20 local freshwater species have been assessed, comprising one plant, two cnidarian, one mussel, five crustacean and ten fish species.

The majority of data for these species, however, are derived from acute toxicity rather than chronic toxicity test endpoints. The latter are required for the derivation of *high reliability* water quality guidelines. Chronic data exist for only five of those species tested, namely the green alga, *Chlorella* sp. (72 hour growth inhibition), the cladoceran, *Moinodaphnia macleayi* (three brood reproductive inhibition), the green hydra, *Hydra viridissima* (96 hour population growth inhibition), the chequered rainbowfish, *Melanotaenia splendida inornata* (seven day survival and growth) and the purple-spotted gudgeon, *Mogurnda mogurnda* (seven day exposure/seven-day post-exposure survival and growth).

Based on a cumulative probability (loglogistic) distribution of no-observed-effect-concentration (NOEC) data for these five species, which range from 18 to 810 μg/L, a site-specific water quality trigger value for uranium of around 6 μg/L has previously been derived. This value represents the concentration that should be protective of 99% of species with 50% confidence. Notably, the trigger value has high uncertainty surrounding it, as demonstrated by the 95% confidence limits of 0.3–103 μg/L. Moreover, two of the five species represented are fish, which appear to be generally less sensitive to uranium than invertebrate and algal species. Thus, in order to increase confidence in the site-specific trigger value, chronic toxicity data for additional species, ideally, representing additional taxonomic groups and trophic levels, were required.

The tropical duckweed, *Lemna aequinoctialis*, is a small aquatic floating macrophyte that occurs in lentic and low-flow waterbodies throughout northern Australia, including the Alligator Rivers Region. The freshwater snail, *Amerianna cumingi*, is a hermaphroditic snail that occurs in lentic (pond) and lotic (flowing) waterbodies within a restricted range that encompasses the Alligator Rivers Region. Both species are of high ecological importance as food sources for other organisms and in their respective roles as a primary producer and detritivore. Toxicant effects on these species are assessed in the laboratory by observing the growth of exposed *L. aequinoctialis* and changes in the egg production of *A. cumingi* over 96 hours and comparing them with individuals of the same species maintained in clean water.

In order to accurately calculate exposure concentrations throughout the tests, it was essential that the fate of uranium in the test system was understood. Adsorption of uranium to the test container can reduce the uranium dissolved in the test waters and result in the organisms being exposed to a lower than expected concentration. Without quantifying this loss, the toxicity of uranium could be significantly underestimated. It is important to note that, in addition to adsorption of uranium to the test containers/tubes, losses of uranium from the test waters can also be due to uptake and accumulation by the test organisms, or by adsorption on to slimes or exudates produced by the organisms.

As the uptake of uranium by the organisms represents the exposure to uranium, the relative proportions of uranium 'lost' from the test waters due to (i) adsorption to test containers/tubes and (ii) accumulation by the test organisms need to be determined before exposure concentrations can be appropriately adjusted. To address this, uranium concentrations were measured in test waters periodically throughout each test and in the duckweed/snail tissues at the conclusion of a test.

A small but significant loss of uranium (8–18%, $P < 0.05$) was detected in the *L. aequinoctialis* test system over the four day duration. Samples taken at 48 hours indicated that the majority of the uranium was being lost within the first half of the test, after which uranium concentrations remained relatively stable. When integrated over a four day period (by calculating the area under the curve) these losses ranged from 6–13%, with the proportion being positively related to the initial uranium concentration of the water. Plant tissue measurements indicated that uranium uptake by the plants accounted for approximately 50% of the uranium 'lost' from the test waters. As the overall 'loss' was quite small and a significant proportion of this was shown to be taken up by the plants, it was decided that no adjustment of the exposure concentrations would be required.

A more substantial loss of uranium was observed from the test waters in the snail (*A. cumingi*) tests, with samples taken 24 hours after each water change containing 30–70% less uranium than at the start of the test. Figure 3.2 shows an example of uranium loss for one of the uranium treatments over the 96 hour test duration. Because waters are changed daily during *A. cumingi* tests, and the loss of uranium over each 24 hour period was found to be gradual and to decrease in magnitude over the duration of the test, it was essential that the final losses were integrated over each 24 hour period, and then over the entire 96 hours before calculating the exposure concentrations. Using data from three different experiments, and regardless of whether total or dissolved uranium concentrations were used, it was found that uranium loss over the entire test duration was approximately 25% of the uranium concentration at the start of the test.

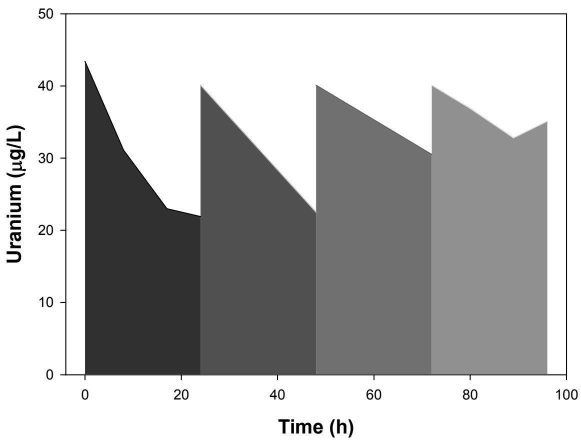


Figure 3.2 Loss of uranium in an *A. cumingi* test solution initially containing 43 μg/L uranium (measured). Each shaded bar represents a 24 hour period between water renewals.

An experiment designed to address the uptake of uranium by the snails was being conducted at the time of preparation of this summary, and hence the results could not be reported at this time. Therefore, the toxicity results reported below are based on uranium concentrations adjusted according to the total losses measured (that is, corrected concentration is 75% of the initial uranium concentration). Should a significant proportion of the 'lost' uranium be found to have been taken up by the snails, then the exposure concentrations will be adjusted accordingly.

The effect of uranium exposure on the growth of *L. aequinoctialis* is shown in Figure 3.3. An IC_{10} (concentration resulting in a 10% inhibition of egg production) of 250 (lower/upper 95% confidence limits: 207/288) μg/L U was calculated from these data. The IC_{10} is generally considered to be a measure of an 'acceptable' concentration (ie, one that will not result in unacceptable ecological effects at the population level). The IC_{50} could not be calculated, but was >2850 μg/L U. When compared to the other local freshwater species that have been assessed for their sensitivity to U, *L. aequinoctialis* was found to be less sensitive than most. Only the two fish species, the northern trout gudgeon (*Mogurnda mogurnda*) and the chequered rainbowfish (*Melanotaenia splendida inornata*), have been reported to be less sensitive.

The effect of uranium exposure to *A. cumingi* is shown in Figure 3.4. Based on four definitive tests, *A. cumingi* was found to be highly sensitive to U, with an IC_{10} of 22 (lower/upper 95% confidence limits: 6/46) μg/L U and an IC_{50} of 250 μg/L U (an upper confidence limit could not be calculated). Based on these data, *A. cumingi* appears to be more sensitive to U than most other species that have been tested. Of the five species already used to derive the current U TV, only the water flea, *Moinodaphnia macleayi*, has been found to exhibit similarly high sensitivity to U. It is noteworthy that although the within-treatment responses of *A. cumingi* tend to be inherently highly variable (as evidenced by the large error bars in Figure 3.4), the between-test concentration-response relationships are quite consistent (data not shown here).

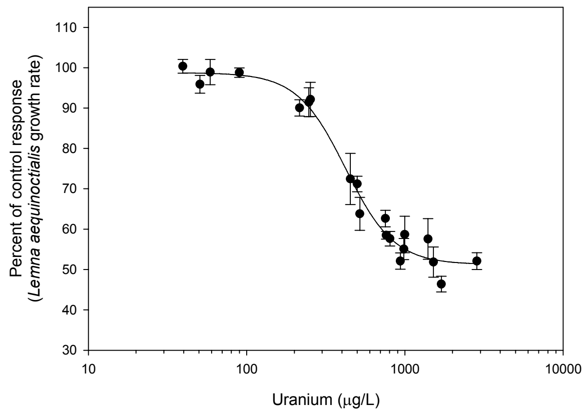


Figure 3.3 Effect of uranium on the growth rate of *L. aequinoctialis*, expressed as a percentage of the control response (Control growth rates for the three tests were 0.43, 0.42 and 0.45, respectively). The fitted curve represents a 4 parameter loglogistic model (r^2 = 0.98, n = 20, P<0.0001).

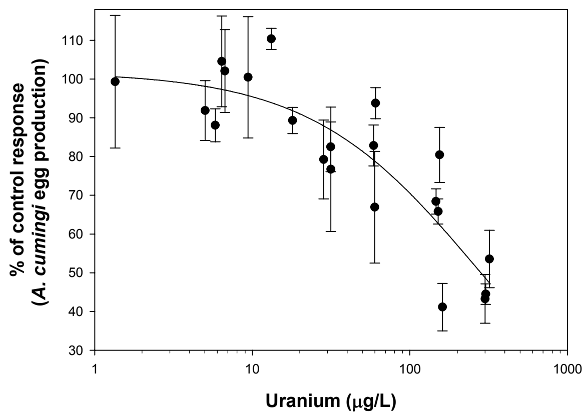


Figure 3.4 Effect of uranium on the egg production of *A. cumingi*, expressed as a percentage of the control response (Control egg numbers for the three tests were 198, 133 and 241, respectively). The fitted curve represents a 3 parameter loglogistic model (r^2 = 0.75, n=21, *P*<0.0001).

3.3 Bioaccumulation of radionuclides in terrestrial plants on rehabilitated landforms

3.3.1 Background

Over the last 25 years radiological data have been gathered on bush foods throughout the Alligator Rivers Region of the Northern Territory. Early studies were focused on aquatic animal and plant species due to the identified importance of the aquatic transport pathway for bioaccumulation of radionuclides in bush foods, particularly during the operational phase of uranium mining operations in the region. However, the terrestrial food component also needs to be included in a complete radiological dose assessment model.

Following rehabilitation of the Ranger mine site, food sources growing on the footprint of the former operational area may become an increasing proportion of the diet of the local indigenous people. It can reasonably be assumed that the highest dose rates to humans will be received from the consumption of foods growing in the vicinity of a contamination source and this aspect needs to be addressed as a component of the radiological protection issues associated with land use by local Aboriginal people. Measurements of the concentrations of radionuclides in the fruits and tubers of terrestrial plants growing in soils spanning a range of concentrations of radionuclides are thus required to provide guidance for the development of soil quality closure criteria. and to enable a radiological risk assessment to be carried out for the rehabilitated site at Ranger.

The issue of radiological content of bush foods also needs to be addressed and assessed for the rehabilitated Nabarlek mine and the abandoned uranium mines in the South Alligator Valley. The dose assessment needs to be site specific, and the radiation dose model has to include local habits and human land use, and land use expectations. This information needs to be coupled with the data being collected and analysed on estimates of terrestrial bush food consumption by local Aboriginal people and site occupancy estimates to develop robust dose assessment models for these locations.

3.3.2 Results

An earlier investigation of uranium series radionuclides in native fruits and vegetables has shown that ^{226}Ra and ^{210}Po make the highest percentage contribution in fruits and yams to committed effective dose from the ingestion of long lived members of the uranium decay series (Table 3.1). This is primarily due to the relatively high dose conversion factors of these two radionuclides. Consequently, subsequent research efforts have focussed on determining concentration factors for ^{226}Ra and ^{210}Po in terrestrial plants.

TABLE 3.1 ESTIMATED PERCENTAGE CONTRIBUTION TO COMMITTED EFFECTIVE DOSE FROM THE INGESTION OF FRUITS AND YAMS FOR LONG-LIVED MEMBERS OF THE URANIUM DECAY SERIES

Species	^{238}U	^{234}U	^{230}Th	^{226}Ra	^{210}Pb	^{210}Po
Fruits	0.5	0.5	1.9	37	17	42
Yams	0.1	0.1	0.3	50	17	33

As part of the development of a dose assessment model, a knowledge management tool called the Bushtucker Spatial Information System (SIS) has been developed to collate and integrate the historical radiological data. The results can be graphically displayed together with contextual data such as satellite imagery, photographs and maps (Figure 3.5). The system has facilitated a quality assessment of the available radionuclide data, recent and historic, aquatic and terrestrial, and has assisted in identifying gaps in knowledge about radionuclide uptake in flora and fauna. It is also highlighting the lack of bush food radionuclide information currently available worldwide.

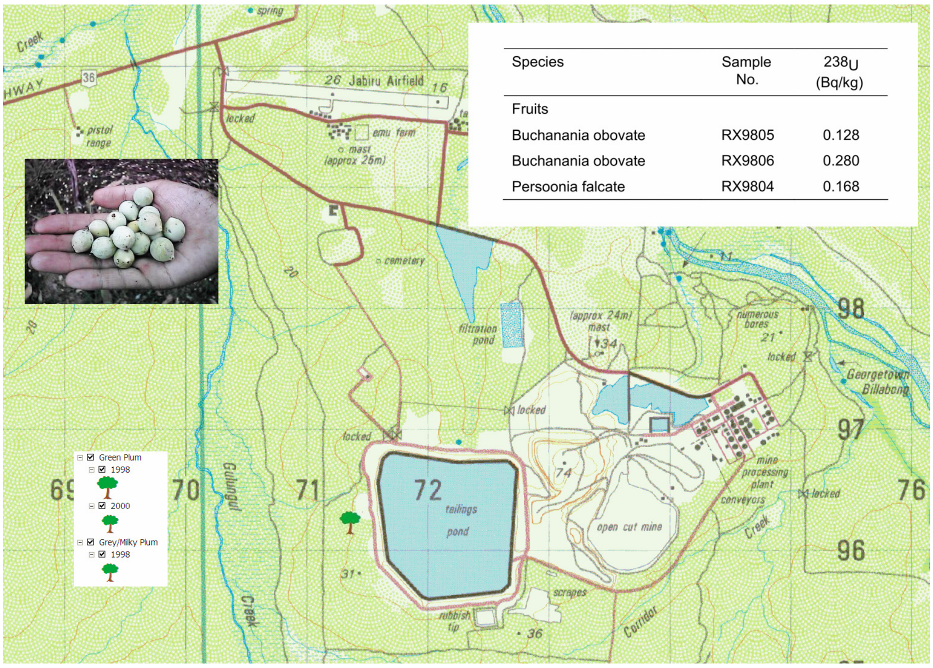


Figure 3.5 Screen shot of the bushtucker SIS showing uranium activity concentrations in terrestrial bush food samples collected in 1998 around the Ranger mine site

The Bushtucker SIS is of particular interest and importance to the local Aboriginal people who rely on traditional bush food sources, as it provides reassurances to people that bush food sources are safe to eat. It is also being used as a communication tool to graphically display and simplify the complex results of radionuclide analyses of food and other associated items in the Region.

The data gathered over the years has made it possible to replace some International Atomic Energy Agency (IAEA) default radionuclide concentration factors for temperate environments with locally derived radionuclide concentration factors for the unique flora and fauna in the Top End region of the Northern Territory. Applying IAEA reference values for fish concentration factors for instance, overestimates thorium and ^{210}Pb uptake and thus the effective dose to people from the consumption of fish in the Alligator Rivers Region. The locally derived values provide a more accurate and realistic estimate.

Gaps identified in our knowledge of radionuclide uptake in terrestrial flora and fauna have resulted in the development of a strategic sampling design that focus future research effort on better defining radionuclide uptake pathways for terrestrial food items. Terrestrial bushtucker samples will continue to be collected and analysed from the Ranger mine site, the rehabilitated Nabarlek mine and the South Alligator Valley.

3.4 Surface water transport of uranium in the Gulungul Creek catchment

3.4.1 Background

Gulungul Creek lies to the west of Ranger mine and flows north to join Magela Creek, a tributary of the East Alligator River. Part of the mine's infrastructure, notably the tailings dam, lies within the Gulungul Creek catchment (Figure 3.6). Flow in the creek occurs mostly in the wet season, during which time it is made up of the main channel and numerous side channels and tributaries, three of which flow from areas possibly influenced by the Ranger mine.

In January 2004, samples taken for weekly routine monitoring recorded higher concentrations of uranium at Gulungul Creek downstream (GCDS) compared to Gulungul Creek upstream (GCUS). This difference in concentrations was greater than in previous years, and coincided with lower pH values, higher EC values and higher sulfate concentrations at the downstream site.

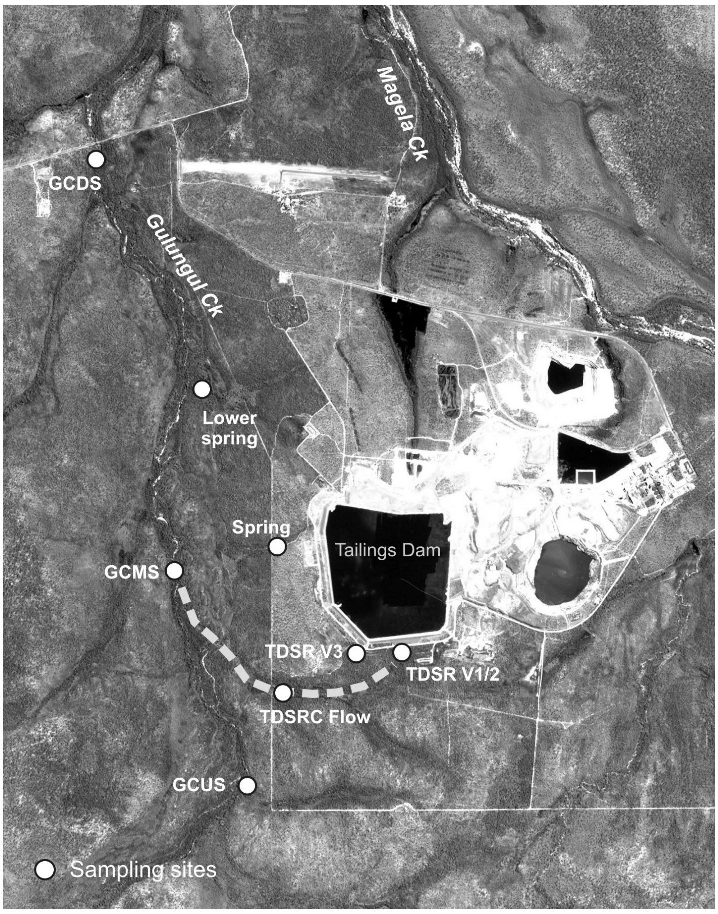


Figure 3.6 The Gulungul catchment and project sampling sites

Whilst the uranium concentrations were more than one order of magnitude less than the limit value of 6 µg/L established for 99% aquatic ecosystem protection, they were comparable to the focus trigger value for G8210009 in Magela Creek. An investigation was therefore initiated in the 2004–05 wet season to identify the source of the increase.

Samples of surface waters were collected during 2005 in (i) February, several days after a four day period of heavy rain that resulted in the flooding of the creek; (ii) in March, towards the middle of the wet season when the creek was reasonably full; and (iii) in May, towards the end of the wet season when water flow was much diminished and sampled tributaries had dried up.

Sites sampled were the upstream (GCUS), downstream (GCDS) and midstream (GCMS) sites and several locations in the vicinity of GCMS – downstream at 'GCMS–10 m', 'GCMS–50 m' and upstream at 'GCMS+50 m' and 'GCMS+150 m'. Additional samples were taken from V-notches (TDSRV 1–3) located upstream of the tailings dam southern road culvert (TDSRC), the overland flow from TDSRC (TDSRC flow), a spring tributary flow (Spring) and from a swampy area produced by another suspected spring (Lower Spring) (Figure 3.6).

Trace concentrations of heavy metals and uranium were measured using the technique of Inductively Coupled Plasma Mass Spectrometry (ICPMS). Activity ratios of uranium isotopes were measured via alpha spectrometry to determine whether there was a difference in upstream and downstream activity ratios that may enable discrete contributing sources to be identified.

3.4.2 Results

Uranium concentrations

Figure 3.7 shows the routine weekly uranium monitoring results for GCUS and GCDS, the difference between downstream and upstream uranium concentrations and the catchment rainfall measured at Jabiru Airport during the 2003–04 and 2004–2005 wet seasons.

Differences between downstream and upstream uranium concentrations in Gulungul Creek during the first part of the 2004–05 wet season were less pronounced than in the previous wet season. Although there is no direct correlation between rainfall and uranium concentration over these wet seasons, it appears that the cumulative effect of heavy rain influences the difference in uranium concentration measured upstream and downstream of the mine. Rainfall was reasonable heavy and constant during December–January (582 mm in 25 days) leading up to the uranium increase at GCDS in the 2003–04 wet season. In the 2004–05 wet season, rainfall was lower and less frequent, apart from two large rain events in early January and February 2005.

Table 3.2 shows the spatial distribution and the percentage increases in uranium concentration along Gulungul Creek measured in 2005. The data indicate that during the peak wet season (February and March), much of the increase in uranium concentration between GCUS and GCDS had already occurred at GCMS. The disparity in uranium input over time indicates that uranium input into the creek may be dependent on specific hydrological conditions. This is supported by the 2005–06 wet season data which exhibit a similar uranium spike as the 2003–04 data and a similar rainfall pattern.

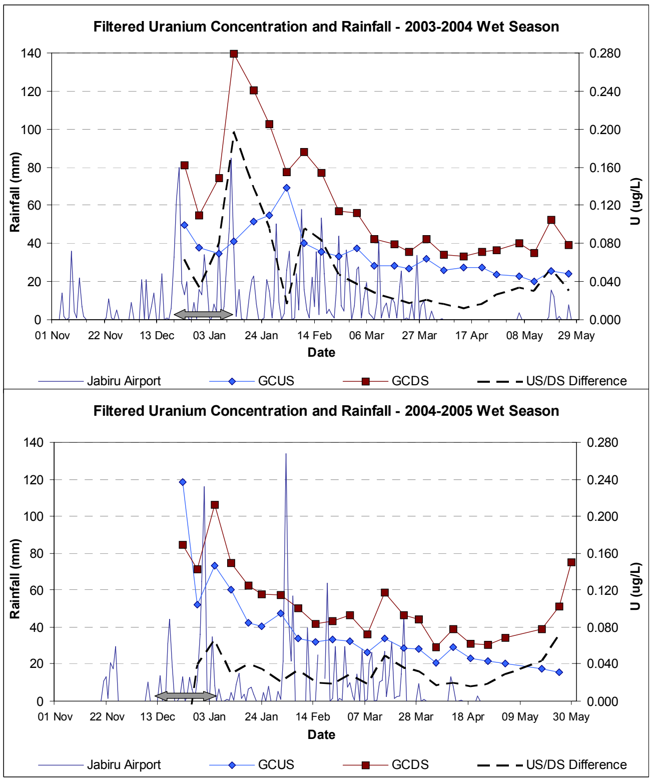


Figure 3.7 Uranium concentration and rainfall time series data in the Gulungul Creek catchment

TABLE 3.2 PERCENT INCREASE IN FILTERED URANIUM CONCENTRATION IN GULUNGUL CREEK IN 2005

Site	Dist (m)	Filtered U (µg/L)			Increase from GCUS to GCDS (%)			Increase above GCUS (%)		
		08/02	18/03	10/05	08/02	18/03	10/05	08/02	18/03	10/05
GCUS	0	0.068	0.060	0.045	0	0	0	0	0	0
GCMS +150 m	1950	ns	ns	0.052	–	–	21	–	–	17
GCMS +50 m	2050	0.087	0.093	0.053	58	74	23	28	56	19
GCMS -10 m	2215	ns	0.105	0.054	–	100	26	–	76	22
GCMS -50 m	2255	ns	ns	0.055	–	–	27	–	–	23
GCDS	6520	0.101	0.105	0.082	100	100	100	48	76	85

ns: not sampled

Uranium isotope activity ratios ($^{234}U/^{238}U$) measured in Gulungul Creek samples from 2004 and 2005 suggest input at GCMS of uranium that has an activity ratio of close to one. This ratio is similar to the ratios measured in the flow from the tailings dam southern road culvert (TDSRC) that enters Gulungul Creek in the vicinity of GCMS and reflects a ratio typical for a mine-related source.

Soil as a possible source

Soil samples were collected in the 2005 dry season along the tributary indicated by the dashed line in Figure 3.6. Uranium concentrations in the soils were found to decrease by almost by three orders of magnitude from the tributary source close to the tailings dam, to where it enters Gulungul Creek, indicating substantial attenuation. Leaching tests show that much of the uranium is able to be readily leached from the dry soils into water.

The previously identified large areas of black soils in the Gulungul catchment thus act as both a sink and a source of contaminants from one season to the next. During the initial phase of the following wet season the metals leached out of the black soils in the vicinity of GCMS are flushed down into Gulungul Creek causing a small spike in concentrations of uranium and a decrease in uranium isotope activity ratios in the vicinity of GCMS. The height of the concentration spike seen at GCMS depends on the ratio of flows in the tributary and Gulungul Creek at the time that this flush occurs.

3.4.3 Future work

A watching brief will be kept on the early wet season concentrations of uranium in Gulungul Creek. The 2006–07 wet season will be of especial interest given the major works currently underway to raise the height of the tailings dam wall. Previous experience has shown that the rock used to armour the walls and to toe load the base of the walls contains leachable uranium.

3.5 Development of a spectral library for minesite rehabilitation assessment

3.5.1 Background

An important component of mine site monitoring and rehabilitation assessment includes an analysis of revegetation success. Traditionally, field-based measurements have been used and data collected that can be used to compare vegetation communities between rehabilitated and reference sites. The disadvantage of these field-based assessments are that they are labour intensive and they sample only a small proportion of the area affected by mining (at field point locations, along transects or within quadrants). The qualitative nature of many methods may also cause problems with consistency when used by different assessors.

Remote sensing techniques are routinely applied for landscape-scale applications. By contrast, minesites are typically characterised by relatively small areal extents, and variability and short range variation in surface cover as a result of the disturbed environment. For these reasons, minesite monitoring and rehabilitation assessment require high spatial and/or spectral and radiometric resolutions.

While very high spatial resolution satellite data have been used contextually to identify temporal changes in minesite vegetation cover, individual species identification has been limited by the resolution of broad multispectral bands. Currently, hyperspectral data with suitable resolving power are limited to airborne platforms. Knowledge of the reflectance characteristics of vegetation species over time is required to develop an understanding of the most appropriate spatial, spectral and temporal scales for revegetation assessment. The Supervising Scientist Division aims to understand the spectral response of vegetation species which are important for mine site rehabilitation assessment, including introduced weeds and natives, in order to make recommendations for monitoring method(s) most appropriate for a given application.

The following pragmatic questions provided the basis for the design of this research project. What are the fortnightly spectral responses of ground cover vegetative species? Can ground-cover vegetative species be distinguished using ground-based reflectance spectra, and if so, what spectral resolution is required? At what vegetative stage is maximum separability detected and is there a phenological time when species are confounding? What are the implications for hyperspectral imaging through-out the year?

To answer these research questions, the research design needed to ensure that the spectral response is not confounded by extraneous factors such as localised changes in atmospheric conditions. With a well designed approach to collecting field spectral measurements and metadata, extraneous factors can be accounted for, accurate processing of spectra can be performed and the first calibrated and validated database of spectra relevant to the mine environment in the Top End can be developed.

3.5.2 Method

Sites with homogenous dense vegetation cover that were unlikely to be regularly disturbed from threats such as fire, development or mowing were located and replicate plots established with support from Commonwealth and Northern Territory Government agencies and private industry. Priority species of plants and weeds were identified with stakeholders.

Dense and homogenous stands of plants selected include pasture species such as Para grass (*Urochloa mutica*), Guinea grass (*Urochloa maxima*), Jarrah grass (*Digitaria milanjiana*), Tully grass (*Urochloa humidicola*), Joint Vetch (*Aeschynomene americana)* and Stylo species (*Stylosanthes* spp*.).* Introduced weeds include Snakeweeds (*Stachytarpheta* spp.), Hyptis (*Hyptis sauveolens*), Mission grasses (*Pennisetum* spp.), wild passionfruit (*Passiflora foetida*), Calopo (*Calopogonium mucunoide*), Gamba grass (*Andropogon gayanus*), Couch grass (*Cynodon dactylon*), Rhodes grass (*Chloris sp.)*, Gambia Pea (*Crotalaria goreensis*), Sicklepod (*Senna obtusfolia*), and native grasses (*Heteropogan* spp. *Sorghum stipodeum, Panicum mindanese* and *Schizachyrium fragile*). Reflectance characteristics of weed and native ground covers over the visible to shortwave infrared (350–2500 nm) are being measured fortnightly from permanent plots around the greater Darwin region using a FieldSpec-FR Analytical Spectrometer.

3.5.3 Results

Standards for the collection, documentation and storage of spectral data and metadata have been developed and implemented. These standards enable a consistent and repeatable method that minimises the influence of extraneous factors in spectral measurement. Figure 3.8 shows the metadata recorded with each spectral measurement. In addition to obtaining meaningful spectra at the time of data collection, concurrently documenting the optical, local environmental, scalar and physical variables will aid in quantifying changes through time at each site.

The temporal measurements of ground-based spectra will provide information on separability likeliness, and plant mixtures and vegetation-soil mixtures will be able to be modelled. This information is useful not only to the local mine environment, but also for weed management in the broader Kakadu National Park, assessing introduced 'weedy' pastures in nearby Arnhem Land, and any remote sensing feasibility study involving weed and native covers.

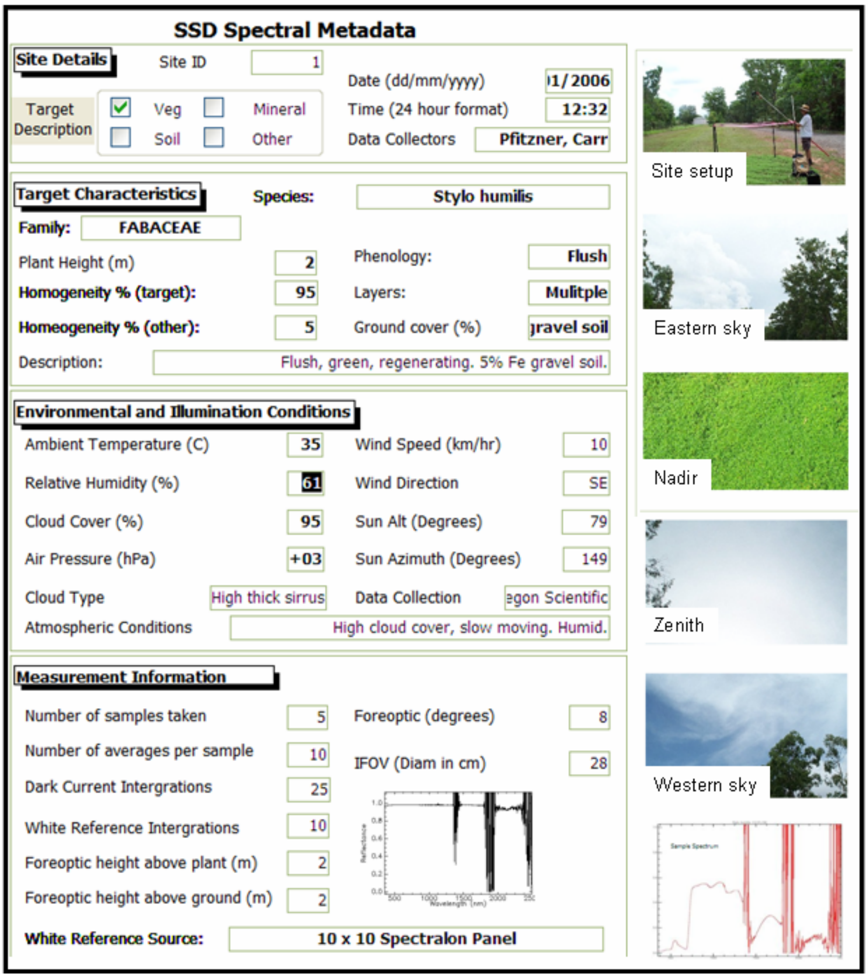


Figure 3.8 SSD's Spectral Database concept – spectral data and metadata records

The acquisition of this high resolution spectral library is proceeding concurrently with the new generation of hyperspectral sensors being implemented on satellite platforms, such as the Compact High Resolution Imaging Spectrometer (CHRIS) flown on the European Space Agency's Project for On-Board Autonomy (Proba) satellite and the German Space Agency's proposed Environmental Mapping and Analysis Programme (EnMAP). The library will provide a strong quantitative basis for translating the remotely sensed data from these platforms to practically useful information for assessing vegetation distribution both on minesites and at a broader regional scale in the northern tropics.

3.6 Monitoring fine suspended sediment movement within the Gulungul Creek catchment

As part of the data set required to assess the success of rehabilitation of the Ranger mine, the baseline loads of suspended sediment in the catchment of Magela Creek need to be quantified. The first stage of this work involves the measurement of suspended sediment loads in Gulungul Creek, a small left bank tributary of Magela Creek (Figure 3.6). Given the location of Gulungul Creek and the potential for erosion and transport of sediment into Magela Creek, the suspended sediment transport characteristics in Gulungul Creek are being investigated before the start of rehabilitation works at the mine site. Of particular importance is the silt/clay fraction (mud) component of suspended sediment, as nutrients and contaminants, including heavy metals and radionuclides, are primarily transported in association with fine suspended particulate matter.

Streamflow and mud concentration data are currently monitored at two gauging stations within the Gulungul Creek catchment – one upstream and one downstream of the Ranger mine (Figure 3.6). Mud transport is monitored at the stations using field-calibrated turbidimeters. Mud loads were determined for eleven runoff events at the stations upstream and downstream of Ranger during the 2005–06 wet season. These upstream and downstream event load data were compared using an event-based Before-After-Control-Impact, paired difference design (BACIP). This comparison of event mud loads observed upstream and downstream of the mine under non-mine impacted conditions will be used to provide the basis for future impact assessment during operations and following closure.

The mean ratio of event mud load measured downstream to event mud load measured upstream along Gulungul Creek for the one-year monitoring period is approximately 1.8 (Figure 3.9). Events that lie greater than two standard deviations above the mean ratio (ie, > +2 SD) indicate that the event mud load observed downstream of the mine is significantly elevated above that observed upstream (compared to other events), which may indicate a possible mine-related impact. During 2005–06 no events were considered to be 'outliers', although there were three successive events above the +1 SD line (Figure 3.9) that occurred during a ten-day period in February 2006. This behaviour indicated that event mud load measured downstream was relatively high compared to the event load measured upstream during this period. It is recommended that event load data are collected for at least two more years within the Gulungul Creek catchment to provide a larger database from which to establish the pre-closure baseline using BACIP analysis before rehabilitation commences at Ranger.

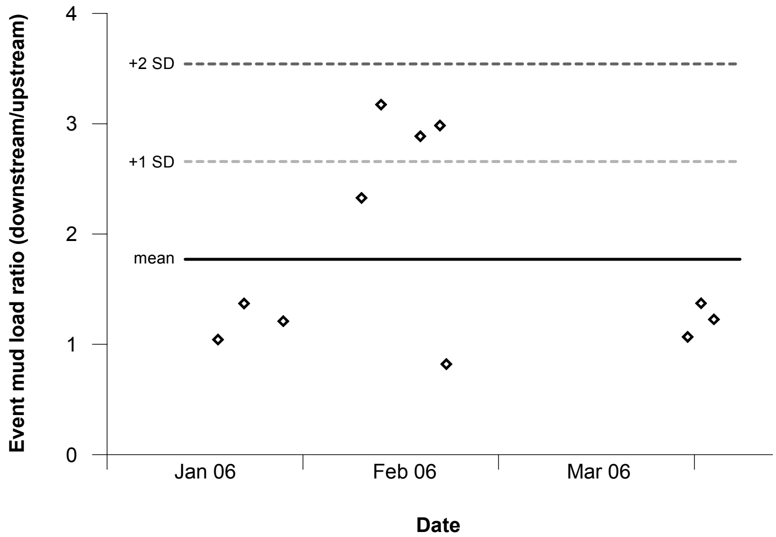


Figure 3.9 Control chart showing temporal variation of the ratio of event mud loads measured downstream to that upstream along Gulungul Creek during 2005–06 (indicated as ◇). The mean ratio and associated standard deviations are also shown.

3.7 Developing water quality closure criteria for Ranger billabongs using macroinvertebrate community data

The approach to deriving water quality criteria from local biological response data outlined in the Australian and New Zealand Water Quality Guidelines (2000) is being applied to the derivation of water quality closure criteria for waterbodies such as Georgetown Billabong, located immediately adjacent to the mine site (Maps 2 & 3). Specifically, if the post-closure condition in Georgetown Billabong is to be consistent with similar undisturbed (reference) billabong environments of Kakadu, then the range of water quality data from the billabong over time that supports such an ecological condition in Georgetown Billabong (as measured by suitable surrogate, biological indicators) may be used for this purpose.

For shallow lowland billabongs such as Georgetown Billabong, distinctive wet season and dry season water quality regimes can be recognised. This is a consequence of flushing of the billabongs during the wet season, followed by contraction in surface area and substantial evaporative concentration of solutes during the six months of the subsequent dry season. If water quality closure criteria were derived from the annual-average water quality record, then the resultant values would be too conservative for the dry season and too lenient for the wet season. For this reason, two sets of water quality criteria are required – one for the wet season and one for the dry season.

Data derived from macroinvertebrates are regarded as most useful for setting water quality criteria because of the enhanced sensitivity of this group of organisms to water quality generally. Hence monitoring of macroinvertebrate communities is being used to develop closure criteria for relevant water quality indicators in the local Ranger billabongs.

Sampling for macroinvertebrates in most of the Ranger and relevant reference water bodies has been conducted previously in 1995 and 1996 and provides a basis for time series comparison. For the 1995 and 1996 surveys, the macroinvertebrate communities of Georgetown Billabong resembled those of reference waterbodies in the Alligator Rivers Region.

Given the changes that have occurred on the mine site since 1996 – in particular the increased wet season loads of solutes entering Georgetown Billabong – a contemporary survey was needed to determine if the macroinvertebrate communities in the billabong were still comparable to reference waterbodies in the region. Accordingly, macroinvertebrates were sampled in May 2006 from Coonjimba, Georgetown and Gulungul Billabongs and Ranger Retention Pond 1 and Retention Pond 2 (mine-water exposed sites) and Baralil, Corndorl, Wirnmuyurr, Malabanjbanjdju, Anbangbang, Buba and Sandy Billabongs and Jabiru Lake (reference sites, not exposed to Ranger mine waters). See Maps 2 and 3 for locations of these waterbodies.

At the time of writing this report, the samples collected in May 2006 were being sorted and the organisms identified and counted. Interim water quality criteria will be derived in December 2006 based on the findings from the three sets of macroinvertebrate and associated water quality monitoring data from Georgetown Billabong in 1995, 1996 and 2006.

Post-closure water quality criteria for Georgetown Billabong – consistent with maintaining the billabong in a condition similar to undisturbed reference waterbodies in Kakadu – will be based on the range of water quality data measured in the billabong over the preceding wet (‘wet season criteria’) and dry (‘dry season criteria’) seasons for each of the three years of macroinvertebrate data. Wet season criteria will be produced from summary statistics of the water quality measured over the period January to May and dry season criteria produced from the worst water quality observed in the preceding dry season, typically for the months September to December.

Macroinvertebrate and associated water quality data gathered from sampling in future years will be used to further revise the criteria current at the time of the new sampling. This adaptive approach to revising criteria to accommodate new findings is consistent with the Australian Water Quality Guidelines (2000) and the stakeholder agreed strategy to periodically update water quality compliance trigger values at G8210009 in Magela Creek.

3.8 Continuous monitoring of water quality

For environmental protection and improved wastewater management associated with the Ranger mine site, there is a recognised requirement to track and quantify the movement of solutes originating from point and diffuse sources through the receiving Magela and Gulungul Creek systems. Continuous in situ measurement of key water quality variables using dataloggers placed at strategic locations on and off-site can meet these needs, particularly when linked to localised and catchment-wide rainfall and stream discharge data. Continuous monitoring can also complement the Supervising Scientist’s routine water chemistry programme, based on weekly grab samples, by capturing possible ‘events’ and exceedances undetected in the routine sampling programme (an advantage also shared by biological monitoring).

To this end and to meet these needs, as part of the 2005–06 wet season water chemistry monitoring programme in situ water quality data (including electrical conductivity [EC], pH and turbidity) were collected at 15–20 minutes intervals using a network of ***eriss*** and ERA dataloggers deployed at key sites in Magela Creek and Ranger mine site tributaries (RP1 and Corridor Creek). Three loggers were deployed in Magela Creek – one located approximately 0.5 km downstream of the Magela upstream control site (but still upstream of mine surface-water influence) and another two located approximately 0.5 km downstream of the Magela downstream compliance point (G8210009), on either side of the western-most channel (see Map 2). Corresponding stream flow data were collected from upstream and downstream gauging stations on Magela Creek (by ERA and NRETA respectively) and from RP1 and Corridor Creek on the mine site (by ERA), enabling integration of both on-site and off-site flow and water quality data. See Map 2 for locations of the upstream and downstream SSD monitoring locations in Magela Creek and the locations of RP1 and Corridor Creek.

The quality-control, spot check measurements made at the Magela Creek sites were very similar to the continuous measured values on both sampling occasions, at approximately 10 µS/cm for the upstream site and 15 µS/cm for the downstream site (Figure 3.10).

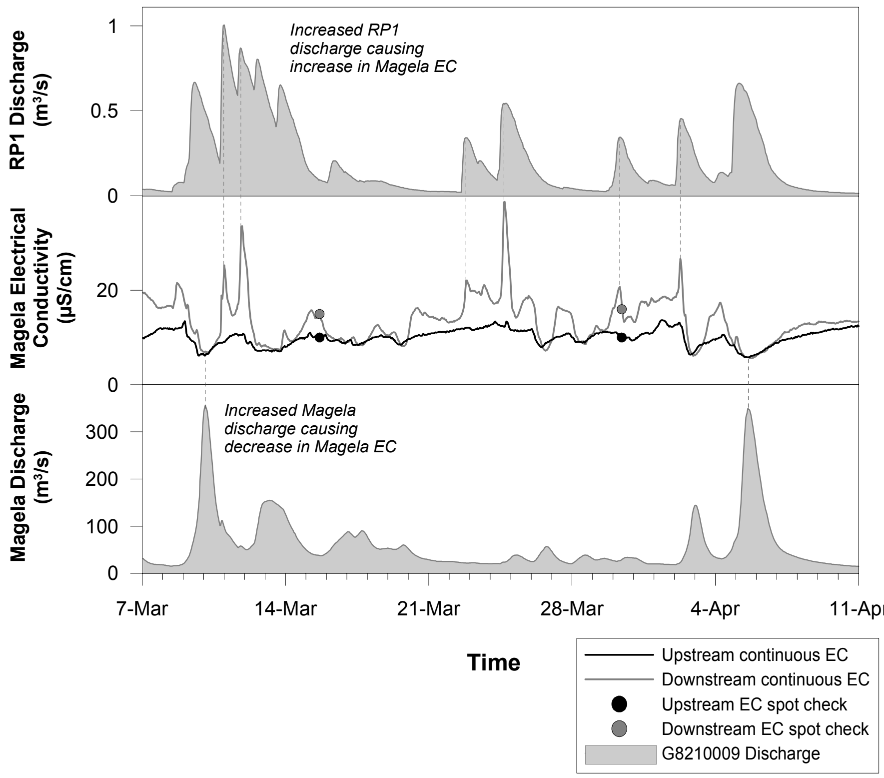


Figure 3.10 Continuous electrical conductivity (EC) at both the upstream and downstream sites on Magela Creek and quality-control spot checks measured using a calibrated portable field meter over mid-wet season months in 2006. The stream discharge measured at G8210009 and RP1 spillway is also shown.

However, the continuous data traces show that the difference between upstream and downstream EC values can be much larger than indicated by spot check data. This demonstrates how lower-frequency, grab sampling methods, as used for the current routine water quality monitoring programme, do not capture the full dynamic range of water quality behaviour.

Continuous, time-series water quality data offer a more complete description of the overall quality characteristics of a waterbody by capturing natural fluctuations in quality that are missed by weekly grab sampling, such as effects caused by variation in flow. Further, assurance and evidence that such short-term variations are having no detrimental effects are obtained from the results of the creekside monitoring programme (each test integrates exposure over a time period of one week).

Although the continuous monitoring data collected during 2005–06 have only undergone preliminary analysis thus far, the interaction between inputs of RP1 water and variable dilution by flow in Magela Creek can be clearly seen (Figure 3.10).

Figure 3.10 shows that EC downstream of the mine is generally higher and much more variable compared with upstream values. Figure 3.10 shows that a number of peaks in downstream EC correspond to increased discharge from RP1, likely due to localised rainfall over the mine site. Water quality measured during some of these events provides evidence that elevated EC observed at the downstream site is attributed to elevated magnesium and sulfate concentrations (and to a lesser extent calcium concentrations) present in discharged mine wastewaters, particularly from RP1. Overall, however, the EC measured at the downstream site remains relatively low and the results of biological (creekside) monitoring and magnesium and sulfate toxicity tests indicate no adverse ecological effects arising from these transiently elevated solute concentrations.

The continuous monitoring data collected during the first year of deployment (2005–06) will be rigorously evaluated during 2006–07 in a whole-of-mine catchment context. Data analysis will include:

- calculation of solute loads to quantify and compare differences upstream and downstream of the mine and to investigate relative contributions from point (RP1 and GC2) and diffuse (Magela Land Application Area) sources;
- interpretation of observed spatial and temporal variation; and
- identification of short-term trends.

The data collected by the continuous loggers will also aid interpretation of results from SSD's biological monitoring programs. Following analysis and interpretation, the continuous monitoring programme will be reviewed and refined, as required, for the second year of deployment.

3.9 In situ toxicity monitoring in Magela Creek

Work commenced in the 2005–06 wet season, to evaluate the potential for in situ deployment inside floating cages in Magela Creek of the same snail and fish tests currently used for the creekside monitoring programme. This technique would provide a much more cost effective way of providing almost continuous biological monitoring of water quality in Magela Creek.

Preliminary studies involved developing a suitable design of holding vessels for test organisms, and assessing the responses of freshwater snails (reproduction) to a number of holding conditions and feeding regimes. The 2005–06 wet season testwork also included a comparison between the in situ deployment and standard creekside tests of egg production by snails. This comparison was done near the upstream water quality monitoring site, MCUS (see Map 2, Magela u/s).

While in situ testing has previously been investigated as a technique for biological monitoring in Magela Creek (Annual Research Summary 1987–88, 1988–89, 1989–90 and 1990–91), the method has remained undeveloped until now because of perceived occupational health and safety advantages of the creekside monitoring procedure (in particular, ready accessibility and safety of staff). However, both the high maintenance costs of the existing creekside monitoring coupled with refinement over the years of the protocols for the snail and fish tests have now led to a re-evaluation of the viability of in situ testing.

Apart from low costs, in situ testing has its own inherent advantages over the established creekside monitoring approach. These include removal of reliance on powered pumping systems in an area of high electrical storm activity, improved water flow-through and contact conditions for the test organisms, and portability. These inherent advantages make the method appealing for future monitoring at Ranger and, potentially, also for use at other mine sites in the Northern Territory and elsewhere.

Preliminary in situ tests were run in parallel with the creekside monitoring tests starting on the 17/02/06, 03/03/06 and 07/04/06 near site MCUS upstream of the Ranger mine. These trials investigated one of two possible feeding regimes (i) daily feeding per current creekside monitoring protocol, and (ii) feeding only once, at the start of each four-day test. Daily feeding enabled the direct comparison of results with those from the existing creekside monitoring programme whilst the inclusion of ‘feeding once only’ (regime ii) enabled investigation of a more cost-efficient feeding regime.

Results from the feeding and in situ versus creekside monitoring comparative tests are presented in Figure 3.11. These data show that snail egg production in the in situ test vessels is comparable to that measured in creekside monitoring tests, and that both feeding regimes should be further evaluated. The results from the daily feeding in situ test are similar to those from the creekside monitoring control site and are almost exactly the same as those from the downstream creekside monitoring site for all three trials (Figure 3.11). The results obtained from the in situ tests in which food was provided only at the start of the test were encouraging, with close resemblance in egg production to that found for the daily feeding in situ test in the first two trials. If start-only feeding can be used for the in situ method, this will have substantial benefits for staff resourcing. It will also mean that this monitoring technique will be much more viable for extended deployment at less accessible (for example, Gulungul Creek) or more remote locations.

An established baseline of creekside monitoring test data has been obtained since 1991–92 (Figure 2.8). Hence it is very important to ensure that the new method yields comparable results before it can be phased in as the sole procedure in the future. To this end, further testing of the in situ vessels and feeding regimes will occur over at least two wet seasons, conducted in parallel with creekside monitoring and extending also to the downstream site. Future comparative tests will focus on the paired-site monitoring design employed for creekside monitoring (described in Chapter 2 of this Annual Report) and compare the 'differences' in responses between upstream and downstream sites for both test conditions and feeding regimes.

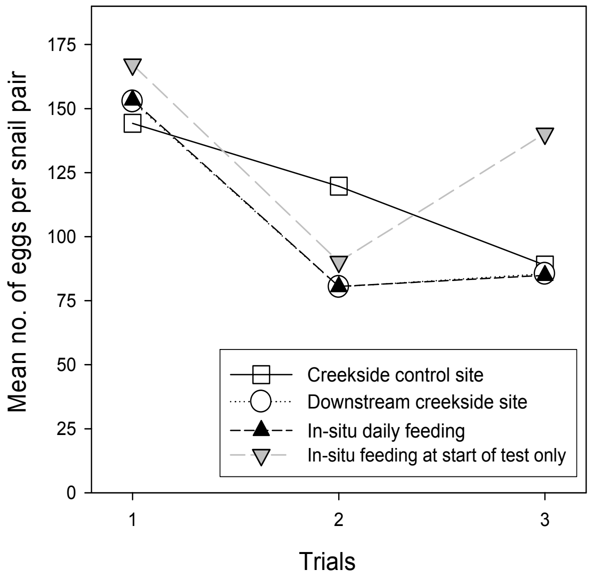


Figure 3.11 Comparison of freshwater snail egg production for routine creekside monitoring and two feeding regimes of in situ toxicity monitoring

3.10 Ecological risk assessment of Magela floodplain from diffuse landscape-scale threats and point source mining threats

This ecological risk assessment is the final project of the landscape-scale analysis of impacts programme, established in 2002 to help differentiate mining and non-mining impacts on the Ramsar-listed Magela Creek floodplain wetlands downstream of the Ranger uranium mine. Ecological risk assessment allows the level of risk to the 'health' of ecosystems exposed to multiple stressors to be quantified in a coherent, robust and transparent manner. A high protection level for the biodiversity of aquatic ecosystems was used as the assessment endpoint, so conclusions here can be regarded as being appropriately conservative.

The key findings from four projects are presented in two parts. Part 1 reports results from a first-cut quantitative ecological risk assessment of the threats posed by diffuse non-mining landscape-scale factors to the condition of selected World Heritage values on the Magela floodplain. Part 2 similarly reports an ecological risk assessment of four key chemical contaminants released from Ranger into the surface water pathway of Magela Creek as mapped out by the conceptual contaminants pathways model presented in the Supervising Scientist's 2004–05 Annual Report.

3.10.1 Part 1: Landscape

The status of past and current ecological values (assets) and threats on Magela floodplain were mapped in a GIS to facilitate spatially explicit risk assessment. Shape-file data layers were converted to raster grid-cell data format at appropriate levels of spatial resolution (here 250 m x 250 m cells). The spatial and temporal scope of many data sets extended beyond the Magela catchment to include Kakadu National Park and the Alligator Rivers Region in general.

Choice of World Heritage values

The two key 'susceptible' World Heritage (and Ramsar) values chosen for assessment are waterbirds and native wetland vegetation. An assessment of change in their 'condition' was undertaken using spatial and temporal data obtained between 1981 and 2003. The initial focus has been on changes in the abundance of 'indicator' species of plants and waterbirds. Future work will examine possible changes in biodiversity.

For vegetation the focus was on: weeds; important bush foods of traditional Aboriginal owners (for example, the red lily); key habitat components of waterbirds for nesting and food (wild rice, *Oryza meridionalis* and *Eleocharis* sedges); and riparian trees susceptible to saltwater intrusion and/or fire (Melaleucas).

For waterbirds, the iconic magpie goose and egret were chosen for initial analysis because they are the most seasonally abundant plant and fish eating birds, respectively, that forage on the Magela floodplain. Additionally, the magpie goose is an important part of the diet of traditional Aboriginal owners in the Alligator Rivers Region.

Results from the long-term observational record of changes in billabong fish community structure were reported in section 3.6 of the Supervising Scientist's 2004–05 Annual Report. Between 1989 and 2005 (16 years) the chequered rainbow fish and two species of glassfish at the Mudginberri monitoring site downstream of Ranger exhibited long-term declines in abundance (13% per annum on average) that are apparently unrelated to mining impacts. Three key correlates and associated working hypotheses that could explain these declines are: (i) increases in mean wet season flow leading to lower water solute concentrations known to be harmful to larval rainbow fish; (ii) decreases in the period of annual drying of the floodplain potentially leading to reduced release of nutrients upon floodplain re-wetting (flood-pulse theory), and thereby reducing fish production in this important breeding and recruitment zone; and (iii) increases in the extent of floodplain grasses, including the introduced para grass, thereby reducing habitat availability and pathways for upstream migration of fish recruits.

Choice of landscape-scale threats

Four major categories of landscape-scale threats to the above selected World Heritage values were identified:

- invasive species – specifically the wetland weeds mimosa, para grass and salvinia, and feral pigs (classified as a 'Threatening Process' under the *Environment Protection and Biodiversity Conservation Act 1999*);
- unmanaged fire;
- infrastructure (eg towns and mines); and
- potential climate change impacts (rising sea level and concomitant salinisation of freshwater ecosystems, increasing intensity and frequency of storms).

Medium to long-term climate change threats, although highly relevant, were beyond the scope of this study.

The ability of wetland weeds to dominate and completely alter aquatic ecosystems has been well documented. The Magela floodplain fortunately remains free of mimosa because of a highly successful 'search and destroy' programme by National Park rangers. The impact of the floating fern salvinia has been greatly reduced by biological control. Hence, para grass was the primary focus of our risk assessment for weeds.

Ground disturbance damage caused by feral pigs has been ascertained across Kakadu during systematic aerial surveys in 1985, 1995 and 2003, and its damage to natural and cultural values has been documented in consultancy reports to Kakadu National Park management.

Dry season fire on the Magela floodplain can be viewed either as a cultural asset if part of an indigenous burning regime, or as a threat if unprescribed by traditional Aboriginal owners or Park management. To determine whether or not fire on the floodplain should be viewed as an asset or a threat would require detailed ethno-ecological knowledge beyond the scope of the present study. However, such a study was completed in the adjacent South Alligator River catchment at Boggy Plain wetland as part of the landscape programme. Infrastructure in the vicinity of the Magela floodplain comprises mostly roads, tracks and fence lines, and these may facilitate the spread of weeds and possibly cause erosion and siltation. Additionally, the minesite and associated township are sources of weeds for the Magela catchment and Kakadu in general.

Key results

Vegetation

The following eight classes of native vegetation were used to analyse change between 1983 and 2003: *Eleocharis* spp, *Oryza* spp, *Pseudoraphis spinescens*, *Hymenachne acutigluma*, *Melaleuca* spp, *Nelumbo nucifera*, *Nymphoides* spp and *Leersia hexandra*. Relative change in abundance was measured by change in percentage cover. The following changes were observed: *Nymphoides* and *Leersia* were not recorded in 1983; *Eleocharis*, an important dry season food of magpie geese, decreased by 57%; Melaleucas decreased by 10%; and *Nelumbo* decreased by 85%. The 10% relative change in paperbark forest and woodland is significant because, on an absolute basis, this corresponds to 5 km^2 or 3% of the floodplain.

Mimosa has been kept under control since the early 1980s through an annual investment (and in perpetuity) of approximately $0.5 million by Kakadu management, and para grass and salvinia have since colonised the floodplain (see weeds section below).

Waterbirds

The number of magpie geese that occupy Magela floodplain in the late dry season has decreased on average by 7% pa between 1981 and 2003 (22 years) (Figure 3.12a, dashed line). In the wet seasons of the early 1980s, magpie geese used the central portion of Magela floodplain for nesting, an area now occupied extensively by para grass (see 2005 map in Figure 3.15). Additionally, in contrast to the early 1980s, areas now colonised by para grass are used less extensively for feeding by magpie geese in the late dry season, and this is possibly related to the 57% reduction in the extent of *Eleocharis* sedge. Similarly, fish eating egrets decreased on average by 9% pa since 1981 and by 2003 they also altered their dry season distribution.

Although the floodplain is about 200 km^2 in area it is still too small to be able to place into context long-term changes in the abundance of highly mobile waterbird species in isolation from regional and national trends. In particular, the effects of anthropogenic-induced changes (for example, the commencement of mining at Ranger; the reduction in buffalo numbers and concomitant increase in pig numbers; and the colonisation of the floodplain by para grass weed; see below). Fortunately concurrent regional and national survey data for magpie geese are available, including surveys started in 1958 by CSIRO and continued to the present by the NT Parks and Wildlife Commission. Analyses at increasing spatial scales (Figure 3.12b) show that trends in the observed abundance of magpie geese in the late dry season on the Magela floodplain were highly concordant with similar trends for the same time period across the Alligator Rivers Region (Figure 3.12a, solid line & filled circles), and between 1983 and 1996 for the 'Top End' of the Northern Territory (Figure 3.12a, solid line & open circles). The latter area includes most of the Australian goose population.

The Northern Territory surveys provide 45 years of almost continuous data that suggest cycles of magpie geese numbers over decadal time scales (20–25 year periods; trendline in Figure 3.12c and verified by time series analysis). Early studies show that the population dynamics of magpie geese are driven to a large extent by deviations in mean annual local rainfall in river catchments, which itself exhibit similar decadal cycles.

The driving variable of magpie geese population dynamics is wetland vegetation (ie, for food and nesting material), which is highly correlated to flow, water depth and ultimately rainfall. Time series and CSUM (cumulative sum of the mean deviations) analyses of wet season flow at three long-term gauging stations across the Northern Territory (Magela Creek at G8210009, 1972–2005; Daly River, 1961–2005; and Katherine River, 1958–2005) all show similar and concordant 20-year periods as that for magpie geese numbers, and are highly cross-correlated. Similar results have been found between flow and indices of barramundi abundance (catch-effort) in the Daly River (via the Tropical Rivers Inventory Assessment Project, Section 3.11).

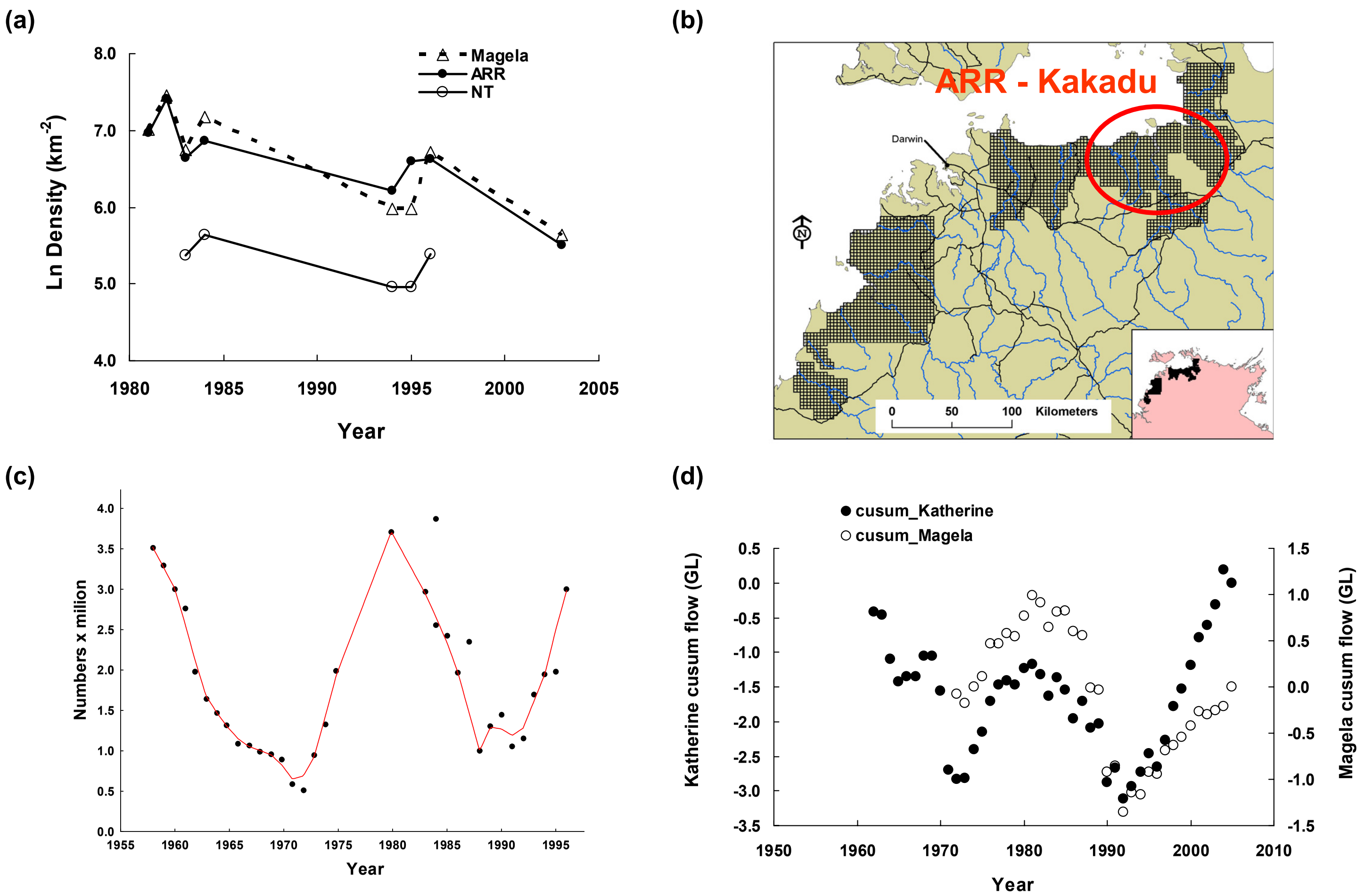


Figure 3.12a–d. (a) Concordant trends in dry season density of magpie geese for the Magela and the Alligator Rivers region (ARR)(1981–2003), and the 'Top End' of the NT (1983–1996). (b) Survey area (shaded) of the annual magpie geese surveys in the NT. Circle is the ARR encompassing the Magela floodplain (K Saalfeld, NT P&WC). (c) Estimated numbers of Magpie Geese in the NT between 1958 and 1996, with a Lowess smoothed trend showing 20-year periods. (d) Cumulative sum (CSUM) of the mean deviations in wet season flow (GL) for Magela Creek at G8210009 (1972–2005) and Katherine River (1958–2005), also showing 20-year periods.

Hence, because of the possibility of large-scale ‘external’ ecological drivers, any meaningful assessment of World Heritage values of waterbirds and other highly mobile water-dependent ‘indicator’ species on Magela floodplain needs to focus on the condition of their seasonal in situ habitats and not trends in abundance.

The relatively long-term patterns of decline in magpie geese, egrets, rainbow and glassfish on Magela floodplain are all most likely related to decadal flow patterns, although local anthropogenic causes cannot be ruled out (for example, the loss of key wetland habitat due to para grass colonisation).

Weeds

In the early 1980s, para grass was present in very small areas of the Magela Creek floodplain. In the mid 1990s, para grass in the vicinity of the largest infestation spread from 132 ha to 422 ha in five years (1991–1996). This core patch of para grass occupies the centre of the floodplain (see Figures 3.14 and 3.15) and is expanding on average at 14% p.a. (Figure 3.13a). That is, doubling in extent every five years. The increase in area of para grass between 1991 and 1996 showed a corresponding decrease in area of a community of wild rice and *Eleocharis* sedge (this study), important food resources for pre-fledging and adult magpie geese, respectively. Para grass currently occupies about 1250 ha (or 10% of the floodplain with 100% cover), with new outbreaks occurring in inaccessible dense Melaleuca woodland.

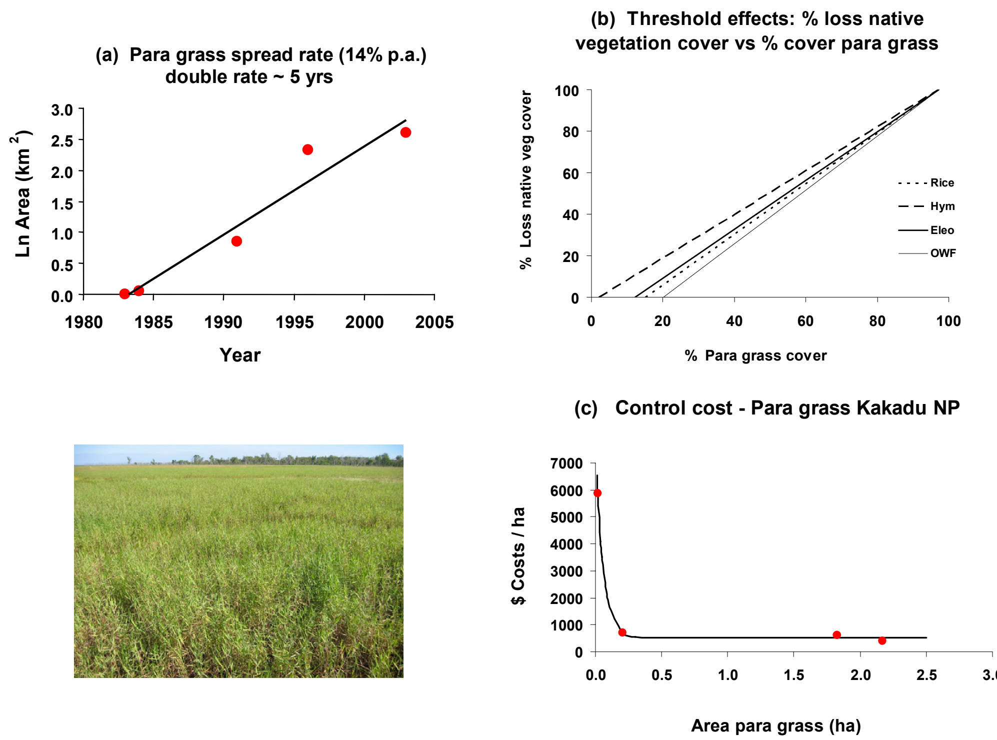


Figure 3.13a–c. (a) Linear regression between Log$_e$ extent (km^2) of para grass and time (years) (R^2 = 69%, P<0.04). (b) Relationship between loss of native vegetation cover (%) of four key wetland plants and increasing cover of para grass. (c) Control-cost curve for para grass (Noulangie floodplain, Kakadu).

Data obtained from sample plots in 2003 show that the percentage of native vegetation (for example, wild rice, *Eleocharis*, *Hymenachne*, open water/lilies & *Leersia*) 'lost' to para grass rapidly increased with increasing weed cover, and importantly that there was a 'threshold' effect for each plant group (Figure 3.13b, minus *Leersia*). Hence, for most floodplain plants, measurable impacts did not occur until para grass reached 15–20% cover, suggesting that this extent of cover may represent a pragmatic, cost-effective and justifiable control target.

Cost-of-control functions have been developed by ***eriss*** for mimosa and now para grass (Figure 3.13c), and are critical for evaluating the benefits and costs of any invasive species management programme, which are essentially risk management programs. The cost-curve for para grass shows that a 15–20% control target would avoid exponentially increasing control costs generally associated with unachievable eradication objectives, or cost-prohibitive 'trace level' objectives (this reasoning may not apply to mimosa, however, because of its massive seed set).

A Bayesian Habitat Suitability Model (HSM) was developed in collaboration with Charles Darwin University to predict current and future distribution (exposure) of para grass and, hence, potential impacts on native wetland vegetation. The methodology has been successfully applied to the Mary River floodplain. The risk-based exposure map incorporates test data from high resolution Quickbird satellite imagery (validated by helicopter and airboat surveys) to provide more reliable information on para grass extent over different temporal and spatial scales (Figure 3.14). The methodology developed to date in the core para grass area of central Magela provides a valuable cost-effective monitoring and assessment tool for park managers.

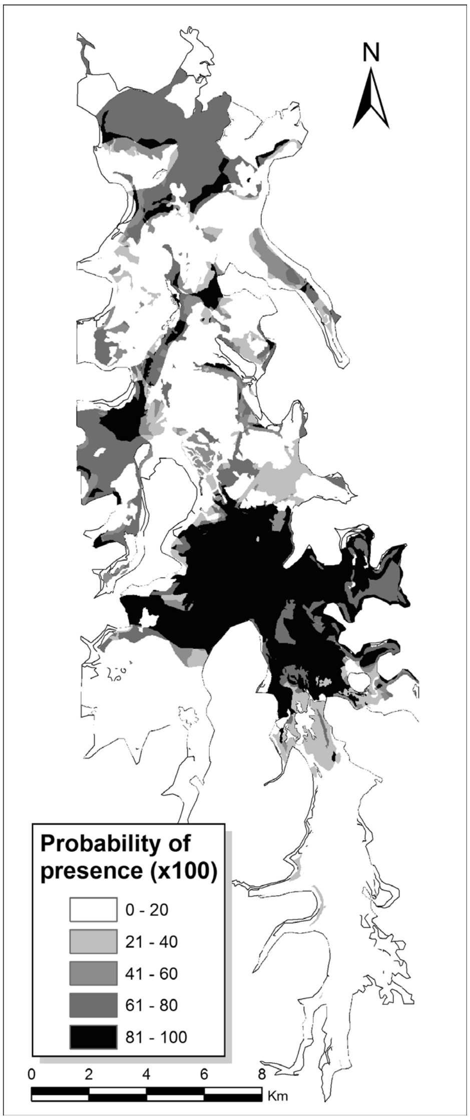


Figure 3.14 Bayesian habitat suitability model for para grass showing exposure probabilities (black is 100% exposure risk or present, white is no exposure risk or absent, with grey scales represening exposure risk in between). The exposure risk map was derived from a Quickbird satellite data capture, helicopter and airboat validation surveys, and GPS observations by Park staff.

A spread rate model was developed to predict para grass extent and, hence, potential ecological impacts over time. Management scenario simulations were undertaken ranging from ‘do nothing’ to a range of initial and maintenance control investments. Initial simulation results suggest that with no control 50% or more of the floodplain will be lost within 20 years (Figure 3.15). However, this time frame may be the ‘best case scenario’ because satellite patches of para grass are now spreading along the entire length of the Magela floodplain, representing new centres for expansion.

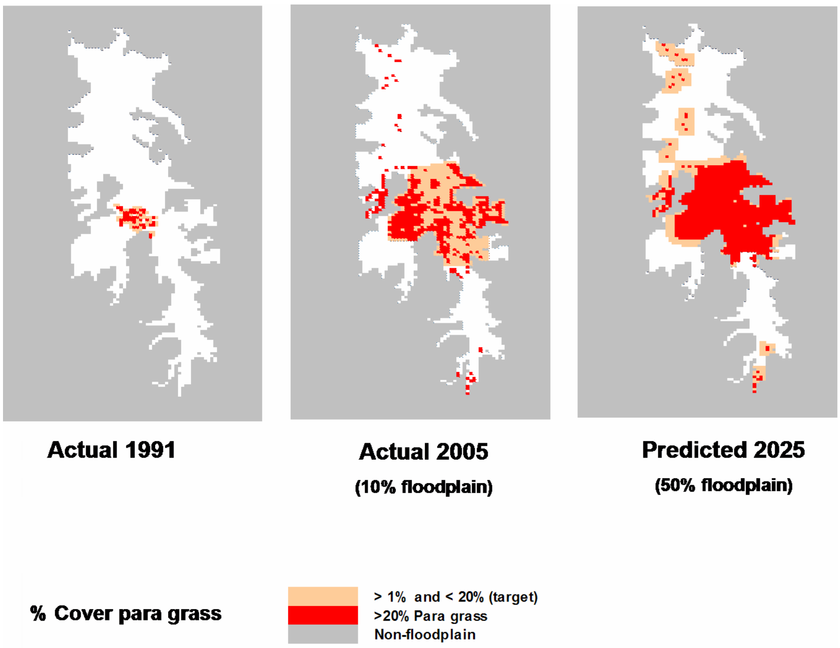


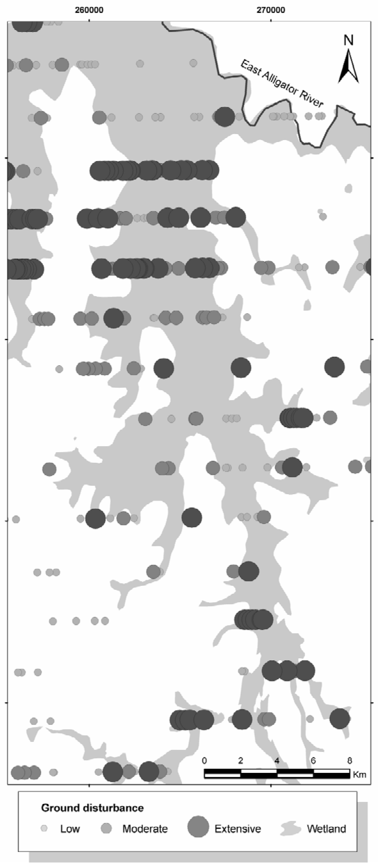
Figure 3.15 The extent of para grass on Magela floodplain in 1991 and 2005, and the predicted extent in 2025 based on habitat suitability, known spread rates and location of known infestations

Pigs

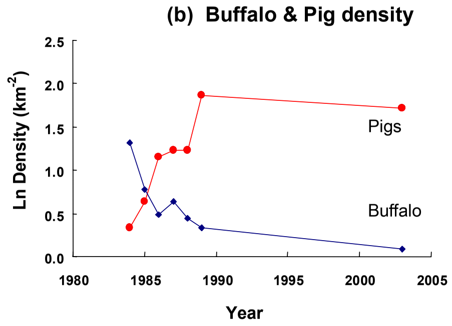
Data for pig density and damage across all floodplains in the Alligator Rivers Region has been used to infer the situation on the Magela floodplain. The extent of pig damage was recorded in four classes (zero, low, intermediate and high) along aerial survey transects divided into 2 km or 5 km units depending on transect spacing. Frequency of occurrence data was then used to estimate probabilities of overall damage.

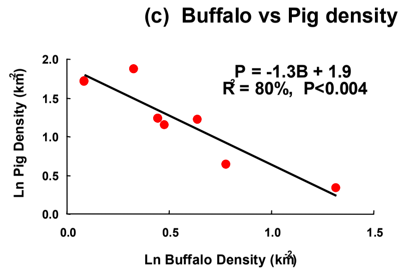
No damage was recorded in 1985, corresponding to low pig densities during the early 1980s when buffalo densities were high.

In contrast, extensive pig damage now occurs across the whole of Kakadu National Park, particularly on floodplains such as Magela (Figure 3.16a). These changes corresponded to a rapid increase in pig numbers following sustained commercial harvesting of buffalo in the 1970s and the Brucellosis and Tuberculosis Eradication Campaign (BTEC) between 1985 and 1989. During this period pig densities increased at a rate close to their maximum rate of population increase for the region (27% per annum, Figure 3.16b).



(a) 2003





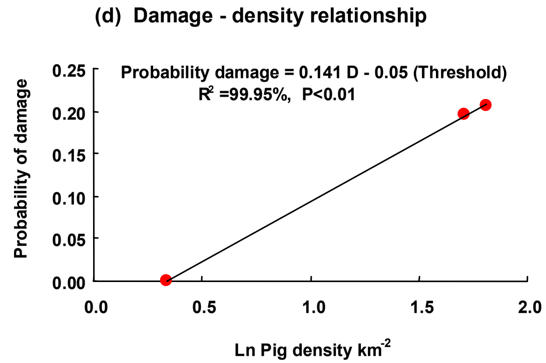


Figure 3.16a–d (a) Distribution and intensity (low, medium & high) of ground disturbance damage caused by feral pigs on Magela floodplain (Nov 2003). (b) Trends in buffalo and pig density (1985–2003) in the ARR (c) Inverse relationship between density of buffalo and pigs in the ARR. (d) Threshold relationship between probability of pig damage and Ln density.

There is a negative relationship between the density of buffalo and pigs since 1983 (Figure 3.16c). A pig control programme was started in 1989 in the northern section of the Park, reducing numbers to about 20% of the initial count by 2003. This probably represents a 'sustained-yield' because the cull rate does not exceed the observed maximum rate of population increase.

Although ground disturbance damage caused by pigs has only been systematically recorded in three of a dozen aerial surveys across the Alligator Rivers Region since 1985, damage and density are nevertheless correlated in a predictable manner and the relationship exhibits a threshold for effects (Fig 3.16d). Control cost functions have been developed by ***eriss*** for pigs in Kakadu using control data collected by Kakadu rangers; the same shoot data were used to derive estimates of absolute density.

Fire

The Bushfires Council of the Northern Territory provided 25 years of Landsat based fire-scar maps for the Northern Territory (1980–2004), which were used to estimate fire occurrence on the Magela floodplain and surrounding Eucalypt woodland.

The frequency of fire over 25 years in each 250 x 250 m grid cell was converted to probabilities for risk assessment. Previous studies have shown that, if the risk of fire in any given location on the floodplain was greater than 0.25 (one in four years), it can be considered a threat to biodiversity values because of suppressed abundances of fire sensitive plant species. However, until recently little was known about the impacts of dry season fires (frequency, intensity and duration) on the structure and composition of wetland vegetation on the Magela floodplain.

Results from the Boggy Plain fire study show that the diversity of wetland plant species increased with the extent of traditional burns if floodplain vegetation was dominated by monocultures of grasses such as *Hymenachne*, particularly if time since last burnt was greater than five years. Therefore, in the ecological risk assessment for fire uncertainty was incorporated by setting the effects probability to 0.50 (that is, hedging bets either way).

The floodplain and surrounding woodland have markedly different fire risk profiles (see histograms in Figure 3.17). Fire on the floodplain occurs on average once every five years (mean P=0.20, median =0.13). In contrast, the surrounding Eucalypt woodland burns on average once every two years (mean P=0.52, median 0.53). A comparison of the shapes of their probability density functions (based on relative frequency histograms) show that fire risk is greater in the woodland because it is more uniformly spread across the entire probability range.

Landscape-scale ecological risk assessment

For landscape-scale (and mining) threats risk is quantified as the probability of an adverse event, or the likelihood of exposure multiplied by the consequences or effects of that exposure (that is, probable risk equals probable exposure times probable effects). Bayes's Theorem was used to derive individual and combined ecological risks. Probability density functions (pdfs) fitted to exposure and effects frequency data were used with Monte Carlo simulation to account for uncertainty.

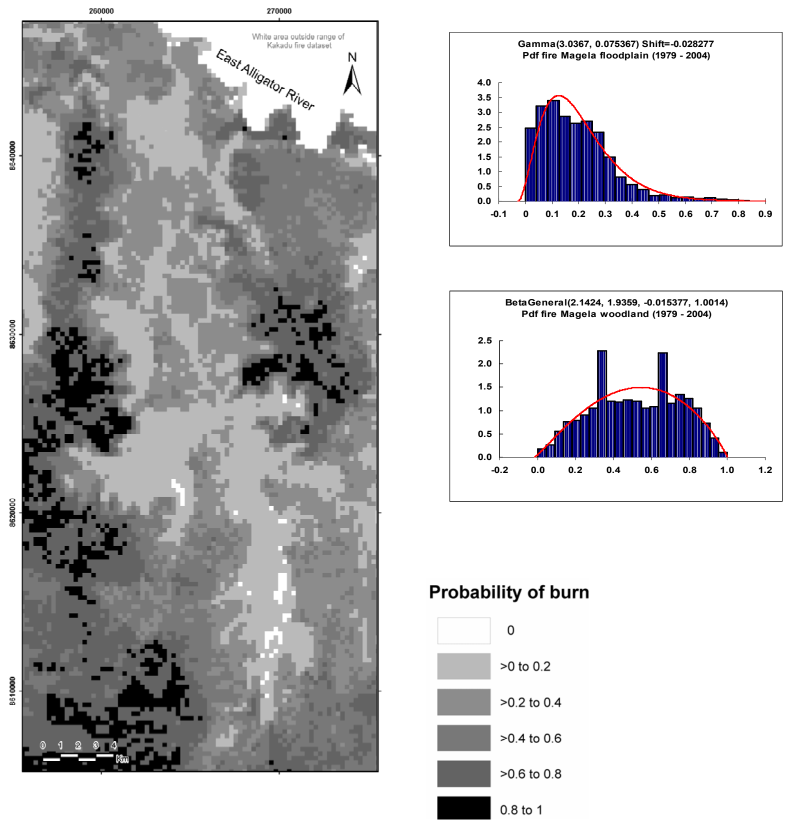


Figure 3.17 Risk of fire on the Magela floodplain and surrounding woodland (1980–2004). Histograms are probability density functions (pdfs) for frequency of fire occurrence on Magela floodplain (top) and surrounding woodland (bottom).

Sensitivity analysis (via regression/correlation methods) was used to rank negative and positive contributions of all inputs into the risk assessment and plotted as Tornado graphs. The end product of the Monte Carlo simulations is a probability density function that characterises all landscape-scale ecological risks in combination, and which can be compared to a similarly derived quantitative risk profile for potential mine-related impacts (see below).

The analysis of the data followed the sequence:

(a) for each risk group derive a probability density function (pdf) for exposure probabilities (P_{exp}) based on spatially derived frequency data in each 250 x 250 m cell across the floodplain (only para grass and salvinia are assessed here as mimosa exposure is < 1%)

(b) derive a pdf for effects probabilities (P_{eff}) of each risk group based on expert knowledge, the literature, and/or experimental or empirical data (if completely unknown set the uncertainty level to 0.50 as for fire; for all others adopt the precautionary principle and set the effects probabilities to 1.0, hence risk assessments will be weighted towards exposure); for each group derive ecological risk ($P_{risk} = P_{exp} \times P_{eff}$) profiles from the exposure and effects probability density functions above using Monte Carlo simulation (10 000 simulations);

(c) combine the risk profiles of all groups;

(d) use sensitivity analysis to rank the contribution of each risk group to total risk, and ascertain the dependencies between and within groups to total risk.

Initial results are presented below. Examples of pdfs for exposure threats are provided above for the occurrence of fire on the Magela floodplain and surrounding woodland (Figure 3.17). The mean landscape ecological risk is 0.21 (Figure 3.18a), with para grass ranking first, pig damage second and uncontrolled fire third (Figure 3.18b).

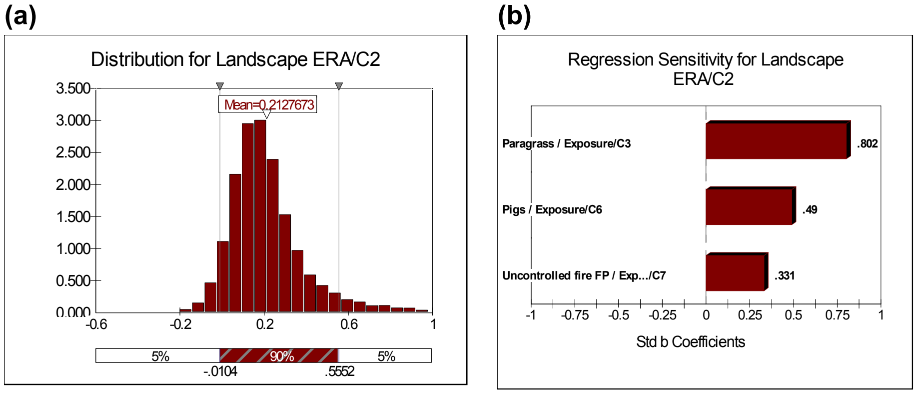


Figure 3.18a & b. (a) Distribution of combined ecological risks for landscape threats. (b) a Tornado diagram illustrating the relative contributions of each risk group to the combined ecological risk assessment for landscape threats

3.10.2 Part 2: Ranger – surface water pathway of chemical contaminants

A similar ecological risk assessment process was used to assess four key solutes found in surface water and seepage discharged from Ranger uranium mine into the surface waters of Magela Creek during the wet seasons between 1998 and 2005. These solutes are uranium, magnesium, sulfate (SO_4) and manganese. Weekly point sample data at the downstream statutory monitoring site (Map 2, Magela d/s) were used to characterise off-lease exposure probabilities to aquatic ecosystems downstream of Ranger on Kakadu National Park.

Ecotoxicological end points for uranium and magnesium were used to derive Species Sensitivity Distribution models in order to predict the contaminant concentration (trigger values) that protect 99% of susceptible aquatic species. The models contain a small yet strategic sample across trophic levels and, comprise the most robust quantification of ecological effects by any single hazard to date. The magnesium effects model is complex because mine-derived calcium ameliorates the toxicity of magnesium. However, recent ecotoxicological work shows that a magnesium:calcium ratio of 9:1 is the threshold for magnesium effects and, hence, this value is incorporated into the risk modelling. The trigger value of 1200 ug/L for mangenese recommended by the National Water Quality Guidelines (NWQG) is based on ecotoxicological end points and so is adopted as an interim value for 99% species protection. A 'low reliability' trigger value of 15 mg/L for sulfate was adopted based on limited site-specific effects data (van Dam pers. comm.).

Best-fit exposure probability density functions were produced for each of the four solutes described above.). The details of this process will also be reported later, and initial results are presented below.

In contrast to the normal-like distribution of the combined landscape risk profile (Figure 3.18a), the combined pdf for minesite risks is approximately bimodal with 90% of values clustered closed to zero (Figure 3.19a). The mean minesite ecological risk of one simulation with 10 000 iterations was only 2.7 x 10^{-4}. Uranium exposure made an extremely small contribution. Similarly, the three other solutes posed insignificant risks because exposure probabilities never exceeded the 1% species-affected concentrations, or other relevant effects thresholds (Figure 3.19b).

(a)

(b)

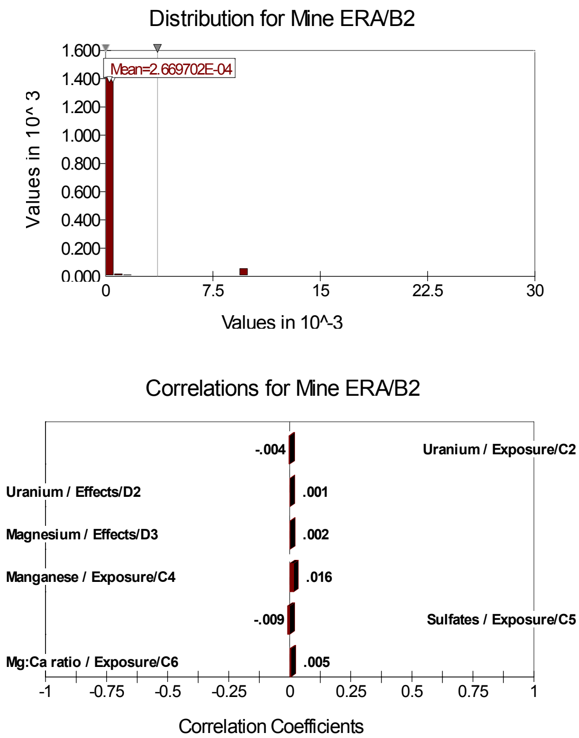


Figure 3.19a&b (a) Distribution of combined ecological risks for minesite chemical threats (note X-axis values are by 10^{-3}), and (b) a Tornado diagram illustrating the relative contributions of each chemical to the combined ecological risk in the surface water pathway.

3.10.3 Conclusions

Two key results from the landscape ecological risk assessment are:

(1) non-mining landscape-scale risks are currently several orders of magnitude greater than mining risks (Table 3.3), although that difference may reduce when on-site water management systems at Ranger change in the transition between mine production and mine closure and rehabilitation; and

(2) Para grass weed (*Urochloa mutica*) is currently the major ecological risk because of its extent (10% cover), effect (a monoculture that displaces native vegetation and wildlife habitat) and rapid spread rate (14% per annum).

The risk posed by para grass has been examined in greater detail by combining the Bayesian habitat suitability model with a spread rate model, therefore encompassing current and future risk to floodplain habitat diversity depending on distance to source and invasion pathways. The overall findings from this landscape ecological risk assessment strongly imply that non-mining landscape-scale risks to Magela floodplain should now receive the same level of scrutiny as applied to uranium mining risks, including an assessment of what appropriate level of investment would be needed to manage these risks.

TABLE 3.3 COMPARISON OF LANDSCAPE AND MINESITE ECOLOGICAL RISKS TO MAGELA FLOODPLAIN, AND THEIR RELATIVE IMPORTANCE RANK

Category	Pathway	Hazard	Risk rank	Action	Time frame
LANDSCAPE	Park-wide	Para grass weed	1	Take active control	In perpetuity
	Park-wide	Pig damage	2	Research effects	In perpetuity
	Floodplains	Unmanaged fire	3	Research effects	In perpetuity
		Total ecological risk =	**0.21**		
MINESITE	Surface water	Uranium	4	Watching brief	2006
	Magela Ck	Sulfate	5	Watching brief	2006
		Magnesium	6	Watching brief	2006
		Manganese	7	Watching brief	2006
		Total ecological risk =	**0.00009**		
		Ra-226	8	Watching brief	2006
	Airborne/wind	Radon (Ra-222)	9	Watching brief	2011

NB: Ra^{226} and Ra^{222} (Radon) are included also

3.10.4 Future work

An analytical decision-making framework combining quantitative and qualitative ecological risk assessments for diffuse landscape and point source mining related threats is currently being developed. This approach is similar to a Bayesian

Network (BN) framework. Different degrees of belief associated with perceptions of risk, ranging from subjective expert opinion (for example, from park managers and traditional Aboriginal owners) to objective quantitative estimates derived from frequentist statistics (for example, the probability density functions reported here), can be integrated and the results communicated using simple influence diagrams and decision trees.

3.11 Tropical Rivers Inventory and Assessment Project (TRIAP)

3.11.1 Background

During 2005–06, the Department of the Environment and Heritage invested $0.3 million from the Natural Heritage Trust to fund the Tropical Rivers Inventory and Assessment Project (TRIAP), administered by Land and Water Australia's Tropical Rivers Programme, and managed by ***eriss***. The TRIAP commenced in late 2004, with the objective of establishing an information base for assessing change, undertaking ecological risk assessments of major pressures, supporting local and indigenous management, and strengthening holistic approaches for managing tropical rivers and their associated wetlands.

The project examines 51 catchments across northern Australia (from Broome in the west to the western tip of Cape York), covering some 1 192 000 km^2 (Figure 3.20). There are three focus catchments, representing each State or Territory within the study region, that are being assessed in more detail. These are the Fitzroy River in Western Australia, the Daly River in the Northern Territory, and the Flinders River in Queensland.

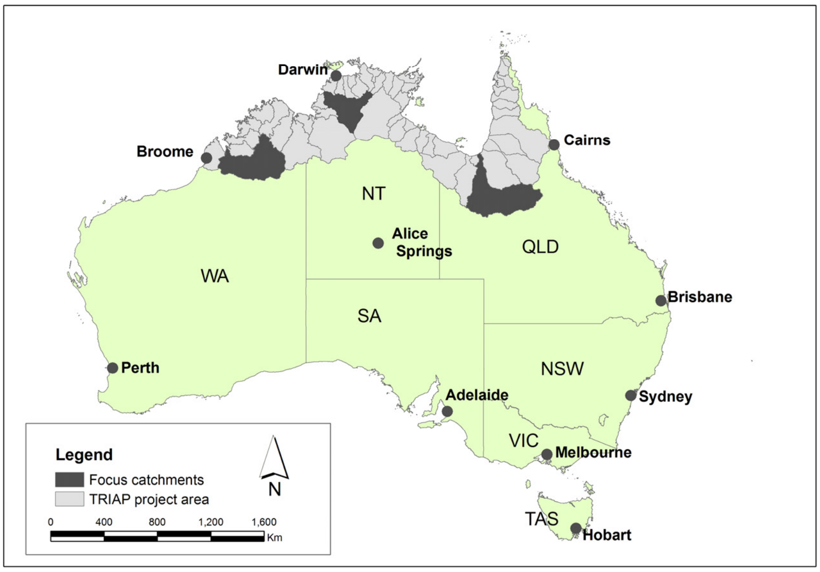


Figure 3.20 Location of Tropical Rivers Inventory and Assessment Project

The outcomes of this project, due for completion in 2006–07, will inform and support holistic approaches for management of tropical rivers and wetlands by the various stakeholder groups in the region. Summaries of progress on two of the TRIAP's three sub-projects (Sub-project 1 – Inventory and mapping, and Sub-project 2 – Risk assessments) are provided below. The third Sub-project (Development of a framework for the analysis of ecosystem services provided by aquatic ecosystems) was completed in November 2005, and a final report is currently in preparation.

3.11.2 Sub-project 1: Inventory of the biological, chemical and physical features of aquatic ecosystems

The main objective of Sub-project 1 is to develop a multiple-scale inventory of the habitats and biota of the rivers and floodplains within LWA's programme area for the Tropical Rivers funding programme. The datasets collated for the project have been created using a consistent and recognised datum and projection, and the metadata records are created and compiled to national and international standards. In many cases this has required a substantial amount of work to bring the originally supplied data set up to the required common standard required for the final project database.

Major activities undertaken through 2005–06 are listed in Table 3.4. These include (i) the ongoing collation of biophysical datasets; (ii) analysis, interpretation and classification of the collated datasets; and (iii) compilation of a Geographic Information System (GIS) and associated standardisation of the datasets and metadata records.

TABLE 3.4 MAJOR ACTIVITIES OF SUB-PROJECT 1

Data and metadata standards	A hierarchical directory structure has been applied for the storage and management of spatial datasets. All spatial datasets are maintained in a geographic projection, using the Geocentric Datum of Australia 1994. Following a review of procedures for the creation and management of metadata within the Department of the Environment and Heritage, metadata for databases/datasets has been progressively created/updated to the ISO19115 standard. Significantly, all datasets now have a metadata record attached to them.
Compile existing GIS datasets at 2.5M, 250K and other scales	Collation and compilation of data for the inventory component of the project has been completed, with data compiled at two broad scales (continental – 1:2 500 000; and catchment scale – 1:250 000). Data for the 'focus' catchments has been collated at the catchment scale, or better.

	Data collation is continuing at a reduced level to support risk assessment activities within the three focus catchment, focussing on the collation of datasets representing the distribution of feral animals, weeds, rare and threatened species, and temporal variations in land useand landcover. During the year, existing collated datasets have been reviewed and updated to ensure that the latest versions of key datasets (geology, topography, hydrology) are held by the project database.
Identify, collate and analyse additional for reach attributes	Additional national (eg AUSRIVAS, OZCAM, BirdsAtlas) and State/Territory faunal and floral databases were accessed and data extracted to identify the distribution of specific species at catchment and focus catchment scale. Additionally, new spatial datasets were created for hydrological, geomorphological and water quality attributes. Analyses have been undertaken to look for patterns/relationships of biophysical attributes across the tropical rivers
Develop geomorphic classification / typology	Continental scale and focus catchment scale geomorphic classifications were completed.
Estuary classification review	Data collected has included information on tidal character and non-tidal processes, cyclone tracks and locations of land crossing, climate change and variability projections and estuarine classification systems. Classification systems have been reviewed. This component is approaching completion.

During the year classification of the geomorphic typology of the river systems was completed at both continental and catchment scales. At the continental scale, seven different classes were used for classification. The total lengths across all 51 river catchments of the different continental geomorphic classes are shown in Table 3.5.

Up to twelve different geomorphic categories were used for the Focus catchment level classification. This more detailed system of classification recognises both the greater amount of information available for the focus catchments as well as the more intensive use that will be made of the classification system to support the risk assessment process. The length of the different classes in each focus catchment is shown in Table 3.6. The Fitzroy River showed the greatest diversity in terms of geomorphic classes identified at the catchment level.

TABLE 3.5 CONTINENTAL GEOMORPHIC CLASSES

Continental geomorphic class	Length of river class (km)
Bedrock channel	10 857
Bedrock confined	13 489
Estuarine	4 400
Lake/swamp	3 373
Level alluvial plain	11 058
Rolling alluvial plain	4 063
Undulating alluvial plain	14 114

TABLE 3.6 FOCUS CATCHMENT GEOMORPHIC CLASSES

Reach Classification	Flinders River (km)	Fitzroy River (km)	Daly River (km)
Bedrock channel	580	609	372
Bedrock confined	3957	3138	2355
Estuary	274	111	80
Billabong / lake / swamp	Not present	5.6	46
Anabranching	23274	3639	847
Non-channelised	238	62	73
Chain of ponds	97	40	454
Meandering	786	302	431
Low sinuousity	450	175	203
Floodout	Not present	40	Not present
Gully	Not present	21	Not present
Wandering	271	Not present	Not present

A preliminary vegetation classification system for each focus catchment has been produced by integrating slope and vegetation datasets. Figure 3.21 illustrates the distribution of the vegetation classes identified within the Fitzroy catchment.

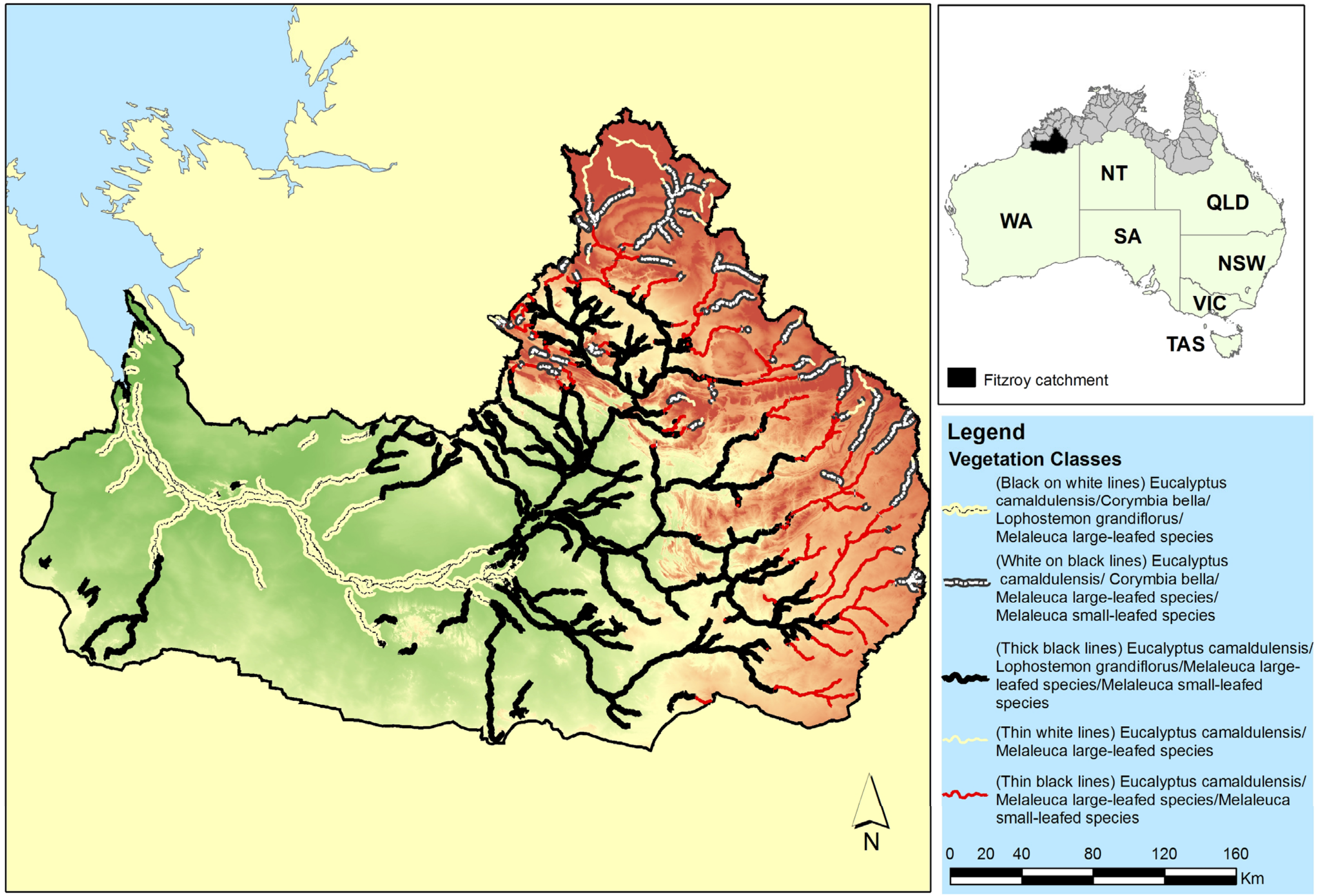


Figure 3.21 Distribution of the vegetation classes within the Fitzroy catchment

A classification system has been developed to describe the hydrological (flow regime) characteristics of each focus catchment. Flow regime is a fundamental characteristic that defines the biological diversity of river systems in the northern wet-dry tropics.

The hydrological variables that can be used to classify flow regime are generally related to overall flow variability, flood patterns and extent of intermittency and can be derived from long-term streamflow data from a gauging station. Long-term flow data for the three focus catchments – Daly River (Northern Territory), Fitzroy River (Western Australia) and Flinders River (Queensland) (Figure 3.22) – were used to derive hydrology variables to classify rivers into flow regime types.

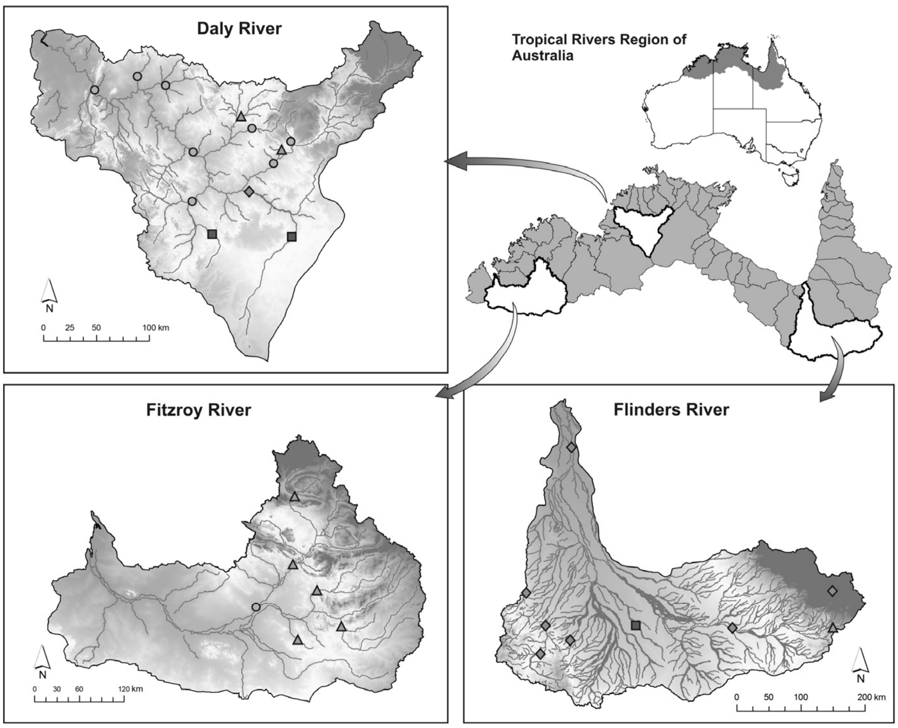


Figure 3.22 Tropical rivers region showing the location of the Daly, Fitzroy and Flinders River catchments. Stations were classified in Section 2 as follows: perennial (○), seasonal (△), dry seasonal (◇) and seasonal-intermittent (□).

Between them, these three river catchments have 28 gauging stations with at least 20 years of complete annual runoff data (Figure 3.22). A selection of hydrology variables was derived for each of these 28 long-term stations. Multivariate cluster analysis of five independent hydrology variables was then used to identify groups of streams with similar flow regimes.

The analysis broadly grouped streams into (1) perennial, (2) seasonal, (3) dry seasonal, and (4) seasonal-intermittent systems. The coefficient of variation of total annual flow and the mean annual number of zero flow days were the two most influential variables for classifying streams into flow regime groups. Since the combination of these two variables explains 94% of the flow regime pattern it is considered that they may be acceptable for classifying the flow regime of streams within the wet-dry tropics. However, many streams throughout the region have little or no flow data available for such analysis, so another method needs to be developed to assign flow regime type.

A selection of basic, independent catchment characteristics (mean annual rainfall, and the topography-related variables of mean catchment slope, mean elevation and drainage density) were derived for each long-term station within the three focus catchments. Using standard multiple regression analysis, significant relationships were found which linked the two most influential hydrological variables, coefficient of variation of total annual flow and mean annual number of zero flow days, to these catchment characteristics. Cluster analysis of these predicted hydrology variables indicated that, by using the topographical characteristics and rainfall regime data, streams could be grouped into the same four classes as derived above using detailed flow records.

The results indicate that the use of catchment characteristics to predict hydrology variables (coefficient of variation of total annual flow and the mean annual number of zero flow days) is an acceptable technique to broadly estimate the flow regime of an ungauged stream within the wet-dry tropics. Additional stations with long-term flow data located within the wet-dry tropics, but outside of the Daly, Fitzroy and Flinders River catchments, should be used to further validate this technique.

3.11.3 Sub-project 2: Assessment of the major pressures on aquatic ecosystems

The objective of Sub-project 2 is to develop a risk assessment framework applicable to both the broad northern tropical rivers region (TRIAP area) and to a more detailed catchment scale. The broad northern Australia overview of the major pressures and threats on tropical Australia's aquatic ecosystems is based on data gathered during this Sub-project and Sub-project 1. The main aim of this component is to identify and describe the key threats, and their relative risks, to aquatic ecosystems. This will be done at a comparatively coarse level, using a catchment scale relative risk model first described by Landis and Wiegers (1997).[2]

Throughout this sub-project a wide range of stakeholders has been consulted to provide primary input and feedback on the development of the framework and aspects and impacts of threats. Semi-quantitative and quantitative risk analyses will be undertaken, where possible, for selected threats.

The risk assessment at focus catchment scale will utilise the same relative risk model applied at the broader overview scale. However the primary assessment unit will be at the sub catchment level. Further more detailed semi-quantitative and quantitative risk assessment is being undertaken for selected pressures and threats for selected sub catchments in the Daly River catchment. A conceptual model (see Figure 3.23) examining the impacts of native

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[2] Landis WG & Wiegers JA 1997. Design Considerations and a Suggested Approach for Regional and Comparative Ecological Risk Assessment. *Human and Ecological Risk Assessment* 3, 287–297.

vegetation clearance and associated land use on ecological endpoints such as barramundi, magpie geese and riparian vegetation has been produced with input from key stakeholders.

A Bayesian Belief Networks (BBN) framework is being developed to undertake the risk analysis for this model (Cain 2001).[3]

An ecological risk assessment GIS is being developed utilising data collected under Sub-project 1 in the context of assets. Further spatial data relating to such impacts as land clearing and land use are being acquired and collated as pressures and threats. The GIS has a hierarchical structure based on asset, pressure/threat and scale (TRIAP area or focus catchment and associated sub catchments), and is crucial to the application of the spatially based relative risk model that is being used to characterise risk.

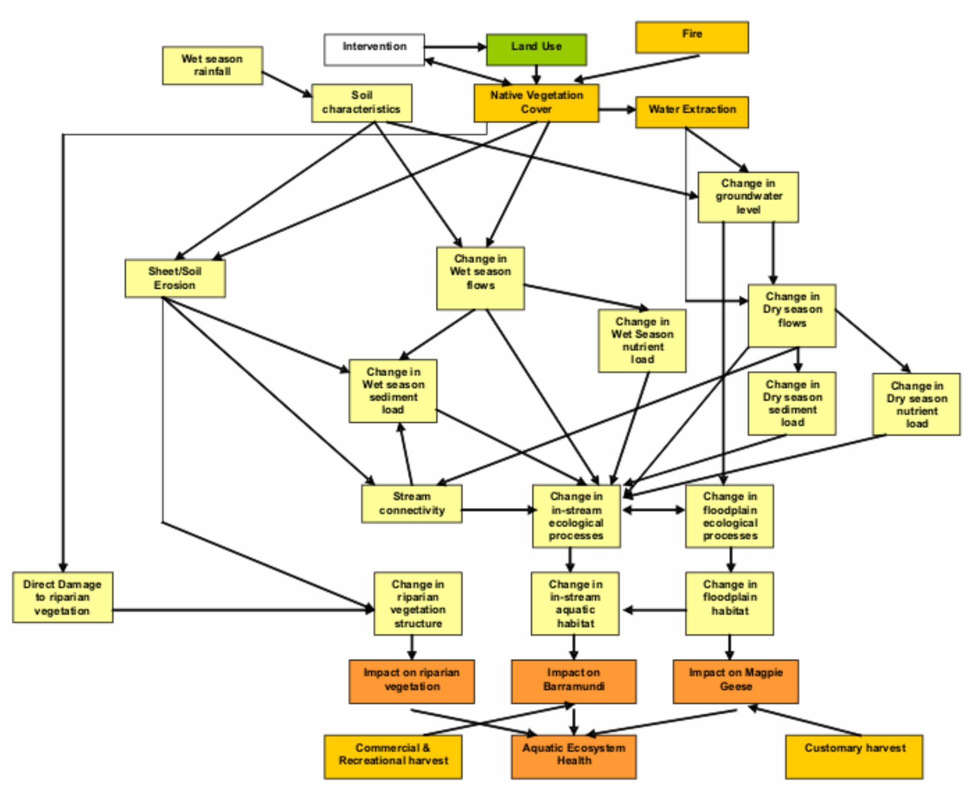

Figure 3.23 Draft conceptual model for impacts on selected endpoints due to native vegetation clearance and associated land use in the Daly River catchment

3 Cain J 2001. *Planning improvements in natural resources management. Guidelines for using Bayesian networks to support the planning and management of development programmes in the water sector and beyond.* Centre for Ecology and Hydrology, UK.

3.11.4 Communications and stakeholder engagement

Key activities that have taken place to support the development of the risk assessment model include stakeholder workshops in two of the focus catchments (Fitzroy and Flinders), the completion and distribution of a risk assessment framework and methodology paper, and the development of several conceptual models for the focus catchments, depicting the inter-relationships between the ecological assets and threats.

Project linkages and communications with stakeholders have continued. Sub-project 2 team members participate in monthly meetings to discuss cross-project collaborations with other groups (Charles Darwin University; the Northern Territory Department of Natural Resources, Environment and the Arts; and CSIRO Northern Australia Irrigation Futures) working on tropical rivers projects. A linkage that has formed from these meetings is with a Daly River fish project being conducted by Charles Darwin University. The Bayesian Belief Network being developed through this sub-project will be utilised by the fish project.

4 STATUTORY COMMITTEES

4.1 Introduction

The Supervising Scientist Division participates in, and provides secretariat and administrative support to, two statutory committees. These committees play important roles in facilitating discussion and consultation on environmental protection issues and in providing peer review of the scientific work of the Division.

4.2 Alligator Rivers Region Advisory Committee

The Alligator Rivers Region Advisory Committee (ARRAC) was established under the *Environment Protection (Alligator Rivers Region) Act 1978* to promote communication between the community and government and industry stakeholders on environmental issues associated with uranium mining in the Alligator Rivers Region.

ARRAC is chaired by Professor Charles Webb, Deputy Vice Chancellor (Teaching and Learning) at Charles Darwin University.

ARRAC offers a valuable forum for stakeholders to exchange views and relevant information on the issues that relate to environmental protection and rehabilitation from the effects of uranium mining.

A key function of ARRAC is to provide transparency in the processes applied to protect the people and environment in the region from the potential impacts of uranium mining.

Public disclosure of environmental performance data is a useful way to enhance trust within the group, thereby reducing the potential for misinformation. Information that is regularly provided to stakeholders through ARRAC meetings includes a summary and interpretation of monitoring data, periodic environmental reports from the mining companies, and audit outcomes for the mines.

A link to the summary records of previous meetings is available on the ARRAC web site at www.deh.gov.au/ssd/communication/committees/arrac/index.html.

ARRAC met twice during 2005–06: in Jabiru in December 2005 and in Darwin in February 2006. Issues discussed during these meetings included:

- water management issues at the Ranger mine, including the status of the Potable Water Treatment Plant;
- the results of chemical, biological and radiological monitoring for Ranger and Jabiluka;
- the outcomes of environmental audits and assessments of Ranger, Nabarlek and Jabiluka;
- the outcomes of Minesite Technical Committee (MTC) meetings;
- ARRTC's Key Knowledge Needs;
- the status of South Alligator Valley mine rehabilitation.

4.3 Alligator Rivers Region Technical Committee

The Alligator Rivers Region Technical Committee (ARRTC) was established under sections 22A–22F of the *Environment Protection (Alligator Rivers Region) Act 1978*.

The primary aim of the Committee is to ensure that the quality of the science used in the research into, and assessment of, the protection of the environment from the impacts of uranium mining in the Alligator Rivers Region is of an appropriately high standard. This involves review of research activities by ***eriss***, ERA and other organisations. It also involves the review of the quality of the science used by ***oss*** and DPIFM to assess and approve proposals by uranium mining companies in the Alligator Rivers Region.

ARRTC reports openly, independently and without restriction. A link to the outcomes of previous ARRTC meetings is available on the ARRTC web site at www.deh.gov.au/ssd/communication/committees/arrtc/index.html.

ARRTC's membership is appointed by the Minister for the Environment and Heritage, and consists of:

- Independent scientific members with specific expertise (including ARRTC's chair), appointed following nomination by the Federation of Australian Scientific and Technological Societies (FASTS);
- Representatives of the Northern Land Council, the Northern Territory Department of Primary Industry, Fisheries and Mines, Energy Resources of Australia Ltd (for Ranger and Jabiluka), Hanson Pty Ltd (for Nabarlek) and Parks Australia North;
- The Supervising Scientist.

ARRTC is chaired by Mr Ray Evans, who succeeded Professor Barry Hart who retired from the role in September 2005. Mr Evans was an existing independent member of ARRTC.

Figure 4.1 ARRTC members with the Director of ***eriss*** and ERA staff at monitoring point **G8210009** downstream of the Ranger mine – September 2005

Professor Jon Nott was appointed to ARRTC on 5 August 2005, replacing Professor Gerald Nanson who resigned in March 2005.

Dr Keith Hayes was appointed to ARRTC on 25 January 2006, filling the vacancy left as a result of Professor Barry Hart's resignation.

ARRTC met twice during 2005–06: from 31 August to 2 September 2005 (ARRTC's sixteenth meeting) and from 27 to 28 February 2006 (ARRTC's seventeenth meeting).

Both meetings were held in Darwin.

At these meetings, ARRTC considered and discussed a wide range of issues, including:

- the research activities conducted by ***eriss*** and ERA, in the context of the Key Knowledge Needs;
- the chemical, biological and radiological monitoring activities being conducted by DPIFM, ERA and the Supervising Scientist;
- specific issues relating to Ranger, Jabiluka and Nabarlek;
- the status of South Alligator Valley rehabilitation activities;
- updates from the various stakeholders represented at ARRTC.

ARRTC's Key Knowledge Needs are an important input into prioritising and planning future research activities, and will provide the basis for mining-related research activities. They are included at Appendix 1 of this Annual Report.

5 COMMUNICATION AND LIAISON

5.1 Introduction

Effective communication with all stakeholders is an integral component of the Supervising Scientist Division's functions. Of particular importance is the need to inform traditional Aboriginal owners and other Aboriginal people living in the Alligator Rivers Region about the activities of the Supervising Scientist including the supervisory activities of the Office of the Supervising Scientist (***oss***) and the research and monitoring programmes undertaken or managed by the Environmental Research Institute of the Supervising Scientist (***eriss***). Communication with research partners and other stakeholders within government, industry, science and the general community is also vital in the context of the research and supervisory functions of the Division. As part of the Department of the Environment and Heritage and as a research institute, the Division contributes substantially to the development of national and international policy and programmes on environmental radiation and nuclear issues.

5.2 Research support and communication

During 2005–06, communication staff continued to provide support across the research and monitoring programmes: firstly by building on existing and initiating new internal communication activities and, secondly, by strengthening stakeholder consultation on the activities being undertaken by the Supervising Scientist within the Alligator Rivers Region. New links have been built and existing ones strengthened with research partners and other groups and networks to promote the work of ***eriss*** and Supervising Scientist within the scientific community.

The Division was actively involved in a number of event-based communication activities such as open days and festivals with local communities in Kakadu National Park and the Alligator Rivers Region (Section 5.2.3). These activities further develop the depth of our interaction with the local Aboriginal community and with other research organisations, non-governmental environmental groups and the general public.

5.2.1 Indigenous employment and consultation

Traditional Aboriginal owners and other local Aboriginal people actively participated in SSD's research and monitoring programme during the year, supporting field activities such as creekside monitoring, the water quality monitoring associated with Ranger mine, collection of mussels and fish, sampling of macroinvertebrates and general field station activities. Indigenous employment provided the opportunity for ***eriss*** staff to work alongside landowners on their country, sharing knowledge and gaining greater insight into traditional cultural values. It also gave indigenous people opportunities to gain first hand knowledge and valuable technical skills and understanding of the research and monitoring programme.

We wrote last year that future development of research support and communication within the Division would focus on identifying ways to enhance our reporting of information to traditional Aboriginal owners and the indigenous communities within the Alligator Rivers Region. A number of initiatives outlined below have progressed this.

For example, a local Kakadu Traditional Owner joined the field station team as an indigenous trainee in 2005. Recently, he was appointed to an ongoing full-time position as Communications and Monitoring Support Officer with ***eriss*** which means that information about the work of the Division can now be delivered in local indigenous language thus strengthening our relationship and ability to communicate with traditional Aboriginal owners and other indigenous people in the Region.

We have maintained regular informal contact with indigenous communities in the Region including the Mirarr people – the traditional owners of the land on which Ranger and Jabiluka lie. This regular contact has afforded more opportunity for understanding of our role and function and helped us keep the local communities well informed about our monitoring and research programmes. Informal contact has involved visits to and from local communities in the Region, including interested indigenous people observing our monitoring and research activities both in the field and in the laboratory.

Figure 5.1 Mudginberri residents visit the Darwin Laboratories. Here they are being shown the steps involved in processing mussel samples in one of the Environmental Radioactivity laboratories.

Communications staff were responsible for consulting not only with traditional owners and other indigenous organisations, but also the Northern Land Council and Parks Australia North on the Division's activities in the area. The consultative process ensures that all stakeholders are provided with information on the research, monitoring and supervisory activities being undertaken by the Division. For example, SSD helped with the initial consultation related to defining closure expectations for the Ranger Project Area. This meeting was held on country with the Mirarr traditional owners. It was a multi-party forum with representatives from various stakeholder groups including SSD, Department of Primary Industry, Fisheries and Mines, Energy Resources of Australia Ltd and the Northern Land Council.

We have also ensured on-going collaborative engagement of Aboriginal people in the closure process through employment of traditional owners in projects associated with development of closure criteria, such as the collection of macroinvertebrates aimed at developing surface water quality closure criteria for Ranger billabongs.

Figure 5.2 Consultation with Mirarr traditional owners at Mula in Kakadu National Park

The Director of ***eriss*** is a member of the Kakadu Research Advisory Committee. This is another way in which we communicate our work to the traditional Aboriginal owners of the Park.

Finally, cross-cultural training for staff to enable more effective communication and working relations with indigenous people continues to be provided at regular intervals. This year the training was provided by a family of traditional owners from western Arnhem Land.

5.2.2 Internal communications

Regular general staff and research programme meetings provide a forum for communication of information between staff at all levels. The formation of support groups (eg Monitoring Support, Spatial Users, Knowledge Management) to address important strategic business issues has enhanced communication of important information around the Division.

A number of IiP (Investor in People) activities have been undertaken including making available Canberra-based seminars by videolink and by holding IiP-supported social functions that help keep people in touch and foster staff relations. Staff have also delivered seminars internally (both at Darwin and Jabiru) on research to be presented at conferences.

The Division's internal weekly staff newsletter, *Newsbrief*, is produced by communications staff and informs staff of activities undertaken by those in Darwin *and* Jabiru. It contains articles on research, field trips and communication activities that are sourced from our staff, profiles and photos of new starters, and a diary of upcoming events and staff movements. *Newsbrief* is also used as a source of articles for external communications such as What's New on the web site and *InsiDEH*, the Department's internal newsletter.

A major Departmental communication initiative has had special significance for SSD. During the year, the Department implemented a major overhaul of the DEH Intranet site. For many internal service areas, this only required an update to, or restructure of, existing content. However, for many Divisions such as SSD, it meant creation of a complete new site under the DEH umbrella. Launched in June 2006, the new Intranet will play an important communications role providing staff with a vital resource for Divisional and Departmental information. Features on the SSD site include brief information about teams and individuals, our business activities, policies and procedures, contact information, a 'how to' index, and links to research and monitoring information on our external SSD web site. User testing was undertaken towards the end of the year highlighting areas for further work.

5.2.3 Communication with technical stakeholders and general community

Coordination of other communication and general public relations activities was facilitated by Division staff throughout the year.

The Division participated in a number of event-based communication activities including exhibits at Gunbalanya Open Day in Arnhem Land, Mahbilil Festival in Jabiru and the CSIRO Top End Science Fair in Darwin. Information stalls were run at various local conferences including Australian Society for Fish Biology 2005 and NARGIS 2005. All of these activities served to enhance understanding of our work and role and raise our profile within the local and wider community.

Figure 5.3 SSD display at the Gunbalanya Open Day

Other communications activities of note during the year included:

- Alligator Rivers Region Advisory Committee (ARRAC) meetings. These meetings bring together members and observers from various stakeholder groups and provide a forum for information exchange on activities in the Region and opportunity to discuss concerns. The traditional associated golf game and social event provide further opportunity to foster external relations.

- Ecosystem Establishment Workshop held with key stakeholders to identify outstanding knowledge needs for the establishment of ecosystems on the Ranger mine site following closure. A key outcome of the workshop was the recommendation and endorsement by all stakeholder participants that demonstration landform vegetation areas be established at Ranger by December 2007.
- Presentation to the Indigenous Mining and Enterprise Taskforce meeting held in Jabiru, outlining the role of SSD in the region with particular focus on indigenous involvement in SSD activities.
- Participation in the Kakadu Junior Ranger Programme, facilitating a lesson on research and monitoring in Kakadu that focused on the role of the Supervising Scientist and the techniques used in SSD monitoring programmes.
- Co-hosting of weeds workshop with Earth Water Life Sciences (EWLS) and Energy Resources of Australia Ltd on identification of existing weeds, the skills needed for identification, and information on potential weeds not yet present in Kakadu.
- Participation in Parks Australia North workshop on the issue of salvinia in Yellow Water in Kakadu.
- Hosting information session centred round a BBQ at Gunbalanya about Nabarlek-related work. Staff also attended the Nabarlek Annual General Meeting and spoke to Nabarlek traditional owners about SSD research work currently being undertaken on the old mine site and on-site supervision and audit activities.

5.3 National and international environmental protection activities

5.3.1 Environmental radiation protection

In December 2003 the International Commission on Radiological Protection (ICRP) decided to develop a framework for the assessment of radiation effects in non-human species. To assist in implementing this decision, the ICRP established Committee 5 to consider the protection of non-human organisms. The former Supervising Scientist, Dr Arthur Johnston, was appointed to this committee which first met in September 2005. Dr Johnston's role with the ICRP continues beyond his retirement from the Australian Public Service.

The ICRP recognises that nations already have highly developed regulatory systems in place for the protection of the environment. For this reason it will not make specific recommendations on a regulatory regime for the protection of the environment from ionising radiation. Rather, it will develop a framework that can then be used by nations to integrate within their own existing legislative and regulatory systems.

5.3.2 Basslink

The recently-commissioned Basslink interconnector allows the trade of electricity between Tasmania and the mainland. The original proposal was assessed and approved under the *Environment Protection (Impact of Proposals) Act 1974*, and one of the conditions of approval required the establishment of the Gordon River Scientific Reference Committee (GRBSRC) to consider a range of scientific and technical issues associated with the implementation of the Gordon River Basslink Monitoring Programme and other Gordon River Basslink scientific reports. In September 2003, Dr Chris Humphrey and Dr Ken Evans of ***eriss*** (SSD) were appointed to represent the Australian Government on the GRBSRC. Drs Humphrey and Evans have undertaken field inspection of Gordon River monitoring sites and assessed the annual monitoring reports and the Basslink baseline report. The Basslink baseline report has been completed, following rigorous review by the GRBSRC during 2005–06. Monitoring and assessment (and their review by the GRBSRC) of Basslink's environmental impacts upon the Gordon River will continue.

5.4 National Centre for Tropical Wetland Research

The National Centre for Tropical Wetland Research (***nctwr***) is a collaborative venture between the Environmental Research Institute of the Supervising Scientist (***eriss***) and three university partners: James Cook University, Charles Darwin University and the University of Western Australia.

Communication and extension activities for a major ***nctwr*** project, the Tropical Rivers Inventory and Assessment Project (TRIAP), have largely been supported by a dedicated officer in ***eriss***. More information about TRIAP is contained in Section 3.11.

More information about ***nctwr*** administrative arrangements during 2005–06 is contained in Section 6.8.

5.5 Science communication and education

Results of research and investigations undertaken by the Supervising Scientist Division are made available to key stakeholders and the scientific and wider community through publication in a range of in-house journals and reports. These include: the Supervising Scientist and Internal Report series for detailed reporting on scientific projects; and the Supervising Scientist Note series, which is used to showcase specific projects to a wider audience. A full list of papers and reports published during 2005–06 is at Appendix 2. (See www.deh.gov.au/ssd for these publications as well as current results for the chemical, biological and radiological monitoring programmes.)

In addition, staff of the Division have contributed articles to a range of external journals and presented papers at various conferences and workshops. Papers given at international and national conferences are included in Appendix 3.

Other media, such as posters and educational or promotional materials, are also produced on a needs basis to suit specific requirements or events. A major overhaul of these materials is planned for next year.

Staff have been involved in the organisation and presentation of conferences, seminars and lectures, at our facility and in partnership with other research organisations such as Charles Darwin University, and professional bodies such as the Royal Australian Chemical Institute, the Australian Water Association, the Spatial Sciences Institute and the Institute of Engineers Australia. Involvement in these activities further illustrates the Division's commitment to the advancement of professional practice and communication of the work of SSD and is an important part of our contribution to the local scientific and professional communities.

Over the year, ***eriss*** has taken on the supervision of a number of students doing post-graduate research projects. This includes students from Charles Darwin University and other universities around Australia. In addition, a number of the Division's staff hold positions within external scientific, technical and other professional organisations, including on various editorial boards and panels. ***eriss*** also hosts researchers from other organisations to undertake collaborative funded projects, or for sabbatical periods.

5.6 International conferences

Staff of the Supervising Scientist participated in a range of international conferences, seminars and workshops during 2005–06 (Table 5.1). Attendance at the majority of these events was funded, either partly or fully, from external sources. Participation in international events allows staff to share their knowledge and expertise with peers and is seen as important in allowing the Supervising Scientist Division to maintain its profile as a part of the broader scientific and technical community.

TABLE 5.1 OVERSEAS CONFERENCES, SEMINARS AND WORKSHOPS ATTENDED BY SUPERVISING SCIENTIST DIVISION STAFF IN 2005–06

Event	Location	Date
Mediterranean Wetlands CODDE Workshop	Lisbon, Portugal	July 2005
9th International Mine Water Association Congress	Oviedo, Spain	September 2005
4th International Conference on Uranium Mining and Hydrogeology	Freiberg, Germany	September 2005
Uranium Mining and Milling Remediation Exchange Group	Freiberg, Germany	September 2005
Organising Committee for the IAEA's 2007 International Conference on Environmental Radioactivity	Vienna, Austria	October 2005
12th Australian and New Zealand Geomorphology Group Conference	Taipa Bay, New Zealand.	February 2006

6 ADMINISTRATIVE ARRANGEMENTS

6.1 Human resource management

6.1.1 Supervising Scientist

The Supervising Scientist is a statutory position established under the *Environment Protection (Alligator Rivers Region) Act 1978*. Section 8 of the Act requires that the Supervising Scientist be engaged under the *Public Service Act 1999*.

Dr Arthur Johnston PSM, who had held the position of Supervising Scientist since June 1999, retired in October 2005. Mr Alan Hughes was appointed to succeed Dr Johnston in December 2005. Mr Hughes had been Acting Supervising Scientist since Dr Johnston's retirement.

6.1.2 Structure

The Supervising Scientist Division consists of two branches, the Office of the Supervising Scientist and the Environmental Research Institute of the Supervising Scientist.

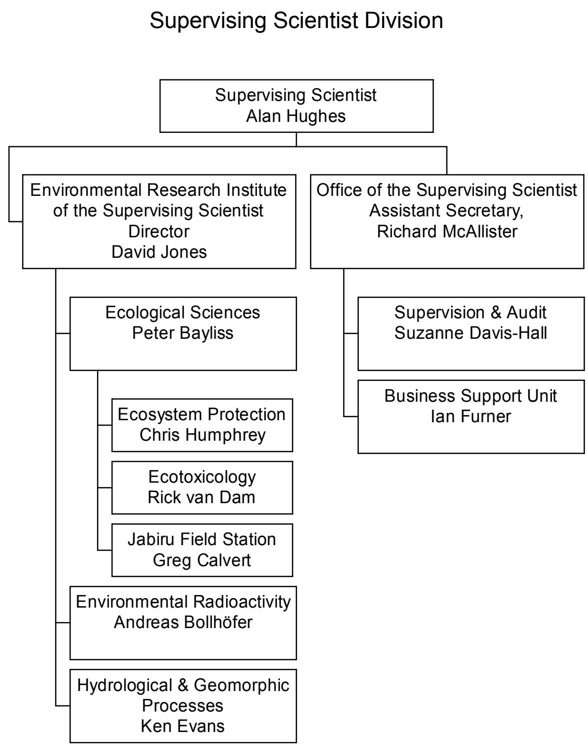

Figure 6.1 Organisational structure of the Supervising Scientist Division (as at 30 June 2006)

The Office of the Supervising Scientist (***oss***) is responsible for supervision, audit, policy, information management and corporate support activities. ***oss*** is headed by Mr Richard McAllister who was appointed in April 2006, replacing Mr Alan Hughes who was appointed to the position of Supervising Scientist in December 2005.

The Environmental Research Institute of the Supervising Scientist (***eriss***) is headed by Dr David Jones and undertakes scientific research activities.

Staffing numbers as at 30 June 2005 and 30 June 2006 are given in Table 6.1.

TABLE 6.1 STAFFING NUMBERS AND LOCATIONS (AT 30 JUNE 2006)

	2004–2005	2005–2006
Darwin	38	43.5
Jabiru	6	7
Total	44	50.5

6.1.3 Investor in People

The Investor in People (IiP) process has continued to encourage a culture of continuous improvement. Reviews of strategic business planning, business processes, staff structures and responsibilities have been undertaken within the Supervising Scientist Division over the past year.

Staff have been encouraged and supported by management in the development of skills through training, attendance at conferences and internal opportunities to act in higher level positions. Through the Performance Development Scheme, staff have identified training requirements to assist them in delivering outcomes in their workplans. SSD staff participation in DEH Internal Seminar Series and other seminars hosted by DEH Canberra has been increased through the installation of video conferencing equipment in the DEH Canberra Bunker Theatre. Other seminars have been hosted locally to provide staff with access to a range of topics relevant to SSD business activities.

Effective communication has also been an integral part of achieving outcomes set by the organisation. SSD continues to produce a fortnightly newsbrief for staff that attracts a wide range of contributors and readership . Management and staff participate in regular structured meetings that ensures information flow within the organisation is maintained. Healthy lifestyle and social activities coordinated by IiP representatives and social club members also enable staff to network in an informal manner.

6.1.4 Occupational Health and Safety

The Supervising Scientist Division continued to maintain a strong commitment to occupational health and safety issues during 2005–06. The Occupational Health and Safety (OH&S) Committee is the primary mechanism in place for the discussion of issues, and for the referral of issues to the Division's senior management team. This staff-based Committee meets on a monthly basis. This year the committee has contributed to the development of a number of OH&S policies and guidelines on issues, for example travel by vehicle and selection of protective clothing suitable for fieldwork.

During the year, we established a substantial OH&S section on the newly launched SSD Intranet site, with content developed and approved by the committee and linked to the relevant Departmental pages. Other OH&S initiatives during the year included an emergency response checklist to ensure staff answering an emergency phone call from the field gather all the necessary information. Further progress was made on the safety manual update. A review has commenced of the Darwin building emergency evacuation procedures. The safety sections (field, chemical, radiation safety) of the project approval form have been revised and work has started on developing a safety approval process for non-project work with a fieldwork element. Workplace inspections were carried out during the period in accordance with OH&S requirements.

Our ARPANSA licence, which is issued to the Supervising Scientist and allows SSD to hold certain radioactive sources, has now been modified to include non-ionising radiation sources as well. SSD is now also licenced to use optical sources (other than a laser) that produce ultra-violet light, and these sources and general control, safety and management plans are now included (since 2005) in the Radiation Source Control Plan of SSD.

6.2 Finance

The Supervising Scientist Division is part of the Department of the Environment and Heritage and full financial statements for the Department are contained in the Department's Annual Report.

A summary of the costs of the Supervising Scientist's contributions to the Department's outputs are provided in Table 6.2. The table aligns the different PBS Output numbers and titles that applied in 2004–05 and 2005–06 so that a comparison can be made between both financial years.

TABLE 6.2 SUMMARY OF COST OF OUTPUTS

PBS Output	2004–2005	2005–2006
Uranium mining		
1.6 Industry/Human settlements (2004–05) 1.5 Response to the impacts of human settlements (2005–06)	$8 458 000	$9 310 000
Tropical wetlands		
1.7 Inland waters (2004–05) 1.2 Conservation of the land and inland waters (2005–06)	$1 364 000	$466 000
Total	$9 822 000	$9 775 000

6.3 Facilities

6.3.1 Darwin facility

The majority of the Supervising Scientist Division's staff are situated at the Department of the Environment and Heritage's Darwin facility adjacent to Darwin International Airport. This facility consists of office accommodation and laboratories.

The office space is shared with Parks Australia North, which is also part of the Department of the Environment and Heritage.

6.3.2 Jabiru Field Station

A Field Station at Jabiru is maintained to support the activities of the Supervising Scientist Division. The staff consist of the monitoring team that carry out the Supervising Scientist's environmental monitoring programme; an employee who is responsible for delivering the Supervising Scientist's Aboriginal communications programme in Jabiru; an employee who undertakes administrative and financial duties; and the Field Station Manager, who has overall responsibility for managing the Field Station as well as supervisory and inspection responsibilities.

The Field Station sustained some damage as a result of Tropical Cyclone Monica which passed close to Jabiru in the early hours of 25 April 2006.

Staff of the Division, in conjunction with Canberra-based Department of the Environment and Heritage facilities management staff, have started reviewing the Field Station with the aim of optimising asset utilisation and ensuring that a safe and appropriate working environment is provided.

Figure 6.2 Tree damage at Jabiru Field Station caused by Tropical Cyclone Monica

6.3.3 Library

The Supervising Scientist Division's library continues to support the work of the Division, as well as Parks Australia North. The services provided include on-line searches, library inductions and document delivery services. Some 1485 items were added during the year.

6.4 Business planning process

The new annual business planning and reporting process has been fully implemented. This Business Plan outlines key issues that the Supervising Scientist Division will face over the coming year. It outlines the direction SSD intends to take, the activities and programmes to be undertaken and how SSD intends to measure performance. Review of progress against strategic priorities and actions is undertaken on regular basis.

6.5 Interpretation of Ranger Environmental Requirements

Section 19.2 of the Environmental Requirements of the Commonwealth of Australia for the Operation of the Ranger Uranium Mine provides for the publication of explanatory material agreed to by the major stakeholders to assist in the interpretation of provisions of the Environmental Requirements. No explanatory material was published during 2005–06.

6.6 Ministerial Directions

There were no Ministerial Directions issued to the Supervising Scientist under Section 7 of the *Environment Protection (Alligator Rivers Region) Act 1978* during 2005–06.

6.7 Sustainability report

The Supervising Scientist Division first participated in the Department of the Environment and Heritage's Triple Bottom Line (TBL) reporting programme during 2003–04. TBL reporting , now referred to by the Department as the Sustainability Report provides a transparent and accountable reporting system in line with international Global Reporting Initiatives (GRI) on the Department's impact on the community and the environment, including details of performance against social, economic and environmental indicators.

For 2005–06, the Division has set goals to reduce our impact on the environment and to introduce additional monitoring systems to gather information on relevant indicators.

The Department is required to present this information in accordance with Section 516A of the *Environment Protection and Biodiversity Conservation Act 1999* which requires government departments to report on:

- how the Department's activities accord with the principles of ecologically sustainable development (subsection 6a);
- how the Department's outcomes contribute to ecologically sustainable development (subsection 6b);

- the environmental impacts of the Department's operations during the year, and measures taken to minimise the impacts (subsections 6c, d and e).

6.7.1 How the Department applies the principles

The principles of ecologically sustainable development[4] are central to the Department's environment and natural heritage protection activities, all of which aim to conserve biodiversity and ecological integrity, and to maintain the health, diversity and productivity of the environment for the benefit of future generations.

The Department administers the *Environment Protection and Biodiversity Conservation Act 1999* and the *Natural Heritage Trust of Australia Act 1997*, both of which explicitly recognise these principles.

6.7.2 Contribution of outcomes

The Department of the Environment and Heritage is the lead Australian Government agency for developing and implementing national policy, programmes and legislation to protect and conserve the natural environment. One of the key functions of the Department is to promote and support ecologically sustainable development.

The Department's outcomes contribute to ecologically sustainable development as follows:

- Outcome 1: Protecting and conserving the environment helps to maintain the ecological processes on which life depends.
- Outcome 2: Australia's Antarctic interests include a strong focus on protecting the Antarctic environment, as well managing the sustainable use of Antarctic marine resources.

The Division's outputs form part of Outcome 1. The results for the Department of the Environment and Heritage as a whole are published separately. Reports are also available on the Department's web site at www.deh.gov.au/about/publications/tbl/index.html.

6.7.3 Summary of performance 2005–06

SSD's Environmental Management System (EMS)

This section reports on SSD's progress towards an EMS certified to ISO 14001: 2004 (*Environmental management systems – Specification with guidance for use*).

The Division reviewed how scientific research activities can be incorporated into the draft environmental management system, and implemented an action plan to track achievement of the goals set in the 2004–05 Triple Bottom Line report against the Global Reporting Initiatives.

To assist further development of the Environmental Management System, a steering group was established in March 2006. This group includes representatives from Senior

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4 The principles of ecologically sustainable development are set out in sections 3A and (in the case of the precautionary principle) 391 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Management, the Environmental Research Institute of the Supervising Scientist research programme and the Office of the Supervising Scientist Supervision and Audit team. The initial task set for the group was to review our current compliance register to include all legislation, regulations, authorisations and codes of compliance our organisation is required to comply with to cover all of SSD's research activities. This is still under development.

Occupancy

During 2005–06 the Supervising Scientist has continued to conduct business from two premises: DEH Darwin and the Jabiru Field Station. The DEH Darwin facility is shared by both the Supervising Scientist Division and Parks Australia North (Table 6.3).

TABLE 6.3 OCCUPANCY AND AREA OF BUILDING 2005–06

	Darwin	Jabiru	Total
SSD staff	43.50	7	50.50
PAN staff	8.25		8.25
TOTAL staff	51.75	7	58.75
Office area m^2	1050 m^2	1207 m^2	2257 m^2
Laboratory area m^2	2450 m^2	1860 m^2	4310 m^2
TOTAL area	3500 m^2	3067 m^2	6567 m^2

Figures reported for waste, electricity, water usage and greenhouse gas emissions (excluding vehicle usage) cover both Supervising Scientist Division and Parks Australia North operations.

Energy

Electricity

Electricity usage by SSD's Darwin and Jabiru offices and Parks Australia North Darwin office increased by 4% from last year due to increased occupancy, however, the total consumption per person decreased by 6% (Table 6.4).

TABLE 6.4 TOTAL POWER CONSUMPTION 2005–06

Power	2004–05	2005–06
Total kWh	922 879	956 559
Total MJ	3 322 364	3 443 613
Total GJ	3322	3444
MJ per person per annum	59 328	58 865
MJ per m^2 per annum	506	524
CO_2(t)	685	710

Fuel and transport

Fuel usage (transport and other usage) was reduced by 17.7% and distance travelled by vehicles decreased by 30.8% for the same period last year (Table 6.5).

TABLE 6.5 PERFORMANCE – TRANSPORT

Fossil fuel	2004–05	2005–06
Total litres	40 853	33 612
Total distance travelled	280 933	229 622
Average (l) per 100 km	14.5	14.63
Total GJ – petrol	613	417
Total GJ – diesel	885	826
Total CO_2(t) – petrol	45	31
Total CO_2(t) – diesel	62	58

Water

Water usage at the Darwin office increased from 724 kL last year to 1403 kL this year, partly because of an increase in aquaculture work at the Environmental Research Institute of the Supervising Scientist.

Materials – paper

It is the Division's practice, where possible, to purchase 'green' stationery and toiletry products rather than standard products. The Division used 20.2% less paper this year than last year, exceeding the 10% target set in the 2004–05 Triple Bottom Line report (Table 6.6). This was achieved through reusing paper printed on one side, installing duplex trays in printers for double-sided printing, encouraging staff to edit documents on screen, and disseminating information electronically.

There was also a 40.4% reduction in the use of non-recycled paper, and an 8.5% reduction in partly recycled paper.

TABLE 6.6 MATERIALS – PAPER

	Virgin	Partly recycled	Total
Total (reams)	127	336	463
Total (sheets)	63 500	168 000	231 500
Per employee (reams)	2.5	6.7	9.2
Per employee (sheets)	1 257.4	3 326.7	4 584.1
Sheets per day per person	5.5	14.5	20

Waste

To reduce landfill waste, staff sort waste including toner cartridges, glass, paper and plastic products into recycle bins. Organic waste is recycled through the worm farm established to provide live feed for breeding populations of fish (the purple spotted gudgeon) used for research purposes (Figure 6.3).

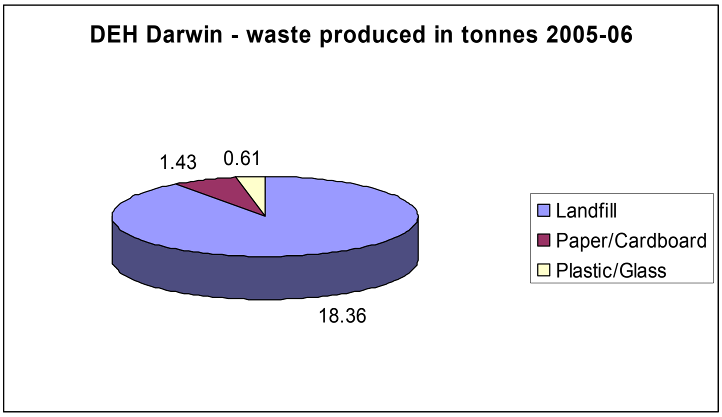

Figure 6.3 Darwin DEH waste produced 2005–06

Greenhouse gas emissions

Greenhouse gas emissions this year are down by almost 380 t (1226 t in 2004–05 compared with 822.67 t in 2005–06). The lower emissions can be attributed to lower fuel usage, reduced distance travelled by vehicles and less waste produced on site (Figure 6.4).

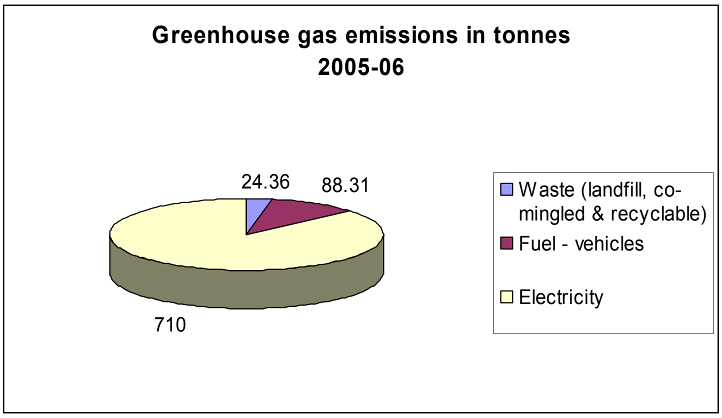

Figure 6.4 Darwin DEH greenhouse emissions 2005–06

6.8 National Centre for Tropical Wetland Research

The National Centre for Tropical Wetland Research (***nctwr***) is a collaborative venture between the Environmental Research Institute of the Supervising Scientist (***eriss***) and three university partners: James Cook University, Charles Darwin University and the University of Western Australia. The activities of the ***nctwr*** are administered through a Board of Management, Advisory Committee and Operational Committee.

Despite two attempts to arrange meetings in 2005–06, the Board of Management was unable to convene. In 2004–05, the Board resolved to initiate a process to establish the future research needs of key stakeholders (ie, government, industry), and that this information be used to identify the necessary research skills and develop a strategic research prospectus for a 'revamped' ***nctwr***. This process was commenced, but has since been subsumed by the larger initiative of the Tropical Rivers and Coastal Knowledge (TRACK) Research Hub, which brings together Australia's leading tropical river and coastal scientists and managers to identify and investigate key social, economic and environmental issues and information gaps that will help ensure the northern rivers and coastal regions are developed in a sustainable manner. The four partner organisations of the ***nctwr*** are involved to varying extents in the TRACK initiative, which has already secured funding under the Commonwealth Environment Research Facilities (CERF) programme and from Land and Water Australia, but is yet to formalise its administrative and operational arrangements. Until this has occurred, further discussion and decisions about the future of the ***nctwr*** have been placed on hold.

For similar reasons as described above, and due to other priorities, the Advisory and Operational Committees also were unable to meet in 2005–06.

The key research activities of the ***nctwr*** during 2005–06 related to the Tropical Rivers Inventory and Assessment Project (TRIAP, managed by ***eriss***), the progress of which is described in Section 3.11 of this Annual Report, and the 'Comprehensive analysis of the freshwater fish faunas and their key management issues across northern Australia' (managed by James Cook University).

6.9 Animal experimentation ethics approvals

eriss seeks the approval of the Charles Darwin University's *Animal Experimentation Ethics Committee* for approval to undertake scientific experiments involving animals.

Table 6.7 provides information on new applications, renewals of approvals and approval expiries for projects during 2005–06.

TABLE 6.7 ANIMAL EXPERIMENTATION ETHICS APPROVALS				
Project Title	Ref no	Initial Submission	Approval/Latest Renewal	Expiry
Larval fish toxicity testing at *eriss*	97016	26 May 1997	13 Mar 2006	13 Mar 2008
Chronic toxicity of uranium to the tropical freshwater fish, *Mogurnda mogurnda* and *Melanotaenia splendida inornata*	A06008	April 2006	24 April 2006	24 April 2008
Monitoring mining impact using the structure of fish communities in shallow billabongs	A00028	25 Sep 2000	4 Feb 2005	4 Feb 2007
Survival of larval fishes in creekside monitoring tests, Magela Creek	A00034	1 Nov 2000	10 Dec 2004	10 Dec 2006
Metal and radionuclide concentrations of fish and mussels associated with the Ranger mine	A02026	31 Oct 2002	28 July 2005	28 July 2007

APPENDIX 1 ARRTC KEY KNOWLEDGE NEEDS

Overall objective

To undertake relevant research that will generate knowledge leading to improved management and protection of the ARR and monitoring that will be sufficiently sensitive to assess whether or not the environment is protected to the high standard demanded by the Australian government and community.

Background

In assessing the Key Knowledge Needs for research and monitoring in the Alligator Rivers Region, ARRTC has taken into account current mining plans in the region and the standards for environmental protection and rehabilitation determined by the Australian Government.

The assumptions made for uranium mining operations in the region are:

- Mining of uranium at Ranger is expected to cease in about 2008. This will be followed by milling until about 2011 [revised to 2014 during 05/06] and final rehabilitation expected to be completed by about 2016 [revised to 2019 during 05/06].
- Nabarlek is decommissioned but has not reached a status where the NT Government will agree to issue a Revegetation Certificate to the mine operator. Assessment of the success of rehabilitation at Nabarlek is ongoing and is being used as an analogue for rehabilitation at Ranger.
- Jabiluka will remain in a care and maintenance condition for some years, at least until mining ceases at Ranger.
- It is unlikely that any proposal will be brought forward for mining at Koongarra in the foreseeable future.

This scenario is considered to be a reasonable basis on which to base plans for research and monitoring, but such plans may need to be amended if mining plans change in the future. ARRTC will develop a series of possible future scenarios regarding uranium mining in the ARR, and will ensure the research and monitoring strategy is flexible enough to accommodate any new knowledge needs.

The Commonwealth Government has specified Primary and Secondary environmental objectives for mining at Ranger in the Ranger Environmental Requirements. Similar standards would be expected for any future mining development at Jabiluka or Koongarra.

Specifically, under the Ranger Environmental Requirements (ERs):

The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:

(a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list;

(b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (ie the wetlands within Stages I and II of Kakadu National Park);

(c) protect the health of Aboriginals and other members of the regional community; and

(d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.

With respect to rehabilitation at Ranger, the ERs state that:

The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.

The ERs go on to specify the major objectives of rehabilitation at Ranger as follows:

(a) revegetation of the disturbed sites of the Ranger Project Area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park;

(b) stable radiological conditions on areas impacted by mining so that, the health risk to members of the public, including traditional Aboriginal owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restrictions on the use of the area;

(c) erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas.

While there are many possible different structures that could be used to specify the Key Knowledge needs, ARRTC has chosen to list the knowledge needs under the following headings:

- Ranger – current operations
- Ranger – rehabilitation
- Jabiluka
- Nabarlek
- General Alligator Rivers Region
- Knowledge management and communication.

1 Ranger – current operations

ARRTC believes that the knowledge (research) needs relating to the current management of the uranium mining operations in the ARR would be best organised within a risk management framework. Such a framework would permit the various risks to the ARR to be assessed using a consistent, quantitative methodology and to be placed in priority order. Risk management is built on the use of quantitative predictive models to link threats or stressors with potential adverse ecological effects.

eriss is undertaking some ecological risk assessment work, but we believe this needs to be upgraded and made the central focus of the research programme. Proposals for research should then be assessed in terms of how the knowledge generated will contribute to the management of risk from the mining operations.

1.1 Reassess existing threats

Surface water transport of radionuclides: Using existing data, assess the present and future risks of health problems to the Aboriginal population eating bush tucker potentially contaminated by the mining operations bearing in mind that the current traditional Aboriginal owners derive a significant proportion of their food from bush tucker.

Atmospheric transport of radionuclides: Using existing data and atmospheric transport models, review and summarise, within a risk framework, dose rates for members of the general public arising from operations at the Ranger mine.

1.2 Ongoing operational issues

Ecological risks via the surface water pathway: In order to place the off-site contaminant issues at Ranger in a risk management context, a conceptual model of transport/exposure pathways should be developed. This process should include a review and assessment of the existing information on the risks of the bioaccumulation and trophic transfer (ie biomagnification) of uranium and other Ranger mining-related contaminants from all exposure pathways and including the identification of key information gaps.

Land irrigation: Investigations are required on shallow groundwaters in the land irrigation areas adjacent to Magela Creek as a diffuse source of contaminants. Contaminants of interest/concern in addition to radionuclides are magnesium, sulfate and manganese. Further, the status of the irrigation areas in relation to decommissioning requirements (including radiological risk) needs to be assessed. Water quality models will be linked to knowledge of ecological effects.

Wetland filters: The key research issue associated with wetland filters in relation to ongoing operations is to determine whether their capacity to remove metals (principally uranium) from the water column will continue to meet the needs of the water management system in order to ensure protection of the downstream environment. Related to this is a reconciliation of the solute mass balance particularly for the Corridor Creek System.

Ecotoxicology: Although a great deal of ecotoxicological research and assessment has been undertaken, there are still a number of key issues that remain to be addressed including uranium toxicity measurements for two additional local native species, completion of research on the toxicity of magnesium including the ameliorative effects of calcium, and an assessment of the toxicity of manganese. Other issues that should be considered could include the relationship between dissolved organic matter and uranium toxicity and the effects of suspended sediment on aquatic biota.

Assurance programme for radionuclide surface water transport: Further research on surface water dispersion of radionuclides is not considered necessary on the basis of risk. However, a continuing programme of monitoring of radionuclides in surface water and in aquatic biota is considered necessary to provide assurance for Aboriginal people who source food items from the Magela Creek system downstream of Ranger.

Radiation exposure of workers: Further work should be considered in three areas: (a) a more robust examination of radon loss from dust particles, (b) development of a system which measures the concentration of radioactive dust and radon progeny in the breathing zone of a worker whilst wearing respiratory protection, and (c) measurement of the AMAD (activity Median Aerodynamic Diameter) and solubility of ore and product dusts in a range of exposure scenarios.

1.3 Monitoring

Surface water, groundwater, chemical, biological, sediment, radiological monitoring: Routine and project-based chemical, biological, radiological and sediment monitoring should continue. There is very little research required for the continued implementation of these programmes although there is scope for some specific research and analysis in relation to the review of the occupational radiological monitoring programme. More specifically, ARRTC supports the design and implementation of a new risk-based radiological monitoring programme based on a robust statistical analysis of the data collected over the life of Ranger.

2 Ranger – rehabilitation

Mining and milling at Ranger is likely to cease by about 2011 [revised to 2014 in 05/06]. Closure of the Ranger mine requires a large number of decisions, many of which will be dependent upon high quality scientific and technical information. The generation of this information will be the major focus of Ranger over the next five years. It will also be necessary to develop a holistic monitoring strategy, based on the risk assessments (and the associated models) recommended above, that aims to quantify changes in the identified high risk areas or test outcomes predicted by the models.

2.1 Landform design

Development and agreement of closure criteria from the landform perspective: Closure criteria from the landform perspective need to be established at both the broad scale and the specific. At the broad scale, agreement is needed, particularly with the traditional Aboriginal owners and within the context of the objectives for rehabilitation incorporated within the ERs, on the general strategy to be adopted in constructing the final landform. These considerations would include issues such as maximum height of the landform, the maximum slope gradient (from the aesthetic perspective), and the presence or absence of lakes or open water. At the specific scale, some criteria could usefully be developed as guidance for the initial landform design such as slope length and angle (from the erosion perspective), the minimum cover required over low grade ore, and the minimum distance of low grade ore from batter slopes. Specific criteria are needed that will be used to assess the success of landform construction. These would include, for example, maximum radon exhalation and gamma dose rates, maximum sediment delivery rates, maximum constituent concentration rates in runoff and maximum settling rates over tailings repositories.

Initial landform design: An initial design is required for the proposed final landform. This would be based upon the optimum mine plan from the operational point of view and it would take into account the broad closure criteria, engineering considerations and the specific criteria developed for guidance in the design of the landform. This initial landform would need to be optimised using the information obtained in detailed water quality, geomorphic, hydrological and radiological programmes listed below.

Water quality in seepage and runoff from the final landform: Existing water quality monitoring and research data on surface runoff and subsurface flow need to be analysed to develop models for the quality of water, and its time dependence, that would enter major drainage lines from the initial landform design. Options for adjusting the design to minimise solute concentrations and loads leaving the landform need to be assessed.

Groundwater modelling: In addition to the seepage and runoff issues discussed above, there is a specific need to address the existence of mounds under the tailings dam and waste rock stockpiles. Models are needed to predict the behaviour of groundwater and solute transport in the vicinity of these mounds and options developed for their remediation to ensure that on-site revegetation can be achieved and that off-site solute transport from the mounds will meet environmental protection objectives.

Geomorphic behaviour and evolution of the landscape: The existing data set used in determination of the key parameters for geomorphological modelling of the proposed final landform should be reviewed after consideration of the near-surface characteristics of the initial proposed landform. Further measurements of erosion characteristics should be carried out if considered necessary. The current site-specific landform evolution models should be applied to the initial proposed landform to develop predictions for long term erosion rates, incision and gullying rates, and sediment delivery rates to the surrounding catchments. Options for adjusting the design to minimise erosion of the landform need to be assessed. In addition, an assessment is needed of the geomorphic stability of the Ranger mine site with respect to the erosional effects of extreme events.

Radiological characteristics of the final landform: The characteristics of the final landform from the radiological exposure perspective need to be determined and methods need to be developed to minimise radiation exposure to ensure that restrictions on access to the land are minimised. Radon emanation rates, gamma dose rates and radionuclide concentrations in dust need to be determined and models developed for both near-field and far-field exposure. The pre-mining radiological conditions should also be assessed so that estimates can be made of the likely change in exposure rates compared to pre-mining conditions.

Testing of 'trial' landforms: Current landforms at Ranger and at other sites such as Nabarlek should be used to test the various models and predictions for water quality, geomorphic behaviour and radiological characteristics at Ranger.

Final landform design: The detailed design for the final landform at Ranger should be determined taking into account the results of the above research programmes on surface and ground water, geomorphic modelling and radiological characteristics.

2.2 Ecosystem establishment

Development and agreement of closure criteria from ecosystem establishment perspective: Closure criteria for ecosystem establishment need to be established at both the broad scale and the specific. At the broad scale, agreement is needed, particularly with the traditional owners and within the context of the objectives for rehabilitation incorporated within the ERs, on the general strategy to be adopted on habitat types to be incorporated and the species composition of trees, shrubs and grasses to be established on the landform. At the specific scale, criteria are needed that will be used to assess the success of ecosystem establishment. These would include, for example, targets for species density and abundance and measures of faunal return.

Characterisation of terrestrial and aquatic ecosystem types at analogue sites: To implement the revegetation strategy for Ranger mine, an understanding of the relationships between vegetation communities and key geomorphic features (parent material, slope, effective soil depth, internal drainage characteristics) in surrounding areas of Kakadu National Park is essential in identifying sustainable and achievable 'landscape' analogues (or target habitats) for the final, post-mine landform at Ranger. Identification and description of these landscape analogues is also the first step in developing robust, measurable, ecologically-based criteria for assessing revegetation performance, function and success.

Establishment and sustainability of ecosystems on mine landform: Research on how the landform, vegetation, fauna habitat, hydrology and geochemistry will be reconstructed at Ranger is essential. Noting that there are no good examples in the wet-dry tropics of successful reclamation of hard rock mines, priority needs to be given to this research. Research sites should be established that demonstrate an ability to reconstruct an ecosystem, even if this is at a relatively small scale. Issues that need to be addressed include species selection, seed collection germination and storage, propagation of recalcitrant species, nursery production of seedlings, fertiliser strategies including application methods and direct seeding techniques. Other issues requiring investigation include the return of fauna habitat, potential plant toxicity problems from waste rock, the exclusion of weeds and the effects of fire, hydrology and erosion on the rehabilitation strategy.

Radiation exposure pathways associated with ecosystem re-establishment: Bioaccumulation studies conducted to date have focused on aquatic animal and plant species because of their importance of the aquatic transport pathway, particularly during the operational phase of uranium mining operations. Information on radionuclide uptake by terrestrial animals and plants is required to enable a radiological risk assessment to be carried out for the revegetation programme. This needs to be coupled with estimates of terrestrial bushfood consumption by local Aboriginal people. Another radiological issue that requires assessment is the potential for tree roots to penetrate any radon barriers that form part of the rehabilitated landscape.

2.3 Groundwater dispersion

Containment of tailings and other mine wastes: The primary method for protection of the environment from dispersion of contaminants from tailings and other wastes will be containment. For this purpose, investigations are required on the hydrogeological integrity of the pits, the long-term geotechnical properties of tailings and waste rock fill in mine voids, tailings deposition methods, geochemical and geotechnical assessment of potential barrier materials, and strategies and technologies to access and 'seal' the surface of the tailings mass, drain and dispose of tailings porewater, backfill and cap the remaining pit void.

Geochemical characterisation of source terms: Investigations are needed to characterise the source term for transport of contaminants from the tailings mass in groundwater. These will include determination of the permeability of the tailings and its variation through the tailings mass, strategies and technologies to enhance settled density and accelerate consolidation of tailings, and pore water concentrations of key constituents. Assessment is also needed of the effectiveness (cost and environmental significance) of paste and cementation technologies for increasing tailings density and reducing the solubility of chemical constituents in tailings.

Aquifer characterisation and whole-of-site model: The aquifers surrounding the tailings repositories (Pits 1 & 3) need to be characterised to enable modelling of the dispersion of contaminants from the repositories. This will involve geophysics surveys, geotechnical drilling and groundwater monitoring and investigations on the interactions between the deep and shallow aquifers.

Hydrological/hydrogeochemical modelling: Predictive hydrological/hydrogeological models need to be developed, tested and applied to assess the dispersion of contaminants from the tailings repositories over a period of 10 000 years. These models will be used to assess whether all relevant and appropriate factors have been considered in designing and constructing an in-pit tailings containment system that will prevent environmental detriment in the long term.

2.4 Water treatment

Active treatment technologies for specific mine waters: Substantial volumes of process water retained at Ranger in the tailings dam and Pit 1 must be disposed of by a combination of water treatment and evaporation during the mining and milling phases of the operation and during the rehabilitation phase. Research priorities include treatment technologies and enhanced evaporation technologies that can be implemented for very high salinity process water.

Passive treatment of waters from the rehabilitated landform: Sentinel wetlands may form part of the final landform at Ranger. Research on wetland filters during the operational phase of mining will provide information relevant to this issue. However, there is a need to assess the long-term behaviour of physical and biotic components of wetlands and the ecological health of wetlands which are used to treat runoff from the proposed rehabilitated landform.

2.5 Monitoring

A monitoring programme to assess the success of rehabilitation at Ranger will be essential. Prior to its design and implementation, clear and agreed closure criteria will be needed as indicated above. These criteria should be used to determine the design of the monitoring programme.

Monitoring of the rehabilitated landform: A new management and monitoring regime for the rehabilitated Ranger landform needs to be developed and implemented. It needs to address all relevant aspects of the rehabilitated landform including ground and surface water quality, radiological issues, erosion, flora, fauna, weeds, and fire.

Off-site monitoring during and following rehabilitation: A monitoring regime for the downstream environment is also required to assess rehabilitation success with respect to protection of the downstream environment. This programme should address the dispersion of contaminants by surface water, ground water and via the atmosphere.

3 Jabiluka

The Jabiluka project has now entered a long-term care and maintenance phase. It is ARRTC's view that ongoing monitoring will be required throughout this period. In addition, a review is needed of knowledge that would be required prior to any proposal to develop Jabiluka. In particular, it will be necessary to identify and implement any projects considered essential in providing this knowledge well in advance of any development plans.

3.1 Monitoring

Monitoring during the care and maintenance phase: The monitoring regime for Jabiluka during the care and maintenance phase needs to be determined, implemented and regularly reviewed. The monitoring programme (addressing chemical, biological, sediment and radiological issues) should be commensurate with the environmental risks posed by the site, but should also serve as a component of any programme to collect baseline data required before development such as meteorological and sedimentary data.

3.2 Research

Research required prior to any development: A review of knowledge needs is required to assess minimum requirements in advance of any development. This review would include the groundwater regime (permeabilities, aquifer connectivity etc), hydrometeorological data, waste rock erosion, assess site-specific ecotoxicology for uranium, additional baseline for flora and fauna surveys.

4 Nabarlek

Nabarlek is decommissioned but has not reached a status where the NT Government will agree to issue a Revegetation Certificate to the mine operator. Since Nabarlek is the first Australian uranium mine of the modern era to complete operations and be rehabilitated, ARRTC believes that Australia needs to ensure that an overall assessment of the success of rehabilitation at Nabarlek is carried out. The Nabarlek site should also be used as an analogue for rehabilitation at Ranger and projects at Nabarlek should be designed to address specific issues of concern at Ranger.

4.1 Success of revegetation

Revegetation assessment: The principal ongoing issue at Nabarlek is the poor revegetation. Assessment of the adequacy of revegetation at the site should continue and, following its completion, management options should be developed and submitted to the mine-site technical committee for its consideration.

Development of revegetation monitoring method: A methodology and monitoring regime for the assessment of revegetation success at Nabarlek needs to be developed and implemented. Currently, resource intensive detailed vegetation and soil characterisation assessments along transects located randomly within characteristic areas of the rehabilitated landform are being undertaken. Whilst statistically valid, these assessments cover only a very small proportion of the site. Remote sensing (satellite) data are also being collected and the efficacy of remote sensing techniques for vegetation assessment should continue. The outcomes of this research will be very relevant to Ranger.

4.2 Assessment of radiological, chemical and geomorphic success of rehabilitation

Overall assessment of rehabilitation success at Nabarlek: The current programme on erosion, surface water chemistry, groundwater chemistry and radiological issues should be continued to the extent required to carry out an overall assessment of the success of rehabilitation at Nabarlek. In particular, all radiological exposure pathways should be evaluated and a comprehensive radiation dose model for Nabarlek should be developed.

5 General Alligator Rivers Region

5.1 Landscape scale analysis of impact

Apart from regular refinement of procedures for the current monitoring programmes, a potential major future research area is the possible development of broader, landscape scale programmes that would enable possible effects of mining to be distinguished from those arising from other causes. Such a programme was recommended by the Independent Science Panel of the World Heritage Committee. Initial studies have been undertaken. However, ARRTC believes that, before committing further resources to this programme, a review of the programme to assist in determining future priorities needs to be undertaken.

Re-assess and prioritise the landscape programme: A review is required, within a modelling conceptual and risk assessment framework, of the landscape wide programme to determine options and priorities for the future development of this programme.

5.2 South Alligator River valley rehabilitation

The focus of work to develop and implement a rehabilitation strategy for historic uranium mining related sites in the South Alligator Valley is the identification of a suitable site for the burial of radiologically active mining residues such as uranium ores or sediments contaminated with tailings. Parks Australia is responsible for this programme. Once potential sites have been identified based upon hydrology, access, stability, cultural and other considerations, groundwater investigations will be required to ensure that the site meets requirements for minimum separation between the base of the repository and top of the water table.

Assessment of mine sites in the South Alligator River valley: SSD conducts regular assessments of the status of mine sites in the SAR valley, provides advice to Parks Australia on technical issues associated with its rehabilitation programme and occasionally conducts a low level radiological monitoring programme, primarily for assurance purposes. ARRTC believes these should continue.

5.3 Develop monitoring programme related to West Arnhem Land exploration activities

Mining exploration is proceeding in the eastern area of the ARR in Arnhem Land outside the Kakadu National Park. In order to overcome the common problem of inadequate baseline data for correctly identifying the cause of environmental change, the SSD and NLC have jointly advocated the strategic collection of regional baseline information on aquatic ecosystems in areas adjacent to mining exploration sites in the ARR.

Baseline studies for biological assessment in West Arnhem Land: In areas adjacent to mining exploration sites, ARRTC believes there is a need to determine a baseline for (a) rare, threatened and endemic biota and (b) indicator species or groups such as macroinvertebrates.

5.4 Koongarra

There are currently no plans for the development of the Koongarra uranium prospect. However, it is ARRTC's view that, subject to the prioritisation of available resources, an ongoing base-line data collection programme could be established and the value of Koongarra as an analogue for pre-mining radiological conditions at Ranger could be investigated.

Baseline monitoring programme for Koongarra: A low level monitoring programme should be developed for Koongarra to provide baseline data in advance of any possible future development at the site. Data from this programme may also have some relevance as a control system for comparison to Ranger, Jabiluka and Nabarlek.

Analogue information for pre-mining conditions at Ranger: The value of Koongarra as an analogue site for pre-mining radiological conditions at Ranger should be investigated. There are some pre-mining radiological data for Ranger but the value of these data could be greatly enhanced if it could be extrapolated, through the use of an undisturbed analogue site such as Koongarra, to provide further information on parameters such as pre-mining gamma dose rates, radon exhalation, and radioactivity concentrations in dust.

6 Knowledge management and communication

The Alligator Rivers Region is one of the most studied regions in Australia. Consequently, a very large amount of knowledge has been accumulated over the years on this system. The stimulus for the research is that knowledge-based management of the uranium mines is the best approach to ensuring minimal risk to the ARR.

ARRTC believes that additional emphasis needs to be put on knowledge management and exchange in the next five years. Key aspects that will need to be addressed include the following.

6.1 Integrated framework

Development of an integrated framework: This has already commenced within a landscape analysis framework and is linked with the development of conceptual models of the ARR recommended above. Such an integrated framework will assist with the communication where the scientific information is relevant, and how it informs on the various risks to the system and its people from the uranium mines.

6.2 Uncertainty analysis

Uncertainty analysis of data and communication: People involved in the management of natural resources rarely have all the information they need. Even in the ARR, where a very large amount of research has been undertaken on the possible impacts of uranium mining, there is still much not known about the risks. ARRTC believes that management of the mining operations would be improved if the uncertainties in the risk assessment were explicitly identified and communicated. Additionally, those high risk areas where the uncertainty is great would be targeted for more research. It is expected that current work on the development of conceptual models of the ARR will clarify many of these uncertainties.

6.3 Effective communication channels between research providers

Establishing effective communication channels between and within research providers: There are a large number of organisations undertaking research in the ARR including SSD, EWLS, ERA, Parks Australia North and CSIRO. Given limited resources, it is critical that research is not being duplicated or previous studies repeated. ARRTC believes that communication between the various research providers could be improved and become more formalised to ensure better outcomes for all parties.

6.4 Effective communication to stakeholders

Effective communication of science to stakeholders: There are a large number of stakeholders with direct and indirect interests in uranium mining in the ARR. It is critical that the results of the high quality research being undertaken in the ARR is communicated to all stakeholders in the most relevant format. ARRTC believes that the various research providers need to target their communication strategies more specifically to the various stakeholder groups.

APPENDIX 2 PUBLICATIONS FOR 2005–2006

Published[5]

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APPENDIX 3 PRESENTATIONS TO CONFERENCES AND SYMPOSIA, 2005–2006[6]

Bollhöfer A 2006. Radiation protection and environmental research in the Alligator Rivers Region. Paper presented at seminar at the German Radiation Protection Agency, Freiburg, Germany, April 2006.

Buckle D, Pidgeon B, Luxon R & Humphrey C 2005. Monitoring of fish communities in deep channel billabongs associated with the Ranger Uranium Mine, Northern Territory. Paper presented at the Australian Society for Fish Biology Workshop and Conference, July 2005, Darwin.

Evans KG, Lowry JB & Moliere DR 2005. Design evaluation of landform stability. Paper presented at Ranger Mine final landform design – Stakeholder workshop, 2 December 2005, Darwin.

Evans KG, Moliere DR & Lowry JB 2006. Ranger Mine final landform design - Stakeholder workshop. Paper presented at Alligator Rivers Region Technical Committee. 17th Meeting, 27–28 February 2006, Agenda Item: 4.2.6.

Finlayson M, Lukacs G, Lowry J, van Dam R, Bartolo R & de Groot D 2005. Benchmarking Northern Australia's tropical rivers before further degradation: Practical approaches and constraints. Paper presented at the 8th International RiverSymposium, Brisbane 6–9 September 2005.

Iles M 2005. Shifting knowledge bases for planning and assessing uranium minesite rehabilitation in north Australia. Paper presented at Uranium Mining Rehabilitation Exchange Group Meeting, Frieberg, Germany, 14 September 2005.

Jones DR 2005. Uranium mining in the Northern Territory – human health assurance. Invited keynote paper presented at Annual Scientific Meeting Royal Australian College of Physicians NT Branch, Darwin NT, 21–22 October 2005.

Lowry J 2005. Review of tools and data requirements for wetland inventory. Paper presented at MedWet Wetland Inventory workshop, July 2005, Lisbon, Portugal.

Lowry J, Moliere D, Boggs G & Evans K 2005. A question of scale: the impact of digital elevation model resolution on the landform evolution modelling process at Nabarlek mine. Paper presented at the North Australian Remote Sensing and GIS Conference, Darwin, 4–7 July 2005.

Luxon R, Pidgeon B & Buckle D 2005. Monitoring of fish communities in shallow lowland billabongs in relation to Ranger Uranium Mine, Northern Territory. Paper presented at the Australian Society for Fish Biology Workshop and Conference, July 2005, Darwin.

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6 Presentations to conferences and symposia that have been externally published in 2005–06 are included in Appendix 2. The presenter of a multi-authored paper is underlined.

Pfitzner K & Carr G 2006. Design and implementation of vegetation reference spectra: Implications for data sharing. Presented at Workshop on Hyperspectral remote sensing and field spectroscopy of agricultural crops and forest vegetation. 10th February 2006, University of Southern Queensland, Toowoomba, Queensland, Australia.

Saynor MJ, Erskine WD, Evans KG & Moliere DR 2006. Morphodynamics of a tropical sand bed stream. Paper presented at Australian & New Zealand Geomorphology Group conference, 13–17 February 2006, Taipa Bay, New Zealand.

van Dam R 2006. Derivation of toxicant trigger values using site-specific ecotoxicological data. Paper presented at Application of Australian Water Quality Guidelines, Australian Water Association and the Royal Australian Chemical Institute Seminar Series, Darwin, 5 April.

van Dam R, Finlayson M, Lowry J, Bartolo R & Lukacs G 2005. Benchmarking the attributes of Northern Australia's tropical rivers: The basis for informed management decisions. Paper presented at Water in the Bush, Australian Water Association – NT Branch Annual Conference, Darwin, 20 October.

INDEX

E

F

G

S

T

U

V

W

Feedback on the Supervising Scientist 2005–06 Annual Report

We hope we have presented a comprehensive and informative account of the activities of the Supervising Scientist Division during 2005–2006.

If you have any suggestions for Supervising Scientist activities that you'd like to read more about and/or different ways you'd like to see the existing information presented, we would value your feedback. Please send your views by post or by e-mail to the addresses given below.

You can also access this and previous Supervising Scientist Annual Reports on the Department of the Environment and Heritage web site:

www.deh.gov.au/about/publications/annual-report/ss05-06/index.html

More Information

More information about Supervising Scientist Division is available at: www.deh.gov.au/ssd/

The full list of Supervising Scientist publications is available at:
www.deh.gov.au/ssd/publications

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