Australian Government
Department of the Environment, Water, Heritage and the Arts
Supervising Scientist

SUPERVISING SCIENTIST

Annual Report

2009–2010

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[1] Following machinery of government changes on 14 September 2010 the department's name was changed in line with the restructure of its portfolio responsibilities.

Australian Government

Department of Sustainability, Environment, Water, Population and Communities
Supervising Scientist

The Hon Tony Burke MP
Minister for Sustainability, Environment, Water, Population and Communities
Parliament House
CANBERRA ACT 2600

18 October 2010

Dear Minister

In accordance with subsection 36(1) of the *Environment Protection (Alligator Rivers Region) Act 1978* (the Act), I submit to you the thirty-second Annual Report of the Supervising Scientist on the operation of the Act during the period of 1 July 2009 to 30 June 2010.

Yours sincerely

Alan Hughes
Supervising Scientist

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Photos (from top left) Measuring stream discharge, sieving soil, field spectral calibration on Jabiluka billabong, testing probes on Ranger trial landform (TL), bushtucker collecting and (inset) green plums, community liaison, ground calibration of satellite image (and below that) soil sampling, spectral sampling on Ranger TL, ARRTC members field trip, biomass survey on Magela floodplain, seminar at SSD, snail aquaculture tanks at Jabiru Field Station, (bottom right) deployment of uranium-spiked sediments.

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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 who, for this reporting period, was the Minister for Environment Protection, Heritage and the Arts;
- 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

The Supervising Scientist plays an important role in the protection of the environment of the Alligator Rivers Region of the Northern Territory 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 of the Ranger 3 deposit cease in 2012 with milling of stockpiled ore expected to continue through until 2020. Recent proposals by ERA to include a heap leach facility at Ranger have not affected the current mining and milling operations timetable but could potentially increase production over the same period.

As the time of mine closure and rehabilitation draws closer, the work of the Supervising Scientist includes a focus on these themes as well as on current operational issues. Staff have been engaged with stakeholders in discussions and research activities associated with rehabilitation and closure.

Staff of the Division remain 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. Significant work has continued in developing improvements to the Supervising Scientist's surface water monitoring program. This program is relevant to both the operational and rehabilitation phases of mining.

At Ranger mine the 2009–10 wet season was around average with rainfall of 1596 mm. During the year there were no reported incidents that resulted in any environmental impact off the immediate minesite. The extensive monitoring and research programs of the Supervising Scientist Division confirm that the environment has remained protected through the period.

Over the past year ERA achieved a small reduction in the process water volumes stored on site by reducing additions to the process water systems through measures including reducing the area of surface runoff catchment reporting to it. However, delays in commissioning of the process water treatment facility and deferred implementation of a proposed enhanced evaporation program mean that the process water inventory at the mine remains a focus.

Monitoring programs by ERA, the NT Department of Resources and SSD continue to indicate that there is no evidence of seepage from the base of the Ranger tailings storage facility (TSF) impacting on Kakadu National Park. ERA has installed additional monitoring bores around the TSF at the request of stakeholders, including SSD.

The SSD surface water quality monitoring program continues to be improved with refinements to the operation of continuous monitoring of pH, electrical conductivity (EC) and turbidity in Magela and Gulungul Creeks upstream and downstream of Ranger mine. Continuous monitoring results indicate that water quality variations, both natural and mine-related, can occur on a time base measured in hours rather than days. This method of monitoring has therefore proven to be superior to the statutory weekly grab sampling technique that is currently employed.

The SSD monitoring stations have also been equipped with autosamplers that collect water samples triggered by in-stream events such as increases in EC or turbidity exceeding defined threshold levels. This has enhanced the capability of the monitoring program by allowing collection of samples outside of normal working hours or when conditions in the creeks are unsafe for manual grab sampling.

During April 2010 there were occasions where EC spikes in Magela Creek triggered the SSD autosampler at the downstream monitoring station. Subsequent analysis of the samples confirmed that the cause was elevated levels of magnesium sulfate in the water and that these events did not contain significantly elevated levels of uranium or radium. It was concluded that the anomalous EC readings were mine-related, having resulted from elevated salt levels in Retention Pond 1.

The principal biologically-based toxicity monitoring approach for 2009–10 was in situ monitoring using fresh water snails, with test organisms deployed in containers floating in the creek water. This program was extended from Magela Creek to include Gulungul Creek during the 2009–10 wet season.

Determination of radionuclide levels in mussels from Mudginberri Billabong has been a continuing element of the SSD monitoring program downstream of Ranger. Results for 2009–10 are similar to previous years and it is concluded that the consistently low levels of uranium and radium in mussels collected downstream of Ranger pose no risk to human or ecological health.

Ecotoxicology research programs in progress include determination of responses for a variety of organisms to pulse event durations for a range of magnesium concentrations. Previous work has confirmed a strong correlation between magnesium and EC in Magela Creek. Use of EC as a surrogate for magnesium has the obvious advantage of being suitable for direct measurement rather than relying on sampling and analysis at a remote laboratory.

An eight hectare trial landform was constructed by ERA during late 2008 and early 2009 adjacent to the north-western wall of the tailings storage facility at Ranger mine. SSD is involved in erosion studies on the trial landform to assist in longer term modelling of the performance of ultimate landform created during rehabilitation of the site.

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

The Nabarlek mine in western Arnhem Land was decommissioned in 1995 and the rehabilitation of this site remains under ongoing assessment. During the year Uranium Equities Limited undertook exploration and rehabilitation activities at Nabarlek. SSD participated in stakeholder inspections and audits of these activities and there were no significant environmental issues identified.

Detailed 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. Highlights of this work are described in this annual report.

In May 2006, the Australian Government announced funding to undertake rehabilitation of former uranium mining sites in the South Alligator River Valley in the southern part of Kakadu National Park. Most of the work associated with this project has now been completed. SSD continues to provide advice and assistance to the Director of National Parks as the rehabilitation works are completed and post works monitoring progresses.

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. Dr Gavin Mudd was appointed to ARRTC as a technical member representing environmental non-government organisations. Dr Carl Grant and Professor Peter Johnston resigned as independent members during 2009–10 and replacement members were appointed in early 2010–11. The new members are Professor David Mulligan and Mr Andrew Johnston. Their areas of expertise are in plant ecology and rehabilitation and in radiation protection respectively.

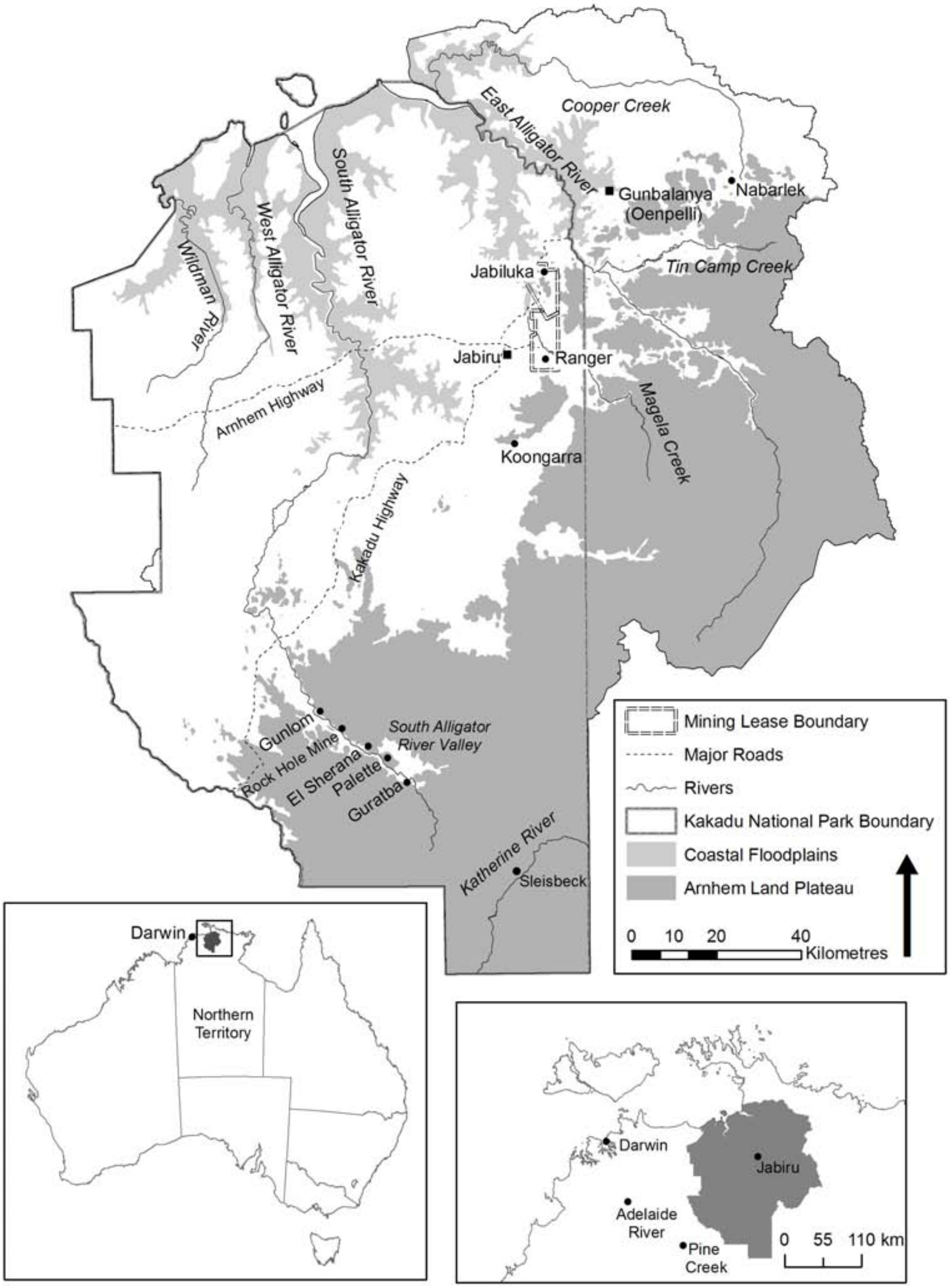
During the reporting period, SSD provided advice to the Approvals and Wildlife Division of the department on referrals submitted in accordance with the EPBC Act for proposed new and expanding uranium mines, including the following projects:

- Olympic Dam Expansion, SA
- Ranger Mine Heap Leach proposal, NT
- Beverley North Project, SA
- Yeelirrie WA

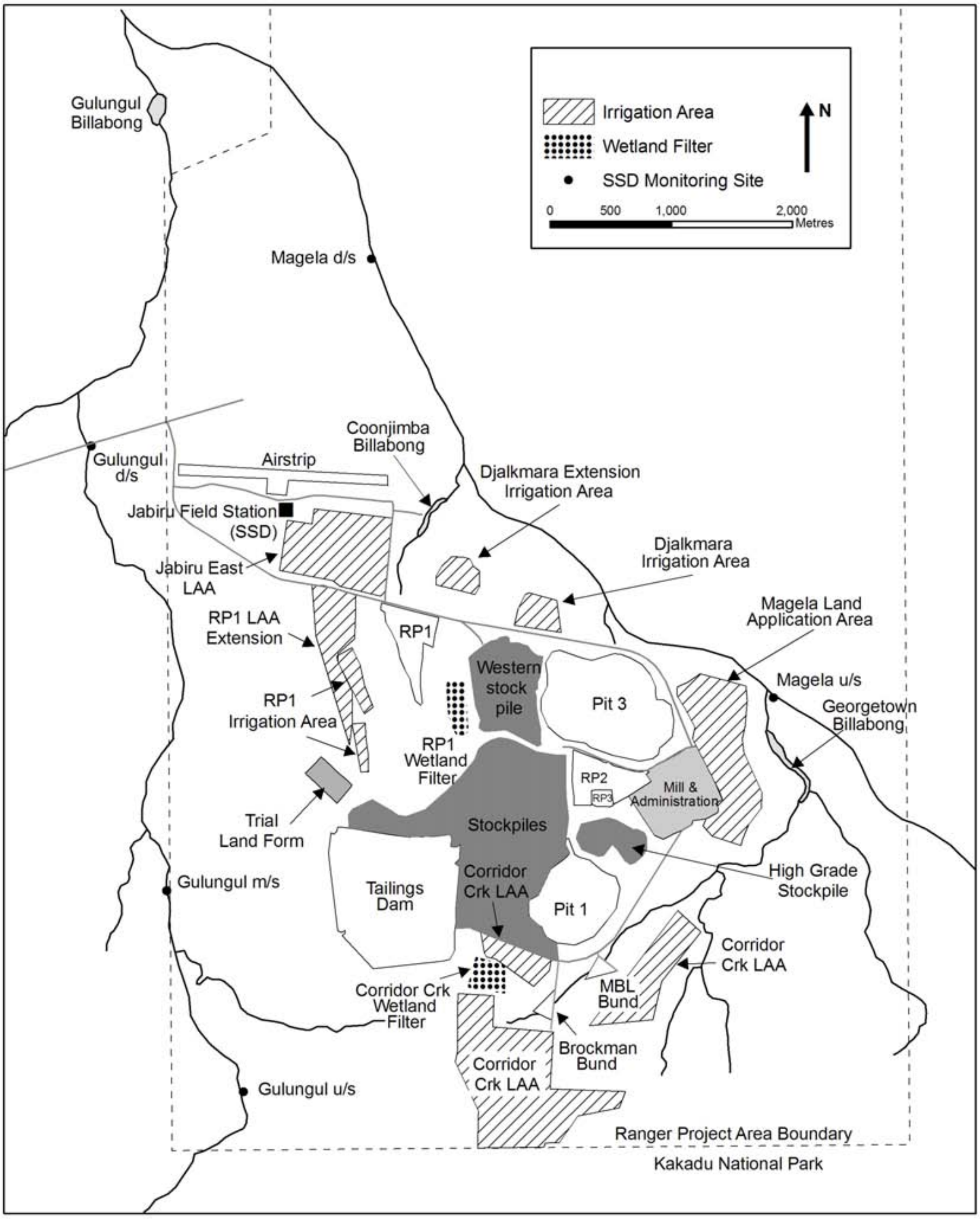
Funds were provided in the 2009–10 Federal Budget for a four-year program to progress and implement environmental maintenance activities, conduct appropriate environmental monitoring programs and develop contemporary site rehabilitation strategies at Rum Jungle under a national partnership agreement between the Northern Territory and the Australian Government. The Rum Jungle Technical Working Group (RJTWG) comprises representatives from the NT Department of Resources, NT Department of Natural Resources, Environment, the Arts and Sport, Australian Government Department of Resources, Energy and Tourism, the Northern Land Council and SSD. SSD has contributed to the work of the RJTWG during the reporting period.

Finally, I would like to offer my personal thanks to all the staff of the Supervising Scientist Division for their continued enthusiasm and efforts during the year. The commitment and professionalism of the Division's staff remain vital factors in the Division being able to fulfil its role in environmental protection.

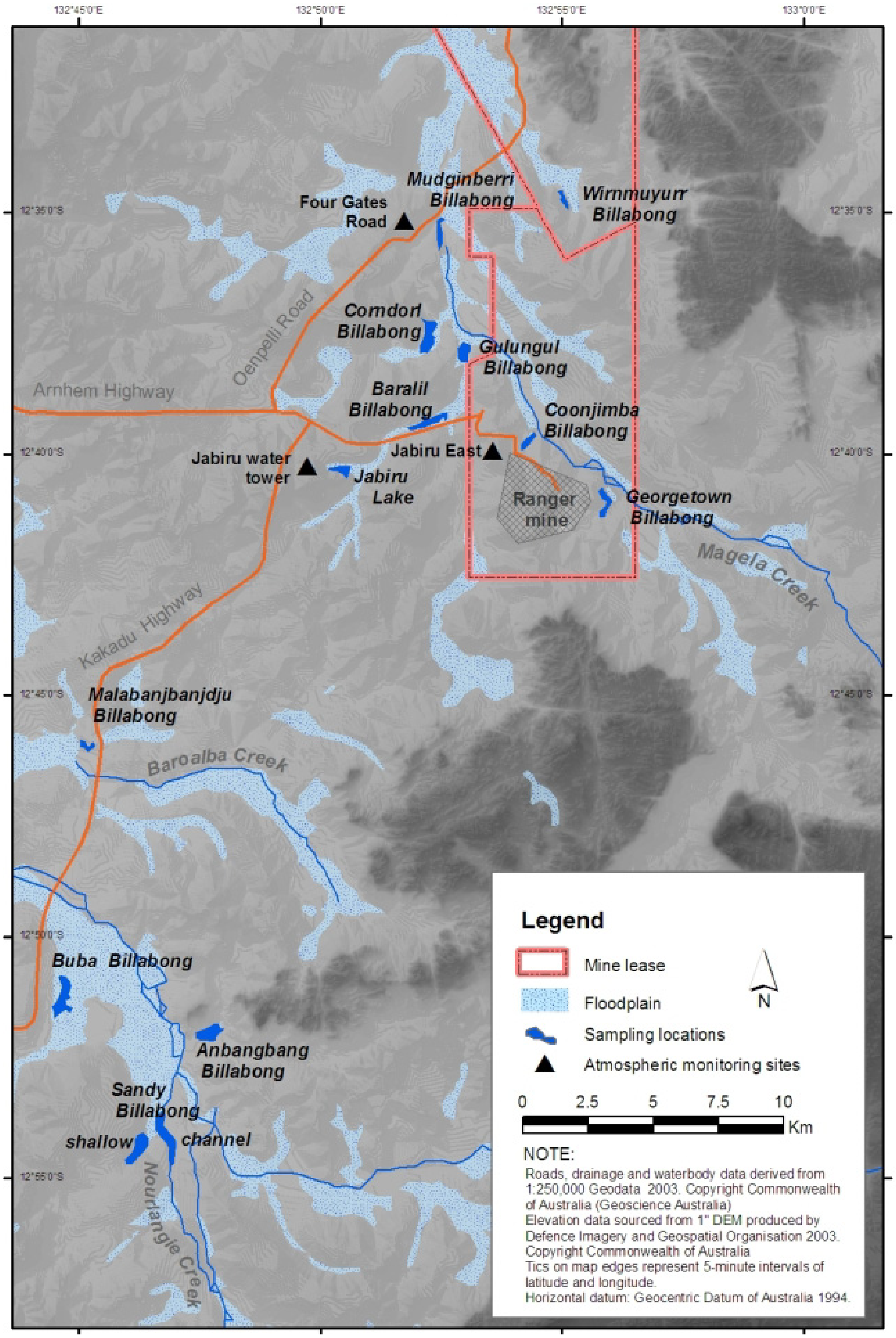
Alan Hughes
Supervising Scientist



Map 1 Alligator Rivers Region



Map 2 Ranger minesite



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

ABBREVIATIONS

ARR	Alligator Rivers Region
ARRAC	Alligator Rivers Region Advisory Committee
ARRTC	Alligator Rivers Region Technical Committee
DEWHA	Department of the Environment, Water, Heritage and the Arts
DRET	Department of Resources, Energy and Tourism
DoR	Department of Resources (formerly Department of Regional Development, Primary Industry, Fisheries and Resources**)**
EMS	Environmental Management System
ERA	Energy Resources of Australia Ltd
ERAES	ERA Environmental Strategy (formerly EWLS)
eriss	Environmental Research Institute of the Supervising Scientist
ERs	Environmental Requirements
G8210009	Magela Creek d/s (downstream) gauging station
GAC	Gundjeihmi Aboriginal Corporation
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
KKN	Key Knowledge Needs
LAA	Land application area
MCUGT	Magela Creek u/s (upstream) site (formerly described as MCUS)
MTC	Minesite Technical Committee
NLC	Northern Land Council
NRETAS	Department of Natural Resources, Environment, the Arts and Sport
oss	Office of the Supervising Scientist
POSS	Parks Operational Support Section
POT	Parks Operation and Tourism Branch
RJTWG	Rum Jungle Technical Working Group
RL	Reduced Level – the number after RL denotes metres above or below a chosen datum
RMC	Rockhole Mine Creek
RPI	Routine Periodic Inspection
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
SSAR	Supervising Scientist Annual Report
SSD	Supervising Scientist Division
TRaCK CERF	Tropical Rivers and Coastal Knowledge Commonwealth Environmental Research Facility
TSF	Tailings Storage Facility
UEL	Uranium Equities Limited

GLOSSARY

1s – 7s	When referring to ore and stockpiles indicates the amount of extractable uranium in the ore (grade). At Ranger, 1s indicates the lowest grade (waste) and 7s indicates the highest grade ore.
airborne gamma survey	Aerial measurements of the terrestrial gamma radiation using a large volume sodium iodide (NaI) detector on board an aircraft.
alpha radiation (α)	A positively charged helium (He^{2+}) nucleus (two protons + two neutrons) that is spontaneously emitted by an energetically unstable heavy atomic nucleus (such as ^{226}Ra or ^{238}U).
application	A document stating how the mining operator proposes to change the conditions set out in the mining Authorisation. These changes need to be approved by all MTC stakeholders.
authorisation	For mining activities authorisation is required under the Northern Territory *Mining Management Act* (MMA) for activities that will result in substantial disturbance of the ground. It details the authorised operations of a mine, based on the submitted mining management plan and any other conditions that the Northern Territory Minister considers appropriate.
becquerel (Bq)	SI unit for the activity of a radioactive substance in decays per second [s^{-1}].
beta radiation (β)	A high energy electron or positron emitted when an unstable atomic nucleus (such as ^{90}Sr or ^{40}K) loses its excess energy.
bioaccumulation	Occurs when the rate of uptake by biota of a chemical substance, such as metals, radionuclides or pesticides is greater than the rate of loss. These substances may be taken up directly, or indirectly, through consumption of food containing the chemicals.
bioavailable	The proportion of the total present (in water, sediment, soil or food) of metals and radionuclides, that can be taken up by biota (see also bioaccumulation).
biodiversity (biological diversity)	The variety of life forms, including plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
biological assessment	Use and measurement of the biota to monitor and assess the ecological health of an ecosystem.
biological community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
bund	Embankment or wall designed to retain contents (usually liquids) in the event of leakage or spillage from a storage facility.
concentration factor	The metal or radionuclide activity concentration measured in biota divided by the respective concentration measured in the underlying soil (for terrestrial biota) or water (for aquatic biota).
damp-proof course	A waterproof barrier comprising bitumen and aluminium.
direct seeding	Vegetation is established by broadcasting seed across the area to be revegetated.
dissolved organic carbon	Natural organic material from plants and animals that has broken down and is able to pass through a very fine (0.45 micrometre) filter.

dose coefficient	The committed tissue equivalent dose or committed effective dose Sievert [Sv] per unit intake Becquerel [Bq] of a radionuclide. See definition of Sievert and Becquerel.
dose constraint	The International Commission on Radiation Protection (ICRP) defines dose constraint as '*a prospective restriction on anticipated dose, primarily intended to be used to discard undesirable options in an optimization calculation*' for assessing site remediation options.
early detection	Measurable early warning biological, physical or chemical response in relation to a particular stress, prior to significant adverse affects occurring on the system of interest.
flume	A channel control structure with known cross-sectional area used to measure flow rate of runoff water.
fulvic acid	A component of dissolved organic carbon that is especially reactive and forms strong complexes with metals. Fulvic acids account for a large part of the dissolved organic matter in natural water.
gamma radiation (γ)	High energy electromagnetic radiation emitted by excited nuclei (for example after an alpha or beta decay) in their transition to lower-lying nuclear levels.
grab sampling	Collection of a discrete water sample for chemical analysis
Gray (Gy)	Name for absorbed dose 1 Gray = 1 Joule·kg^{-1}. The absorbed dose gives a measure for the energy imparted by ionising radiation to the mass of the matter contained in a given volume element.
half-life	Time required to reduce by one-half the concentration (or activity in the case of a radionuclide) of a material in a medium (eg soil or water) or organism (eg fish tissue) by transport, degradation or transformation.
Hydstra	Hydrology data management software package.
IC50	The concentration of a compound that causes a 50% inhibition in a particular response (eg growth, reproduction) of an organism relative to that of a control organism (ie an organism not exposed to the compound).
ionising radiation	Sub-atomic particles (α, β) or electromagnetic (γ, x-rays) radiation that have enough energy to knock out an electron from the electron shell of molecules or atoms, thereby ionising them.
land application	A method for management of excess accumulated water by spray irrigation. The method depends on the evaporation from spray droplets, and from vegetation and ground surfaces once its reaches them.
laterite	In the Ranger mine context, laterite is a local term used to describe well weathered rock and soil profile material that consists primarily of a mixture of sand and silt/clay size particles. It may or may not exhibit characteristics of a fully-developed laterite profile.
LC50	The concentration of a compound that causes the death of 50% of a group of organisms relative to that of a control group of organisms (ie a group of organisms not exposed to the compound).
MOL	Maximum Operating Level. The maximum level at which a liquid containing impoundment can be operated.
MCUGT	Current acronym for the upstream station u/s (formerly described as MCUS).
ore	A type of rock that bears minerals, or metal, which can be extracted.

permeate	The higher purity stream produced by passage of water through a reverse osmosis (RO) treatment process.
polished	Water that has been passed through a wetland filter.
pond water	Water derived from seepage and surface water runoff from mineralised rock stockpiles as well as runoff from the processing areas that are not part of the process water circuit.
potable water	Water suitable for human consumption.
process water	Water that has passed through the uranium extraction circuit, and all water that has come into contact with the circuit. It has a relatively high dissolved salt load constituting the most impacted water class on site.
radiologically anomalous area	Area that displays significantly above background levels of radioactivity.
radionuclide	An atom with an unstable nucleus that loses its excess energy via radioactive decay. There are natural and artificial radionuclides. Natural radionuclides are those in the uranium (^{238}U), actinium (^{235}U) and thorium (^{232}Th) decay series for example, which are characteristic of the naturally occurring radioactive material in uranium orebodies.
radium	A radioactive chemical element that is found in trace amounts in uranium ores.
radon	Colourless, odourless, tasteless, naturally-occurring radioactive noble gas formed from the decay of radium.
Sievert (Sv)	Name for equivalent dose and effective dose 1 Sievert = 1 Joule·kg^{-1}. In contrast to the Gray, the Sievert takes into account both the type of radiation and the radiological sensitivities of the organs irradiated, by introducing dimensionless radiation and tissue weighting factors, respectively.
sonde	A water quality instrument that is immersed in water for measuring (typically) electrical conductivity, pH, turbidity and dissolved oxygen.
speciation (of an element)	The forms in which an element exists within a particular sample or matrix.
stable lead isotopes	Lead has four stable isotopes, three of which, ^{206}Pb, ^{207}Pb and ^{208}Pb, are end members of the natural uranium, actinium and thorium decay series, respectively. ^{204}Pb is primordial only.
tailings	A slurry of ground rock and process effluents left over once the target product, in this case uranium, has been extracted from mineralised ore.
thoriferous	Containing thorium.
toxicity monitoring	The means by which the toxicity of a chemical or other test material is determined in the field over time. The monitoring comprises field toxicity tests which are used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).
tube stock	Seeds are germinated in a plant nursery and the young seedlings are then planted out.
uraniferous	Containing uranium.
uranium oxide	An oxide of uranium which occurs naturally or is produced by a uranium extraction process. This is the product from the Ranger mine.
water treatment plant (WTP)	The process system that removes undesirable chemicals, materials, and biological contaminants from water thereby decreasing its ability to harm the environment.

1 INTRODUCTION

1.1 Role and function of the Supervising Scientist

The position of Supervising Scientist was established under the Commonwealth *Environment Protection (Alligator Rivers Region) Act 1978* (the EPARR Act) in response to a recommendation of the second and final Fox Commission report in May 1977.

The roles and responsibilities of the Supervising Scientist are to:

- develop, coordinate and manage programs 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 this report, the Australian Government Minister for Environment Protection, Heritage and the Arts) with scientific and technical advice on mining in the Alligator Rivers Region;
- on request, provide the Minister (for this report, the Australian Government Minister for Environment Protection, Heritage and the Arts) with scientific and technical advice on environmental matters elsewhere in Australia.

The Supervising Scientist heads the **Supervising Scientist Division (SSD)** within the Department of the Environment, Water, Heritage and the Arts.[2] The Division comprises two branches.

The **Office of the Supervising Scientist (*oss*)** undertakes supervision, audit and assessment activities and provides policy advice to the Australian Government in relation to the environmental performance of uranium mines in the Alligator Rivers Region. ***oss*** also provides business and administrative support to the Supervising Scientist Division.

The **Environmental Research Institute of the Supervising Scientist (*eriss*)** undertakes environmental monitoring and scientific research into the impact of uranium mining on the environment within the Alligator Rivers Region to support the work of the Supervising Scientist. ***eriss*** also conducts research into the sustainable use and environmental protection of tropical rivers and their associated wetlands.

[2] Following machinery of government changes on 14 September 2010, the department's name was changed from Department of the Environment, Water, Heritage and the Arts to the Department of Sustainability, Environment, Water, Population and Communities in line with the restructure of its portfolio responsibilities.

1.2 Performance summary

As a Division of the Department of the Environment, Water, Heritage and the Arts, SSD is funded under the Portfolio's departmental output appropriation and contributes to the delivery of the Department's Outcome 1:

> The conservation and protection of Australia's terrestrial and marine biodiversity and ecosystems through supporting research, developing information, supporting natural resource management, regulating matters of national environmental significance and managing Commonwealth protected areas

Outcome 1 is divided into five Outputs. During the 2009–10 financial year, the Supervising Scientist contributed to Program 1.2: Environmental regulation, information and research.

Further details on SSD activities during 2009–10 contributing to Program 1.2 are provided in Chapters 2, 3 and 5 of this Annual Report.

Communicating the outcomes of research, monitoring and supervision activities to relevant stakeholders and the broader scientific community is a key part of the work of the Division. Of particular importance is the ongoing communication and consultation SSD undertakes with the Aboriginal people living in the Alligator Rivers Region. Further details on SSD communications activities during 2009–10 are provided in Chapter 5.

1.3 Business planning

SSD undertakes a strategic business planning approach to ensure outputs are achieved in the most effective and efficient way. SSD prepares an annual Business Plan that outlines the main goals and challenges for the Division over the coming year, the range of activities and programs to be undertaken and associated performance measures. Progress against strategic priorities and key result areas is assessed on an ongoing basis.

1.4 The Alligator Rivers Region and its uranium deposits

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

The Ranger, Jabiluka and Koongarra uranium deposits within the Alligator Rivers Region are not, and never have been, located within 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. Mining ceased at Jabiluka in 1999 and the site is under long-term care and maintenance. Mining at Nabarlek ceased in 1980 and the site has been decommissioned and is subject to ongoing rehabilitation. Development of the Koongarra uranium deposit is subject to traditional owner approval as required under the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976*.

There are also a number of former uranium mines in the South Alligator River Valley that operated during the 1950s and 1960s which are currently being rehabilitated.

1.4.1 Ranger

Energy Resources of Australia Ltd (ERA) operates the Ranger uranium mine, which is located 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. 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 late 1994 and excavation of Orebody No 3 began in 1997.

Current ERA planning is for mining at Ranger to cease in 2012 with processing of stockpiled ore to continue until 2020.

1.4.2 Jabiluka

The Jabiluka mineral lease abuts the northern boundary of the Ranger project area and the Jabiluka site is situated 20 km north of the Ranger minesite. It is also owned by ERA.

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 Australian Government completed its assessment of ERA's Environmental Impact Statement, which provided for milling of Jabiluka ore at Ranger, in 1997.

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

During 2003, discussions commenced between ERA, the Commonwealth and Northern Territory Governments, the Northern Land Council (NLC) and Gundjeihmi Aboriginal Corporation (GAC) which represents the area's traditional Aboriginal owners, the Mirarr people. Following these discussions, an agreement was reached between the parties that resulted in Jabiluka being placed in long-term care and maintenance. This agreement included an undertaking by ERA not to engage in mining activities at Jabiluka without the consent of the Mirarr people. The agreement was endorsed by the NLC in 2004 and was approved by the then Australian Government Minister for Immigration and Multicultural and Indigenous Affairs in 2005.

1.4.3 Nabarlek

Nabarlek is about 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 while the mill was operational.

Decommissioning of the mine was completed in 1995 and the performance of the rehabilitation and revegetation program continues to be monitored by SSD.

In early 2008, Uranium Equities Limited (UEL) bought Queensland Mines Pty Ltd thereby acquiring the Nabarlek lease. Since then UEL has developed plans to further explore the lease, clean up the site and continue revegetation and rehabilitation works.

1.4.4 Koongarra

The Koongarra deposit is about 25 km south-west of Ranger, in the South Alligator River catchment. The Koongarra deposit is owned by Koongarra Pty Ltd, a subsidiary of the French company AREVA. The site is subject to the provisions of the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976*, which requires that traditional owner approval must be obtained before any application for a mining title can be made to the Northern Territory Government.

1.4.5 South Alligator Valley mines

During the 1950s and 1960s, several small uranium mines and milling facilities operated in the South Alligator River Valley, in the southern part of the Alligator Rivers Region. Mining occurred at several locations – principally at El Sherana, El Sherana West, Rockhole Creek and Coronation Hill (Guratba). Milling occurred at Rockhole Creek within the South Alligator Valley and 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 this period.

These sites, excluding Moline, are the responsibility of the Australian Government Director of National Parks and are administered through Parks Australia.

SSD is assisting Parks Australia with the implementation of the $7.3 million four year project for rehabilitation of abandoned uranium mining sites in the valley, announced by the Australian Government in May 2006. Further details on SSD involvement in this project are provided in Section 2.5.1 of this Annual Report.

2 ENVIRONMENTAL ASSESSMENTS OF URANIUM MINES

2.1 Supervision process

The Supervising Scientist utilises a structured program of audits and inspections, in conjunction with the Northern Territory Government and the Northern Land Council, to supervise uranium mining operations in the Alligator Rivers Region (ARR). 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 Supervising Scientist Division staff, 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 and Commonwealth legislation. Each MTC is made up of representatives from the Northern Territory Department of Resources (DoR – 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 Ranger and Jabiluka MTC meeting. Other organisations or experts may be co-opted from time to time as required to assist MTC members.

2.1.2 Audits and inspections

The Supervising Scientist, in consultation with the applicable MTC members, has developed and implemented a program of environmental audits and inspections at Ranger mine, Jabiluka project area and Nabarlek mine. ***oss*** staff also participate in audits of exploration operations throughout the ARR.

Routine Periodic Inspections (RPI) take place monthly at Ranger, being the only operating minesite in the region, and quarterly at Jabiluka, which is 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***, DoR and the NLC.

The rehabilitated former abandoned minesites locations at South Alligator Valley are also routinely inspected at least once annually.

Environmental audits are conducted by a team of qualified audit staff from ***oss***, DoR 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 audits of Ranger and Jabiluka occur 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). Audit findings are followed-up as required through the RPI process. The Nabarlek program is slightly different in that an inspection is carried out early in the dry season and the annual environmental audit is conducted later in the year.

The audit outcomes are described later in this Annual Report.

2.1.3 Assessment of reports, plans and applications

The Authorisations for Ranger mine and the Jabiluka project area are issued under the Northern Territory *Mining Management Act 2001.* 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 DoR, which then considers applications after ***oss*** and the NLC have assessed the proposal and provided feedback. This provides the primary mechanism for the Supervising Scientist's participation in the regulatory processes of the Northern Territory Government and is supported by section 34 of the Act which requires the Northern Territory Government to act in accordance with the advice of the Commonwealth Minister.

The main reports and plans assessed by the Supervising Scientist during 2009–10 included:

- Ranger Amended Plan of Rehabilitation No 35
- Ranger Mine Water Management Plan
- 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 Program quarterly and Annual Reports
- Jabiluka Project Plan of Rehabilitation No 13
- ERA weekly environmental monitoring data and quarterly reports submitted in accordance with the Authorisations
- Applications by the mining companies for amendments to their Authorisations

2.2 Ranger

2.2.1 Developments

Mining and milling of uranium ore at Ranger continued throughout 2009–10, with further development of the orebody in Pit 3. The Ranger mill produced 4222 tonnes of uranium oxide (U_3O_8) during 2009–10 from 2 282 670 tonnes of treated ore (Table 2.1). Production statistics for the milling of ore and the production of U_3O_8 at Ranger for the past five years are shown in Table 2.2.

TABLE 2.1 RANGER PRODUCTION ACTIVITY FOR 2009–2010 BY QUARTER

	1/07/2009 to 30/09/2009	1/10/2009 to 31/12/2009	1/01/2010 to 31/03/2010	1/04/2010 to 30/06/2010	Total
Production (drummed tonnes of U_3O_8)	1404.5	1100.2	887.5	829.7	4222
Ore treated (‘000 tonnes)	532	583	564	604	2283

TABLE 2.2 RANGER PRODUCTION ACTIVITY FOR 2005–2006 TO 2009–2010

	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010
Production (drummed tonnes of U_3O_8)	5184	5261	4926	5678	4222
Ore treated (‘000 tonnes)	1960	2136	2001	2042	2283

2.2.1.1 On-site activities

Ranger Heap Leach Project

In March 2009 ERA submitted a referral under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the construction of a heap leach facility to treat low grade ore at Ranger. This referral was determined to be a controlled action and is to be assessed by an environmental impact statement (EIS) managed under a bilateral agreement by the Northern Territory Government. ERA is in the process of preparing an environmental impact statement in accordance with the guidelines prepared by the Northern Territory Government.

Ranger Exploration Decline Project

In April 2009 ERA submitted a referral for the proposed construction of an exploration decline to provide exploration access to mineralisation in the Ranger 3 deeps area. In May 2009 this proposal was deemed not to be a controlled action and will not require further assessment under the EPBC Act. This proposal will be submitted to the Minesite Technical Committee and will be assessed in accordance with the Working Arrangements between the Northern Territory and Commonwealth Governments.

Exploration

ERA is continuing to conduct exploration drilling within the Ranger Project Area. Recent exploration efforts have focussed on the Ranger orbit which includes Ranger 3 south east deeps, Ranger 1 deeps and Anomaly 8. ERA also plans to explore Ranger North and East in 2010.

Pilot covered evaporation tunnels and process water tunnel evaporators

ERA submitted a proposal to the MTC in July 2009 for the development of four covered tunnels to trial enhanced process water evaporation. The pilot tunnels were constructed in the Pit 1 catchment on a compacted clay base with designated bunded area equipped with a double liner and leak detection system. Laserlite roof sheeting allowed solar radiation to pass through to the water thus heating the interior of the tunnel. Evaporative rates achieved with the pilot program were consistently reported at ~8–10 mm/day. Based on the results of the pilot program, on 25 June 2010 ERA gained approval to construct up to 150 tunnels at a brownfield location on the project area.

Disposal of RP1 water to Magela Creek via MG001

In January 2010 ERA installed pipeline infrastructure to enable discharge of RP1 waters directly to Magela Creek at MG001. Discharging RP1 waters at MG001 under favourable conditions provides for greater mixing of released waters prior to the compliance and monitoring stations downstream of the confluence of Coonjimba Billabong and Magela Creek. Ceasing controlled discharge of waters directly to Coonjimba Billabong reduces the risk of potential negative impacts to Magela Creek when the billabong backflows under low flow conditions in Magela Creek. Discharge of RP1 water to MG001 is discussed further in Section 2.2.2.

Pit 3 modifications for bullnose failure

In June 2009 ERA became aware of geotechnical instability in Pit 3 below the old southern ramp. ERA undertook to install monitoring equipment in the area and found that movement measured during the monitoring period was directly related to routine blasting on the eastern side of the southern bullnose. On 31 October about 200 tonnes of material moved from the -55mRL batter to the floor of that batter in Pit 3. Safety restrictions were imposed in Pit 3 as ERA determined that ~3.4 Mt of material needed to be removed from the southern bullnose to maintain the integrity of Pit 3 in this area. ERA confirmed to stakeholders that there was no compromise to the integrity of the wall of RP2 as a result of the movement or remedial works. Works to remove the material from the southern bullnose have continued throughout this reporting period.

Jabiru East accommodation village

On 8 March 2010 ERA submitted a proposal to MTC members to construct a 1000 bed accommodation village at Jabiru East to service Ranger mine. It is proposed that the current

100-bed Ranger accommodation village will be removed once the Jabiru East village is completed. The Jabiru East village is proposed to be self contained with a variety of recreational facilities including a wet mess. Stakeholders are still considering the proposal and have requested additional information.

2.2.2 On-site environmental management

2.2.2.1 Water management

All water on site is managed in accordance with the Water Management Plan which is updated annually and subject to assessment by the Minesite Technical Committee (MTC) before approval. The 2009–10 Water Management Plan was submitted for approval by ERA on 30 September 2009. SSD endorsed the plan on 9 March 2010, however, final regulatory approval is still awaiting input from other stakeholders. Until this plan is approved, the existing 2008–09 plan remains in force. The plan describes the systems for routine and contingency management of the three categories of water on site, ie process, pond and potable.

Water management remains critical at Ranger mine. As shown in Figure 2.1, the 2009–10 wet season was close to average with a total of 1596 mm recorded at Jabiru Airport to 30 June 2010 compared with an annual average of 1584 mm. The pond water inventory has increased in comparison to this time last year while the process water inventory has decreased slightly.

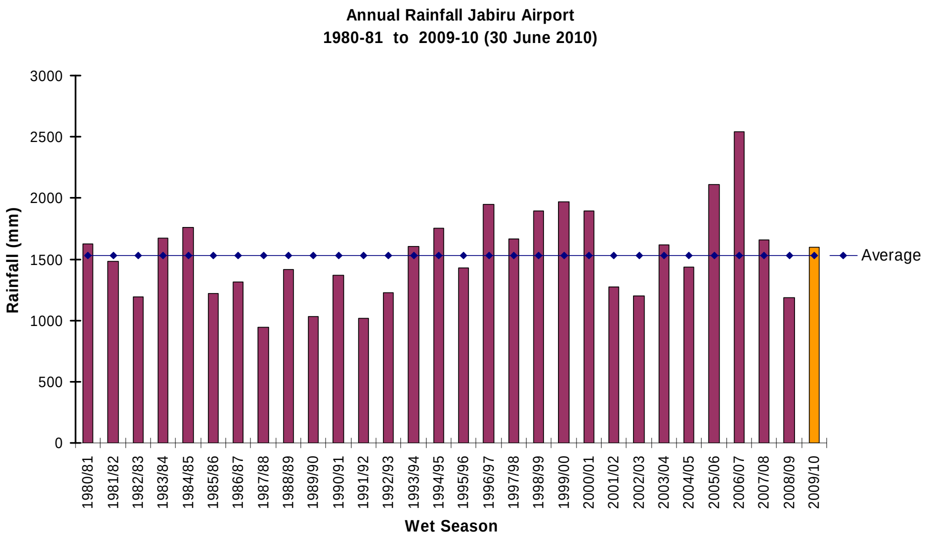


Figure 2.1 Annual rainfall Jabiru Airport 1980–81 to 2009–10 (data taken from Bureau of Meteorology)

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. Process water is currently stored in the Tailings Storage Facility (TSF) and in Pit 1. There were no releases of untreated process water to the surrounding environment during the reporting period.

The Process Water Treatment Plant was commissioned in late 2009 and commenced discharge of process water permeate to the Corridor Creek Wetland Filter on 9 October 2009 at a rate of approximately 0.7 ML per day until 28 December 2009. Further treatment capacity is expected to come on line late in 2010 with ERA being granted approval to construct 150 solar evaporation tunnels to the north of the TSF.

Following a lift of the TSF crest level to RL54m, on 18 December 2009 ERA was approved to raise the maximum operating level of the TSF to RL53m generating additional process water storage capacity in the dam.

At the end of the reporting period, the process water inventory was 9890 ML, of which 9680 ML is stored in the TSF. This represents a slight decrease over the previous years total of 9982 ML.

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. Water is managed within this system by quality. The pond water system consists primarily of Retention Pond 2 (RP2), Retention Pond 3 (RP3) and Pit 3. Water from RP2, RP3 and Pit 3 may not be released without prior treatment through wetland filtration and/or irrigation. At the end of the reporting period 1285 ML was contained within the system representing an increase of 393 ML over the previous year. The increased pond water inventory is due to unseasonably late rainfall in April 2010 combined with pumping of water from RP1 to RP2 as a result of poorer water quality in RP1.

Methods of disposal of pond water

Passive release water

Rainfall runoff discharges from the Ranger site during the wet season primarily via Corridor Creek and Coonjimba Creek with much lesser amounts via Gulungul Creek and minor amounts via overland flow direct to Magela Creek. RP1 and the Corridor Creek wetland filter act as sediment traps and solute polishing systems 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. The surfaces of these stockpile areas are compacted to minimise infiltration and hence contribution of additional water to the RP2 pond water system via seepage. RP1 receives sheeted runoff from the northern waste rock stockpiles and overflows passively via a constructed weir into Coonjimba Creek every wet season. Controlled discharge of RP1 via siphons/pumping over the weir occurred from January through to mid-April 2010 to assist with the removal of poorer quality water during periods of higher flow in Magela Creek. Passive release of water over the RP1 weir occurred intermittently from February through to mid-April 2010 and was managed by use of sluice gates on the weir. In Corridor Creek, passive release of waters retained upstream of GC2 occurred throughout the 2009–10 wet season. ERA also manually controls the discharge of runoff water via four sluice gates along the Ranger access road. Release from these gates occurred on several occasions from March through to mid-April 2010.

Pond water treatment

The two pond water treatment plants were in operation between January and May 2010. Treated permeate was discharged to the Corridor Creek wetland filter and from there passively released to Magela Creek via GCMBL and GC2.

RP1 Discharge to MG001

ERA was granted approval in January 2010 for the interim discharge of RP1 water to Magela Creek from the MG001 site. Discharge occurred at the end of January and again in April under high-flow conditions in Magela Creek. During both discharges ERA undertook studies to determine the rate of mixing and any potential effect on downstream water chemistry. Stakeholders are considering ERA's application for approval to routinely release RP1 water at MG001, under high-flow conditions, in light of the data provided by the two previous discharge studies.

Stockpile sheeting

Runoff from sheeted stockpiles into the Corridor Creek wetland filter generated from the first 200 mm of rainfall continues to be diverted into the pond water system. This initial runoff generally contains higher levels of mine-derived solutes due to the leaching of solutes that occurs in the early stages of the wet season, from freshly mined rock.

Wetland filters and land application areas

Two wetland filter systems operated during 2009–10: the Corridor Creek system and the RP1 constructed wetland filter in the RP1 catchment.

Jabiru East and RP1 land application areas were operational during the 2009 dry season. Corridor Creek and RP1 land application areas are being utilised during the 2010 dry season. In keeping with ERA's commitment that only treated or wetland polished water would be irrigated from 2009, there has been no direct irrigation of RP2 water in 2009 or 2010.

2.2.2.2 Tailings and waste management

Tailings

From August 1996 to December 2008 no process residue from the milling of ore was deposited into the TSF, with Pit 1 being the sole receptor. Over this period 20 Mm^3 of tailings were deposited in Pit 1 including 1.8 Mm^3 transferred from the TSF by dredging. Transfer of tailings into Pit 1 from the milling and processing of ore from Pit 3 ceased in December 2008 when tailings reached the maximum permitted level of RL12. Tailings are now discharged to the TSF via a floating discharge pipe that is moved regularly to achieve an even deposition of tailings across the footprint of the dam.

The average density of tailings in Pit 1 at June 2010 was 1.37 t/m^3, which exceeds the minimum target density of 1.2 t/m^3.

2.2.2.3 Audit and Routine Periodic Inspections (RPIs)

Eleven inspections and one audit were undertaken at Ranger during the 2009–10 reporting period. Findings from the May 2009 environmental audit were reviewed throughout the following RPIs until an acceptable outcome was achieved. An audit of the Ranger Radiation Management Plan was undertaken in May 2010. RPIs were carried out for each other month of the 2009–10 reporting year with the exception of May. Table 2.3 shows the focus areas for the audit and RPIs for the year.

TABLE 2.3 AUDIT AND RPI

Date	Foci
21 July 2009	Turbo burning yard, product packing, heavy equipment workshop, Ranger 3 deeps exploration
18 August 2009	Vehicle washdown bay, pilot covered evaporation pond construction, controlled area access signs to Pit 3, RP1 land application area
15 September 2009	Jabiru east land application area; potential heap leach facility sites and associated EIS works, trial landform, audit follow up
20 October 2009	Water treatment plant, Corridor Creek wetland filter, pilot covered evaporation ponds, bullnose cutback, tailings corridor, GCMBL
17 November 2009	Anomaly 4, bullnose cutback, Djalkmara sump
15 December 2009	TSF, v-notch drains, drainage lines, check dams, sumps, Sed2B, CB2, CB4, RP1, RP2, GCMBL, Djalkmara sump, access road culverts
20 January 2010	Sand filters, SW TSF sed sump, Sed2B, CB2, Corridor Creek wetland filter, GCMBL, Djalkmara sump, audit findings
17 February 2010	RP1 weir, MG001 discharge location, pilot covered evaporation tunnels, TSF wall and ring road water management
17 March 2010	Processing plant, turbo burning yard, TSF NW sump, trial landform
14 April 2010	TSF wet season inspection
17–19 May 2010	Audit: Ranger Radiation Management Plan
16 June 2010	Exploration decline box cut location, 100 man camp, confluence of Magela Creek and Coonjimba Billabong, Swift Creek, Djarr Djarr

Audit outcomes

Closeout of findings from the May 2009 environmental audit

The May 2009 audit delivered 7 significant findings, ranked:

- 1 x category 2 non-conformance
- 6 x conditional

These findings were followed up via the monthly RPI process with all corrective actions implemented.

May 2010 environmental audit

The 2009 environmental audit of Ranger mine was held on 17–18 May 2010. The audit team was made up of representatives from the NLC, DoR and ***oss***. The subject of the 2010 audit was the Ranger Radiation Management Plan.

Thirty commitments were audited against the ranking system shown in Table 2.4. Use of this ranking system ensures the outcomes of the Ranger auditing process are consistent with other mines in the Northern Territory.

TABLE 2.4 GRADING SYSTEM

Category 1 Non-Conformance (CAT 1)	A category 1 non-conformance refers to a situation where an identified activity is not in compliance with the Authorisation, approval document or applicable legislation and could result in a high risk or is a persistent Category 2 non-conformance.
Category 2 Non-Conformance (CAT 2)	A category 2 non-conformance relates to an isolated lapse of control or an identified activity that is not in compliance with the Authorisation, approval document or applicable legislation that could result in a low or moderate risk.
Conditional (C)	This includes items that have been identified during planning that meet the established criteria and have commenced but have yet to be completed.
Acceptable (A)	This includes items that have been identified during planning that meet the established criteria and have been completed.
Not Verified (NV)	This is where compliance with the item has not been assessed. This may also include items that have been identified during planning but have yet to commence.
Observation (O)	An area that has notably improved or has the potential to be improved, or is outside the scope of the audit but is notable.

The audit tested 30 commitments, and determined the following significant findings:

- 2 x category 2 non-conformances
- 6 x conditional

All other findings were ranked as acceptable or not verified.

The first of the category 2 non-conformances related to management of surface contamination whereby all workers are required to ensure that all plant, including vehicles, are cleaned of radioactive material before leaving a Controlled Area. It is also the responsibility of all workers to ensure that any vehicles that they are driving in Supervised Areas are not contaminated with radioactive material.

The audit randomly inspected two controlled area vehicles. One vehicle was without the rear vision mirror tag stating that the vehicle was a controlled area vehicle. This same vehicle had an internal ‘controlled area’ sticker, however, it was located under the driver’s sun visor therefore not readily visible. The second vehicle inspected had a controlled area vehicle tag attached to the rear vision mirror (and an internal controlled vehicle label) that had expired in 2009. This criteria has been ranked as a category 2 non-conformance as it does not appear that the system for managing controlled area vehicles is appropriately executed to ensure that all workers are aware of the requirements for use of controlled area vehicles across the site.

The second of the two category 2 non-conformances related to staffing levels and expertise within the Radiation and Hygiene Management Section (RHMS). For ERA Ranger operations the radiation monitoring program is administered by members of the RHMS. The RHMS comprises 4 permanent positions in the ERA structure: a Specialist Radiation and Hygiene Advisor (team leader) and 3 radiation and hygiene advisors – there is also a casual position of laboratory technician. The RHMS is part of the Health and Safety Department (H&S). The Specialist Radiation and Hygiene Advisory reports directly to the Manager H&S, who in turn reports directly to the General Manager – Operations.

At the time of the audit, ERA advised that it does not currently employ a Specialist Radiation and Hygiene advisor (the previous incumbent left ERA in November 2009). ERA appointed a person to act in this position in December 2009. ERA also advised that current staff levels within the Radiation and Hygiene Team were reduced to a Superintendent (Radiation & Hygiene), two advisors and two full-time laboratory technicians. Of the advisors, one had already resigned and another would be finishing within 1 month of the audit. ERA advised that it has engaged the services of two radiation consultants to provide support to the Radiation and Hygiene Team. ERA advised that the process of recruiting to replace these positions had commenced. This criteria has been graded as a Category 2 non-conformance as ERA currently do not have the resources to completely implement the requirements of the radiation management plan.

The 6 conditional findings related to the following:

- Document control – the current version of the plan underwent minor revision in November 2009 but had not received signoff by the General Manager – Operations.
- Sealed sources storage – the current storage for no-longer-used sealed sources is in need of repair or a suitable replacement storage area needs to be found.
- Radiation signage – hazard signs adjacent to a sealed source gauge in the CCD area were not clearly visible.
- Controlled areas – the current version of the Radiation Management Plan has not been updated to include the following controlled areas; the laterite treatment plant, radiometric sorting plant and heavy vehicle wash down bay.
- Surface contamination checks – random checks of vehicles, change rooms and areas of the processing plant are to be undertaken monthly. The last recorded inspection in the register was dated 4 months prior to the audit in January 2010.
- Monitoring program – the Q4 2009 and Q1 2010 quarterly radiation and atmospheric monitoring reports noted a failure to undertake the full statutory monitoring program. This issue has been dealt with previously by the regulator outside of the audit process, however, it has been ranked conditional on the basis ERA resolve the outstanding resourcing issues.

oss will continue to follow up on the identified non-conformances and ensure the close-out of corrective actions through the RPI process.

2.2.2.4 Minesite Technical Committee

The Ranger Minesite Technical Committee met five times during 2009–10. Dates of meetings and issues discussed are shown in Table 2.5. Significant agenda items discussed at MTCs included updates from ERA on site activities, updates from the Ranger Closure Criteria Working Group, the Radiation Management Plan and a raise to the TSF maximum operating level. The Ranger Closure Criteria Working Group reconvened in June 2008. Terms of reference have been established for the group, which is working to develop and agree upon closure criteria for Ranger. Throughout 2009–10 the working group met following each Ranger and Jabiluka MTC.

TABLE 2.5 RANGER MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant agenda items in addition to standing items
7 July 2009	Application to optimise the Radiation and Atmospheric Monitoring Program, groundwater monitoring around the TSF, Water Management Plan, application to raise the MOL of the TSF, Heap Leach referral, exploration decline referral, APR #34, exploration
November 2009	Radiation and atmospheric monitoring program, groundwater monitoring near the TSF, Water Management Plan, wet season report, TSF maximum operating level, exploration drilling rehabilitation, electromagnetic radiation survey, heap leach facility referral
February 2010	Expanded covered evaporation ponds program, RP1 release to MG001, 2010 exploration drilling program, expanded accommodation plans, bullnose cutback, mine closure, Information and Compliance Policies and Procedures
March 2010	Radiation and atmospheric monitoring program, Information and Compliance Policies and Procedures, water management plan, annual plan of rehabilitation #35, RP1 release to MG001, accommodation facilities
May 2010	Radiation and atmospheric monitoring program, information and compliance policies and procedures, covered evaporation ponds program, RP1 release to MG001, 250 bed extension to Ranger village.

2.2.2.5 Authorisations and approvals

The Ranger Authorisation 0108-10 was replaced with Authorisation 0108-11 on 16 November 2009 approving a cut back to the wall of Pit 3 outside of the previously approved ‘Shell 50’ design.

On 18 December 2009 Ranger Authorisation 0108-11 was replaced with 0108-12 approving a raise in the Maximum Operating Level of the TSF to RL53m and changing the submission date of Ranger Water Management Plan.

2.2.2.6 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 any incident, ***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, 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 environmental incident report summary (EIRS) and any open issues. Where incidents are considered to have any potential environmental significance or represent repetitions of a class of occurrences, an on-site 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.

Pond water connection

On 5 August 2009, an ERA contractor was found using the wrong connection on a pond water line. The contractor was pressure washing in the CCD area and connected a garden hose to a pond water connection. The contractor responsible was stood down and ERA met with management of the contracting company and required the company's workers to go through another induction and training session. There was no impact to the surrounding environment.

Elevated EC in SMP4

On 19 November 2009 Ranger MTC stakeholders received notification of elevated EC levels in SMP4 from readings taken on 22 October. SMP4 is a bore monitoring the performance of the seepage limiting barrier constructed along the south-eastern wall of Pit 1. Data provided to SSD indicated that water quality continued to deteriorate after that date. ERA undertook weekly investigative sampling of SMP4 and found results showing further increases in EC within the bore. Further investigations are ongoing to determine the source and pathway of the contaminated water. ERA has informed stakeholders that a final report of the investigation is expected in July 2010.

Sand filter

On 24 December 2009 stakeholders were notified that approximately 500 L of pregnant liquor spilled onto the road behind the administration building and into a storm drain that drains into RP2. ERA determined the cause of this incident to be a corroded sand filter. The spill area was cleaned up and later cleared of any radiation contamination. Water was sampled at the RP2 entry point to monitor for any adverse impact on RP2 water. Having reviewed the data, SSD determined that the impact on RP2 water quality was negligible. Stakeholders inspected the area during subsequent RPIs and have noted the repair works and the maintenance works on the three other sand filters. ERA has advised it proposes to update the maintenance schedule for the sand filters to include a manual clean every 6 months and lining inspection every 2 years.

South west TSF runoff sump wall breach

A breach in the south west TSF runoff sump occurred on 29 December 2009 due to heavy rains. The sump collects sediment and runoff from the TSF walls. It contained approximately 6 ML when the breach occurred. ERA collected water samples at the tributary leading into Gulungul Creek as well as at Gulungul upstream and downstream monitoring points. Results showed no discernable increase in turbidity. This may be attributable to the incident occurring during the first significant rainfall and an associated flush of sediments through the catchment. ERA continued to collect and report water quality measurements for a number of weeks following the incident. ERA created a bund along the TSF road to divert water and sediment away from the sump and has committed to completing a wider catchment review of the area to model inputs into the sediment sump. SSD continues to monitor this progress through the RPI and MTC process.

2.2.3 Off-site environmental protection

2.2.3.1 Surface water quality

Under the Authorisation, ERA is required to monitor and report on water quality in Magela and Gulungul Creeks adjacent to Ranger mine. Specific water quality objectives must be achieved in Magela Creek.

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, including Magela and Gulungul Creeks upstream and downstream of the mine, to the major stakeholders (the Supervising Scientist, DoR 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 program, the Supervising Scientist conducts an independent surface water quality monitoring program that includes measurement of chemical and physical variables in Magela and Gulungul Creeks, and biological monitoring in Magela and Gulungul Creeks as well as other reference creeks and waterbodies in the region. Key results (including time-series charts of key variables of water quality) are reported by the Supervising Scientist through the wet season on the Internet at www.environment.gov.au/ssd/monitoring/index.html. The highlights of the monitoring results are summarised below.

Chemical and physical monitoring of Magela Creek

The Supervising Scientist Division (SSD) modified its wet season monitoring program in 2008–09 to enhance the ability of SSD to independently detect changes while reducing replication of monitoring activities that are already carried out by other agencies (see 2009 Annual Report, chapter 3, section 3.1).

From the 2008–09 wet season there has been close integration of the routine water chemistry weekly grab sampling monitoring program with continuous water quality monitoring and in situ toxicity monitoring programs. The weekly grab samples, as for previous seasons, are measured for key mine site analytes, including physicochemical parameters. Map 2 shows the location of the upstream and downstream monitoring sites and key features of the Ranger minesite.

Flow was first recorded for the 2009–10 wet season at the Magela Creek upstream monitoring station on 24 December 2009. At the downstream monitoring station flow started on 27 December 2009.

The first water chemistry grab samples for the Supervising Scientist's 2009–10 wet season surface water monitoring program were collected from Magela Creek on 30 December 2009. Weekly sampling continued throughout the wet season and was still underway as of 30 June 2010. The continuous monitoring of EC and turbidity was maintained at both the downstream and upstream sites throughout the wet season.

The increase in rainfall in the Magela Creek catchment in late December 2009 resulted in increased flow, with consequent decreased manganese concentration, electrical conductivity and pH, and increased turbidity at both the upstream and downstream sites. This behaviour is typical of first flush conditions.

During late January the continuous monitoring data showed there were a series of minor electrical conductivity events (Figure 2.2).

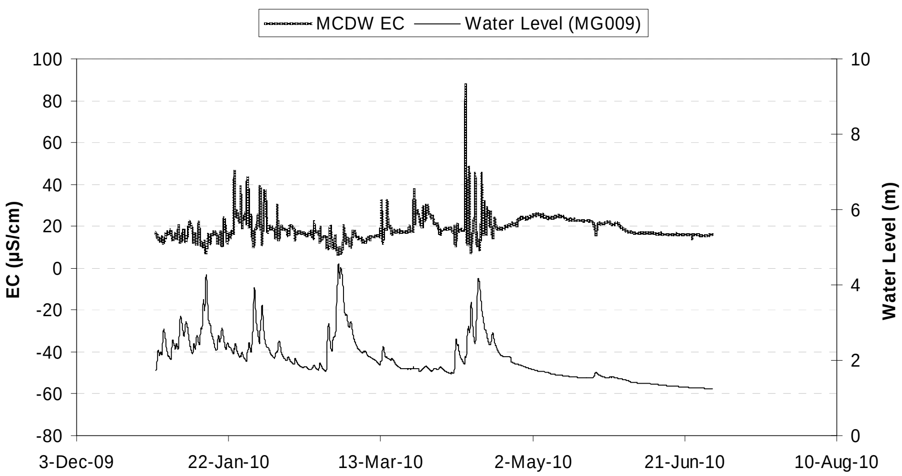


Figure 2.2 Electrical conductivity and discharge measurements in Magela Creek between December 2009 and July 2010 – continuous monitoring data

These are likely to be associated with the release of mine-derived solutes from Retention Pond 1 (RP1) to Coonjimba Billabong. These EC events lasted between 9 and 13 hours. During two of these events the EC remained above the EC guideline value of 43 µS/cm for periods of 2.25 and 0.83 hours.

On 3 February, uranium concentration peaked at approximately 3% of the limit and measured 0.175 µg/L at the SSD downstream site compared with 0.024 µg/L at the upstream site (Figure 2.3). This concentration is similar to uranium concentrations measured by the creekside field toxicity monitoring program on two occasions in 2002–2003 and once in the 2006–2007 wet season.

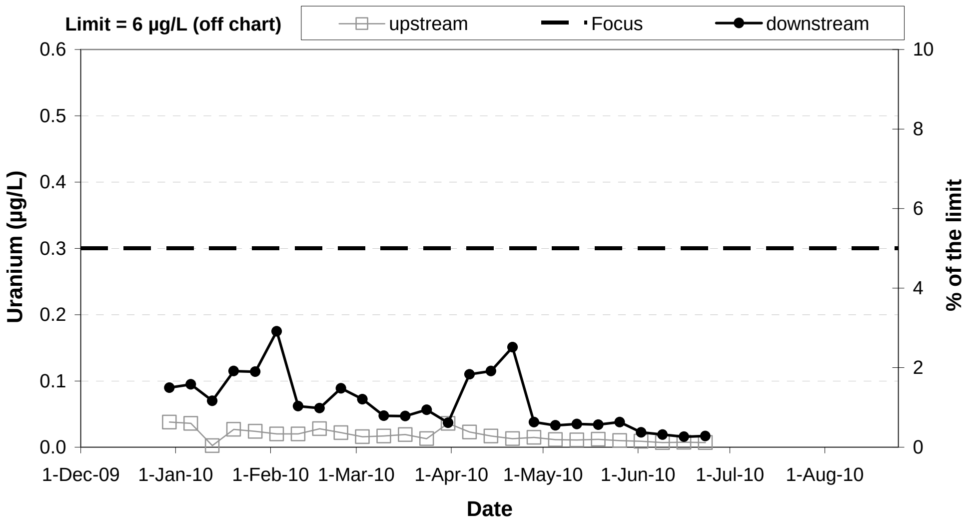


Figure 2.3 Uranium concentrations measured in Magela Creek by SSD between December 2009 and June 2010

Water levels within Magela Creek remained low during mid-February. High rainfall in late-February resulted in high creek levels from 26 February – 3 March 2010. Below average rainfall during March resulted in very low creek levels and increased values for electrical conductivity and pH and higher magnesium and sulfate concentrations. Heavy rainfall during mid-April resulted in seasonally low solute concentrations and increased turbidity due to high water flows (Figure 2.4).

Continuous monitoring data show several EC events during this period of high creek levels. These events coincided with increased discharge of water from Retention Pond 1 (RP1), with values of EC exceeding the EC guideline of 43 µS/cm for between 2.75 and 8.5 hours, with maximum conductivities from 48 to 90 µS/cm.

SSD considers these pulses of high conductivity water likely originated from RP1 (via Coonjimba Billabong). It is probable that an increase in flow (and water level) in Magela Creek had initially restricted flow from Coonjimba Billabong.

As the Magela Creek water level dropped, water held back in Coonjimba Billabong drained out causing the increase in EC at the downstream site (Figure 2.2) as a consequence of the reduced dilution. Ecotoxicological research conducted by SSD suggests that no detrimental environmental impacts would have resulted from these short-lived EC events.

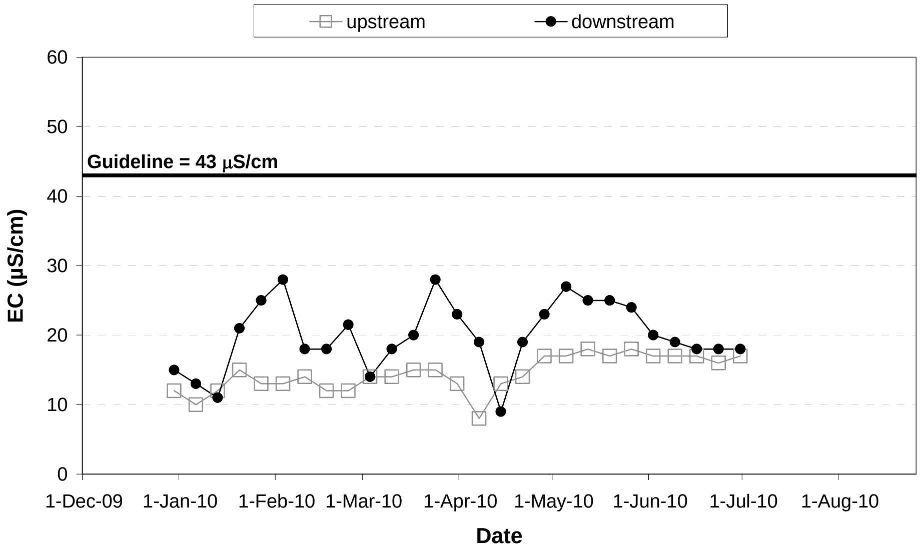


Figure 2.4 Electrical conductivity measurements in Magela Creek (SSD data) between December 2009 and June 2010 – grab sample data

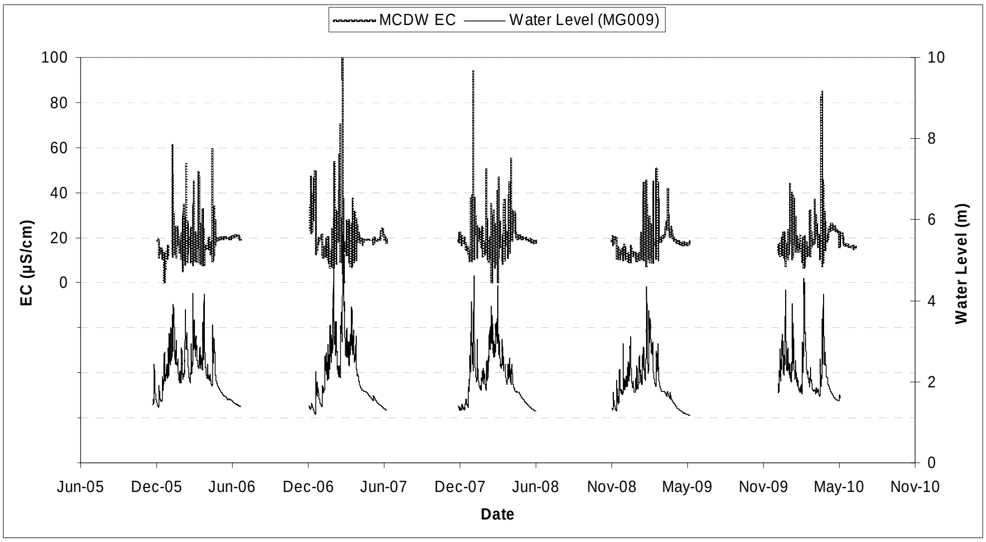
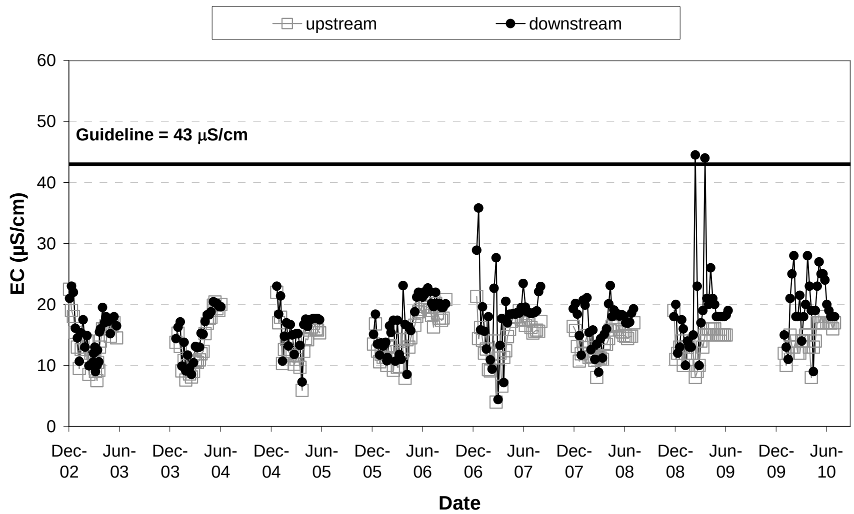


Figure 2.5 Electrical conductivity measurements and water level (lower trace) in Magela Creek (SSD data) between December 2005 and July 2010 – continuous monitoring data

From late-April, typical end of wet-season trends were apparent as the water level decreased. Manganese concentrations at the downstream site increased as groundwater influences started to dominate, and electrical conductivity between the upstream and downstream sites became similar as minesite influences decreased.

Overall, the data from the continuous monitoring and grab sample monitoring programs indicate that water quality in Magela Creek was comparable with previous seasons for the west channel (Figures 2.5 & 2.6). Figure 2.7 shows that uranium concentrations measured during the 2009–2010 wet season are comparable with previous seasons for the downstream west channel of Magela Creek.



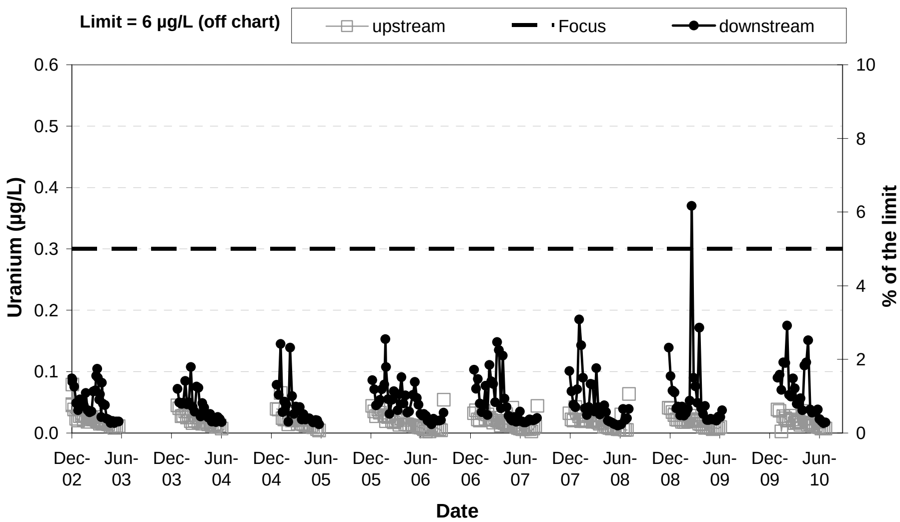


Figure 2.6 (top) Electrical conductivity measurements in Magela Creek (SSD data) between December 2002 and July 2010 – grab sample data. **Figure 2.7** (bottom) Uranium concentrations in Magela Creek since the 2002–03 wet season – grab sample data.

Radium in Magela Creek

Radium-226 (^{226}Ra) results for the 2009–10 wet season can be compared with previous wet season data from 2001-02 (Figure 2.8). The data from sample composites (weekly collected samples were combined from 2006–07 onwards to give monthly averages) show that the levels of ^{226}Ra are very low in Magela Creek, including downstream of Ranger mine. The anomalous ^{226}Ra activity concentration of 8.8 mBq/L in a sample collected from the control site upstream of Ranger in 2005 was probably due to a higher contribution of ^{226}Ra-rich soil or finer sediments that are present naturally in Magela Creek. This result has previously been explained in the 2004–05 Supervising Scientist Annual Report.

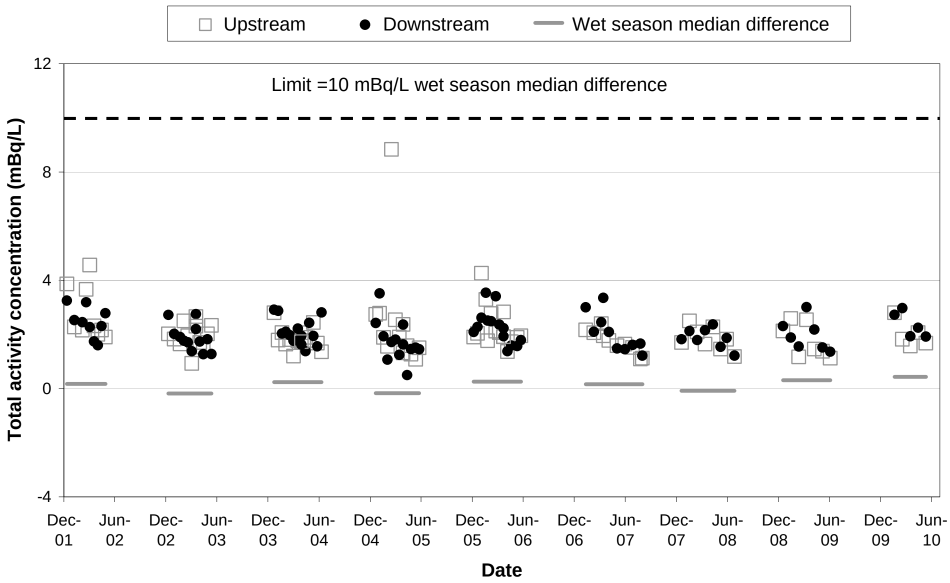


Figure 2.8 Radium-226 in Magela Creek 2001–2010 (SSD data)

The limit for total ^{226}Ra activity concentration has been defined for human radiological protection purposes. The medians of all ^{226}Ra data collected over the 2009–10 wet season are calculated for both the upstream and the downstream sites. The median of the upstream data is then subtracted from the median of the downstream data. This difference value, called the 'wet season median difference', should not exceed 10 mBq/L.

All wet season median differences (shown by the grey solid line in the graphs) from 2001 to 2010 are close to zero, indicating that ^{226}Ra levels at both sites in Magela Creek are due to the natural occurrence of radium in the environment. Thus, it is concluded that there is no significant input of ^{226}Ra from the Ranger minesite into Magela Creek.

Chemical and physical monitoring of Gulungul Creek

Weekly grab sampling for routine analysis of water chemistry variables was discontinued at the upstream site from the commencement of the 2008–09 wet season, as this site does not represent a useful reference site (ie water chemistry measured at this site may show upstream (natural) catchment influences that compromise its effectiveness for assessing downstream impacts from the mine). However, during the 2009–10 wet season grab samples were taken at the upstream site corresponding to the period of trial deployment of the in situ toxicity tests using the freshwater snail reproduction methodology. Weekly monitoring was continued at the downstream site. The continuous monitoring of EC and turbidity has been maintained at both the downstream and upstream sites.

The first water chemistry samples for the SSD 2009–10 wet season surface water monitoring program were collected from Gulungul Creek on 30 December 2009. Weekly sampling from the downstream site continued throughout the season while the creek was flowing until 24 June when MTC stakeholders agreed that surface flow had ceased in Gulungul Creek.

All weekly grab sample data show electrical conductivity measurements (EC) below the Magela Creek guideline value of 43 µS/cm (Figure 2.9). However, continuous monitoring data (Figure 2.10) shows two exceedances of this guideline during the peak of EC events on 26 January and 24 March 2010. These events lasted 14 and 21.5 hours respectively, during which time the EC remained above the guideline value for 3 hours during the January EC event and 1.25 hours during the March event.

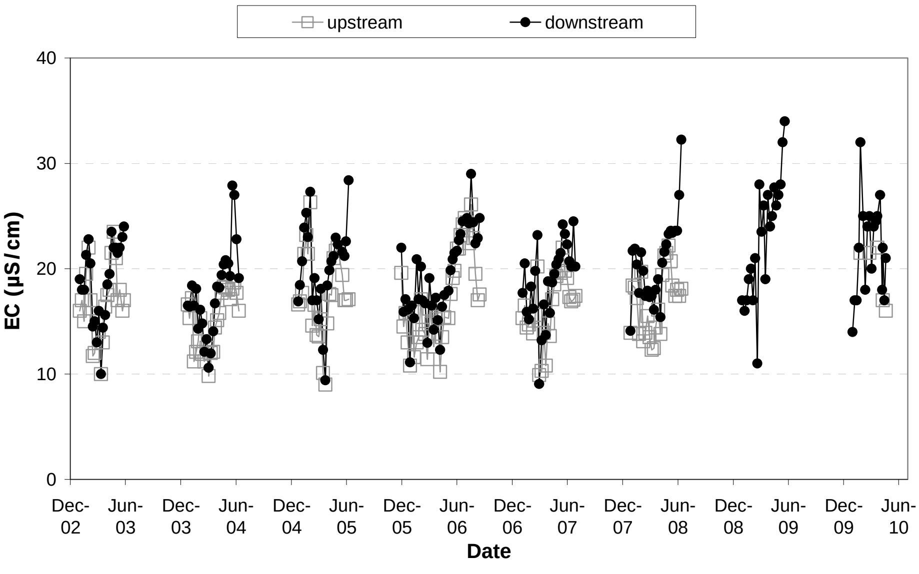


Figure 2.9 Electrical conductivity measurements in Gulungul Creek (SSD data) between December 2002 and June 2010 – grab sample measurements

The increased electrical conductivity and concentrations of magnesium and sulfate measured by both SSD and ERA were proposed to have originated from surface water runoff from an area of material used in the construction of the road at the base of the TSF. This runoff appears confined to the NW area of the TSF. ERA constructed a sump to collect the surface runoff and redirect it to the pond water circuit if of unacceptable quality, or allow it to overflow naturally across a rock-lined spillway if of appropriate quality. ERA will undertake a program of investigative works over the dry season to remove any problematic material.

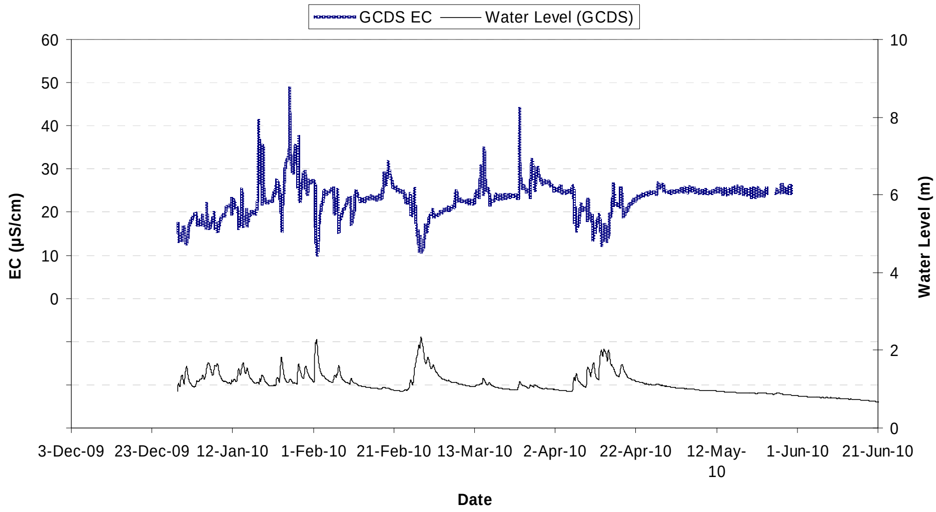


Figure 2.10 Electrical conductivity measurements in Gulungul Creek between December 2009 and June 2010 – continuous monitoring data

Figure 2.11 displays uranium concentrations measured by SSD at the downstream Gulungul Creek monitoring site for the 2009–10 wet season. Figure 2.12 shows the uranium data acquired by SSD for the 2002–03 to 2009–10 wet seasons to provide context. On 6 January 2010, uranium was 0.32 µg/L at the downstream site (<6% of the Magela Creek limit). This did not coincide with elevated EC, magnesium or sulfate concentrations, which were 17 µS/cm, 0.8 mg/L and 1.1 mg/L respectively at this time.

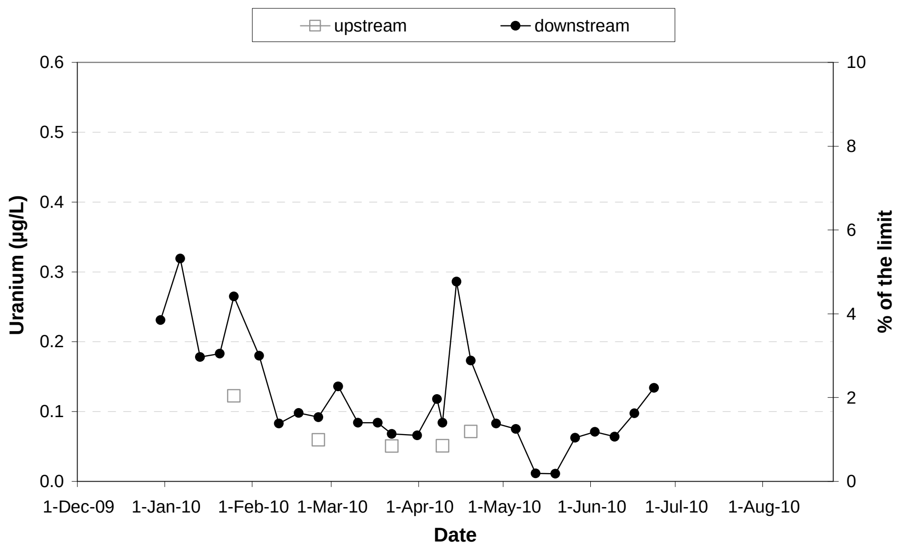


Figure 2.11 Uranium concentrations measured in Gulungul Creek by SSD between December 2009 and June 2010 – grab sample measurements.

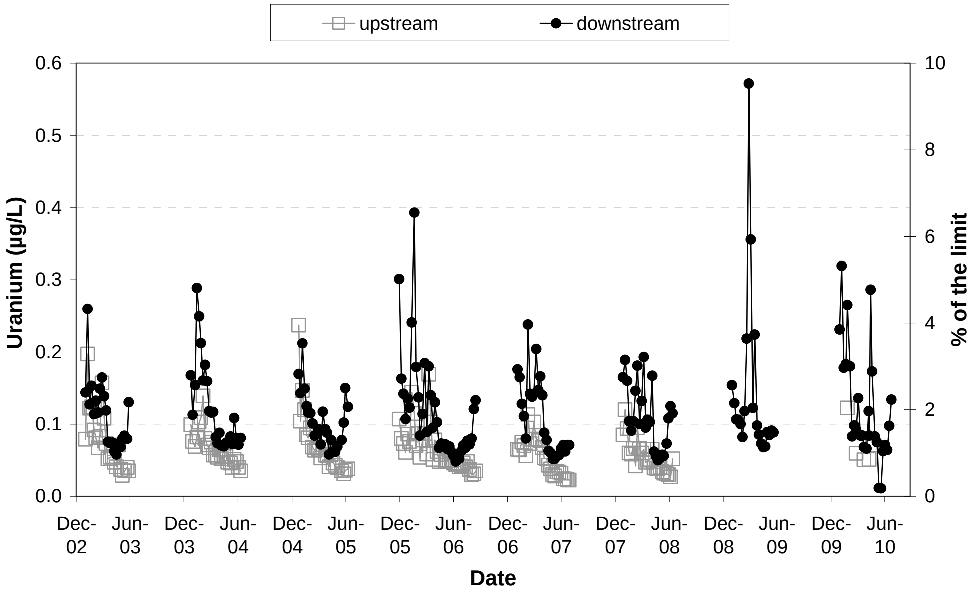


Figure 2.12 Uranium concentrations measured in Gulungul Creek by SSD between December 2002 and June 2010 – grab sample measurements.

On 25 January 2010 uranium measured 0.27 µg/L at the downstream site and coincided with slightly elevated EC (32 µS/cm), and magnesium (1.8 mg/L) and sulfate (4.4 mg/L) concentrations. Ecotoxicological research conducted by SSD suggests that no detrimental environmental impacts would have resulted from these short-lived EC events, and toxicity monitoring (creek side and/or in situ) has shown no biological effects for solute concentrations at this level.

Overall, the water quality measured in Gulungul Creek for the 2009–10 wet season indicates that the aquatic environment in the creek has remained protected from mining activities.

2.2.3.2 Biological monitoring in Magela Creek

Research conducted by the Environmental Research Institute of the Supervising Scientist (***eriss***) since 1987 has been used to develop biological techniques to monitor and assess the potential effects of uranium mining on aquatic ecosystems downstream of Ranger mine. Two broad approaches are used: early detection and assessment of overall ecosystem-level responses.

Early detection of effects in Magela Creek is done using two techniques: (i) in situ toxicity monitoring for detection at a weekly timescale of effects arising from inputs of mine waters during the wet season, and (ii) bioaccumulation, used to measure over a seasonal timescale a potential developing issue with bioavailability of mine-derived solutes (metals and radionuclides) in aquatic biota.

For *ecosystem-level responses*, benthic macroinvertebrate and fish community data from Magela and Gulungul Creek sites are compared with historical data and data from control sites in streams unaffected by contemporary mining.

The findings from toxicity monitoring, bioaccumulation, and fish and macroinvertebrate community studies conducted during the 2009–10 wet and early dry seasons are summarised below.

Toxicity monitoring

In this form of monitoring, effects of waters dispersed from the Ranger minesite on receiving waters are evaluated using responses of aquatic animals exposed in situ to creek waters. The response measured is reproduction (egg production) in the freshwater snail *Amerianna cumingi*. Each test runs over a four-day exposure period. This species has been shown to be among the most sensitive, to both uranium and magnesium, of SSD's suite of six local species as determined using standardised laboratory toxicity test protocols.

For the 1990–91 to 2007–08, wet seasons toxicity monitoring was carried out using the 'creekside' methodology. This involved pumping a continuous flow of water from the adjacent Magela Creek through tanks containing test animals located under a shelter on the creek bank. In the 2008–09 wet season, this method was replaced by an in situ testing method. The in situ testing was implemented following a rigorous three year period of development and comparative (creekside and in situ) testing to ensure that both methods produced similar results (see section 3.2 of the 2007–08 Supervising Scientist Annual Report for rationale and results).

Nine in situ toxicity tests were conducted on a fortnightly frequency (ie every other week) over the 2009–10 wet season. The first started on 4 January 2010 and the final test started on 3 May 2010. Results are plotted in Figure 2.13b with egg production at upstream and downstream sites, and differences in egg production between the sites being displayed.

On average, egg numbers at the downstream site are slightly greater than that measured at the upstream control site (Figure 2.13a&b), This 'normal' level of response is most likely the result of input to Magela Creek, between the upstream and downstream test locations, of billabong-tributary waters. Inflows from Georgetown and Coonjimba Billabongs have higher water temperatures, a higher organic carbon content than Magela Creek water and (Coonjimba in particular) higher concentrations of mine-derived solutes (including $MgSO_4$ and Ca) relative to the background very soft, low solute Magela Creek water. Higher water temperatures will enhance reproductive activity in *Amerianna cumingi*. The inputs of dissolved salts, increased nutrients and natural organic matter would supplement the food supply and thereby also enhance egg production by the downstream snails.

The measured difference in water quality between the upstream and downstream sites is also highly affected by creek hydrology. On a falling hydrograph in the creek, outflowing of previously-ponded waters from billabongs located between the upstream and downstream sites occurs, accentuating solute and nutrient differences between the sites (higher concentrations measured at the downstream site, particularly along the west bank).

A different pattern of results for the 2009–10 wet season was seen from those reported in previous wet seasons. Unlike previous wet seasons, snail egg production during the 2009–10 season was *consistently* higher (8 out of 9 tests; Figure 2.13b) at the downstream site compared with the upstream site. The positive difference was particularly marked in the 3rd test and to a lesser extent in the 4th and 5th tests.

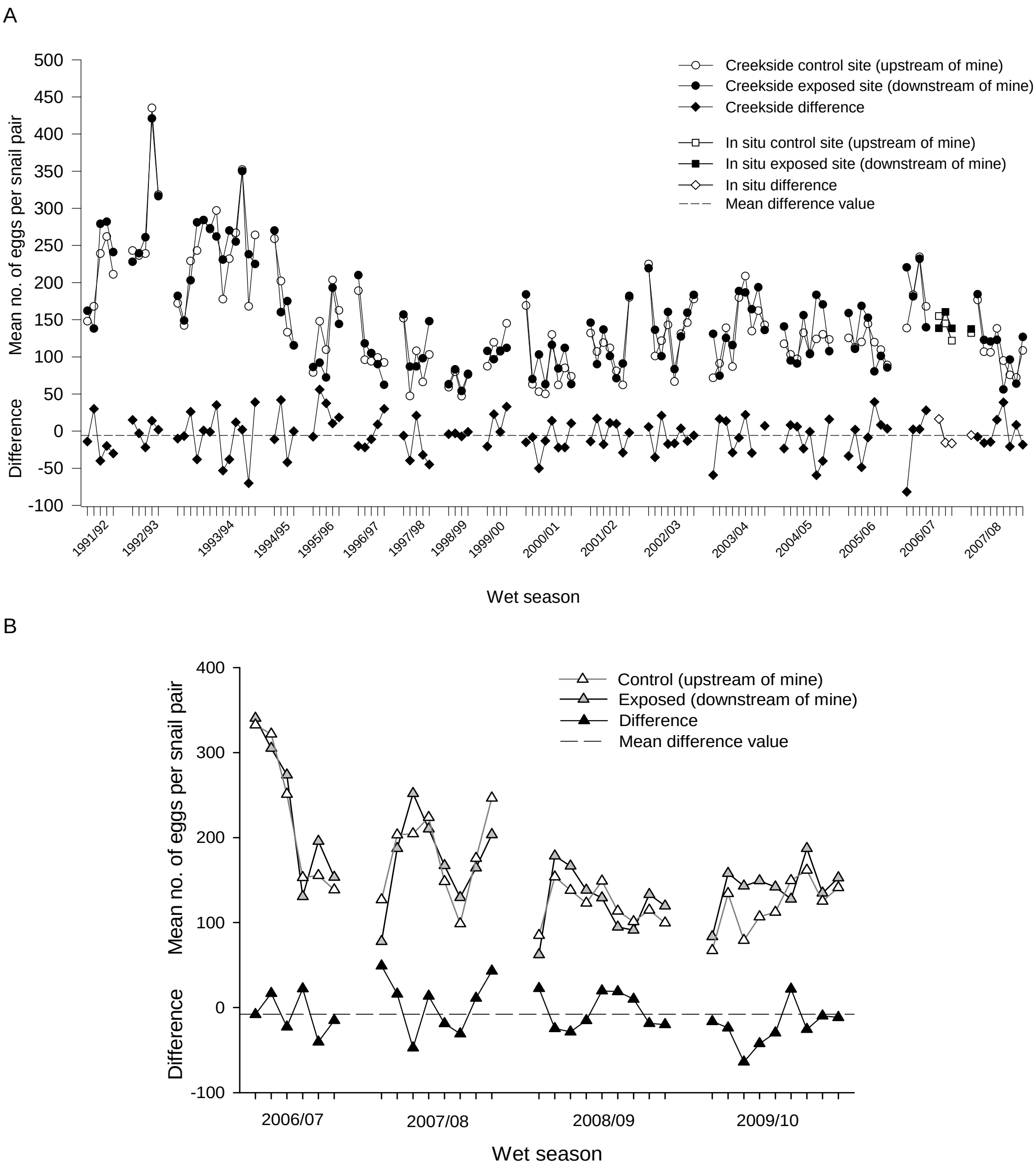


Figure 2.13 Time-series of snail egg production data from toxicity monitoring tests conducted in Magela Creek using A: (mostly) creekside tests, and B: in situ tests

Analysis Of Variance (ANOVA) testing was used to test for differences in the upstream-downstream difference values between test results for the 2009–10 wet season and all previous wet season data (see ANOVA details, section 2.2.3 of the 2007–08 Supervising Scientist Annual Report). For the first time, a significant difference was found between the data for the most recent year and that from previous wet seasons (p = 0.046), confirming the generally higher downstream egg production in 2009–10 evident in Figure 2.13b. A number of factors have the potential to cause the different behaviour observed for the 2009–10 wet season: methodological or systematic operator problems during the wet season; an unusual suppression in egg number upstream over the wet season; or enhancement of egg number downstream that may be associated with inputs of water (as measured by EC or turbidity data) from the Ranger site.

Each of the above potential causative factors was assessed in detail using the extensive available historical grab sampling and continuous water quality monitoring datasets. No correlation was found between any of these factors and the positive downstream effect on egg production. Specifically there was no evidence of any mine-related influence from either the water quality data or the macroinvertebrate community studies (reported below) that are conducted by SSD in the late wet season recessional flow period each year.

At this time it appears as though the most probable explanation is an increase in food supply downstream as a result of increased settling out of particulate matter. Field monitoring staff have noted that in recent times there has been a deepening of the channel at the downstream site. This deepening would result in a relative reduction in water velocity across the stream profile and hence an increased likelihood for deposition of suspended material. A visible increase, compared with previous years, in the amount of particulate material trapped inside the toxicity monitoring containers at the downstream site was in fact noted during the 2010–11 wet season.

Experimental studies to examine the responses of freshwater snails to a limited matrix of water quality variables, including Mg and organic carbon at low concentrations, may provide further insights into the effects of otherwise subtle variations on biological responses. A means to quantify the amount of particulate matter trapped in the test containers during the period of in situ deployment will be developed for implementation in future wet seasons.

Bioaccumulation in freshwater mussels

Mudginberri Billabong is the first major permanent waterbody downstream (12 km) of Ranger mine (Map 3). Local Aboriginal people harvest aquatic food items, in particular mussels, from the billabong and hence it is important to provide assurance that they are fit for human consumption from chemical and radiological perspectives. Concentrations of metals and/or radionuclides in the tissues and organs of aquatic biota attributable to inputs of mine-derived solutes must remain within acceptable levels. Increased body burdens of mine-derived solutes in biota compared with control sites could provide early warning of the effects of inputs of solutes. In extreme cases the concentrations could potentially reach levels that may harm the organisms themselves. Hence the bioaccumulation monitoring program serves an ecosystem protection role in addition to the human health aspect.

Uranium and radium bioaccumulation data were obtained intermittently from Mudginberri Billabong between 1980 to 2000. Since 2000, mussels have been collected annually and fish every two years, respectively, from Mudginberri (the potentially impacted site, sampled from 2000 onwards) and Sandy billabongs (the control site, sampled from 2002 onwards). The monitoring data showed that radionuclide burdens in mussels from Mudginberri Billabong were generally about twice as high compared with mussels from Sandy Billabong. A longitudinal study was conducted in 2007 to measure radium loads in mussels along

Magela Creek, upstream and downstream of the mine. The objectives were to identify whether the higher radionuclide loads are related to natural or mine inputs and whether Sandy Billabong is an appropriate control site for mussels in Mudginberri Billabong.

It was found that of all sites investigated along the Magela channel, Mudginberri Billabong mussels exhibit the lowest radium loads, age-for-age, and that differences in mussel radionuclide activity loads between Mudginberri and Sandy Billabong mussels are due to natural catchment rather than mine influences. A longitudinal study of radium uptake in mussels in Mudginberri Billabong was undertaken and showed that the location of sampling in the billabong had no significant effect on the mussel radium loads. In addition the concentration factor for radium uptake in mussels from Mudginberri Billabong has not changed significantly over the past 25 years.

Nine years of monitoring of the levels of radionuclides and metals in fish has not revealed any issues of potential concern with regards to bioaccumulation.

Given the above findings, the effort on the bioaccumulation component of the monitoring program has been reduced to analysing annually a bulk sample of mussels for radionuclides and metals, while the two yearly fish sampling program has been discontinued. The fish bioaccumulation program will be restarted in the event that it is shown that levels of metals being input from the mine increase above the current condition.

Uranium in freshwater mussels

Uranium concentrations in freshwater mussels, water and sediment samples collected annually from Mudginberri and Sandy Billabongs are shown in Figure 2.14.

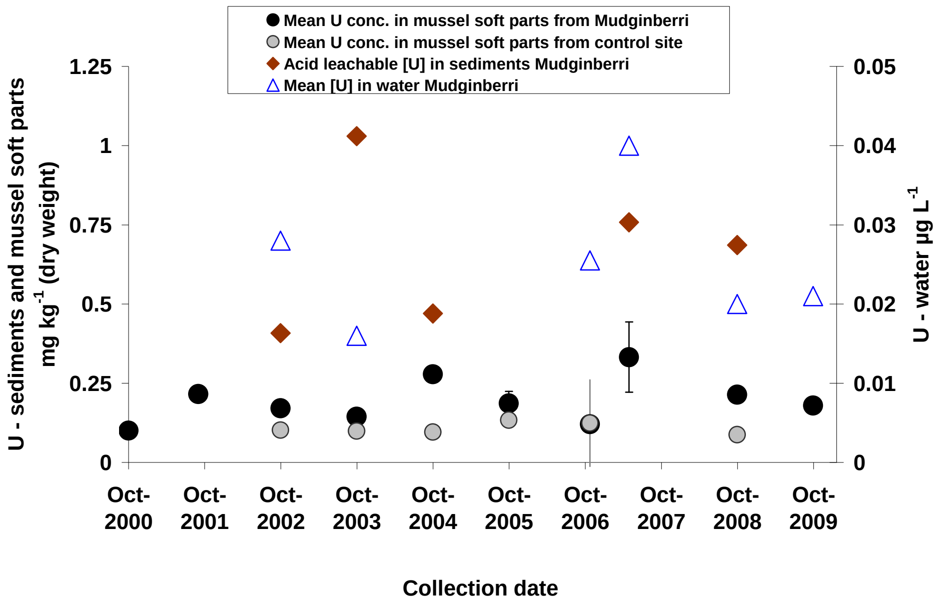


Figure 2.14 Mean concentrations of U measured in mussel soft-parts, sediment and water samples collected from Mudginberri Billabong and Sandy Billabong since 2000

This plot includes the 2009 data for the composite mussel sample and water quality data in Mudginberri Billabong. Low concentrations of uranium have been measured in mussels from Mudginberri Billabong from 2000 onwards, with no evidence of an increasing trend in concentration over time. Notwithstanding some bioaccumulation with age, uranium appears to have a short biological half-life, a conclusion that is supported by the data in Figure 2.14, with the uranium concentrations in mussel flesh being very low.

The lack of any increase in concentration of U in mussel tissues through time, with essentially constant levels observed between 1989 and 1995 (previous reports), and consistently low levels from 2000 to the last sample taken in October 2009, indicates absence of any mining influence on U levels in mussels.

Radium-226 and lead-210 in freshwater mussels

Activity concentrations of ^{226}Ra and ^{210}Pb in mussels are age-dependent and are also related to growth rates and seasonally-changing soft body weights. Consequently, ^{226}Ra and ^{210}Pb activity concentrations in mussels can vary depending on the time of collection during the year.

The average annual committed effective dose for a 10-year old child (the most conservative case) who eats 2 kg (wet weight) of mussel flesh from Mudginberri Billabong is calculated from the concentrations of ^{226}Ra and ^{210}Pb in mussel flesh. The average for all collections from 2000 to 2009 is 0.175 mSv. Figure 2.15 shows the doses estimated for the individual years, and the median, 80 and 95 percentiles for all collections. As can be seen, annual committed effective doses from the consumption of mussels collected in 2009 are indistinguishable from previous collections (Figure 2.15). Committed effective doses due to ingestion of these mussels are of no concern to human health. The Ra in the mussels is largely derived from natural catchment geology, rather than mining influences.

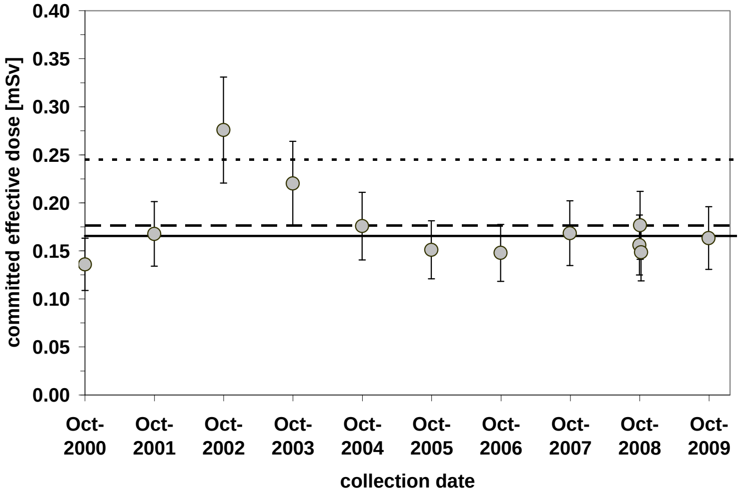


Figure 2.15 Annual committed effective doses from ^{226}Ra and ^{210}Pb for a 10 year old child eating 2 kg of mussels (wet) collected at Mudginberri Billabong. Median over all collections (solid line), the 80th percentile (dashed line) and 95thpercentile (dotted line) are also shown.

The bulk ^{226}Ra activity concentration (in Bq kg^{-1} dry weight) in Mudginberri Billabong mussels is similar for all collections from 2000 to 2009. The higher committed effective dose for the 2002 and 2003 collections is an artefact caused by higher dry:wet weight ratios due to a change in the mussel preparation method. During shucking, or opening, of the mussels, liquid inside the mussel is usually retained and included in the wet weight of the mussels. During the 2002 and 2003 collections, the liquid was drained before wet weights were measured, resulting in a higher dry:wet weight ratio. As the activity concentration (dry) is similar for all years, this results in a higher radionuclide intake per 2 kg (wet weight) of mussels ingested, and consequently a higher committed effective dose for those two years.

Monitoring using macroinvertebrate community structure

Macroinvertebrate communities have been sampled from a number of sites in Magela Creek at the end of significant wet season flows, each year from 1988 to the present. The design and methodology have been gradually refined over this period (changes are described in the 2003–04 Supervising Scientist Annual Report, section 2.2.3). The design is now a balanced one comprising upstream and downstream sites at two ‘exposed’ streams (Gulungul and Magela Creeks) and two control streams (Burdulba and Nourlangie Creeks).

Samples were collected from each site at the end of each wet season (between April and May). For each sampling occasion and for each pair of sites for a particular stream, dissimilarity indices are calculated. These indices are a measure of the extent to which macroinvertebrate communities of the two sites differ from one another. A value of ‘zero%’ indicates macroinvertebrate communities identical in structure while a value of ‘100%’ indicates totally dissimilar communities, sharing no common taxa.

Disturbed sites may be associated with significantly higher dissimilarity values compared with undisturbed sites. Compilation of the full macroinvertebrate dataset from 1988 to 2009, and data from the paired sites in the two ‘exposed’ streams, Magela and Gulungul Creeks, for 2010, have been completed with results shown in Figure 2.16. This figure plots the paired-site dissimilarity values using family-level (log-transformed) data, for the two ‘exposed’ streams and the two ‘control’ streams.

In the 2007–08 Supervising Scientist Annual Report (section 2.2.3), improvements to the presentation and statistical analysis of macroinvertebrate data were described. By deriving dissimilarity values for each of the five possible randomly-paired upstream and downstream replicates, powerful analyses are available that can be used to test whether or not macroinvertebrate community structure has altered significantly at the exposed sites for the recent wet season of interest. For this multi-factor ANOVA, only data gathered since 1998 have been used. (Data gathered prior to this time were based upon different and less rigorous sampling and sample processing methods, and/or absence of sampling in three of the four streams.)

Inferences that may be drawn from the data shown in Figure 2.16 are weakened because there are no baseline (pre-1980) data upon which to assess whether or not significant changes have occurred as a consequence of mining. Notwithstanding, a four-factor ANOVA based upon replicate, paired-site dissimilarity values and using the factors Before/After (BA; fixed), Control/Impact (CI; fixed), Year (nested within BA; random) and Site (nested within CI;

random) showed no significant difference between the control and exposed streams in the change (in dissimilarity) from values from earlier years (back to 1998) to those from 2009 (ie the BA x CI interaction is not significant). While the Year x Site (BA CI) interaction is significant in the same analysis (p = 0.011), this simply indicates that dissimilarity values for the different streams – regardless of their status (Before, After, Control, Impact) – show differences through time. The dissimilarity plots shown in Figure 2.16 corroborate these results, showing reasonable constancy in the mean dissimilarity values for each stream across all years.

Dissimilarity indices such as those used in Figure 2.16 may also be 'mapped' using multivariate ordination techniques to depict the relationship of the community sampled at any one site and sampling occasion with all other possible samples.

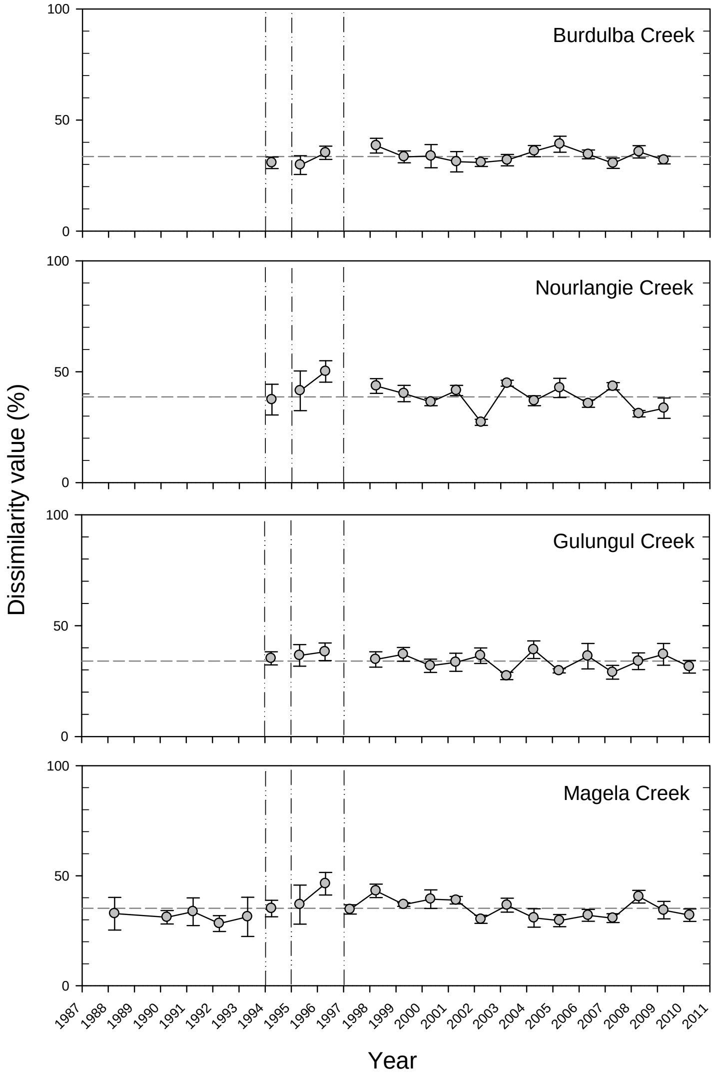


Figure 2.16 Paired upstream-downstream dissimilarity values (using the Bray-Curtis measure) calculated for community structure of macroinvertebrate families in several streams in the vicinity of the Ranger mine for the period 1988 to 2010. The dashed vertical lines delineate periods for which a different sampling and/or sample processing method was used. Dashed horizontal lines indicate mean dissimilarity across years.

Dissimilarity values represent means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of upstream-downstream replicate samples within each stream.

Samples close to one another in the ordination indicate a similar community structure. Figure 2.17 depicts the ordination derived using the *pooled* (average) within-site macroinvertebrate data (unlike the replicate data used to construct the dissimilarity plot from Figure 2.16). Data points are displayed in terms of the sites sampled in Magela and Gulungul Creeks downstream of Ranger for each year of study (to 2010), relative to Magela and Gulungul Creek upstream (control) sites for 2010, and all other control sites sampled up to 2009 (Magela and Gulungul upstream sites, all sites in Burdulba and Nourlangie). Because the data-points associated with these two sites are generally interspersed among the points representing the control sites, this indicates that these 'exposed' sites have macroinvertebrate communities that are similar to those occurring at control sites. This was verified using ANOSIM testing (ANalysis Of SIMilarity, effectively an analogue of the univariate ANOVA), a statistical approach used to determine if exposed sites (Magela and Gulungul downstream) are significantly different from control sites in multivariate space. ANOSIM conducted on (i) pooled (within-site) data from all available years and sites, and (ii) replicate data from 2010 (Magela and Gulungul Creeks only), showed no significant separation of exposed and control sites for the respective comparisons (P>0.05).

Collectively, these graphical and statistical results provide good evidence that changes to water quality downstream of Ranger as a consequence of mining during the period 1994 to 2010 have not adversely affected macroinvertebrate communities.

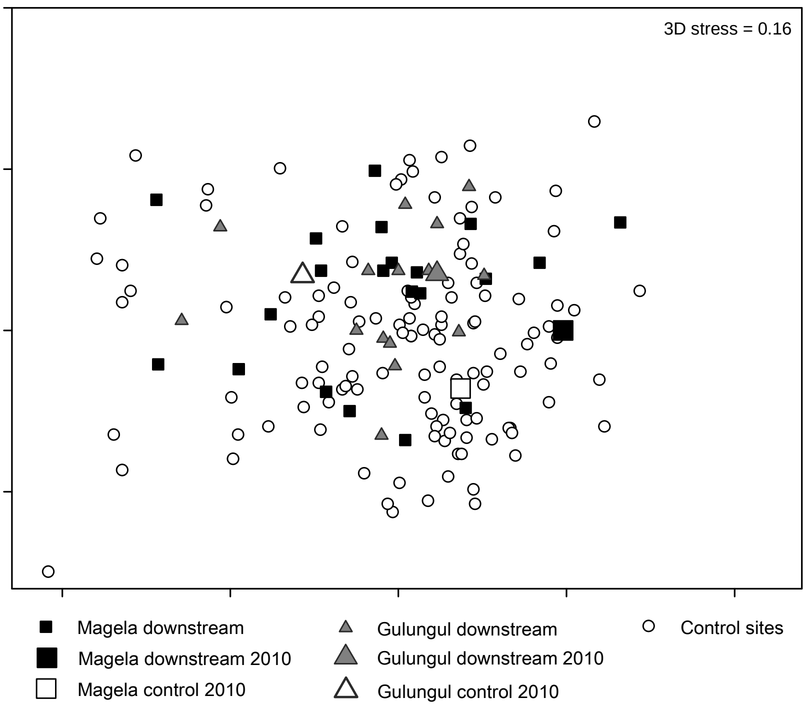


Figure 2.17 Ordination plot of macroinvertebrate community structure data from sites sampled in several streams in the vicinity of Ranger mine for the period 1988 to 2010. Data from Magela and Gulungul Creeks for 2010 are indicated by the enlarged symbols.

Monitoring using fish community structure

Assessment of fish communities in billabongs is conducted between late April and July each sampling year. Data are gathered using non-destructive sampling methods from 'exposed' and 'control' sites in deep channel billabongs annually, and shallow lowland billabongs dominated by aquatic plants, biennially (every other year). Details of the sampling methods and sites were provided in the 2003–04 Supervising Scientist Annual Report (Supervising Scientist 2004, chapter 2, section 2.2.3). These programs were reviewed in October 2006 and the refinements to their design detailed in the 2006–7 and 2007–08 Supervising Scientist Annual Reports (shallow and channel billabong fish communities respectively).

For both deep channel and shallow lowland billabongs, comparisons are made between a directly-exposed billabong (Mudginberri) in the Magela Creek catchment downstream of Ranger mine versus control billabongs from an independent catchment (Nourlangie Creek and Wirnmuyurr Creek). The similarity of fish communities in exposed sites to those in control sites is determined using multivariate dissimilarity indices, calculated for each sampling occasion. The use of dissimilarity indices has been described and defined in 'Monitoring using macroinvertebrate community structure' section. A significant change or trend in the dissimilarity values over time could imply mining impact.

Channel billabongs

The similarity of fish communities in Mudginberri Billabong (directly exposed site downstream of Ranger in Magela Creek catchment) and Sandy Billabong (control site in the Nourlangie Creek catchment) was determined using multivariate dissimilarity indices calculated for each annual sampling occasion. A plot of the dissimilarity values from 1994 to 2010 is shown in Figure 2.18.

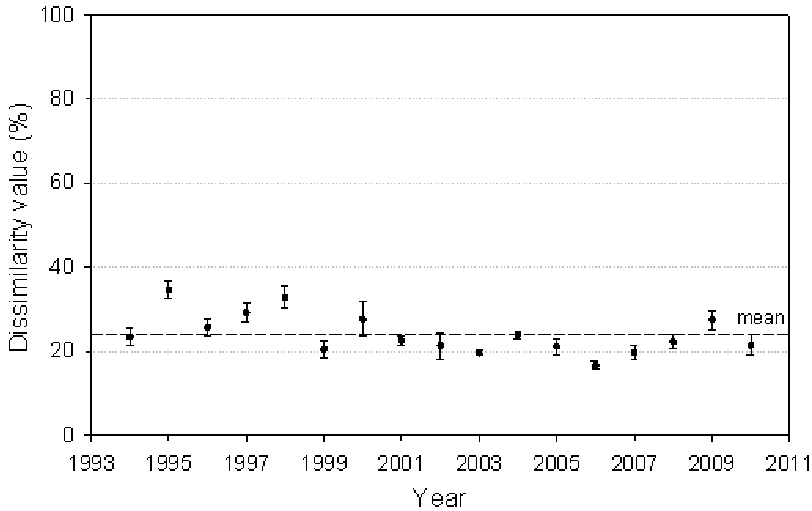


Figure 2.18 Paired control-exposed dissimilarity values (using the Bray-Curtis measure) calculated for community structure of fish in Mudginberri ('exposed') and Sandy ('control') Billabongs in the vicinity of the Ranger mine over time. Values are means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of transect data between the two.

In previous Supervising Scientist Annual Reports (up to 2008–09), a decline in the annual paired-site dissimilarity measure over time has been noted, corresponding to changes in field observation method between 2000 and 2001 and also to longer-term changes (decrease) in abundance in Magela Creek of the chequered rainbowfish (*Melanotaenia splendida inornata*), the species that has had most influence on the change in the paired-billabong dissimilarity value. In the Supervising Scientist Annual Report for 2008–09, it was observed that the changes in abundance of chequered rainbowfish in Magela Creek over time were unrelated to changes in field observation method and, importantly, to any change in water quality over time as a consequence of water management practices at Ranger uranium mine.

Rainbowfish abundance in Mudginberri Billabong for the 2010 sampling was greatly reduced from the higher fish numbers recorded in 2009 (Figure 2.19). In the Supervising Scientist Annual Report for 2008–09, the amount of wet season discharge in Magela Creek had been identified as a possible cause of natural shifts in rainbowfish abundance in Mudginberri Billabong. Specifically, that report provided evidence that larger wet season discharges result in reduced abundances of rainbowfish. The low abundances observed in 2010 support this finding, as the preceding wet season discharge was above average (Figure 2.19). Furthermore, the late rains during April may have resulted in greater migration of rainbowfish, upstream and past Mudginberri Billabong, thereby reducing the reliance of fish to use the billabong as a dry season refuge.

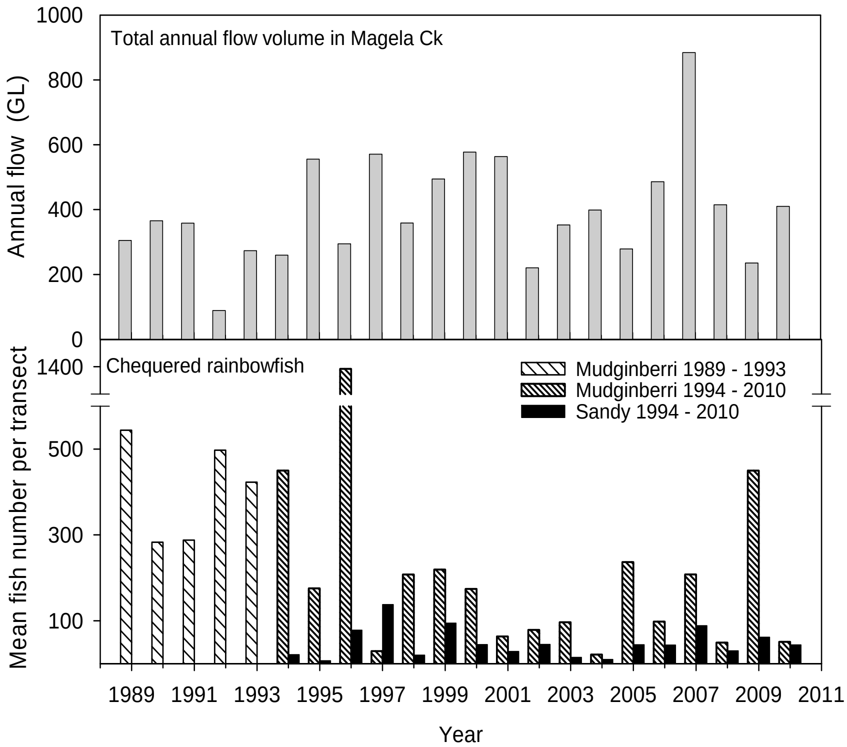


Figure 2.19 Relative abundance of chequered rainbowfish in Mudginberri and Sandy billabongs from 1989 to 2010 with associated total discharge in Magela Creek (gauging station G8210009)

A full analysis of community structure, and in particular chequered rainbowfish abundance, data for the channel billabongs in 2010 was still being conducted at the time of completing this report. At this stage, however, the conclusion reached in the previous (2008–09) Supervising Scientist Annual Report of no evidence for mine-related impact, appears to be applicable also to the results for 2010. In particular, the dissimilarity value observed in 2010 is consistent with the range of values reported since 2001, a period over which there has been no evidence of mine-associated changes to fish communities in Mudginberri Billabong, downstream of Ranger.

Shallow lowland billabongs

Monitoring of fish communities in shallow billabongs is conducted every other year (see SSAR 2006–07). The last assessment of fish communities in shallow lowland billabongs was conducted in May 2009 with results reported in SSAR 2008–09. The next assessment will be conducted during recessional flows sometime between the late April and June 2011.

2.3 Jabiluka

2.3.1 Developments

The site continues to be maintained under the long-term care and maintenance regime of management. There has been no change to the statutory monitoring program undertaken by ERA in Swift Creek (Ngarradj) during the reporting period. SSD continues to monitor downstream water quality at Ngarradj.

2.3.2 On-site environmental management

2.3.2.1 Water Management

The site continues to be maintained as a passive discharge site.

2.3.2.2 Audit and Routine Periodic Inspections (RPIs)

Three inspections were undertaken at Jabiluka during 2009–10 (Table 2.6). An environmental audit was held in May 2010 and RPIs were held in August, November and February.

TABLE 2.6 RPI FOCUS DURING THE REPORTING PERIOD

Date	Inspection type	Foci
18 August 2009	RPI	Access Road, Interim Water Management Pond, Helipad area
17 November 2009	RPI	Helipad area, Clean stockpile area, Main site / portal area, IWMP and associated choke structure, Silt trap opposite former turkey nest dam, JSC compliance point, Djarr Djarr, Ngarradj sampling location
17 February 2010	RPI	IWMP and drop structure, Hardstand revegetation, Fly-over of the JSC and JSCUS monitoring stations, Mine Valley remediation works and Djarr Djarr Camp.

2009 Audit review outcomes

Observations from the May 2009 Environmental Audit were followed up through the RPI process.

It is a requirement of long-term care and maintenance of the site that the vent rise infrastructure will be decommissioned and the vent shaft capped and converted to a decline water sampling point. ERA has reaffirmed its commitment to convert the vent raise to a sampling point and there have been no further issues identified with the reporting of water chemistry data.

The redundant boreholes in Mine Valley are required to be capped as part of the site's long-term care and maintenance. Works to rehabilitate these bore holes is ongoing. Works have commenced and stakeholders are awaiting submission of the Phase 1 report.

2010 Audit outcomes

The annual environmental audit of Jabiluka was held in May 2010 and tested compliance against 22 specific commitments taken from Authorisation 0140-05. The information collected against each criteria was assessed and given a ranking as per the grading system provided in Table 2.4. The audit process found evidence to grade one criteria as conditional and one as not verified while all other criteria was found to be acceptable. The conditional finding relates to:

- Capping of redundant boreholes in mine valley. ERA informed stakeholders works in mine valley to rehabilitate redundant bore holes are ongoing. Works have commenced and stakeholders are awaiting submission of the Phase 1 report. This aspect of this criteria has been ranked conditional on ERA providing stakeholders with the Phase 1 report in order to progress towards finalising rehabilitation of this area.

The not-verified condition relates to:

- Removal of buildings, infrastructure and miscellaneous items from the mine site and Djarr Djarr Camp. The audit team were not able to visit Djarr Djarr due to access restrictions therefore this aspect of this criteria was unable to be verified.

2.3.2.3 Minesite Technical Committee

The Jabiluka MTC met five times during 2009–10. Dates of meetings and significant issues discussed are shown in Table 2.7.

2.3.2.4 Authorisations and approvals

No applications to alter the Jabiluka Authorisation, 0140-5, were received during the reporting period.

2.3.2.5 Incidents

There was one incident reported for the 2009–10 period of a minor nature and did not require investigation or assessment.

TABLE 2.7 JABILUKA MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant agenda items
7 July 2009	Annual Plan of Rehabilitation #12, progress of Mine Valley Bores, comments regarding the wet season report
12 November 2009	Mine Valley bore rehabilitation program, wet season report, SSD monitoring program at Ngarradj
12 February 2010	Mine Valley rehabilitation program, Annual Environment Report, Annual Plan of Rehabilitation #12, MTC member website
11 March 2010	Mine Valley rehabilitation program, Annual Environment Report
13 May 2010	Mine Valley rehabilitation program, Annual Environment Report, Annual Plan of Rehabilitation

2.3.3 Off-site environmental protection

2.3.3.1 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, DoR 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 program, the Supervising Scientist conducts monitoring in Ngarradj Creek. Jabiluka has been in a long-term care and maintenance phase since late 2003 and poses a low risk to the environment. As a consequence of this low risk and the good data set acquired over the last seven years indicating the environment has been protected, the monitoring program has been systematically scaled down.

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

Since 2009/10, the Supervising Scientist Division has collected continuous monitoring data (electrical conductivity, pH and turbidity) from the downstream statutory compliance site only. ERA collects monthly grab samples from both the upstream and downstream site. Previous grab sample monitoring data can be found at www.environment.gov.au/ssd/monitoring/ngarradj-chem.html on the SSD website and have been reported in previous Annual Reports.

Chemical and physical monitoring of Ngarradj Creek

The first flush conditions in Ngarradj resulted in the highest EC record of the season at 26.1 µS/cm (Figure 2.20). EC levels gradually reduced during January and stabilised between 15–20 µS/cm. The EC sensor was damaged during a flood event and was inoperative from 7–25 February.

On 18 March the gauge board reading indicated water levels had dropped to <0.51 m. The low water level resulted in the EC sensor being out of the water, so there is a gap in the EC time series data around this time. The EC trace resumed with the increase in water level that occurred during April. 'Cease to flow' at the Oenpelli Highway was called by stakeholders on 23rd May 2010.

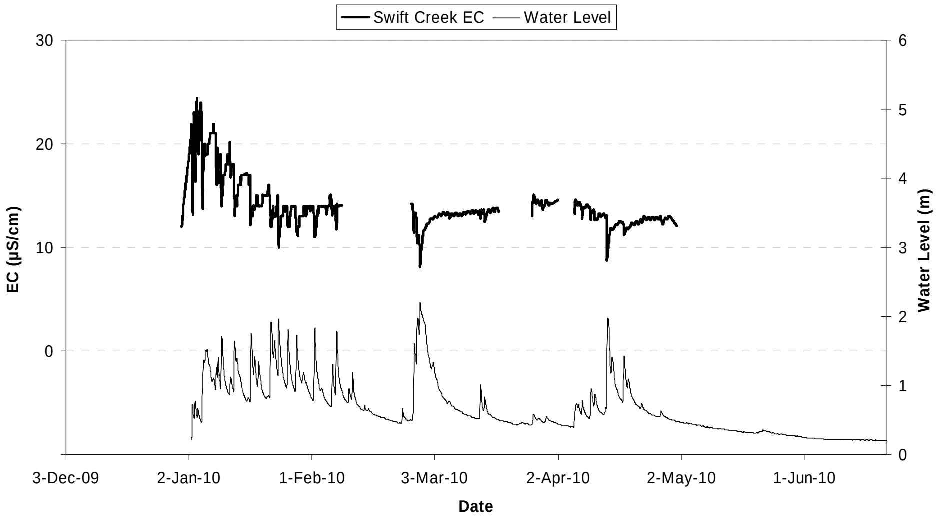


Figure 2.20 Electrical conductivity measurements in Ngarradj between December 2009 and June 2010 – continuous monitoring data

2.4 Nabarlek

2.4.1 Developments

In early 2008, Uranium Equities Limited (UEL) bought Queensland Mines Pty Ltd, thereby acquiring the Nabarlek lease, and has since developed plans to further explore the lease, clean up the site and continue revegetation and rehabilitation works. Authorisation 0435-01 was granted to UEL on the 28 May 2008 allowing exploration and rehabilitation works at Nabarlek to proceed. A revised Mining Management Plan (MMP), including revised rehabilitation bond calculations, was submitted to the Supervising Authority for approval in July 2009. The revised MMP was approved by DoR in September 2009 with $1.8 million currently held as security bond for the site. A MMP for the 2010–11 operating year was submitted to DoR on 15 June 2010 and is awaiting approval.

2.4.1.1 Minesite Technical Committee

The Nabarlek MTC has met once during the reporting period. The following items were discussed at a meeting held on 26 November 2009:

- Closure criteria
- Recalculation of the security bond
- Solute concentrations in groundwater
- Asbestos removal

2.4.1.2 Authorisations and approvals

There was no change to the Authorisation during 2009–10.

2.4.1.3 Incidents

There were no incidents reported at Nabarlek during 2009–10.

2.4.2 On-site conditions

The site is subject to at least two formal visits from ***oss*** staff during the year. In addition, ***oss*** may carry 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:

- 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;
- Annual audit (pre-wet season) of compliance with the Nabarlek Mining Management Plan.

2.4.2.1 Audit outcomes

The 2009 audit was held on 3 November 2009 and tested compliance with 237 commitments taken from the 2009 Nabarlek Mining Management Plan as submitted by UEL. Of the 237 commitments, 152 were graded Acceptable, 11 Conditional, and 42 were Not verified, with 32 Observations being made. The audit team were generally satisfied that UEL were making appropriate progress toward achieving the commitments stated in the MMP. A large portion of audit commitments remained not verified due to delays in the proposed drilling program.

2.4.2.2 Post-wet season inspection

Stakeholders inspected Nabarlek on 22 June 2010 with site operators UEL and representatives from DoR. UEL is currently in the process of scoping the works required to complete clean up and disposal of the asbestos throughout this area. It is proposed that a pit will be dug on site for disposal of the camp infrastructure. The concrete pads and roadway will be left in place at this time. UEL has obtained approval for on-site asbestos disposal from NT NRETAS

Two new revegetation plots were planted in February 2009. The 1450 seedlings comprised mainly *Corymbia* sp, *Eucalyptus miniata* and *E. tetradonta*. A further 2500 tubestock were planted during the 2009–10 wet season, however, lack of immediate rain following planting may have an impact on survival rates. Stakeholders observed significant growth in 2008–09 wet season planting and reasonable success of 2009–10 wet season planting.

The former waste rock runoff pond was re-contoured in 2008. Minimal erosion was noted on the western edge of the recontoured area only minor works would be required to restabilise this area. UEL advised that it is planning to plant 10 000 tubestock in this area in the upcoming wet season.

2.4.2.3 Radiologically anomalous area (RAA)

The area of the RAA is approximately 0.4 ha and is located immediately south-west of the former pit area. The RAA exhibits elevated levels of radioactivity and has been identified to contribute about one-quarter of the total radon flux from the rehabilitated minesite and three-quarters of the radionuclide flux from the site via the erosion pathway (more detail is provided in Supervising Scientist Annual Report 2004–05).

The issue remains a standing item on the Nabarlek MTC agenda. UEL has conducted a detailed gamma survey of the area and is currently evaluating remediation strategies for the RAA which will be put to the MTC for approval once finalised. UEL plans to characterise the RAA during the 2010 dry season with a further view to disposing of the material with higher radiological signature in a disposal pit on site during a subsequent dry season.

2.4.3 Off-site environmental protection

Statutory monitoring of the site is the responsibility of DoR and the operator, UEL. DoR carries out surface and groundwater monitoring on and off site, including surface water monitoring downstream of the mine in Kadjirrikamarnda and Cooper Creeks, and reports the results of this monitoring in the six-monthly Northern Territory Supervising Authorities Environmental Surveillance Monitoring in the Alligator Rivers Region reports.

2.5 Other activities in the Alligator Rivers Region

2.5.1 Rehabilitation of the South Alligator Valley uranium mines

Background on the remediation of historic uranium mining sites in the South Alligator Valley has been provided in the 2008–09 Supervising Scientist's Annual Report.

Construction of a new containment facility at the location of the old El Sherana airstrip for the final disposal of historic uranium mining waste was completed over the 2009 dry season by Parks Australia. Material was recovered from the following sites for co-disposal in the new facility:

- South Alligator Village containment
- El Sherana Camp containment
- El Sherana Weighbridge containment
- Battery Bund containment
- Contaminated soil stored in containers at South Alligator Village

In addition to this, all material with readings in excess of 1.25 µSv/h (±20%) from the following locations was placed in the new containment facility:

- Rockhole uranium processing plant tailings residues
- El Sherana mine
- Palette stockpile area

oss staff inspected both the new containment and historic containment sites on 21 June 2010. Revegetation appears to be progressing well over the old containment areas. ***eriss*** will conduct a close out radiological survey of the old containment areas during July 2010 to ensure that all radiologically contaminated material has been removed.

At the new containment site erosion was noted in the capping material and further earth works will be required to stabilise the site prior to the onset of the 2010–11 wet season. ***oss*** staff will inspect the site again in the late 2010 dry season to ensure the site is appropriately prepared for the 2010–11 wet season.

2.5.2 Exploration

oss undertakes a program of site inspections at exploration sites in west Arnhem Land where Cameco Australia Pty Ltd (Cameco) and UEL are exploring for uranium. During the reporting period, this entailed inspections of Myra Falls and King River Camps and their respective exploration activities. The inspections were held on 7–8 September 2009, when the camps were operating and exploration was being actively undertaken.

There were no drill rigs operating within reasonable proximity to Myra Falls Camp to enable inspection during the site visit. Stakeholders inspected an operational heli rig close to the King River Camp. There were no significant issues identified with the drilling operations or the operations at either camp.

2.6 Radiological issues

2.6.1 Background

2.6.1.1 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 radiation dose limit to the public from a practice such as uranium mining recommended by the ICRP is 1 mSv per year. This limit applies to the sum of all sources and exposure pathways. As outlined in the 'Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing' (2005), it is the operator's and employer's responsibility to 'ensure that the workplace and work procedures are designed, constructed, and operated so as to keep exposures to ionising radiation as low as reasonably achievable'.

The Code further recommends to separate 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.

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

- the public (1 mSv)
- non-designated workers (5 mSv)
- designated workers (20 mSv per year over 5 years with a maximum of 50 mSv in any one year).

In addition, the ICRP (2006) recommends the use of dose constraints for the optimisation of radiation protection:

> The principle of optimisation is defined by the Commission as the source related process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable below the appropriate dose constraints, with economic and social factors being taken into account. According to the Commission's revised recommendations, this process of optimisation below constraint should be applied whatever the exposure situation; ie planned, emergency, or existing. [3]

2.6.1.2 Monitoring and research programs

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

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.

An application to optimise the Radiation and Atmospheric Monitoring Plan was submitted to the MTC in November 2008. A second and third version of the application were received in July and December of 2009. The revised application to optimise the radiation and atmospheric monitoring plan remains under consideration by the Supervising Authority at the point of reporting.

All ERA quarterly reports, due during the reporting period, were received and reviewed by the Supervising Scientist Division.

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[3] ICRP 2006 *Assessing dose of the representative person for the purpose of radiation protection of the public and the optimisation of radiological protection: broadening the process*. International Commission on Radiation Protection Publication 101, Elsevier Ltd.

2.6.2 Radiation at and from Ranger

2.6.2.1 Radiological exposure of employees

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

- inhalation of radioactive dust
- exposure to external gamma radiation
- inhalation of radon decay products (RDP).

Table 2.8 shows the annual doses received by designated and non-designated workers in 2008, and a comparison with the average doses from the year before as reported by ERA. The average and maximum radiation doses received by designated workers in the 2009 calendar year were approximately 5.5% and 23% respectively of the recommended ICRP (2007) annual dose limits.[4]

TABLE 2.8 ANNUAL RADIATION DOSES RECEIVED BY WORKERS AT RANGER MINE

	Annual dose in 2008		Annual dose in 2009	
	Average mSv	Maximum mSv	Average mSv	Maximum mSv
Non-designated worker	Not calculated[1]	0.6	Not calculated	0.9
Designated worker	1.3	4.5	1.1	4.5

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.

Mine production and processing production workers received the majority of their radiation dose from external gamma, with average doses remaining unchanged from the previous year at 0.6 mSv and 0.8 mSv respectively. The dose to processing production workers from the inhalation of radioactivity trapped in or on dust fell from an average of 1.4 mSv last year to an average of 0.6 mSv this year. The majority of the radiation doses received by workers in the processing maintenance area and electricians was received from the inhalation of dust at 0.6 mSv and 0.3 mSv respectively. Radon decay product concentrations are highest for workers in the mine area but formed an average contribution of only 0.3 mSv to that work group during 2009.

2.6.2.2 Radiological exposure of the public

The ICRP (2007) recommends that the annual dose received by a member of the public 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 which ranges from 1–10 mSv per year, depending on location.

[4] ICRP 2007. *The 2007 recommendations of the International Commission on Radiological Protection*. International Commission on Radiological Protection Publication 103, Elsevier Ltd.

The ICRP furthermore recommends a dose constraint to be selected below 1 mSv per year according to the situation to allow for exposures to multiple sources.

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 minesite into the air, and the ingestion pathway, which is caused by the uptake of radionuclides into bush foods 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, SSD monitoring focuses on those three population centres in the region (Map 3). Airborne RDP and LLAA concentrations are measured monthly and the results compared with ERA's atmospheric monitoring results from Jabiru and Jabiru East. Of the two airborne pathways, RDP accounts for most of the dose received by the public. In the 2009 annual radiation monitoring report, Ranger reported the average mine derived airborne RDP concentration at Jabiru as 0.029 $\mu J/m^3$, in addition to background, for the 941 hours in which the wind was blowing from the mine to Jabiru. This equates to a mine derived dose from RDP of 0.03 mSv in addition to the natural background dose of 0.6 mSv per year.

Figures 2.21 and 2.22 present radon decay product (RDP) and long lived alpha activity (LLAA) data measured at Jabiru and Jabiru East, and a comparison with ERA data from July 2004 up to March 2010. 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. Higher RDP concentrations are expected in the dry season due to dry soil allowing greater permeation of radon into the atmosphere, and LLAA concentrations are higher due to the dustier conditions during the dry season.

In 2009, the dry season average RDP concentrations measured by ERA were 2–3 times higher than those measured by SSD during the same time period (July –September). It is possible that this was caused by differences in sampling time and duration. Increases in radon and RDP concentrations have been observed during times when inversions form and inhibit effective mixing of air masses near the earth's surface. Radon becomes 'trapped' in this lower layer of air and consequently radon concentrations increase. This increase in radon concentration is most marked in the dry season when combined with the enhanced radon emanation from the soil. ERA measurements in the dry season may have captured such inversion conditions which were missed by the SSD sampling schedule. The generally higher LLAA concentrations measured by ERA in Jabiru East are due to the different sampling locations (SSD Field Station and Airport car park, respectively).

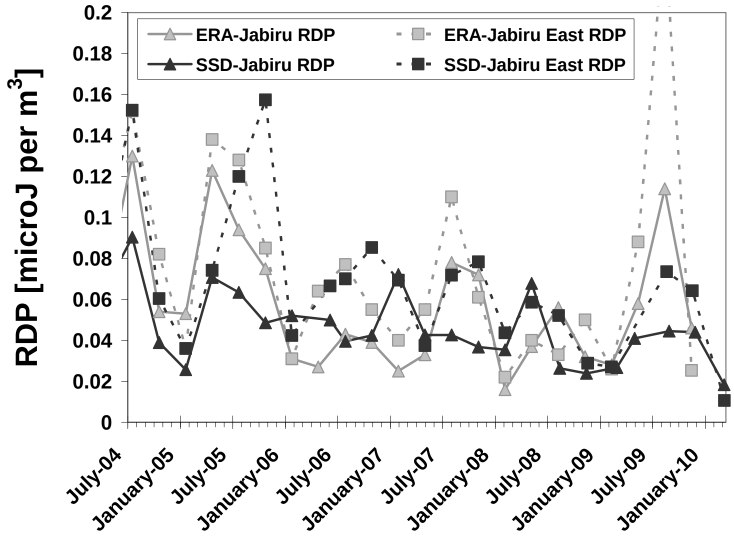


Figure 2.21 Radon decay product concentration measured by SSD and ERA in Jabiru and Jabiru East from January 2004 to March 2010

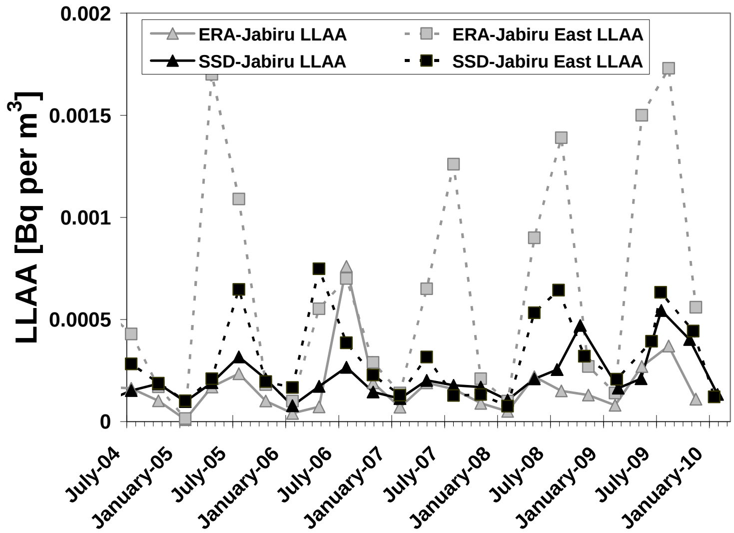


Figure 2.22 Long lived alpha activity concentration measured by SSD and ERA in Jabiru and Jabiru East from January 2004 to March 2010

Table 2.9 also 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 h (one year) and a dose conversion factor for the public of 0.0011 mSv per µJ·h/m^3. Mine derived annual doses from the inhalation of radon progeny, as reported by ERA, are shown in this table as well.

TABLE 2.9 RADON DECAY PRODUCT CONCENTRATIONS AT JABIRU AND JABIRU EAST AND TOTAL AND MINE-DERIVED ANNUAL DOSES RECEIVED AT JABIRU 2006–09*

		2006	2007	2008	2009
RDP concentration [μJ/m³]	Jabiru East	0.071 (0.066)	0.059 (0.064)	0.033 (0.046)	0.100 (0.055)
	Jabiru	0.039 (0.046)	0.038 (0.049)	0.037 (0.038)	0.066 (0.039)
Total annual dose [mSv] Jabiru		0.38 (0.44)	0.37 (0.47)	0.36 (0.37)	0.64 (0.38)
Mine derived dose [mSv] at Jabiru		0.003	≈ 0	0.001	0.03**

* Numbers in brackets refer to SSD data

** Mine-derived dose calculated from the RDP concentration difference of 0.029 μJ/m³ that persisted for 941 hrs during 2009. Data provided in the ERA Radiation Protection and Atmospheric Monitoring Program Annual Report 31 December 2009

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 concern about the radionuclide concentration in mussels from Mudginberri Billabong. Consequently, SSD routinely monitors the aquatic aspects of the ingestion pathway and bioaccumulation monitoring samples have been collected each year and analysed for both radionuclides and heavy metals (see discussion above for details on the monitoring program for Ra in mussels). The collections include yearly collections of mussels at Mudginberri Billabong (the potentially contaminated site) and Sandy Billabong (control site in the Nourlangie catchment).

Routine monitoring results from 2000–2009 show that on average the ^{226}Ra activity concentration in mussel flesh from Mudginberri Billabong is higher than at Sandy Billabong and the committed effective dose from the ingestion of ^{226}Ra and ^{210}Pb in mussels from Mudginberri Billabong is about twice the committed effective dose from the ingestion of Sandy Billabong mussels (results for the 2009 collection are discussed in chapter 2, section 2.2.3). Historical data, however, show that there is no indication of an increase of ^{226}Ra (or uranium) 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 include the mineralised nature of the Magela Creek catchment area and the associated naturally higher ^{226}Ra content in Mudginberri Billabong sediments and water, and the lower Ca and Mg concentration in water compared with Sandy Billabong. In addition, differences in mussel growth and health may affect radium uptake (see chapter 3, Supervising Scientist Annual Report 2007–08, for more detail).

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. New data, in particular for terrestrial food items, are acquired on an ongoing basis and are used to replace IAEA default radionuclide concentration factors with locally derived values. This provides a more reliable estimate of ingestion doses. In addition, local radionuclide concentration factors will be used to derive soil closure criteria for the rehabilitation of Ranger.

2.6.3 Jabiluka

2.6.3.1 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.

2.6.3.2 Radiological exposure of the public

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

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). RDP and 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 2.23 shows the quarterly averages of RDP and LLAA concentrations measured at Four Gates Rd radon station by SSD up to March 2010.

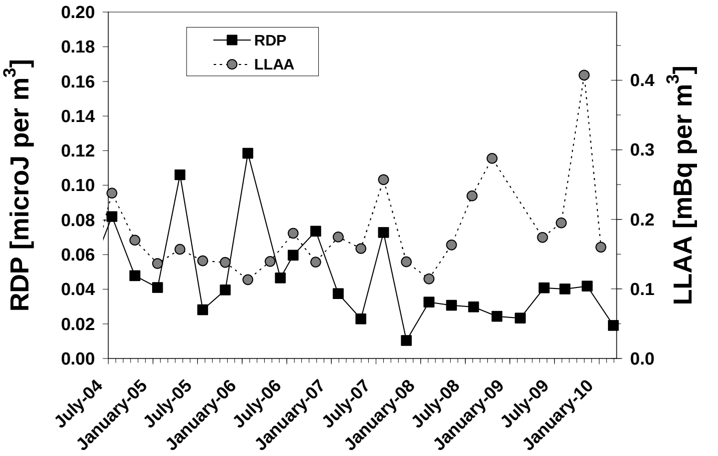


Figure 2.23 Radon decay product (RDP) and long lived alpha activity (LLAA) concentrations measured at SSD's Mudginberri Four Gates Rd radon station from July 2004 to March 2010

The average airborne radionuclide concentrations measured in 2009 would translate into an annual total effective dose, including natural background, of 0.35 mSv from RDP ~ 0.015 mSv from LLAA. Only a small fraction of these doses would be due to mine-derived radionuclides.

2.7 EPBC assessment advice

oss continues to provide advice to the Approvals and Wildlife Division (AWD) of DEWHA on referrals submitted in accordance with the EPBC Act for new and expanding uranium mines. ***oss*** provided coordinated responses from SSD on the Olympic Dam, Four Mile and Beverly uranium projects in South Australia and the Yeelirrie project in Western Australia during the reporting period.

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 (see Map 1). The scope of the research program was widened in 1994 following amendments to the Act. The Alligator Rivers Region Research Institute was subsequently renamed the Environmental Research Institute of the Supervising Scientist (***eriss***).

The core work of ***eriss*** comprises ongoing monitoring and conduct of research to develop and refine leading practice monitoring procedures and standards for the protection of people and the environment, focusing on the effects of uranium mining in the Alligator Rivers Region (ARR). The expertise of the Institute is also applied to conducting research on the sustainable use and environmental protection of tropical rivers and their associated wetlands.

The content and outcomes of the ***eriss*** research program are assessed annually by the Alligator Rivers Region Technical Committee (ARRTC) using identified Key Knowledge Needs (KKN). These KKNs define the key research topics within each of the geographic domains in the ARR relating to monitoring, closure and rehabilitation for current (Ranger and Jabiluka), rehabilitated (Nabarlek) and legacy (South Alligator River Valley) sites. The charter and activities of ARRTC are described in chapter 4 of this Annual Report and the current list of KKNs is provided for reference in Appendix 1.

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
- Spatial sciences and remote sensing

Highlights from the 2009–10 research program are presented in this report, with an overview introduction to these topics below.

Ongoing enhancement of monitoring methods is one of the key processes followed by SSD to ensure that leading practice continues to be employed for detection of possible impacts arising from the Ranger mining operation.

SSD has been undertaking an intensive evaluation since 2005–06 (see previous Annual Reports for details) of the use of continuous monitoring to provide essentially real time coverage of changes in water quality upstream and downstream of the Ranger minesite, in both Magela and Gulungul Creeks. This effort represents a major investment of Divisional resources and will result in substantially improved surveillance capacity compared with the historical weekly grab sampling approach to monitoring water quality. For wet seasons up to

2009–10 the grab sample and continuous monitoring programs were run in parallel. It is now planned that, starting with the 2010–11 wet season, the continuous monitoring system with associated event-based automatic sampling will become SSD’s primary water quality monitoring platform.

To meet this goal has meant that FY 2009–10 has been a year of consolidation for all components of the research program that underpin the acquisition and interpretation of the continuous monitoring data. This has included enhancing the capability of the deployed instrumentation, improving the capacity for data transmission and analysis in Darwin, and continuing to completion the extensive ecotoxicological testwork, involving exposure of a suite of five aquatic test organisms to pulses of magnesium over periods of 4, 8, and 24 h (see 2008–09 Annual report for details), required to derive appropriate trigger values spanning this range of exposure conditions. Since this development work is incremental and will not be completed until the third quarter of 2010, it was decided to defer further reporting until the next Annual Report when the monitoring system will have been fully implemented and the interpretation framework developed and in place.

In the last Annual Report the major program of works being done by ***eriss*** to instrument four erosion plots on an eight hectare trial landform constructed during late 2008 and early 2009 by Energy Resources of Australia Ltd (ERA) was described. Data required to derive sediment and solute export concentrations and loads were collected through the 2009–10 wet season. An initial assessment is presented here of the very large amount of information obtained during the first wet season following construction. Updates of the findings from this multi-year project will be presented in future Annual Reports.

Gulungul Creek (see Map 2), a tributary of Magela Creek, is assuming increasing importance in the context of potential for runoff from the recently lifted tailings dam walls and the prospect of future mine-site infrastructure that may be located in the catchment of this creek. Accordingly, biological monitoring using the aquatic snail in situ method – described for Magela Creek in previous Annual Reports and in Chapter 2 of this report – was deployed in Gulungul Creek for the first time during the 2009–10 wet season. This first year was a pilot to establish the deployment logistics and investigate snail survivability in a new catchment regime. The snail data provided by this and subsequent wet seasons will provide a response baseline against which to assess the effects any future increases in mine-related activity on the aquatic ecosystem health of Gulungul Creek.

Research on the effect of dissolved organic carbon (DOC) on modulating metal toxicity was extended to aluminium during 2009–10. Aluminium is a potentially important component of the early first flush waters in the ARR given the acidic pH of the rain at the start of the wet season. It is also contained in acidic seepage and runoff waters from many operating and legacy minesites (including Rum Jungle) in the northern tropics. The results from this work have shown that the DOC naturally present in water in the Magela Creek catchment can substantively ameliorate the toxicity of Al.

Commissioning of the process water treatment plant at Ranger was completed in October 2009. As part of this process ***eriss*** undertook toxicity testing of the final treated water stream (reverse osmosis permeate) to confirm that there was no unanticipated toxicity, and that the toxicity of water produced by the full scale operating plant was comparable with that of the treated water originally produced by the pilot plant in 2001.

Accurate characterisation of the pre-mining radiological baseline is an essential precursor to being able to quantify rehabilitation success for a uranium minesite and to provide assurance that the requisite international standards for protection of members of the general public post rehabilitation are being met. In the case of Ranger mine, there was insufficient on-ground pre-mining survey work done to provide this baseline assessment. Consequently substantial research effort is being devoted to inferring this baseline using a combination of aerial radiometrics acquired for the lease area before mining started and contemporary intensive ground characterisation of undisturbed radiological anomalies (radiological analogues).

Since 1985, pond water stored in Retention Pond 2 and in the mine pits (firstly Pit 1 and then Pit 3) during the wet season has been disposed of on site using land application methods. This water contains uranium and other radionuclides (such as radium 226) that become bound to the near surface horizon of the soil. Over time the radiological load of the land application areas has increased. A comprehensive collaborative study is currently underway to definitively characterise the radiological status of these areas in the context of determining the extent of rehabilitation that will be needed for them. The contribution that ***eriss*** is making to the characterisation of the land application areas is described in this chapter.

In this report the first stage of developing a remote sensing monitoring framework for the ARR is described. The framework will provide the basis for efficiently and cost-effectively acquiring the spatial data needed to be able to place the land surface status of operating and rehabilitated minesites into a regional context.

Measurement of the radionuclide content of traditional bushfoods or 'bushtucker' obtained from many locations has been made by ***eriss*** over the past three decades. This unique resource continues to be updated on an annual basis. Emerging technologies such as Google Earth, Arc Explorer and ArcGlobe are being used to develop a user-friendly system to store and retrieve the data, and to present it in an understandable way to members of the local community.

During 2009–10 a project was commissioned to integrate the large volumes of knowledge acquired by ***eriss*** across its research program areas into a series of conceptual models describing potential contaminant transport pathways associated with uranium mining in the Alligator Rivers Region. This is being done as part of the evolving ecological risk assessment framework being developed by the Supervising Scientist for the operating phase of the mine. One of the key objectives of the project is to determine if there are any significant gaps in our scientific knowledge about the pathways that could potentially adversely impact on the health of the environment outside of the mine lease.

More comprehensive descriptions of ***eriss*** research are published in journal and conference papers and in the Supervising Scientist and Internal Report series. Publications by Supervising Scientist Division staff in 2009–10 are listed in Appendix 2. Presentations given during the year are listed in Appendix 3. More information on the Division's publications, including the full list of staff publications from 1978 to the end of June 2010, is available on the SSD web site at www.environment.gov.au/ssd/publications.

3.1 Monitoring of erosion and solute loads from the Ranger trial landform

3.1.1 Introduction

A trial landform of approximately 200 m x 400 m (8 ha) was constructed during late 2008 and early 2009 by Energy Resources of Australia Ltd (ERA) adjacent to the north-western wall of the tailings storage facility (TSF) at Ranger mine (Map 2). The trial landform will be used to test landform design and revegetation strategies to assist ERA develop a robust rehabilitation strategy for deployment once mining and milling have finished.

The landform was designed to test two types of potential final cover layers:

1 Waste rock alone

2 Waste rock blended with approximately 30% v/v fine-grained weathered horizon material (laterite).

The landform is divided into six treatment areas (Figure 3.1).

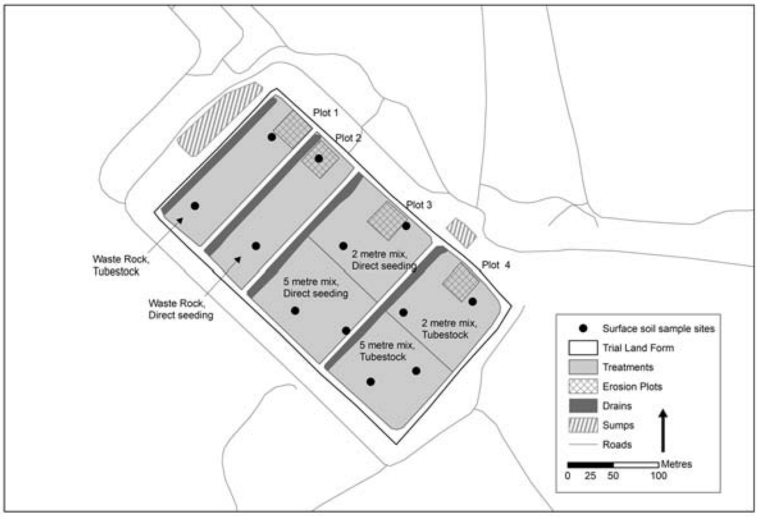


Figure 3.1 Layout of the plots on the trial landform

Each treatment was designed to test different planting methods and substrate types as follows:

1 Tube stock planted in waste rock material

2 Direct seeded in waste rock material

3 Direct seeded in waste rock mixed with laterite to a depth of 2 m

4 Direct seeded in waste rock mixed with laterite to a depth of 5 m

5 Tube stock planted in waste rock mixed with laterite material to a depth of 2 m

6 Tube stock planted in waste rock mixed with laterite material to a depth of 5 m

During the 2009 dry season, surface samples were collected by spade to a maximum depth of 10 cm from 12 randomly chosen locations over the trial landform surface to characterise the particle size distribution. Eight mixed and four waste rock only samples made up the total of 12. For all 12 samples, more than half of each sample (by weight) (53–78%) was larger than 2.0 mm in diameter showing the influence of the waste rock on the composition of the cover treatments. The fraction greater than 2.0 mm from surface soil on the natural surrounding Koolpinyah surface is always less than 50% and is generally no greater then 10%.

Four erosion plots (30 m x 30 m) (location marked by cross hatched small squares on Figure 3.1) were constructed on the landform surface and physically isolated by engineered borders from runoff from the rest of the area. Half-section 300 mm diameter U-PVC stormwater pipes were placed at the down slope ends of the plots to catch runoff and channel it through rectangular broad-crested (RBC) flumes (Figure 3.2) where rainfall event triggered discharge is measured. A reservoir (stilling basin) is located upstream of the inlet to each flume to trap coarser material eroded from the plot. The outlet of each erosion plot was instrumented with the following sensors:

- pressure transducer and shaft encoder to measure stage height
- a turbidity probe
- electrical conductivity probes located at the inlet to the stilling well and in the entry to the flume to provide a measure of the concentrations of dissolved salts in the runoff
- an automatic water sampler to collect event based samples
- a data logger with mobile phone telemetry connection

Figure 3.2 Runoff through flume on trial landform erosion plot 3 during a storm event

A rain gauge was also installed at the downstream end of each plot near the instrument shelter. Data acquired during the 2009–10 wet season were downloaded daily by mobile phone access and then stored in the hydrological database Hydstra.

During the 2009–10 wet season runoff, turbidity (surrogate of fine suspended sediment), bedload (coarser material deposited in the stilling basin) and EC (surrogate of water quality) were measured. The first rainfall event of 26 mm occurred on 23/9/09 and the last significant rainfall event of 17 mm occurred on 17/4/10. The total rainfall for the 2009–10 wet season (averaged across the four plots) was 1491 mm.

During rainfall induced runoff events water samples were collected by automatic water samplers triggered by pre-programmed increases in stage height, turbidity and EC. The trial landform was visited once a week to collect the water samples and the bedload. This task was shared between staff from SSD and ERA, with the allocation of staff resources and workplan defined in a formal memorandum of understanding between SSD and ERA. SSD was responsible for processing and analysis of all of the samples collected for the sediment transport component of the project; ERA was responsible for chemical analysis of the water samples.

3.1.2 Topographic surveys

Two topographic surveys of the trial landform were completed during 2009–2010. The first manual survey using a total station was undertaken in December 2009 prior to the onset of heavy rains. A total of 1737 points were collected across the surface at approximately 5-metre intervals and used to generate a medium resolution (5 metre) digital elevation model (DEM) (Figure 3.3).

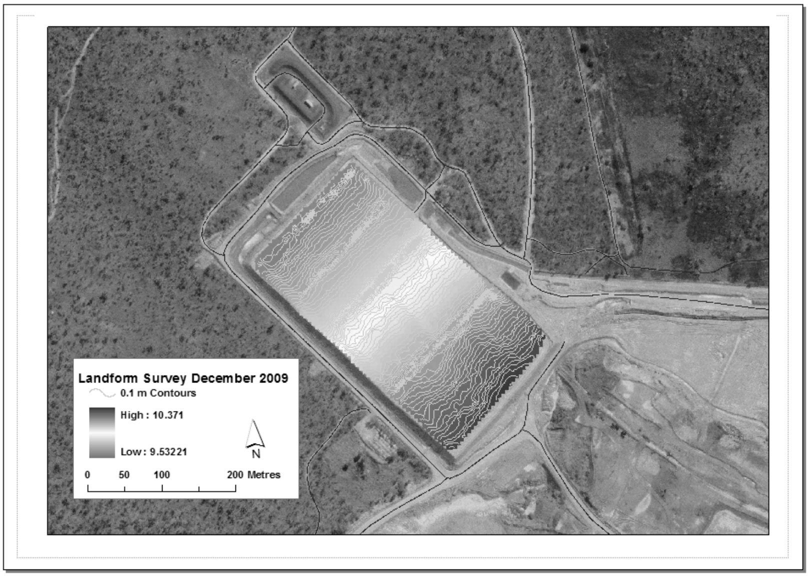


Figure 3.3 Digital Elevation Model of trial landform (with overlaid 0.1 m contour lines) produced from the December 2009 survey

During the course of this survey it was noted that the vegetation growth that will occur over the next few years will progressively compromise line-of-sight or optical surveying methods. Consequently, it will be necessary in the future to employ survey technologies (for example, LIDAR – Light Detection and Ranging) capable of penetrating through vegetation cover to measure ground level.

A second survey was undertaken in June 2010 during the early dry season using a Leica ScanStation2 laser scanning instrument and differential GPS. In contrast to the earlier manual point survey, the use of the laser scanner enabled both surface elevation data as well as surface features (such as the current status of vegetation communities) to be captured.

Twenty-five scans were made across the landform (Figure 3.4). Three scans were undertaken within each of the erosion plots, at a scan resolution of 2 cm. A further 13 scans were made across the landform at a coarser resolution of 20 cm.

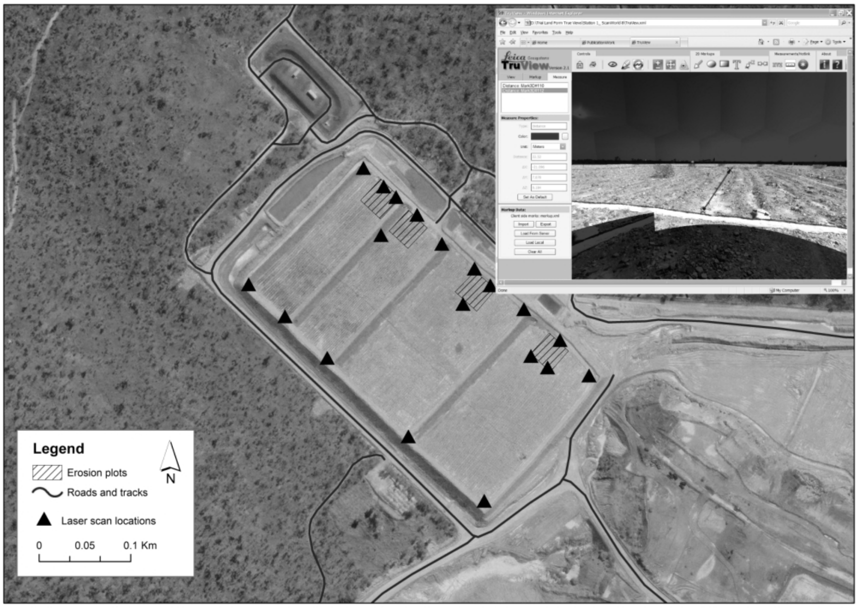


Figure 3.4 Locations (marked by triangles) of scanning laser instrument. Inset shows an example of the type of composite digital image synthesised from multiple images captured at each scan location.

The data collected from the second survey are currently being processed to provide a very high spatial resolution DEM of the surface. To date, data have been extracted to generate a DEM for Erosion Plot 2 with a horizontal resolution of 20 cm (Figure 3.5). The DEM spans an elevation range of 1.24 m between the highest and lowest points in the plot. At this resolution, the rip lines, boulders and pits in the plot are clearly visible

The very high resolution digital elevation model was acquired to underpin several components of ***eriss***’s minesite rehabilitation research. In particular, it will provide the input data needed for the CAESAR and Siberia landform evolution models that are being used to test the long-term stability of the trial landform against the erosive effects of high intensity rainfall events.

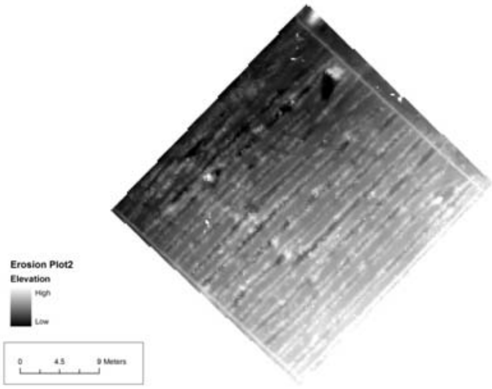


Figure 3.5 High resolution digital elevation model of erosion plot 2. Lighter colours represent areas of greater elevation. Riplines, boulders (light) and pits (dark) visible on surface.

3.1.3 Sediment transport

Fine suspended sediment

Turbidity sensors were installed at the exit to each of the settling basins on each of the erosion plots. Turbidity provides a measure of the concentration of fine suspended sediment. It is this fine material that is of most immediate relevance from the perspective of the potential for downstream environmental impact of material eroded from a newly constructed mine landform.

An example of concurrent typical turbidity events occurring across each of the four erosion plots in response to a rainfall event is shown in Figure 3.6 below.

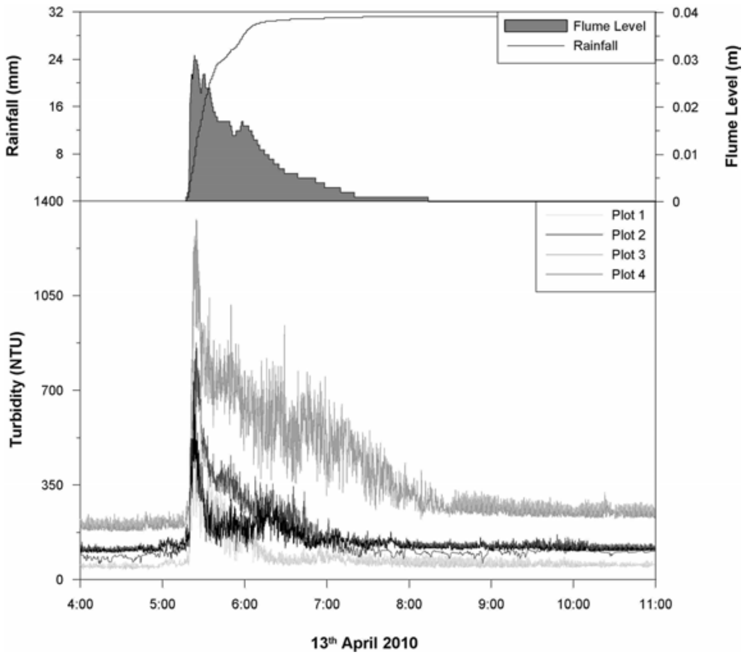


Figure 3.6 Rainfall induced turbidity events occurring between 4 and 11am on 13 April 2010. Top panel shows the cumulative rainfall and flume water level (surrogate of flow) for plot 2. The bottom panel displays the continuous turbidity data from each of the four erosion plots.

The magnitude of the pulses for the waste rock plots (plots 1 and 2) are generally similar to one another and lower than the pulses observed for the mixed waste rock and laterite plots (plots 3 & 4). Throughout the season, the turbidity measured at plot 3 was consistently higher than that measured at plot 4.

Water samples were collected during rainfall events using autosamplers activated using a combination of pre-programmed stage height, EC and turbidity values. All samples triggered by turbidity were analysed for total suspended sediment (TSS) concentration (sediment fraction between 63 µm and 0.45 µm). The TSS concentration was determined by firstly passing the water sample through a 63 µm sieve and then filtering a standard volume through a 0.45 µm filter. The weight of the dried residue on the filter paper was then measured. The TSS data will be used to define the relationship between TSS and turbidity measured in situ, allowing estimation of continuous TSS concentration from the continuous turbidity data.

The TSS is the most readily transportable fraction of sediment and is a key indicator of landform surface erosion rates. Selected TSS samples will be analysed for associated trace metal concentrations (including uranium) to derive the loads of sediment-associated contaminants transported from each of the erosion plots during the 2009–10 wet season.

Bedload

The coarser bedload material is deposited in both the half pipe defining the downslope boundary of the plot and in the stilling basin upstream of the flume. The total amount of bedload collected from each plot over the wet season is shown in Table 3.1. Similar amounts of bedload material were washed from each of the plots, with no systematic difference between the two surface treatments.

TABLE 3.1 TOTAL BEDLOAD COLLECTED FOR 2009–10 WET SEASON

Erosion plot	Basin (kg)	Half-pipe (kg)	Total (kg)
EP1	24.2	71.7	95.9
EP2	9.6	117.6	127.2
EP3	15.9	86.3	102.3
EP4	64.9	57.4	122.3

The particle size distributions measured for bedload samples collected on 17/03/2010 and 15/04/2010 are provided in Table 3.2 to illustrate the different behaviours between the plots, and the influence of rainfall event magnitude. Sieving was used for size classification above 63 µm. The hydrometer (gravity settling) method was used for more detailed classification (not shown here) of the less than 63 µm fraction.

TABLE 3.2 BEDLOAD PARTICLE SIZE DISTRIBUTION DATA (DRY WEIGHT BASIS) FOR SAMPLES COLLECTED ON 17 MARCH 2010 AND 15 APRIL 2010

Sample erosion plot	Sample date	Sample mass (kg)	% > 2.00 mm	% < 2.00 mm	
				% > 0.0063 mm	% < 0.0063 mm
EP1	17/03/2010	1.5	18.7	73.6	7.7
EP2	17/03/2010	1.9	17.9	59.7	22.4
EP3	17/03/2010	1.3	28.2	61.0	10.8
EP4	17/03/2010	1.5	15.0	75.1	9.9
EP1	15/04/2010	14.4	33.3	61.7	5.0
EP2	15/04/2010	15.2	24.6	63.7	11.7
EP3	15/04/2010	12.9	53.6	44.5	1.9
EP4	15/04/2010	12.4	45.2	52.2	2.6

The rainfall events that produced the amounts of bedload reported in Table 3.2 are shown in Table 3.3. The bedload collected on 17/3/10 resulted from 49 mm of rainfall over 4 events and was correspondingly much lower in mass than the bedload collected from 15/4/10 which was the result of 254 mm of rainfall over 8 events.

TABLE 3.3 RAINFALL EVENTS DURING THE WEEK PRIOR TO BEDLOAD COLLECTION

Sample date	Total rain (mm)	No of events	Event 1 (mm)	Event 2 (mm)	Event 3 (mm)	Event 4 (mm)	Event 5 (mm)	Event 6 (mm)	Event 7 (mm)	Event 8 (mm)
17/3/10	49	4	5	16	9	15				
15/4/10	254	8	58	5	11	47	30	41	25	26

3.1.4 Solute transport

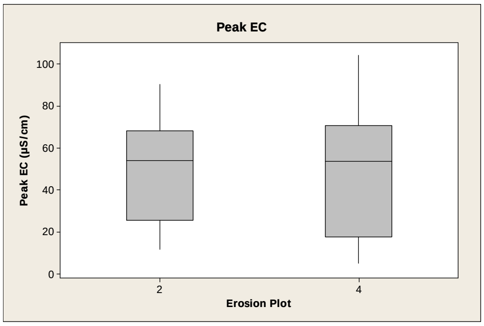
EC sensors were installed at the entrance and the exit of the sediment settling basin at each of the erosion plots. The information from both of the sensors was used to derive event-based EC data for each site over the 2009–10 wet season. The behaviour of EC observed over an event will be determined by the condition of the basin preceding the rainfall. Two possible conditions apply for this system:

1. The basin was empty and clean prior to rainfall, in which case the EC is indicating the composition of surface runoff throughout the event.

2. The basin was full prior to rainfall, in which case the EC trace measured at the exit to the basin could be impacted by ‘stale’ water that has remained in the basin between rainfall events.

Condition 1 events give a clear indication of the surface runoff water quality. Condition 2 events are confounded due to the mixing of the surface runoff with ‘stale’ water in the basin that has accumulated from a varying number of antecedent events. While the majority of events occurring throughout the wet season occurred under condition 2, the potential confounding caused by the ‘stale’ water can be removed by comparison of the EC values measured at the entrance and the exit of the basin. The time at which the two EC readings converge will indicate when complete flushing of the ‘stale’ water has occurred. Detailed analysis of the time series EC data for the condition 2 events is still in progress. Consequently the results reported here will focus on condition 1 events.

Thirteen condition 1 events occurred during the 2009–10 wet season. However, the intensity of the rainfall and associated runoff volume for the majority of these events was low, with only five of the 13 events falling in the upper 50th percentile of rainfall volume and intensity for the season. Figure 3.7 shows summary statistics describing the peak (maximum) EC values recorded for each of the 13 events for plots 2 and 4, representing the waste rock and waste rock mixed with laterite, respectively. The box and whisker plot shows that the medians and general distribution of the peak EC values for each plot are similar. The scatter plot shows that the distribution of peak EC values as a function of total rainfall for each event are similar for both plots, indicating that the total amount of solutes derived from both treatments are similar (for condition 1 events less than 35 mm).



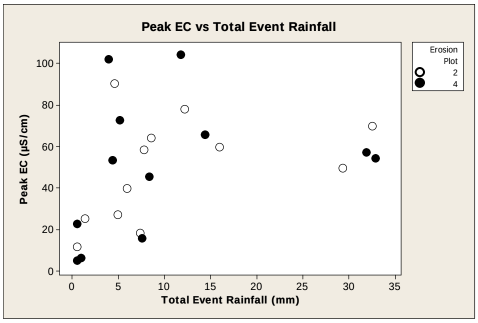


Figure 3.7 Box plot summarising the mean, maximum, minimum, third quartile and first quartiles of the maximum first flush EC values; and scatter plot of the maximum first flush EC values and total event rainfall

Water samples were collected for chemical analysis from each of the erosion plots using autosamplers which were activated using a combination of stage height and EC triggers. The EC-triggered samples were analysed by ERA in its on-site laboratory for a suite of trace elements and major ions. The results obtained for Mg, SO_4 and U only are presented here (Figure 3.8) since these solutes are the most relevant for potential environmental impact from the site. The box plots in Figure 3.8 show the concentration means and ranges measured for each of the three solutes in the water from each of the four plots.

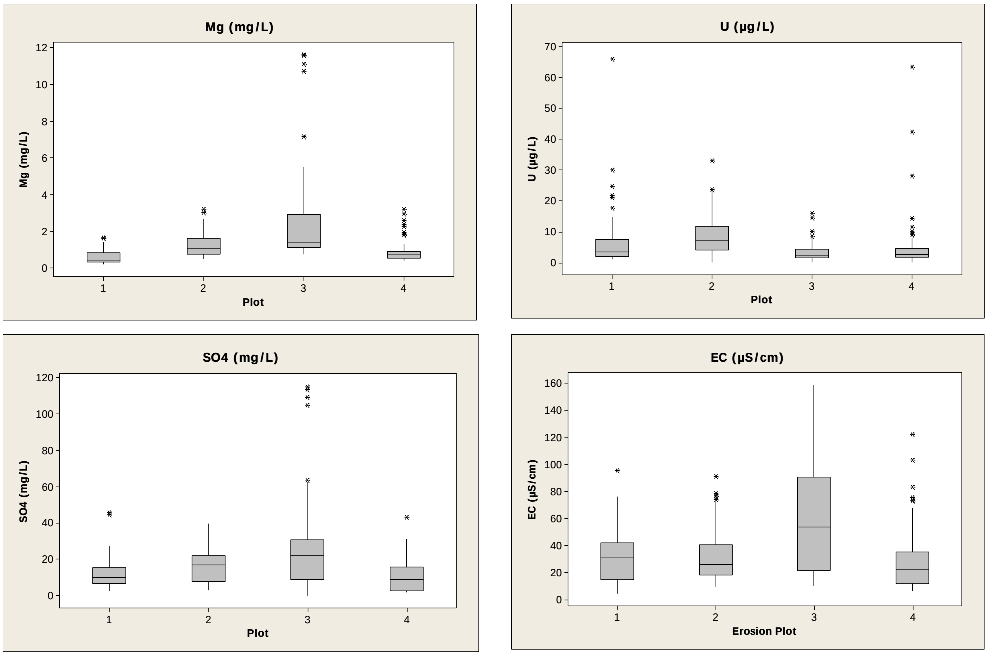


Figure 3.8 Box plots showing the mean, maximum, minimum, third quartile and first quartile values of Mg, SO4, U and EC measured in the water samples collected from each plot over the 2009–10 wet season. The number of data points (n) for erosion lots 1, 2, 3 and 4 are 54, 76, 67 and 86, respectively.

The summary statistics provided show that:

- Mg and SO_4 exhibit similar behaviour over the four erosion plots
- EC exhibits similar behaviour to Mg and SO_4, indicating that these ions are major contributors to the EC of the surface runoff from each plot
- Plots one, two and four all have similar concentration ranges for both Mg and SO_4 (and hence EC). However, plot three has a broader range and maximum values at least double that of each of the other plots
- The highest concentrations of U were measured for plots one and four, noting that the majority of U concentrations were less than 30 µg/L and that the means, except for plot two, were all less than 6 µg/L, which is the current ecotoxicologically derived limit for U in Magela Creek.

Apart from some individual higher U concentrations measured for plots one and four, each of the plots show a similar distribution of U concentrations. While plot three stands out from the others due to the generally higher solute concentrations, plots one, two and four exhibit similar surface runoff water quality.

Being a composite of all of the data, the box plot summaries do not demonstrate the dynamic range of concentrations that occur through a rainfall event. To do this, individual events need to be analysed. Figures 3.9 and 3.10 show examples of the time series concentrations of Mg and U measured through two rainfall events that produced sustained flow through the installed flumes.

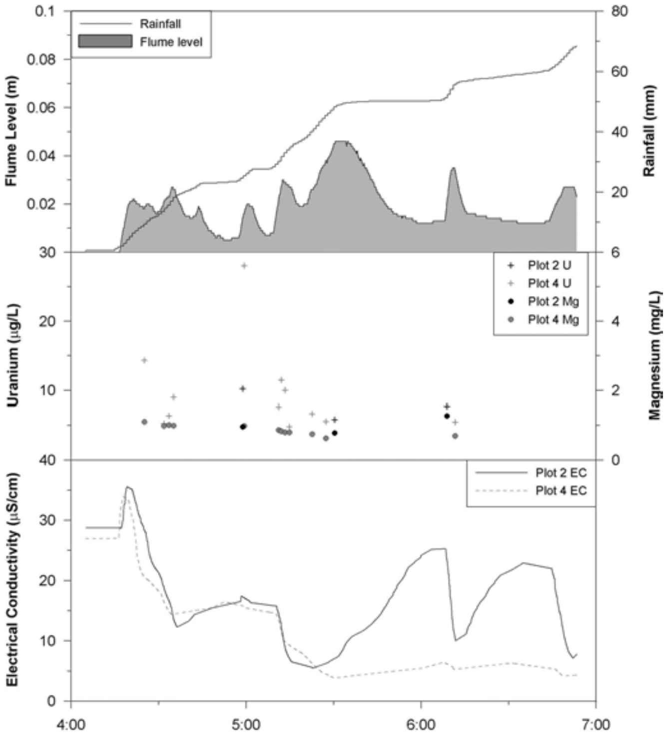


Figure 3.9 Rainfall event occurring between 4 and 7 am on 1 February 2010. Rainfall, EC, Mg, U and flume level from plots two and four are shown for comparison between wasterock and laterite treatments.

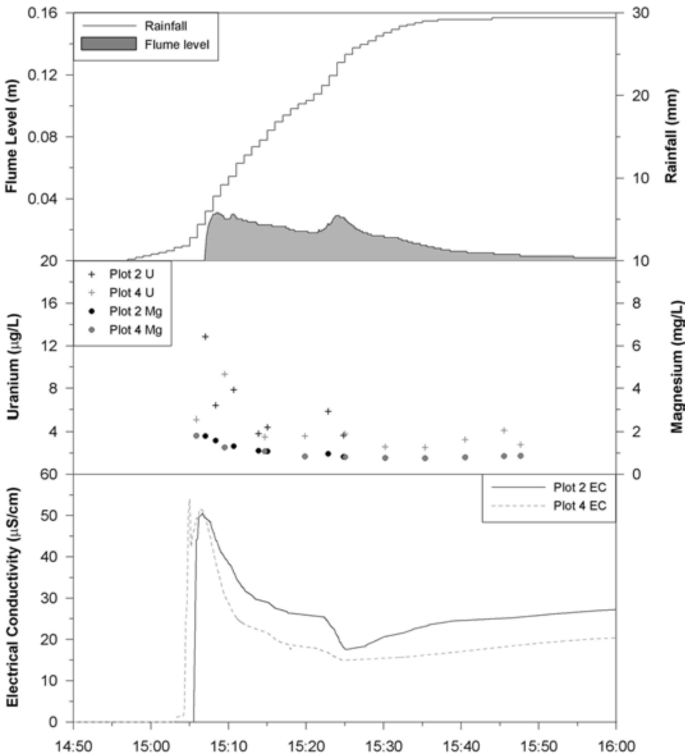


Figure 3.10 Rainfall event occurring between 3 and 4 pm on 23 March 2010. Rainfall, EC, Mg, U and flume level from plots two and four are shown for comparison between waste rock and laterite treatments.

The concentrations of Mg and U are very similar between the two plots for these events. There is a difference in EC between 0530 and 0700h in Figure 3.9. However, this particular event represents the low end of the EC range (0–700 µS/cm) measured over the wet season so the effect on solute load of the differences observed between the plots for this event is low. Further data analysis is required to statistically define the significance of such variation.

3.1.5 Future work

Considerable resources are being devoted to processing, collating and analysing the large amounts of data produced from the trial landform during the 2009–10 wet season. Examples have been provided in this report of the wide range of information that is being produced by the project. The findings will be used to inform analysis of the suitability of options for the design and revegetation of the final rehabilitated Ranger site. During Q1 and Q2 of the 2010–11 financial year it is anticipated that loads of solutes, suspended sediment and bedload material will be derived for each of the plots, enabling quantitative comparison of the behaviours of the two types of surface treatments. These results will be documented in the next Annual Report.

The scope of the trial landform monitoring program for the 2010–11 wet season will be refined using the findings from the 2009–10 season, with more selective sampling and analysis of the runoff streams.

3.2 In situ biological monitoring in Gulungul Creek

In recognition of the increasing importance of Gulungul Creek in the context of runoff from the recently lifted tailings dam walls and the prospect of future mine-site infrastructure that may be constructed in the catchment due to proposed expansion of mining and milling at Ranger, SSD has increased its environmental monitoring effort in this creek. In addition to upgrades of the continuous monitoring equipment in the creek, biological (toxicity) monitoring also commenced in the 2009–10 wet season with the trial in situ deployment of the freshwater snail reproduction technique. This method of biological monitoring has been routinely deployed in Magela Creek over many years with the results documented in previous Annual Reports. As with toxicity monitoring in Magela Creek (section 2.2.3.2), it is intended that in situ biological monitoring will be used in Gulungul Creek as an early detection method for identifying changes in water quality.

The trial deployment was conducted firstly to establish the logistics of reliably conducting toxicity monitoring procedures in the creek and secondly to start acquiring biological response data to develop a baseline prior to any significant future disturbance in the catchment. The test design was the same as that used for the routine monitoring of Magela Creek (see section 2.2.3) with upstream ‘control’ and downstream ‘exposed’ sites co-located with water quality monitoring (Gulungul u/s and Gulungul d/s on Map 2). While the control and exposed sites in Magela Creek are accessible by boat throughout the wet season, the upstream control site on Gulungul Creek is not accessible by boat at any time, nor by road for the majority of the wet season. Hence it is necessary to access this site by helicopter.

Five tests were conducted through the 2009–10 wet season, over a range of flow conditions, and in alternate weeks to the routine Magela Creek testing. Tests were conducted in the periods 25–29 January, 22–26 February, 22–26 March, 9–13 April and 19–23 April 2010. The results, together with comparative results from Magela Creek, are shown in Figure 3.11. The range in egg number observed in Gulungul Creek was similar to that recorded in Magela Creek (Figure 3.11).

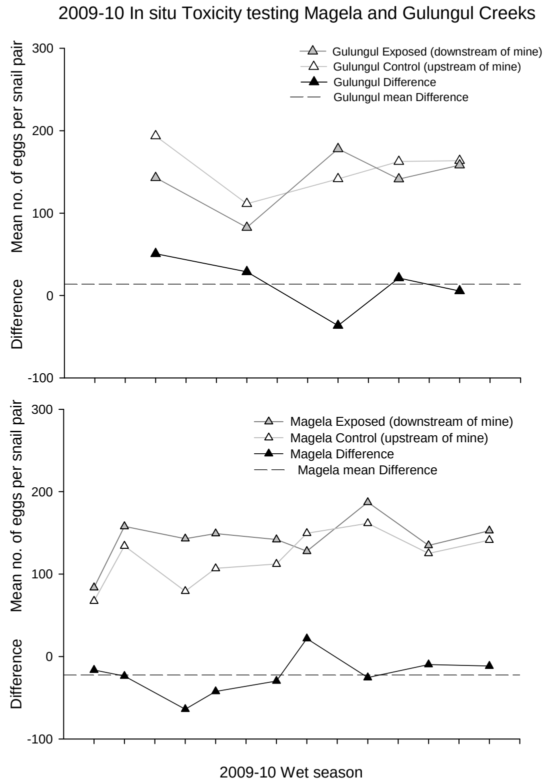


Figure 3.11 In situ toxicity monitoring results for freshwater snail egg production for Gulungul Creek compared with results from Magela Creek, 2009–10 wet season

Four out of the five tests resulted in positive difference values, ie egg production was higher upstream than downstream. This pattern was opposite to that observed in Magela Creek during the same period, where eight of the nine tests resulted in a negative difference value (Figure 3.11). High statistical power in this toxicity monitoring technique is potentially available when, in the absence of human-related disturbance downstream of potential sources of impact, the responses measured at upstream and downstream sites are very similar in magnitude to one another over time. This concordance (or 'tracking') in egg number between upstream and downstream sites is the typical pattern in Magela Creek (Figure 3.11), and also appears to be the pattern in Gulungul Creek.

It is anticipated that fortnightly in situ toxicity testing will be implemented in Gulungul Creek during the 2010–11 wet season.

3.3 Developing sediment quality criteria for uranium

Research and monitoring of the impacts of mining at Ranger have historically focused on the water column, as this environmental compartment is the primary transport vector for solutes released from the minesite. However, since uranium (U, present in water as the uranyl ion) has a high affinity for sediments, sediment quality assessment and the derivation of protective trigger values for sediments are aspects of aquatic ecosystem protection that also need to be considered. Such trigger values will have application both for operational water management and for the development of sediment quality closure criteria for the Ranger site.

There has been little work conducted on the toxicity of U in sediments to aquatic biota, and the toxicity estimates produced by the few international studies that have been published have varied by at least three orders of magnitude (from 5.3 to >5000 mg U/kg dry weight). The lack of a robust toxicity guideline for U is of concern – not only for the local situation but also nationally given the projected expansion of the uranium mining industry.

On the Ranger lease, concentrations of U in the sediments of mine-influenced waterbodies such as Georgetown Billabong (GTB, up to 45 mg/kg) are higher than reference waterbodies (1.2–4.3 mg/kg). While U concentrations in the sediments of GTB have been higher than in other billabongs of the region since before the start of mining, there appears to have been a further increase in GTB since about 2002. Additionally, the communities of benthic macroinvertebrates in the mine-influenced waterbodies, Georgetown and Coonjimba Billabongs, currently exhibit lower diversity than reference billabongs.

Concurrent investigations are presently underway to determine whether the observed impoverishment of benthic macroinvertebrates is due to the presence of higher concentrations of U, or other mining or non-mining (for example, differences in natural habitat such as bed sediment type) related factors. This report documents the progress that has been made over the past year to develop U sediment quality criteria for the protection of sediment-dwelling biota. These criteria are required for both the operational life of the mine and for its successful closure. In particular, sediment quality criteria will be required for on-site sentinel wetlands, which will serve to capture and 'polish' seepage and runoff waters from the rehabilitated mine site, as well as for downstream receiving waterbodies in the rehabilitation phase.

A pilot field sediment U toxicity study was undertaken, in collaboration with the CSIRO Centre for Environmental Contaminants Research and Charles Darwin University, during the 2009–10 wet season. Field studies have several benefits over laboratory assessments. In particular, a field experiment can be more time and cost-effective than a laboratory approach (not requiring selection and culturing of numerous suitable local test species, nor development of test protocols); and will be able to assess responses of whole communities of organisms with the results more likely to be directly applicable to managing the natural environment.

The experimental approach involved the deployment of U-spiked sediments (in retrievable containers) in (unimpacted) Gulungul Billabong over the duration of a wet season. At the end of the exposure period, the extent of colonisation of macroinvertebrate, microinvertebrate and microbial communities was measured in the control and U-treated replicates. Research activity during 2009–10 focused on analysis of data collected during a site characterisation field trip, and undertaking of a pilot experiment during the 2009–10 wet season.

3.3.1 Site characterisation

Eighteen sediment samples (~20 cm × 20 cm × 10 cm; ~4000 cm^3) were collected from Gulungul Billabong in April 2009 to determine the baseline physico-chemical and biological conditions of the study site. Baseline whole sediment concentrations for key metals were: Al – 49 000 mg/kg (dry weight); As – 2 mg/kg; Cu – 30 mg/kg; Fe – 11 700 mg/kg; Mn – 61 mg/kg; Pb – 12 mg/kg; U – 6 mg/kg; and Zn – 13 mg/kg. The sediment is classified as a granular medium sand, with approximately equal proportions of sand (<2 mm – >0.063 mm), silt (<0.063 mm – >0.0039 mm) and clay (<0.0039 mm). There was zero gravel (>2 mm) present (Wentworth grain size scale).

Taxa numbers and abundances of macroinvertebrates in the sediments (>500 µm fraction) were low (mean ± standard deviation of 8.4 ± 2 taxa and 335 ± 183 organisms per sample respectively; n = 18), possibly reflecting the fine-grained sediment particles (restricting habitat availability) and low dissolved oxygen environment characteristic of billabong waters at depth during the late wet season. Microinvertebrate taxa numbers in the sediments were higher than for macroinvertebrates (mean ± standard deviation of 18 ± 5 and 12 ± 3 taxa per sample for 63–125 µm and 125–500 µm fractions respectively; n = 3) while microinvertebrate abundances were orders of magnitude higher (mean ± standard deviation of 180 000 ± 37 000 and 18 000 ± 9 000 organisms per sample for 63–125 µm and 125–500 µm fractions respectively; n = 3).

Sample processing for microinvertebrates in particular, is a very laborious process, requiring meticulous separation of (often) cryptic (ie concealed or camouflaged) organisms from the fine-grained sediment particles using fine tungsten needles. Consequently, only three of the original 18 samples were processed for microinvertebrates. Among the samples processed, the fauna were dominated by protists (in particular, Rhizopoda, Difflugiidae – amoeboids inhabiting a test or shell) and rotifers (in particular, the Lecanidae).

Characterisation of the microbial assemblage in the sediment was done by extracting DNA and using the technique of terminal restriction fragment length polymorphism (TRFLP). This revealed over 130 ‘operational taxonomic units’ (OTUs; bacterial species and/or strains of species) with a mean ± SD of 38 ± 25 OTUs per sample (n = 18). A metagenomic analysis of the sediments was also conducted, using pyroseqencing techniques. Most of the bacteria identified in the TRFLP data also appear in the metagenomic analysis, although numerous other bacteria were identified with pyrosequencing. Analysis at the phylum level revealed that the community composition along the transect was relatively uniform, with the soil bacteria *Acidobacteria*, *Proteobacteria* and *Actinobacteria* well represented. Of the total number of OTUs revealed, 40–50% from each site represented yet to be identified bacteria.

3.3.2 Pilot study

Preparations for the pilot study over the 2009–10 wet season, commenced in August 2009. A bulk sample of moist sediment (~150 kg) was collected from the exposed littoral zone at the study site in Gulungul Billabong. The sediment was frozen for 1 week (to kill the majority of the biota resident in the samples) then wet sieved through a 2 mm mesh size with deionised water. This created a slurry (1:1.4 sediment to water ratio) suitable for spiking with U. The slurry was split into four 30 kg batches for the following treatments: zero addition control; 5400 mg/kg (sodium) sulfate control; 400 mg/kg U; and 4000 mg/kg U (U was added as uranyl sulfate). The batches were mixed in a cement mixer for 1 hour once every 2 days for 14 days.

Following mixing, the sediments for each treatment were placed in the dark at 4°C for 21 days to allow time for adsorption of spiked metal (or ion) to the sediment. Following a 10-d period of drying at ambient temperature (24–35°C), the sediments were transferred to the experimental containers. There were nine containers (~20 × 20 × 15 cm plastic containers with ~5 mm mesh size sides and base) for each treatment, with each container holding ~2 L (or 2000 cm^3 – 20 × 20 × 5 cm) of sediment. The test containers were then placed in holding containers, covered, and left in the dark at 4°C for approximately 10 weeks prior to their deployment in the field. Sub-samples for sediment and porewater chemistry were collected at regular intervals throughout the equilibration periods.

The sediments were deployed at pre-determined locations at the study site on 9 December 2009 (Figure 3.12), approximately 2 weeks prior to the onset of the first monsoonal rains of the wet season. At this time, replicates of an additional control treatment (Gulungul Control; GC) were included in the design, namely natural surface sediment from the study site that had not been pre-treated in the same manner as the other four treatments. For this GC treatment, natural sediments were excavated and placed in test containers of the same type used for the other four treatments. Because the GC sediments were essentially dry, they were broken down by hand and moistened using deionised water so that they filled the containers with no significant air spaces remaining.

Equivalent volumes of natural sediments at the site were excavated at the designated locations, to create cavities for the field placement of the test containers. The containers were set such that the surface of the sediment in the container was flush with that of the surrounding natural sediment. The field placement for the 5 × 9 (treatment × replicates) containers used a statistical design that ensured the elimination of biases in potential environmental gradients at the site that could otherwise potentially confound results.

By early January 2010, the site was inundated with water (Figure 3.12), and remained so for the rest of the wet season The containers of test sediment were retrieved on 30 March 2010, after being submerged for 3 months. Prior to processing, cores of sediment (30–50 mm depth × 15 mm diameter) were obtained from each container for detailed chemical and microbial analysis. The contents of each replicate container was then elutriated through stacked sieves of 8 mm, and 500, 125 and 63 μm mesh, with the > 500 μm fractions retained for macroinvertebrate characterisation and each of the smaller mesh fractions preserved separately in 90% ethanol for microinvertebrate (125 and 63 μm) characterisation.

Water and sediment material left over from the processing of the two uranium treatments were combined in a bulk container and retained for later safe disposal using an approved protocol.

At the time of collection of the retrieved samples it was observed that the method of preparation in the laboratory followed by exposure to hot and dry conditions in the field for about three weeks prior to inundation, had profoundly altered their physical condition compared with the undisturbed in situ sediment. In particular, the samples had a compacted and hardened ('baked') appearance, unlike that of the naturally occurring mostly softer and yielding sediments at the site, and that of the GC controls that had been prepared at the time of deployment of the extensively pre-treated material. At this time it was suspected that the greatly changed physical nature of the pre-treated sediment could have inhibited penetration and colonisation by organisms present in the surrounding natural sediments and surface waters, thereby creating an experimental artefact.

Initial results appear to confirm this expectation, with densities of macroinvertebrates appreciably lower in the extensively manipulated treatments compared with the GC controls. Processing of additional replicates will be done to determine the extent to which the method of preparation compromised the validity of the pilot trial. The work program for 2010–11 will focus on developing methods for sediment preparation and spiking that do not so greatly disturb the physical characteristics of the sediment. Pending the outcome of these investigations, the conduct of a comprehensive uranium sediment toxicity field trial has been deferred until 2011–12.

Figure 3.12 Top: deployment of uranium-spiked sediments for pilot experiment at Gulungul Billabong study site, 9 December 2009. Bottom: Gulungul Billabong study site, 7 January 2010.

3.4 Toxicity testing of Ranger process water permeate

Active treatment of process water at Ranger was implemented in late 2009 to accelerate reduction of the process water inventory. Untreated process water typically has a pH of ~4, an electrical conductivity > 25 000 µS/cm and contains highly elevated concentrations of sulfate – >30 000 mg/L, magnesium – >5000 mg/L, total ammonium ~900 mg/L, uranium (U) – >25 mg/L, aluminium – >400 mg/L and manganese – >2000 mg/L).

The treatment of process water comprises lime and carbon dioxide softening, followed by microfiltration/ultrafiltration, and finally reverse osmosis. The water treatment plant was designed to produce water to a standard such that the treated water, after an additional passive wetland polishing treatment, would be suitable for release to the off-site aquatic environment with no measurable biological impact. The final wetland step was specifically intended to remove residual ammonia (present in solution as ammonium ion) given that it was anticipated that the reverse osmosis treated water (permeate) from the water treatment plant could contain up to 20 mg/L of this species. Ammonia is both a toxicant and a nutrient so it is important that its concentration is reduced to environmentally acceptable levels prior to release of the final treated water.

A key question to be addressed from both an operational and environmental perspective, notwithstanding the wetland biopolishing step, was the extent to which the permeate contained residual toxicity, and whether this toxicity could be accounted for by the ammonium present. Toxicity testing in 2001 of the permeate produced from a pilot water treatment plant indicated low toxicity to three aquatic species, with IC/LC50 ratios ranging from 44% to >100% permeate. The aims of the present study were to (i) assess the toxicity of permeate from the full scale treatment plant commissioned at Ranger mine and, if residual effects were observed, to (ii) identify the cause/s of the effects.

Commissioning of the process water treatment plant at Ranger was completed in October 2009. On 26 October 2009, following advice from ERA that the permeate being produced was representative of typical outputs, SSD staff collected a sample for toxicity testing in the SSD Darwin laboratories. Separate samples of the permeate were collected for analysis of chemical constituents.

The chemical composition of permeate is compared with process water and Magela Creek water in Table 3.4. The treatment process was highly effective in removing major ions and metals from process water, including U. Analytes present in the permeate at concentrations substantially above those of natural Magela Creek water included ammonia (6.7 mg/L, as total ammonia-N), boron (236 µg/L), bromine (49 µg/L), rubidium (4 µg/L) and rhenium (10 µg/L). The ammonia concentration, although greatly reduced by the treatment process , was still at least seven times higher than the Australian and New Zealand water quality trigger value of 0.9 mg/L applying at the pH of the permeate (pH 8). Existing toxicity data suggest that the other analytes listed above were unlikely to be a concern.

Although the concentration of U (0.07 µg/L) in the permeate was an order of magnitude greater than background concentrations in Magela Creek water (0.005 µg/L), it was two orders of magnitude lower than the derived site-specific Limit for uranium in Magela Creek of 6 µg/L. Hence U is not a toxicant of concern in the permeate sample submitted for testing.

TABLE 3.4 WATER QUALITY OF MAGELA CREEK WATER AND UNTREATED AND TREATED PROCESS WATER FROM RANGER URANIUM MINE

Variable	Magela Creek water	Process water	
		Untreated [a]	Treated)
pH	6.2	3.9	8.3
Electrical conductivity (µS/cm)	18	28 200	91
Dissolved organic carbon (mg/L)	2.6	NM[b]	1.5
NO_3_N (mg/L)	<0.005	1.77[c]	0.005
NH_3_N (mg/L)	<0.005	1040[c]	6.8
Ca (mg/L)	0.2	602[c]	<0.1
Mg (mg/L)	1.1	6390[c]	<0.1
Na (mg/L)	1.3	97[c]	4.9
SO_4 (mg/L)	0.3	38 600[c]	2.4
Al (µg/L)	5.5	491 000	3.1
B (µg/L)	12	NM	236
Br (µg/L)	10	NM	49
Cu (µg/L)	0.23	12 600	0.2
Fe (µg/L)	40	10 300	<20
Mn (µg/L)	2	2 520 000	<0.01
Pb (µg/L)	0.22	4480	0.05
Rb (µg/L)	0.5	NM	4
Re (µg/L)	<0.05	NM	10
U (µg/L)	0.005	32 300	0.074
Zn (µg/L)	0.5	6130	<0.1

a Unless otherwise stated, values for untreated process water represent measurements from a sample collected on 2 November 2009, one week after the permeate sample for toxicity testing was collected. Data supplied by Energy Resources of Australia Ltd (ERA).

b NM: Not measured

c Values supplied by ERA from a sample collected on 30 November 2009

The toxicity of permeate was assessed using five local freshwater organisms – a unicellular alga (*Chlorella* sp), macrophyte (duckweed; *Lemna aequinoctialis*), cnidarian (*Hydra viridissima*), crustacean (*Moinodaphnia macleayi*) and a fish species (northern trout gudgeon; *Mogurnda mogurnda*). The test organisms were exposed to concentrations of 6.25%, 12.5%, 25%, 50% and 100% permeate, as well as a Magela Creek water control. The permeate used for testing was diluted with fresh Magela Creek water.

Significant effects of permeate were observed for all species, at concentrations above 12.5% permeate, with the responses ranging from growth stimulation to moderate toxicity (Figure 3.13, Table 3.5).

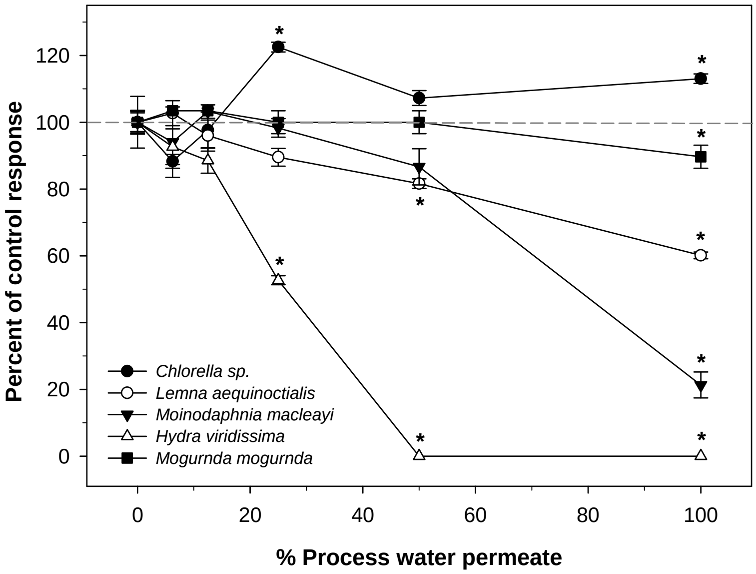


Figure 3.13 Responses of five tropical freshwater species to treated process water from Ranger Uranium Mine, expressed as percentages of the control response (see Table 3.5 for control response data). Data points represent the mean ± standard error of three replicates (10 replicates for *Moinodaphnia macleayi*). Asterisks denote treatments that are significantly different ($P \leq 0.05$) from the control response.

TABLE 3.5 TOXICITY ESTIMATES FOR TREATED PROCESS WATER FROM RANGER URANIUM MINE

Species	Control response (mean ± standard error)	Toxicity (% process water permeate)	
		IC10[a] (95% CL)[b]	IC50[a] (95% CL)
Chlorella sp	Doublings per day = 1.6±0.04	NC[c]	NC
Lemna aequinoctialis	Growth rate = 0.43±0.01	22 (0–45)	NC
Moinodaphnia macleayi	Offspring per adult = 35.2±2.7	43 (5–54)	78 (69–83)
Hydra viridissima	Growth rate = 0.31±0.01	10 (0–18)	26 (23–29)
Mogurnda mogurnda	Percent survival = 97±3	67[d] (0–100)	NC

a IC10 and IC50: concentrations that result in a 10% and 50% inhibition of response compared to the control (ie unexposed) response, respectively. Estimates were derived using linear interpolation (ToxCalc V5.0.23).

b 95% CL: 95% confidence limits

c NC: Not able to be calculated since there was insufficient response across the dilution gradient

d Value represents an LC05 (ie concentration resulting in 5% mortality of larval *M. mogurnda*; derived using non-linear interpolation; ToxCalc V5.0.23). A lower effect level than 10% was selected given the test is an acute test.

Chlorella sp growth rate was significantly enhanced at permeate concentrations of 25% (22% enhancement compared with the control) and 100% (13% enhancement). Exposure of *L. aequinoctialis*, *M. macleayi*, *H. viridissima* and *M. mogurnda* to 100% permeate resulted in significant reductions in responses of 40%, 80%, 100% and 10%, respectively. *Hydra viridissima* exhibited the strongest response of all the species, with a full response at 50% permeate and 47% reduction in growth rate at 25%. Based on the extent of response (negative or positive) at 100% permeate, the order of sensitivity of the species (from highest to lowest) was: *H. viridissima* > *M. macleayi* > *L. aequinoctialis* > *Chlorella* sp ≈ *M. mogurnda*.

The process water treatment process is clearly effective at removing the majority of contaminants and hence reducing or eliminating toxicity, compared with the composition of the untreated process water.

The effects of the reverse osmosis permeate, including the stimulatory response by *Chlorella* sp, are hypothesised to be primarily due to residual ammonia (present largely as ammonium ion). Alternatively, or in addition, the adverse responses of some of the species could be due to the very low concentrations of nutrients (other than N) or essential trace elements in permeate preventing normal growth, development and/or survival. This was previously shown to be the case for treated pond water permeate from Ranger (see 2007–08 ***eriss*** Research Summary). Additional work is being undertaken to confirm if the effects of permeate are largely caused by the residual concentration of ammonium ion. This will involve the selective removal of ammonia (as ammonium) from the permeate followed by toxicity testing of the residual solution.

3.5 Influence of dissolved organic carbon on the toxicity of aluminium to tropical freshwater biota

This work is part of a PhD project studying the influence of dissolved organic carbon (DOC) on metal toxicity to freshwater organisms. The first part of the project assessed the effects of DOC on uranium toxicity and the results were presented in the 2008–09 Annual Report.

Aluminium (Al) is a metal of general ecotoxicological concern for the mining industry. Inputs of Al to surface waters can occur through acidic seepage or discharge of acidic mine waters from legacy, closed and operating mine sites. Examples of such sites in the Northern Territory include the legacy Rum Jungle and Rockhole Creek uranium mines and metal mine sites throughout the Pine Creek Geosyncline metal province. The outcomes of the assessment done by the Supervising Scientist Division for the Rockhole Mine Creek site located in the Alligator Rivers region were documented in the 2008–09 Annual Report.

The classic acid drainage conditions exhibited at these sites provide an environment in which the bioavailability and toxicity of Al to biota are potentially much increased. In the case of fish , Al binds to the gills where it leads to respiratory dysfunction. Al has also been found to bioaccumulate in filter feeding invertebrates, in particular those feeding on benthic detritus. There are few toxicity data for Al in freshwater, particularly at acidic pH. The only water quality guideline available for Al in freshwater at low pH is a *low reliability* trigger value of 0.8 µg/L Al.[5] This guideline also does not incorporate the influence of DOC, which can form strong complexes with Al and potentially influence its bioavailability and toxicity.

The objective of this study was to quantify the influence of DOC on the toxicity of Al to three tropical freshwater species at low pH (5.0) and alkalinity (2–14 mg/L as $CaCO_3$). The selected tropical species, green hydra (*Hydra viridissima*), green alga (*Chlorella* sp), and the cladoceran (*Moinodaphnia macleayi*) were chosen to cover a range of trophic levels.

The influence of DOC was assessed using two sources of DOC: (i) the international standard Suwannee River fulvic acid (SRFA) and (ii) a local DOC present in water sourced from Sandy Billabong located adjacent to Magela Creek upstream of Ranger mine in Kakadu National Park. Four concentrations – 1, 2, 5 and 10 mg/L – of SRFA and local DOC were used and test species were exposed to up to 5 mg/L total Al. For the SRFA, toxicity testing was conducted using diluted (25% dilution with Milli-Q water) Magela Creek water (DMCW), containing a natural DOC concentration of <1 mg/L, as the test medium. DMCW, rather than synthetic Magela Creek water (SMCW), was used as the diluent because its low concentrations of background DOC (~1 mg/L) and alkalinity were required to provide buffering capacity to maintain the low test pH of 5.0 (SMCW, which lacks DOC, was not able to hold pH at a pH lower than pH 6).

For the local DOC, Sandy Billabong water (SBW), naturally containing 10 mg/L DOC, was diluted to the required DOC concentrations (1, 2, 5, 10 mg/L) using SMCW containing a similar inorganic composition to SBW but lacking in DOC. For the *Chlorella* test, nitrate and phosphate were added as nutrients (3.28 mg/L nitrogen and 0.046 mg/L phosphorus).

Test systems were static, with 24 h renewal of test solutions for *H. viridissima* only (there was no renewal for the *Chlorella* sp or *M. macleayi* tests). Test temperatures were maintained at 27 ± 1ºC for *M. macleayi* and *H. viridissima* and 28 ± 1ºC for *Chlorella* sp. For each species, four tests were conducted for SRFA and three tests for the SBW DOC, in order to fully characterise the concentration-response relationships.

Test durations and endpoints were as follows: *H. viridissima* – 96-h population growth rate; *Chlorella* sp – 72-h growth rate; *M. macleayi* – 24-h neonate survival. For all tests, general water parameters (pH, DO and EC) were monitored daily. At the beginning of each test, water samples were taken for analyses of DOC, alkalinity, hardness and a standard suite of metals and major ions. For each species, response data from the tests were pooled, and concentration-response relationships were determined using non-linear regression analyses.

Concentration-response relationships and associated linear regressions of toxicity (expressed as IC_{50} – the concentration that results in a 50% inhibition of the test response relative to the control response) against fulvic acid concentration are shown in Figures 3.14 and 3.15, respectively, while the toxicity summary data are shown in Table 3.6. Al toxicity was reduced in the presence of both DOC sources. For *H. viridissima*, SRFA was ~5 times more effective (based on the increased slope of the IC_{50} versus DOC plot) at reducing Al toxicity than the local SBW DOC. For *Chlorella* sp, SRFA was only ~2 times more effective at reducing Al toxicity than the local DOC. For *M. macleayi*, Al toxicity was reduced by a similar factor in the presence of both DOC sources.

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5 ANZECC/ARMCANZ 2000. Australian and New Zealand guidelines for fresh and marine water quality. National Water Quality Management Strategy Paper No 4. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

TABLE 3.6 EFFECT OF TWO DIFFERENT FORMS OF DISSOLVED ORGANIC CARBON (DOC), (I) SUWANNEE RIVER FULVIC ACID STANDARD I, AND, (II) DOC IN SANDY BILLABONG WATER, ON THE TOXICITY OF ALUMINIUM TO THREE LOCAL FRESHWATER SPECIES

Species	DOC[a] (mg/L)	IC_{50}[b] (95%CL)[c]		Extent of amelioration of Al toxicity (µg Al mg/L DOC^{-1})[d]	
		DMCW+SRFA[e]	SBW diluted with SMCW[f]	DMCW +SRFA	SBW
Hydra viridissima	1	35 (29–39)	49 (NC–149)	21	4.0
(green hydra)	2	59 (40–71)	61 (48–72)		
	5	119 (91–138)	69 (54–81)		
	10	226 (204–242)	87 (65–101)		
Chlorella sp	1	275 (189–384)	437 (315–679)	225	115
(unicellular alga)	2	805 (560–1032)	801 (560–1134)		
	5	1427 (1242–1582)	1251 (870–1724)		
	10	2260 (1830–2867)	1635 (1410–1895)		
Moinodaphnia macleayi	1	164 (123–206)	950 (939–983)	147	141
(cladoceran)[g]	2	691 (610–767)	905 (608–1293)		
	5	1162 (972–1390)	1214 (868–1510)		
	10	1584 (1277–1930)	2113 (2083–2140)		

a DOC: dissolved organic carbon, b IC_{50}: the concentration that results in a 50% inhibition of the test response relative to the control response; c 95% confidence limits; d extent of amelioration is the slope of the regression between IC50 and the concentration of DOC (Figure 3.15). e SRFA made up in dilute Magela Creek water (25%) ; f SBW diluted with SMCWr; g For *M.macleayi*, toxicity estimates relate to concentrations that affect percentage survival (as a % of control survival), compared to sub-lethal endpoints, such as growth and reproduction, for the other species.

Physicochemical variables were input into the WHAM (Windermere Humic Aqueous Model) chemical speciation computer model to estimate the effect of DOC on Al speciation, which was related back to Al toxicity. For both DOC sources, the decrease in Al toxicity with increasing DOC can be attributed to a reduction in the free (Al^{3+}) and monomeric hydroxy ($Al(OH)_2^+$) ion concentrations (the two most toxic species), due to Al being bound by DOC. These results and those of additional speciation modelling used to investigate finer aspects of the observed responses to Al, will be presented in more detail in subsequent publications.

Based on the responses of the three test species to Al in the presence of 1 mg/L DOC (IC_{50}s ranging from 50–950 µg/L Al), it appears that the current *low reliability* trigger value of

0.8 µg/L Al, which does not account for the influence of DOC, is likely to be overly protective for natural waters containing this level, or greater, of DOC.

Extending the number of species tested to 5 or 6 would enable a high reliability trigger value to be derived for Magela Creek (and similar composition) waters. However, to do this would be technically very challenging. For a species to be suitable for this testing it would need to be able to tolerate water at pH 5 and exhibit effects within the solubility limits of Al (which for water at pH 5 is around 400–500 µg/L).

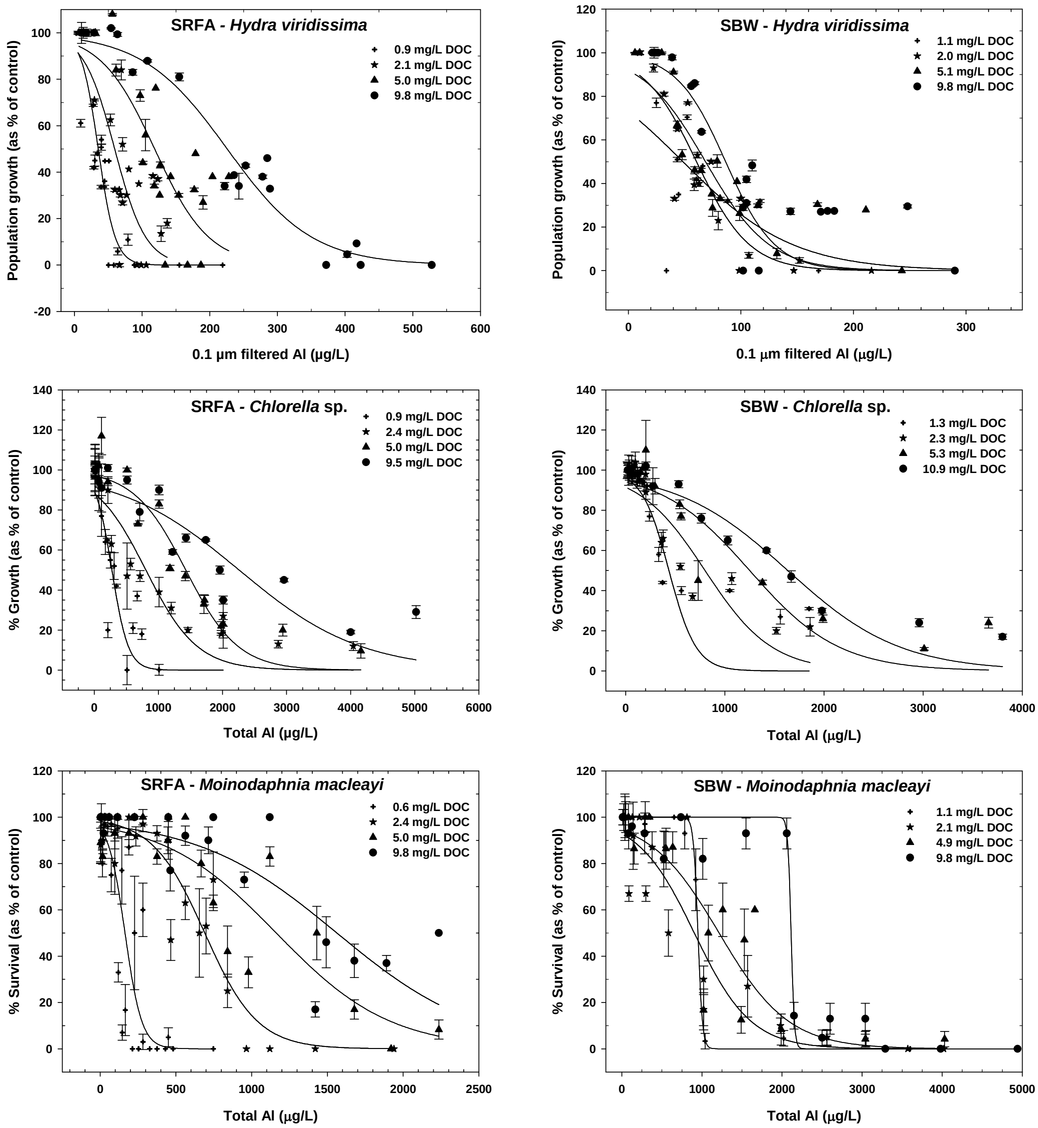

Figure 3.14 Concentration-response plots for Al exposures. Left: using Suwannee River fulvic acid (SRFA) in dilute Magela Creek water, 4 pooled tests for each species. Right: Sandy Billabong Water (SBW) diluted in synthetic Magela Creek water, 3 pooled tests for each species. Data points represent the mean of 3 replicates ± SE for *Chlorella* sp and *M. macleayi*, and 2 replicates ± SE for *H. viridissima*.

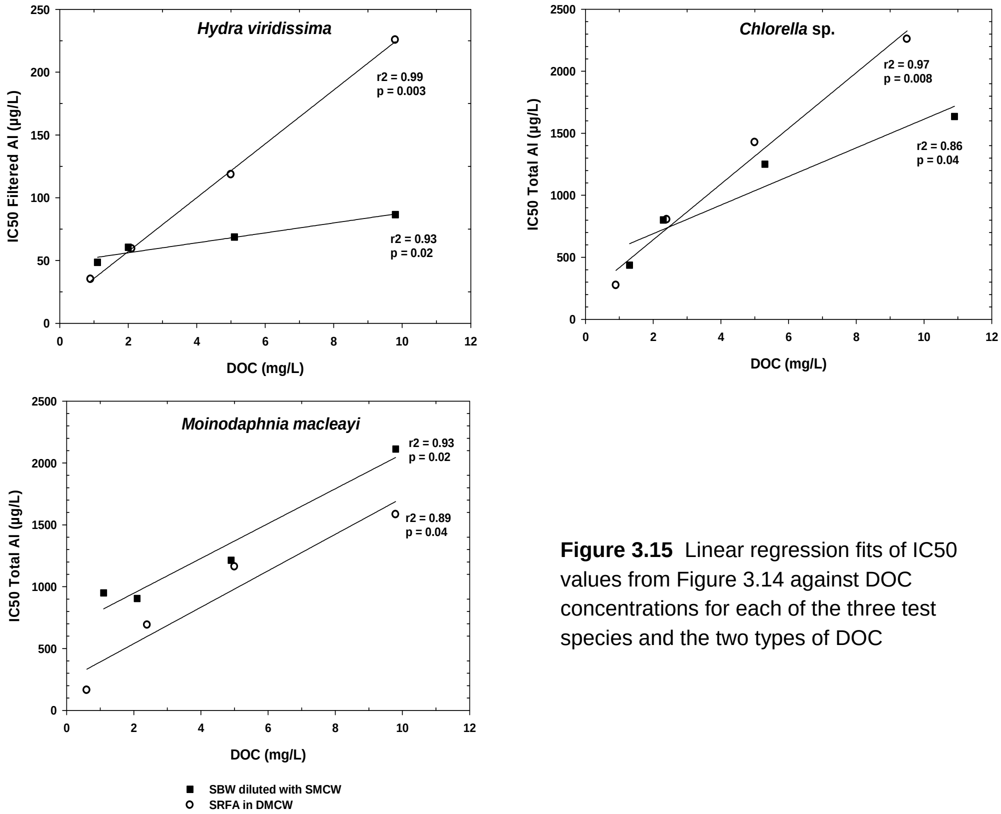

Figure 3.15 Linear regression fits of IC50 values from Figure 3.14 against DOC concentrations for each of the three test species and the two types of DOC

3.6 Characterisation of the pre-mining radiological footprint at Ranger

The ICRP recommends that the total annual effective radiation dose to a member of the public from practices such as uranium mining should not exceed 1 millisievert (mSv). This dose is on top of the natural pre-mining background dose and includes the external gamma, inhalation and ingestion pathways. In a high natural background area such as the area around Ranger mine, determining an additional dose due to mining activities presents a challenge, especially when pre-mining data are scarce and focus on delineating the extent and location of an orebody, rather than determining area wide radiological conditions.

Pre-mining radiological conditions need to be quantified so that post-mining changes can be assessed in the context of the success of rehabilitation from a radiological perspective. Historical airborne gamma surveys (AGS), coupled with ground truthing surveys, have the potential to provide a powerful tool for an area wide assessment of pre-mining terrestrial gamma dose rates. AGS and ground truthing surveys have been commissioned and used for regional assessments of radiological conditions at rehabilitated and historic mine sites elsewhere in the Alligator Rivers Region. Whilst a pre-mining AGS was flown over the Alligator Rivers Region including the Ranger site in 1976, no ground radiological data of the resolution and spatial coverage needed to calibrate the AGS data are available from that time. The novelty of this project is to use recently measured high resolution ground data from an appropriate undisturbed radiologically anomalous area to calibrate the AGS survey data for this anomaly, and then to use the calibrated 1976 AGS to infer pre-mining radiological conditions over the whole Ranger lease.

3.6.1 Methods

1976 AGS data were acquired from Rio Tinto by the NT Government and are available in the public domain (the *Alligator River Geophysical Survey*). Data were re-processed in 2000 by the Northern Territory Geological Survey (NTGS) and then resampled by NTGS at a pixel size of 70 m in 2003. The line spacing of the survey was 300 m, however, the flying height is unknown. The 1976 AGS has been used to identify undeveloped radiological analogues in the vicinity of the Ranger lease as potential candidates for ground truthing. A comparison of signal intensity with known uranium occurrences in the MODAT database suggested that Anomaly 2 to the south of the Ranger lease may be a suitable analogue site for Ranger pre-mining radiological conditions as it exhibits a strong airborne gamma signal in the data, has not been mined, nor is it influenced by operations associated with the Ranger mineral lease.

In addition, Energy Resources of Australia (ERA) has made data available to SSD from an AGS that was flown in 1997 at a low flying height (50 m) and a higher spatial resolution (200 m line spacing) than the 1976 survey. This dataset was used to further refine extensive groundtruthing fieldwork conducted in the dry seasons 2007 to 2009 to establish the exact location and intensities of the Anomalies immediately south of the Ranger lease. To date approximately 2000 external gamma dose rate measurements have been conducted using environmental dose rate meters, in addition to the determination of soil uranium, thorium and potassium activity concentrations via gamma spectrometry at selected sites.

Dry season radon exhalation was measured using conventional charcoal cups, with 3 charcoal cups deployed at each of the 25 sites for a period of three days. The charcoal cups were then analysed using the SSD NaI gamma detector. In addition, external gamma dose rates were measured and soil scrape samples were taken at the 25 sites for high resolution gamma spectrometry analyses. Track etch detectors were also deployed for three months at these sites to measure dry season airborne radon concentration and to establish whether there is a correlation between airborne radon concentration and radon exhalation flux or soil ^{226}Ra activity concentrations. At some of the sites, track etch detectors were deployed at various heights to represent the breathing zones of a person lying down with the head slightly raised, sitting and standing, to investigate changes in radon concentration with distance from the ground.

3.6.2 Results

Groundtruthing of the airborne gamma survey

Figure 3.16 shows the results from the 1997 ERA AGS data (total counts) compared with external gamma dose rate measurements ($\mu Gy \cdot hr^{-1}$) from SSD's groundtruthing. It is apparent that the groundtruthing survey has clearly distinguished Anomalies 2A (in the middle) and 2B (to the northeast), and a third Anomaly further to the southwest. Maximum uranium concentrations at the surface of Anomaly 2A are greater than 6000 mg/kg and maximum gamma dose rates measured at 1m height exceed 20 $\mu Gy \cdot hr^{-1}$. Typical environmental background uranium concentrations in the vicinity are 4–6.5 mg/kg and background gamma dose rates are approximately 0.16 $\mu Gy \cdot hr^{-1}$.

To groundtruth an AGS, the data acquired in the field (gamma dose rates, uranium, thorium, and/or potassium concentrations) are plotted against the count rates from the respective channels in the AGS. As the groundtruthed data at Anomaly 2 have been acquired at a much higher resolution than both the 1997 and 1976 AGS data, the image is much ‘sharper’, and it is thus essential to determine appropriate 2-dimensional smoothing algorithms which allow a comparison to be made between the groundtruthed and the AGS data. Ground-based data are typically smoothed by averaging such that the resolution is similar to that of the AGS.

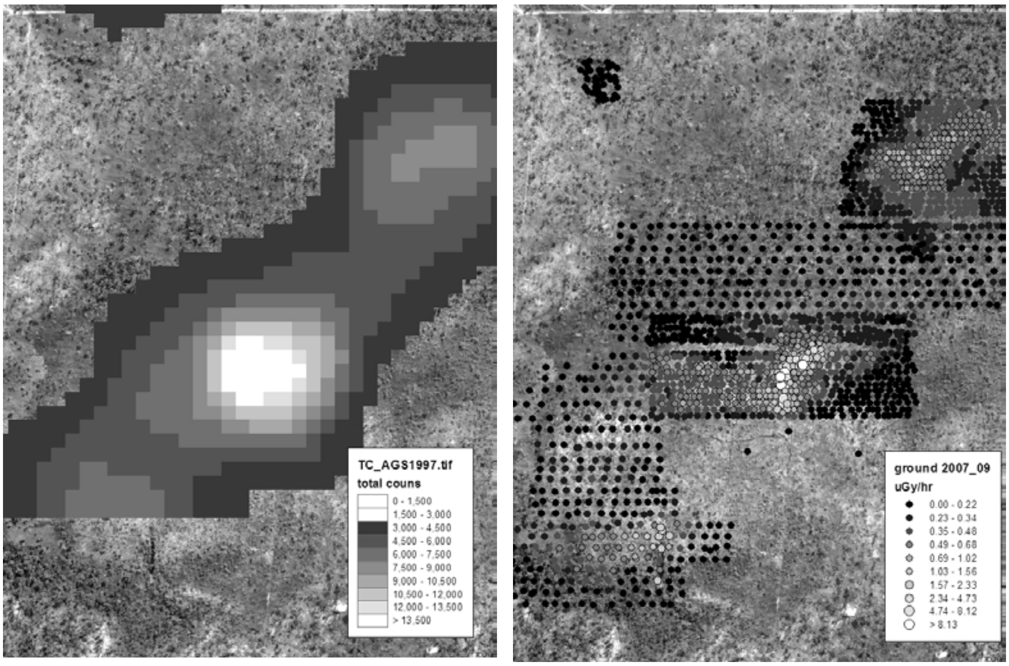

Figure 3.16 1997 AGS data (courtesy of ERA, left) and the results of the on ground gamma dose rate measurements (right) performed from 2007 to 2009, overlaid on a 2006 Quickbird image of the area immediately south of the Ranger lease

The best correlation between the 1997 AGS and the ground based dataset using a circular footprint is achieved after applying a small spatial shift and using a smoothing radius of ~80 m for the ground data. To take into account the fact that the plane is in motion as data is being acquired, more work is currently underway to investigate the effects of using an ellipsoidal footprint to smooth the ground data.

Radon

Radon (^{222}Rn) is a radioactive noble gas and part of the ^{238}U decay series. It is exhaled from soils and rocks, and exhalation is generally higher for fine grained soils rich in its parent, ^{226}Ra. Once airborne, the shortlived radon decay products (^{218}Po, ^{214}Pb, ^{214}Bi) are produced by the decay of radon and it is these decay products that deliver a radiation dose following inhalation, rather than the radon gas.

To determine the source strength, or radon flux, expected for an undisturbed uranium anomaly, radon flux densities have been measured across the Anomaly 2 area. In addition, gamma dose rates and soil ^{226}Ra activity concentrations were measured at these sites to investigate whether they can be used as a proxy to predict radon flux from the area. Figure 3.17 shows the geometric means of the radon flux densities versus the soil ^{226}Ra activity concentrations measured at the sampling sites, both plotted on a logarithmic scale.

In Figure 3.17 the sampling sites have been divided according to soil type (identified by visual inspection in the field) and sampling location, and results are plotted for fine gravel, loamy sand and coarse gravel/rocks on top of the anomalies. It appears that radon exhalation does not change significantly with increasing ^{226}Ra activity concentration of the soil directly above the outcropping anomaly, where typical radon flux densities (geometric mean) are 5.6 ± 2.4 $mBq \cdot m^{-2} \cdot s^{-1}$, similar to values measured above the Ranger #1 and #3 orebodies before mining started (2.5–5.5 $mBq \cdot m^{-2} \cdot s^{-1}$). For soil ^{226}Ra activity concentrations in the range of 10–2500 $Bq \cdot kg^{-1}$, radon flux densities can be predicted by multiplying the measured soil ^{226}Ra activity concentrations by 2.2 $g \cdot m^{-2} \cdot s^{-1}$. This value is similar to those reported earlier for non-compacted fine grains in the region (2.7 ± 0.4 $g \cdot m^{-2} \cdot s^{-1}$).

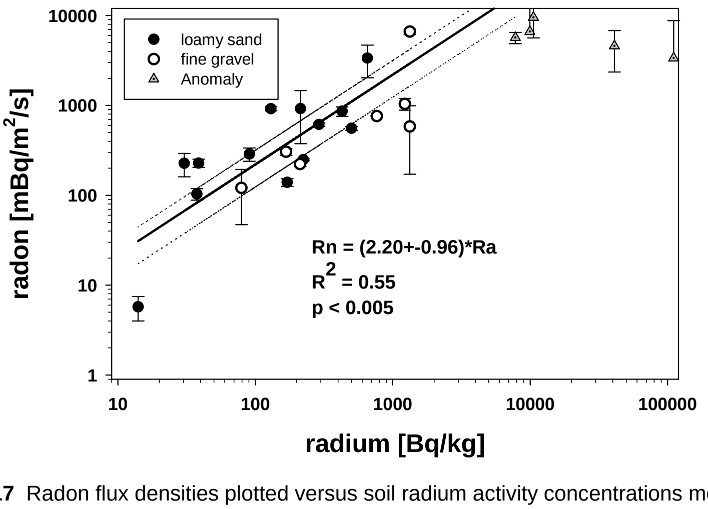

Figure 3.17 Radon flux densities plotted versus soil radium activity concentrations measured at Anomaly 2. The solid line is a linear fit to the data, the dotted line represents the 95% confidence interval.

Whereas radon flux density from the soil into air varies by three orders of magnitude, the radon activities measured in air ($Bq \cdot m^{-3}$) at 1.5 m height vary much less, indicating good lateral mixing. However, there is still a positive correlation ($p < 0.005$; $R^2 = 0.4$) with radon exhalation flux densities from the soil underneath. The typical dry season radon concentration (geometric mean) 1.5 m above Anomaly 2 is ~150 Bq·m^3, which is about 5 times higher than typical dry season radon concentration measured at Jabiru, but lower than the Australian indoor reference level for existing and new dwellings of 200 Bq·m^3. The radon concentration increases by ~1 Bq·m^{-3} for every 370 Bq·kg^{-1} increase in soil ^{226}Ra activity concentration. Wet season radon concentrations in air are generally lower than the values given above as previously determined at other areas in the Alligator Rivers Region.

Figure 3.18 shows the radon concentration measured at three different heights at various sites across the area surveyed, and the corresponding soil ^{226}Ra activity concentrations. The figure illustrates that at areas away from 'hot spots' radon concentration is relatively uniform vertically, but concentrations, and thus inhalation doses, are significantly higher when sitting or lying in close vicinity to the outcropping uranium anomalies with high ^{226}Ra activity concentrations. This potential exposure route and its dependence on height needs to be taken into consideration, in addition to land use, including diets, of indigenous people in the area, when assessing potential doses to humans in the region before mining started.

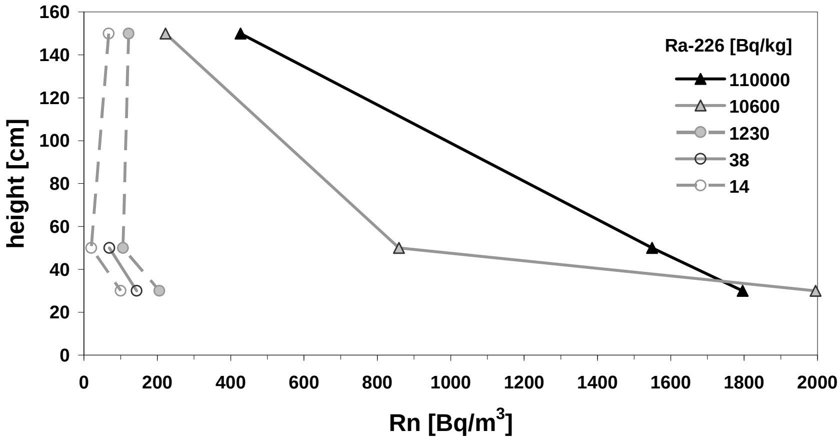

Figure 3.18 Radon concentration in air for various heights (30 cm, 50 cm, 150 cm) above the ground

3.6.3 Conclusion and future work

The correlation of historical AGS data from Anomaly 2 with recent ground truthed data from the area will allow determination of average external gamma dose rates across the Ranger lease area before mining started. The spatial resolution of the extrapolated dose rates is limited by the resolution of the AGS, which is at least 1ha for the 1976 AGS, but this resolution will suffice to determine pre-mining averages across orebodies #1 and #3 and other areas on site. The behaviour of radon in the vicinity of Anomaly 2 has also been studied, and the results will allow the determination of doses from the inhalation of radon progeny above the pre-mining footprint at Ranger, using appropriate equilibrium and dose conversion factors, respectively.

The potential contribution from the dust inhalation pathway still needs to be established and a separate study is currently underway to quantify the resuspension of dust in the area. Published resuspension factors for the region are comparatively high and need to be verified before radionuclide activity volume concentrations in air ($Bq \cdot m^{-3}$) are inferred from soil radionuclide activity concentrations extrapolated from the AGS survey data.

Further work is required on algorithms to upscale the results from the groundtruthing, in particular taking into account that the aircraft is in motion as data are being acquired, so that a similar comparison can be made with the 1976 AGS. Once data analysis is complete, the radiological conditions on ground around Anomalies 2A and 2B will be correlated to the pre-mining 1976 airborne signal to extrapolate to the area wide radiological conditions at the Ranger lease area before mining commenced. The results will be reported in a subsequent Annual Report.

3.7 Radiological characterisation of Ranger mine land application areas

3.7.1 Background

Water management is a major issue at Ranger uranium mine, given its location in the wet-dry tropics where up to 2 m of rainfall can occur within a single wet season. Release of water from the site into the downstream environment is minimised by the use of a series of retention ponds (RP1–RP3) (see Map 2). RP1 water is of relatively good quality, and free release into Magela Creek occurs routinely during most wet seasons. Since 1985 water stored in RP2 during the wet season has been disposed of on site using land application methods. RP2 receives runoff and seepage from the low grade ore and waste stockpiles and other areas on the minesite.

The history of development of the land application areas (LAAs) on the Ranger site is summarised in Table 3.7. The Magela Land Application Area (MLAA) was the first to be established using the spray irrigation method. Additional LAAs were developed as the amount of water to be disposed of rose through time as a result of the increasing area occupied by waste and low grade ore stockpiles. Starting in 1995, the RP1 and Djalkmara wetland filters were used to polish RP2 water before it was applied to the RP1 and Djalkmara East and West LAAs. In this context, and in contrast to the other LAAs, it should be noted that the MLAA has received untreated RP2 water throughout its entire operational life. It is therefore likely to contain the highest concentrations of metals and radionuclides.

From 2006 onwards increasing volumes of pond water have been treated by microfiltration/reverse osmosis (MF/RO) water treatment during the wet season, with the RO permeate being discharged along the Corridor Creek catchment line. The introduction of active pond water treatment during the wet season has progressively reduced the volume needed to be disposed of by land application during the dry season.

TABLE 3.7 SOURCES OF WATER FOR LAND APPLICATION AREAS AT RANGER URANIUM MINE

Land Application Area	Source of applied water	Total area (ha)	Year commissioned
Magela –Area A (MALAA)	RP2 water	33	1985
Magela –Area B (MBLAA)	RP2 water	20	1994
RP1	polished RP2 water	46	1995
Djalkmara East (E. Dj)	polished RP2 water	18	1997
Djalkmara West (W. Dj)	polished RP2 water	20	1999
Jabiru East (JELAA)	RP2 water	52	2006
RP1 Extension (RP1 ext)	RP2 water	8	2006
Corridor Creek (CCLAA)	RP2 water	141	2007

The use of land application as a water treatment method relies on the fact that radionuclides and most heavy metals have a tendency to bind to the organic rich surface horizons of soil profiles. These bound metals and radionuclides have a low leachability and will therefore be unlikely to impact the aquatic environment downstream of Ranger. However, there has been ongoing stakeholder concern about the radiological status of the Ranger LAAs, in particular with regards to the Magela LAAs and their capacity to continue to adsorb radionuclides at the current rate of application. The concentration of radionuclides adsorbed in the soil could potentially require the area to be rehabilitated at closure, based on current ICRP recommendations.

The Environmental Strategy Department within ERA, in collaboration with *SafeRadiation*, Brisbane and the Environmental Research Institute of the Supervising Scientist (***eriss***), has initiated a project to identify and quantify current radiological issues associated with the LAAs. The aims of this project are to characterise the magnitude and extent of radiological contamination at each of the Ranger LAAs and to suggest options for their rehabilitation. The nature of these options will strongly depend on the estimated post rehabilitation radiation doses to people from data produced by this current project.

3.7.2 Methods

Soil samples were collected at various distances (0–15 m) from the sprinkler heads at all LAAs and also included samples not influenced by irrigation. Soil samples were taken to a depth of 10 cm. In addition, ten soil cores were collected and sampled at a resolution of 5 cm down to 20 cm depth. Whole soil samples were dried and crushed, and prepared for radionuclide analysis via gamma spectrometry at ***eriss***. Leaf litter samples were also taken at various distances from the sprinklers. This material was ashed and homogenised and analysed by gamma spectrometry. The radionuclide activity concentration results were used to determine vertical and horizontal depositional patterns and to calculate the total load of radionuclides retained in LAA soils. These loads (in kBq·m^{-2}) were then compared with loads calculated from the known volumes and water quality data provided by ERA for the water applied at the various LAAs over the years.

Radon (^{222}Rn) exhalation flux density was also determined at various distances from the sprinkler heads using conventional charcoal cups. There was no irrigation of mine waters during and immediately prior to charcoal cup exposure. The charcoal cups were analysed using the ***eriss*** NaI gamma detector. Measurements were made in the dry season 2008 and in March 2009 (wet season) to quantify the effect of season.

Passive dust collection stations were established along transects that intersect the boundaries of the Magela A and Magela B land application areas (see Figure 3.19 for transect locations). The stations are triangular in shape and approximately 2 m high. Each face of the stations has four collector panels made of sticky vinyl, centred at 0.3, 0.7, 1.2 and 1.5 m above ground, representing the breathing zones of a person lying down, sitting, a juvenile standing and an adult standing, respectively. The stations were deployed in the dry season of 2008 and remained in place until the end of the dry season 2009. The sticky vinyl panels were changed every three months so that the deposition rates were measured quarterly over a seasonal cycle.

3.7.3 Results

Soil and leaf litter radionuclide activity concentration

The maximum ^{238}U soil activity concentration measured was 28 000 Bq·kg^{-1} (2270 mg·kg^{-1} uranium) and the average was ~1700 Bq·kg^{-1} (137 mg·kg^{-1}). In contrast, the maximum measured ^{226}Ra soil activity concentration was only a little above 1000 Bq·kg^{-1}, with an average of ~190 Bq·kg^{-1}. A large number of ^{226}Ra activity concentration values are in the range 100–500 Bq·kg^{-1}. Most samples exhibit an activity concentration trend of ^{238}U >> ^{226}Ra > ^{210}Pb, which reflects the signature of RP2 water applied to the soils. This is important for the external gamma pathway, as uranium is only a weak gamma emitter. The majority of the terrestrial gamma dose rate measured in air originates from ^{226}Ra decay products (^{214}Bi and ^{214}Pb) rather than uranium.

Although the activity concentration in surface leaf litter (Bq·kg^{-1} dry weight) is ~10 times higher than that measured in the underlying soil, only a small fraction of the total load of applied radionuclides appears in the leaf litter. It was found that approximately 90% of the applied radionuclides have been retained in the top 10 cm of the soils, in agreement with earlier studies conducted in the MLAA.

To put the radiation source term of the MLAA into context it should be noted that the concentration of uranium in waste rock can be up to 200 mg·kg^{-1}, which translates to ~2100 Bq·kg^{-1} of ^{226}Ra in radioactive equilibrium with ^{238}U. The combined exposure to the external gamma radiation and radon progeny inhalation pathways is a function of both the magnitude of ^{226}Ra activity concentration in the soil and its depth of occurrence. The typical diffusion path length for radon in soil is 1–2 m. Thus the 10 cm effective depth of elevated ^{226}Ra (maximum value of 1000 Bq·kg^{-1}) in the soil of the LAA needs to be compared with the potentially many metres of depth of waste rock containing up to 2100 Bq·kg^{-1}. Consequently annual doses via those two pathways will be less significant over the footprints of the LAAs compared to areas that will contain substantial depths of waste rock after remediation of the site.

The ^{238}U and ^{226}Ra soil activity concentrations in the top 10 cm decrease with distance from the sprinkler heads. This decrease can be approximated mathematically using an exponential equation, which has been used to estimate radionuclide activity loads deposited within the sprinkler wetting zone. The results derived from the direct measurement of soil activities, and subsequent integration over the LAA areas, compare well with the applied loads calculated from historical radionuclide inventories in RP2 water and irrigation rates provided by ERA.

The activity ratio of ^{226}Ra/^{210}Pb has been used to distinguish areas affected by application of mine waters from areas that may have naturally higher soil radionuclide activity concentrations. For environmental background soils, ^{226}Ra and ^{210}Pb are in radioactive equilibrium within the soil grains but deposition of ^{210}Pb from the atmosphere (which is produced by ^{222}Rn decay in air) shifts the ^{226}Ra/^{210}Pb activity ratio to values less than one. For natural uranium mineralised areas, the ^{226}Ra/^{210}Pb activity ratio is close to one and the effect of ^{210}Pb deposited from the atmosphere on the ^{226}Ra/^{210}Pb activity ratio is negligible due to the much higher concentrations of ^{226}Ra and ^{210}Pb arising from the uranium mineralisation. For soils subject to land application of pond water, the ratio should be greater than one as RP2 water contains significantly higher amounts of ^{226}Ra compared with ^{210}Pb.

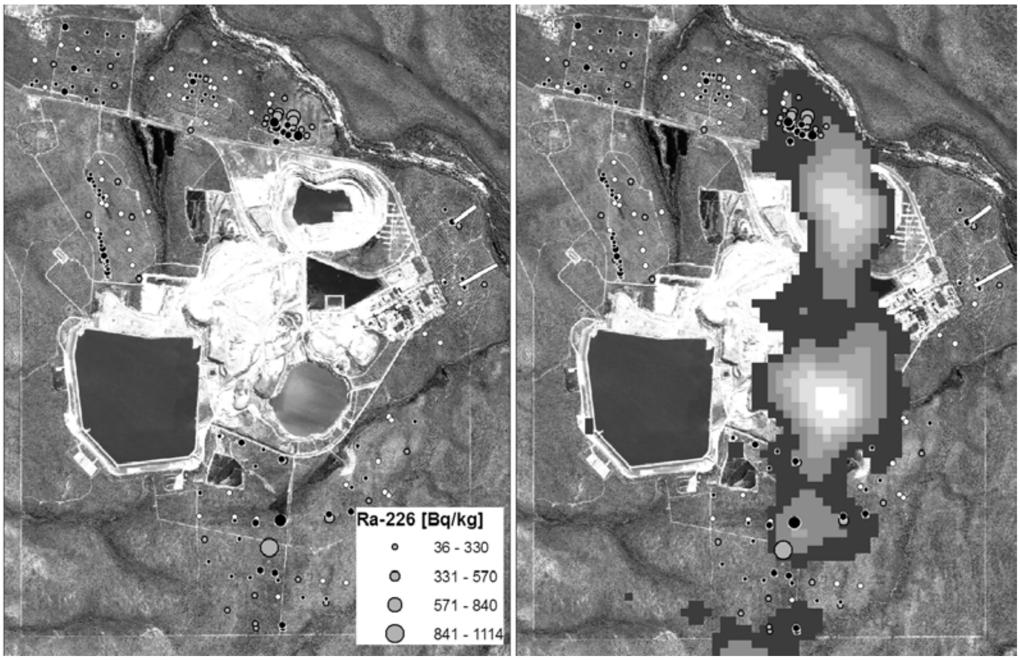

Figure 3.19 (a) ^{226}Ra/^{210}Pb activity ratios (white: ^{226}Ra/^{210}Pb < 0.9; grey: 0.9 < ^{226}Ra/^{210}Pb < 1.1; black: ^{226}Ra/^{210}Pb > 1.1) and ^{226}Ra activity concentrations of the soils collected. (b) Data overlaid on results from a 1976 airborne gamma survey (courtesy of the Northern Territory Geological Survey). Indicated are areas exhibiting counts per seconds in the airborne gamma survey significantly above background, black is lowest white is highest. White lines to the east show the locations of the dust transects at the MLAA.

Most samples measured exhibit a $^{226}Ra/^{210}Pb$ activity ratio of ≥ 1, whereas most of the lower activity soils have a $^{226}Ra/^{210}Pb$ activity ratio < 1. However, there are some areas of relatively high ^{226}Ra and ^{210}Pb activity concentrations with $^{226}Ra/^{210}Pb$ activity ratios close to radioactive equilibrium, indicating that in some areas within the LAAs naturally elevated ^{226}Ra activity concentration exists that is not attributed to irrigation.

Figure 3.19a (left) shows the location of the soil samples collected and a classification with regards to their ^{226}Ra activity concentration (indicated by the size of the circles) and their $^{226}Ra/^{210}Pb$ activity ratio (indicated by their colour). The white circles ($^{226}Ra/^{210}Pb$ < 0.9) are generally small in size and some of the samples are outside the zone of influence from the sprinklers. Figure 3.19b (right) shows the same data overlaid on results from an airborne gamma survey conducted in 1976. Soils with high ^{226}Ra activity concentration that exhibit a $^{226}Ra/^{210}Pb$ activity ratio of approximately 1 (big grey circles) are located within areas that exhibited higher natural backgrounds before mining started. This is particularly obvious in samples from the Djalkmara East LAA, to the northwest of Pit 3. This finding is important in the context of post irrigation dose assessment, as a proportion of the determined radiation doses will be due to existing natural radiation anomalies at these areas. Estimation of pre-mining doses at Ranger are subject of a separate project being conducted by ***eriss*** (see Section 3.6 – Characterisation of the pre-mining radiological footprint at Ranger in this report).

Radon exhalation

Dry and wet season measurements of radon flux densities were conducted in 2008–09 and a summary of the results is shown in Figure 3.20. In this figure average radon flux densities measured in the dry (August 08) and wet season (March 09) are plotted versus distance from the sprinklers at the various LAAs.

The decrease of radon flux densities with increasing distance from the sprinklers is more pronounced during the wet season compared with the dry. The Jabiru East, Corridor Creek and Djalkmara LAAs show on average higher radon flux densities during the dry season as compared with the wet, most likely due to lower soil moisture during the dry season. However, the trend appears to be opposite in the Magela and RP1 LAAs. This could potentially be an effect of the higher radium loads in the top few centimetres of the soils in these areas, in particular at the MLAA, that dry out more quickly compared with the deeper sections of the soil profile, and thus contribute relatively more to the radon flux than at the other areas.

Typical environmental (ie background) radon flux densities measured in the region are approximately 40–70 $mBq \cdot m^{-2} \cdot s^{-1}$. The Magela, Corridor Creek and East Djalkmara LAAs exhibit geometric means that are higher, whereas the remaining LAAs exhibit no noticeable increase above background. It is likely that the higher average radon flux densities at the Corridor Creek and East Djalkmara LAAs are caused by the presence of natural radiogenic anomalies (see Figure 1), whereas the increase at the MLAA (Area A) is largely due to the application of mine waters. However, it is known that natural anomalies are also present underneath and in the vicinity of the MLAA (Area A).

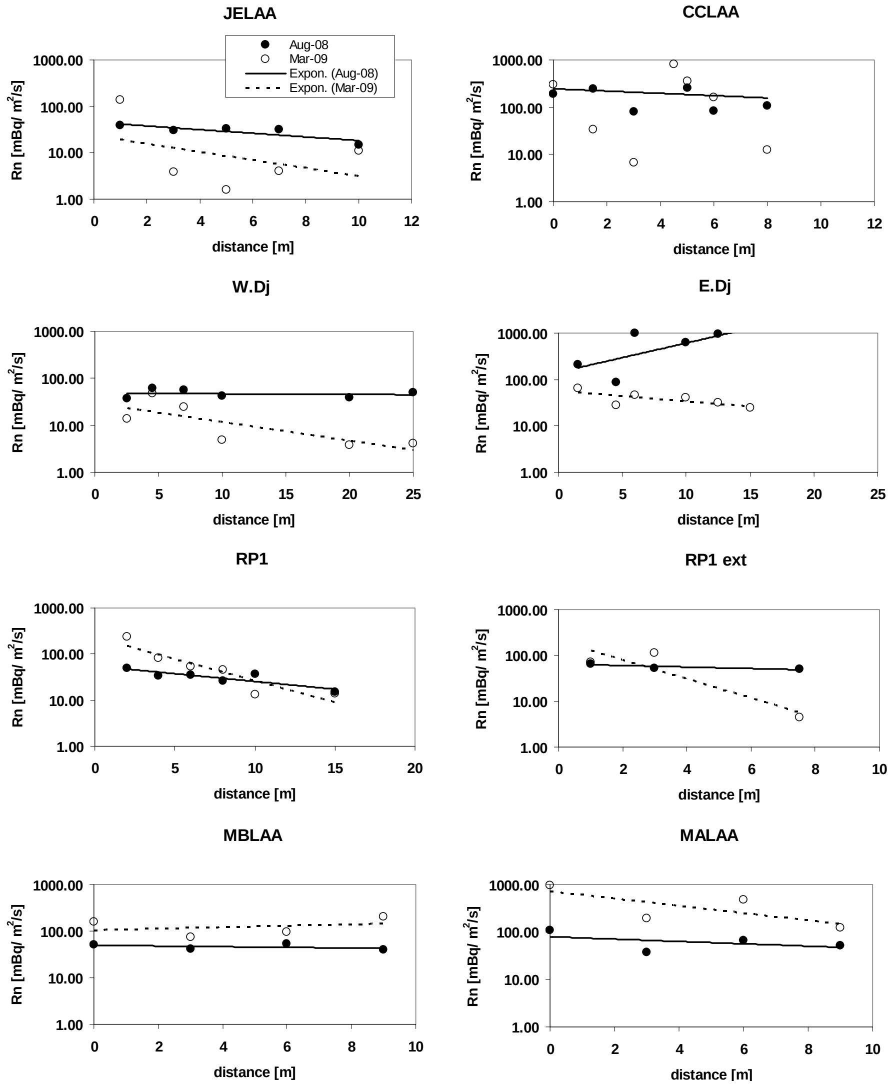

Figure 3.20 Radon flux densities measured in the dry and wet season, respectively, at various distances from the sprinklers at LAAs on the Ranger lease. The lines are exponential fits to the data.

Dust

Although it has been shown that the inhalation of dust contributes little to the radiological dose to the public in the off minesite areas of Jabiru East or Jabiru, it is possible that people accessing the LAAs may receive a higher dose from the inhalation of radionuclides in dust resuspended from the top few centimetres of LAA soils. This is an important factor to quantify in the context of assessing the rehabilitation requirements for the LAAs.

Dust samples were collected on sticky vinyl panels mounted on dust collector stations located along transects in the Magela LAAs (Figure 3.20). The panels were analysed for total alpha activity (Figure 3.20). The analyses showed that alpha activity is generally higher in samples closer to the ground indicating that a person sleeping will receive a higher dose from inhalation of dust than a person standing up. There is also a sharp drop of more than one order of magnitude in total alpha activity within the first 70 m outside the LAA boundary.

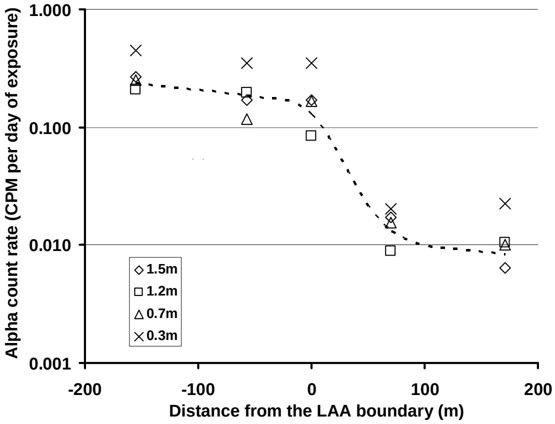

Figure 3.21 Total alpha activity (logarithmic scale) collected on sticky vinyl at various heights above ground in the dry season 2008 along a transect in the Magela B land application area. Positive distances shown on the x axis are outside the boundary of the LAA, negative distances are within.

Total alpha activity drops to about 0.01 cpm (counts per minute) per day between 100–200 m, a value similar to values measured at the ***eriss*** field station, about 4 km northwest of the transect. This indicates that while there is only limited transport of dust away from the LAAs, it may be a significant contributor to dose in the event of accessing or camping on the LAAs for an extended period of time. Further work is being done to verify published dust re-suspension factors and to quantify the dust inhalation pathway.

3.7.4 Conclusions and future work

This investigation has shown a substantial increase of radionuclide activity concentration in soils at the Magela, Djalkmara and RP1 LAAs due to irrigation of polished and unpolished RP2 water. However, this accumulation of radionuclides is restricted to the top 10 cm of the soil profile where most of the applied load is captured. There is very good agreement between measured radionuclide loads in the LAAs, and loads inferred from water quality data and irrigation rates over the past 25 years.

It can be expected that doses received via the external gamma and radon progeny inhalation pathways will only be little above background in the LAAs, in agreement with predictions from earlier studies. The dust inhalation pathway in the LAAs may become increasingly important and efforts currently focus on determining the resuspension factors for the area to quantify this pathway.

There are several rehabilitation options that could be used to reduce exposure of people potentially accessing the footprint of the LAAs, in the event that it was determined that such a reduction was needed. These options include removal of the top 10 cm of contaminated soil and placing it into the pit, tilling of the soil, or a mixture of both.

The extent of above background doses at Ranger post-remediation depends on pre-mining radiological conditions and future use of the area by indigenous people. The status of determining pre mining radiological conditions using Ranger Anomaly 2 as an analogue is addressed in the preceding section of this chapter. An agreed position by stakeholders on future land use and occupancy of the area is required as a pre-requisite to being able to predict applicable doses to humans post-remediation, and the possible need to carry out specific rehabilitation of the LAAs.

3.8 Remote sensing framework for environmental monitoring within the Alligator Rivers Region

Broad scale characterisation of landscapes in the Alligator Rivers Region (ARR) is required to be able to place the land surface status of operating and rehabilitated minesites into a regional context. To date there is little information on landscape ecology variables (in the context of rehabilitation, close out and known risks and threats) and their scale of interaction. Application of remote sensing technologies to address this knowledge gap requires the development of a remote sensing monitoring framework. The framework will provide the basis for most efficiently and cost effectively acquiring the required data by direct investment.

In May 2010 a systematic remote sensing data capture, incorporating full ground control and coincident spectral data collection, was done of the Magela floodplain and Ranger uranium mine. The data capture was undertaken in collaboration with the Tropical Rivers and Coastal Knowledge research hub's Theme 5.3 project (Food webs and biodiversity: river–floodplain food web studies). Three World-View 2 images covering 730 km^2 of the Magela Creek catchment were acquired. Table 3.8 shows the spectral bandwidth resolution of the satellite's sensor. The spatial resolution supplied is 0.5 m for the panchromatic band and 2.0 m for the multispectral bands.

The following scene parameters and data format were requested from the supplier: nadir angle less than 20º; cloud cover threshold 0–15%; and 16 bit data format. The potential capture dates for the imagery provided were May 6, 11, 14, 22 and 25. In order to ensure all required field and calibration data were available at the time of image capture, locational positioning and spectral calibration needed to be collected. Therefore, ground targets with accurate known locations had to be deployed prior to 6 May and suitable spectral calibration targets had to be in position, with spectral characteristics measured as close as possible to the time of image acquisition.

TABLE 3.8 SPECTRAL BANDS FOR THE WORLD-VIEW 2 SENSOR

Sensor band	Wavelength
Panchromatic	450–800 nm
Coastal	400–450 nm
Blue	450–510 nm
Green	510–580 nm
Yellow	585–625 nm
Red	630–690 nm
Red Edge	705–745 nm
Near-IR_1	770–895 nm
Near-IR_2	860–1040 nm

Historically there has been poor ground control for acquiring remote sensing data for the Magela Creek floodplain. High accuracy ground control is especially important in this case given the very low topographic relief of the area. This was achieved for the current capture by collecting 33 ground control points across the image acquisition area (Figure 3.22a).

Twenty-seven 3.5 x 3.5 m square silver-coloured tarpaulins were positioned on the ground prior to the image acquisition window and six image objects (features such as cross roads evident in previous image data) were selected for measurement. The centre of each of the tarpaulins and image objects were measured with a dGPS (Figure 3.22c) to within 12 mm x,y accuracy. These ground control points enable accurate orthorectification of the imagery.

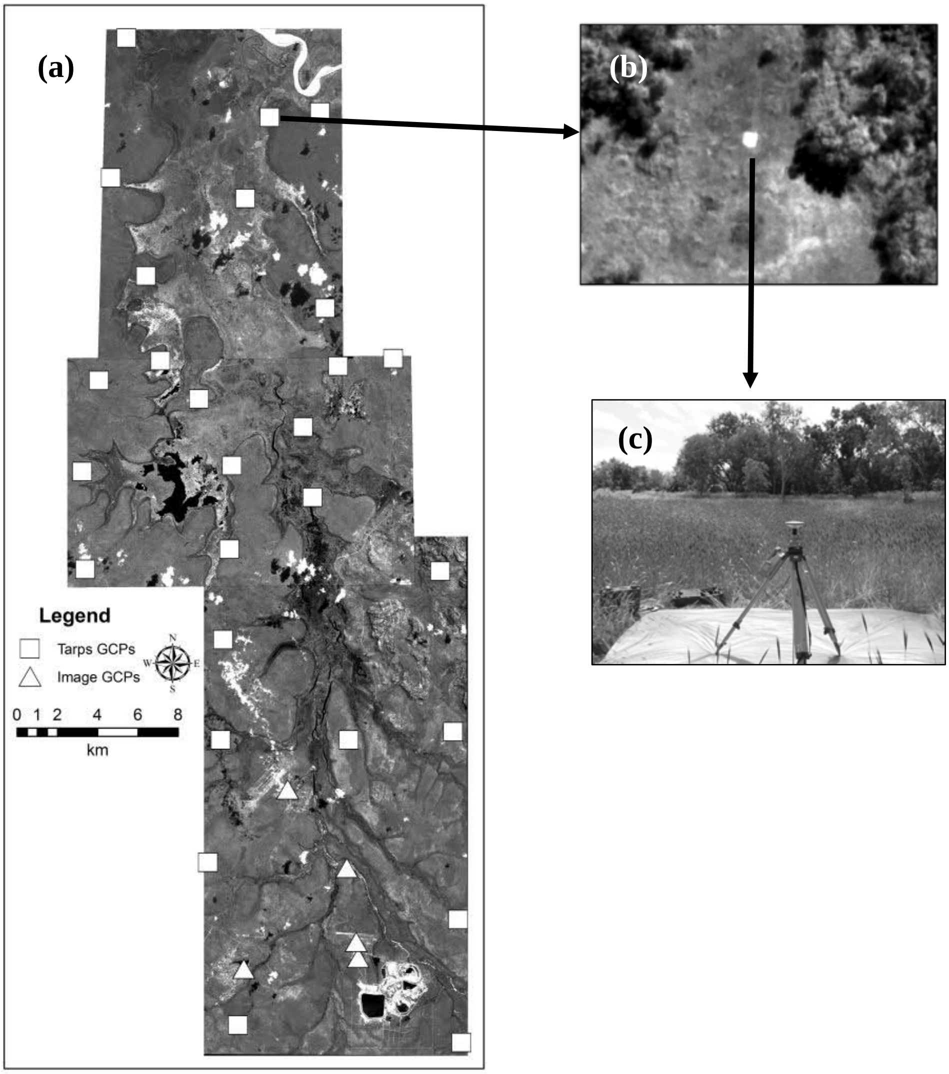

Figure 3.22 (a) Distribution of the Ground Control Points (GCPs) across the WV-2 imagery, (b) example of a tarpaulin GCP (site 2) captured by the WV-2 satellite in the panchromatic band, (c) collection of the dGPS data from the site 2 GCP

Atmospheric correction of satellite imagery using an empirical line method requires that high quality spectral measurements of suitable ground targets are acquired as close as possible to the time of image acquisition (in this case 10:30 am). After testing, using laboratory measurements of reflectance spectra, the suitability of various industrial products as ground targets, four materials were chosen to represent dark and bright targets. These were: black synthetic upholstery material (2% reflectance); silver plastic weave tarpaulin (23% reflectance); white plastic weave tarpaulin (67% reflectance); and Tyvec, a building insulation product (95% reflectance). The targets needed to be sufficiently large enough to be detected in the satellite imagery (Figure 3.23).

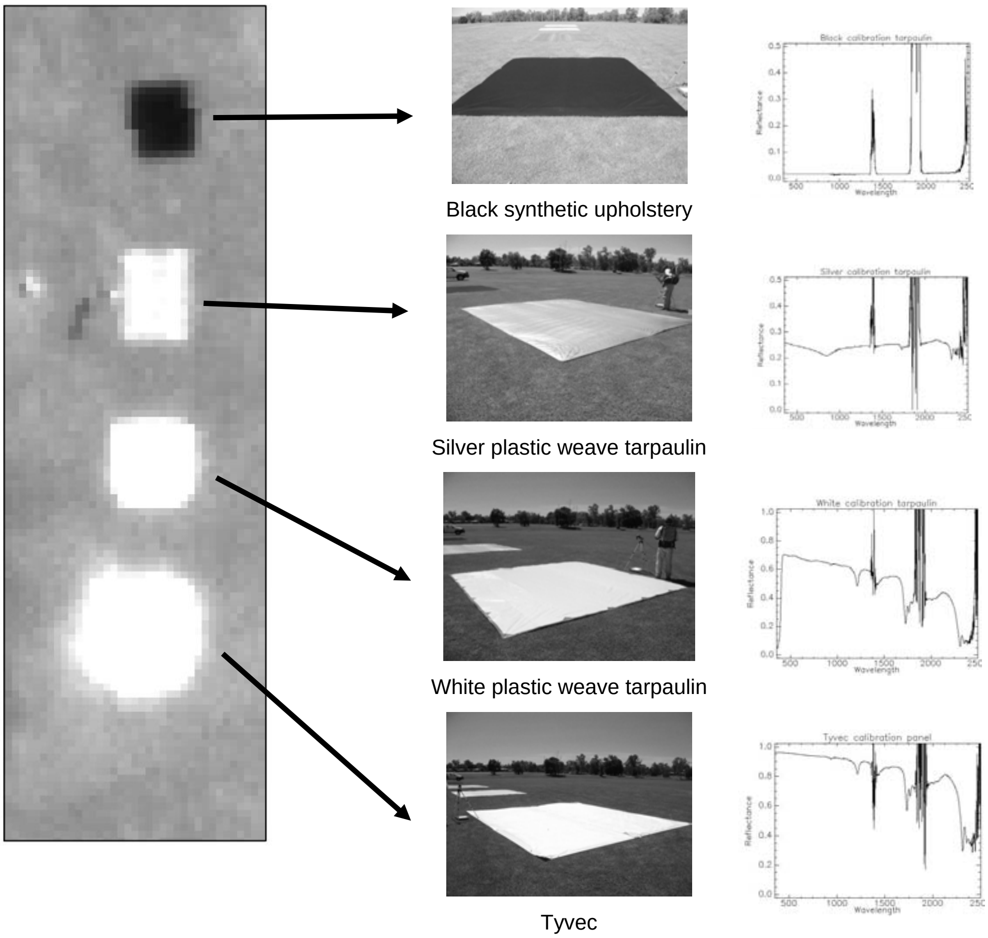

Figure 3.23 Calibration tarpaulins as captured by the WV-2 satellite (panchromatic band), photographs of target set up on Jabiru Oval, and the spectral signal of each tarpaulin as measured with the ASD SpecPro spectrometer

Prior to the 10:30 am satellite overpass, the four targets were deployed on Jabiru Oval. During the satellite overpass atmospheric solar irradiance data were collected using the ASD FieldSpecPro Spectrometer. Following the measurement of the solar irradiance data, multiple measurements of each of the four ground targets were collected. To assess the accuracy of the empirical line method for calibration of the WV-2 data, spectra of various invariant targets such as deep water, bare earth and well maintained golf green were also collected. These spectra were measured on the day of the overpass.

The majority (95%) of the areas of the three requested scenes were captured with the specified scene parameters (nadir angle of 13.8º and total cloud cover <2%) on 11 May. The remaining 5% of one of the scenes was captured on 22 May (nadir angle of 11.6º). All 27 ground control tarpaulins were visible in the imagery. Figure 3.22b shows an example of how ground targets appear in the imagery.

To produce a quality final product suitable for high resolution mapping of vegetation and habitat types, orthorectification of the imagery, atmospheric correction and the development of mapping applications will be required. This detailed work will be done over the next year.

3.9 The Bushtucker database

3.9.1 Background

For the past 30 years, information on the bioaccumulation of radionuclides in traditional bushfoods or ‘bushtucker’ has been gathered by SSD from many locations for a wide range of species. The database continues to be updated on an annual basis with data from routine monitoring programs and sometimes more opportunistically, for example in relation to the rehabilitation of the old mine workings in the South Alligator River Valley. Although the methodology and findings have been the subject of several journal and conference papers, as well as previous SSD Annual Reports and Research Summaries, there has been no prior integration of this material in an easily accessible format.

Newly available spatial technologies such as the 3-Dimensional virtual Earth/Globe viewing programs (hereafter referred to as virtual globe) such as Google Earth, Arc Explorer and Arc Globe offer a means to integrate and display this complex information in a format that is available to a wide range of potential users.

It is intended to develop a user friendly system to store and retrieve the data and present it to the local people of the area and to the wider public. The virtual globe environment will allow the user to navigate around the Alligator Rivers Region using high resolution satellite imagery and ‘fly’ to sampling sites to view available information. This gives the user a unique perspective of the terrain and appreciation of where the sampling sites are located relative to uranium mines, populated places and favoured bushtucker hunting and gathering sites. The virtual globe software is free for non-commercial applications and is easily downloaded from the internet, making it generally available to the community.

3.9.2 Scope of work

It is anticipated that three platforms will be developed – two for public viewing and a third for internal research use only. The first public viewing product is a Keyhole Markup Language file (KML) that contains all of the virtual globe features such as callout boxes, terrain flyovers and internet page hyperlinks. This compressed file will be available as a download from the internet or on a CD if necessary. It is simply loaded into the virtual globe program and the information tour starts automatically. KML files can also be loaded into web-based viewers such as Google Maps, Bing Maps, Yahoo Maps and Whereis.com to name a few.

The second public viewing product for non-internet users is a movie that has been created in a virtual globe environment and copied to a DVD. The movie will take the viewer on a tour of the bushtucker sampling sites with 'pop-up' information appearing along the way.

There is a need for caution when presenting data of this nature to the public because interpretation of the results is usually complex and there is potential for confusing or misleading interpretations to be made from individual numbers. In the event of data having been published previously in reports or papers, links will be provided to this reference source since they typically contain more detailed explanations/interpretations of the data.

The third 'internal use only' product would be similar to the first product but would contain all of the detailed radionuclide information. This product will enable SSD research staff to readily locate all of the available information in a spatial context and facilitate the use of the data across the Division.

3.9.3 Status

Figure 3.24 shows a sample Google Earth image with a callout box containing a graphic, text and links to, in this case, the catchments where bushtucker has been sampled.

The aims of this phase of the project are to make the information more accessible and understandable. In particular, to make the exploration of data more entertaining using the power of the virtual globe and the ability to 'fly' around the region and zoom in on features such as the escarpment, floodplains, billabongs and mining infrastructure. Included are many high quality photographs of the bushtucker fauna and flora species.

In Figure 3.25, the dialog box contains icons that provide a clickable link to web pages with information on radionuclides, aspects of the species' biology and available information on how local Aboriginal people may catch and prepare the food. Both English (upper) and Gundjeihmi (lower) language names for the species are provided. Gundjeihmi is the major local indigenous language group.

Work on development of the primary KML files and construction of the internet pages is largely complete. These components provide the basis for all three outputs from this phase of the project. The KML files and internet pages can be readily updated to incorporate new data that become available from the Environmental Radiation group at ***eriss***. This approach to data presentation could be followed for other spatially-based datasets (for example, soils and vegetation) acquired by ***eriss*** over the years.

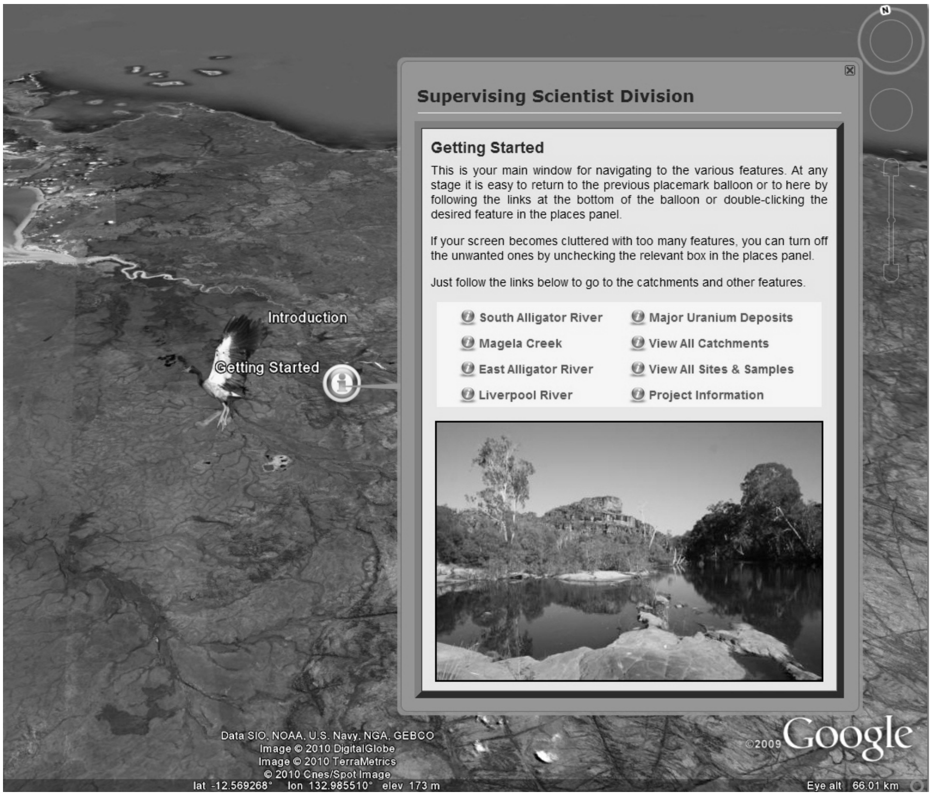

Figure 3.24 Google Earth snapshot with an information callout box and customised icons

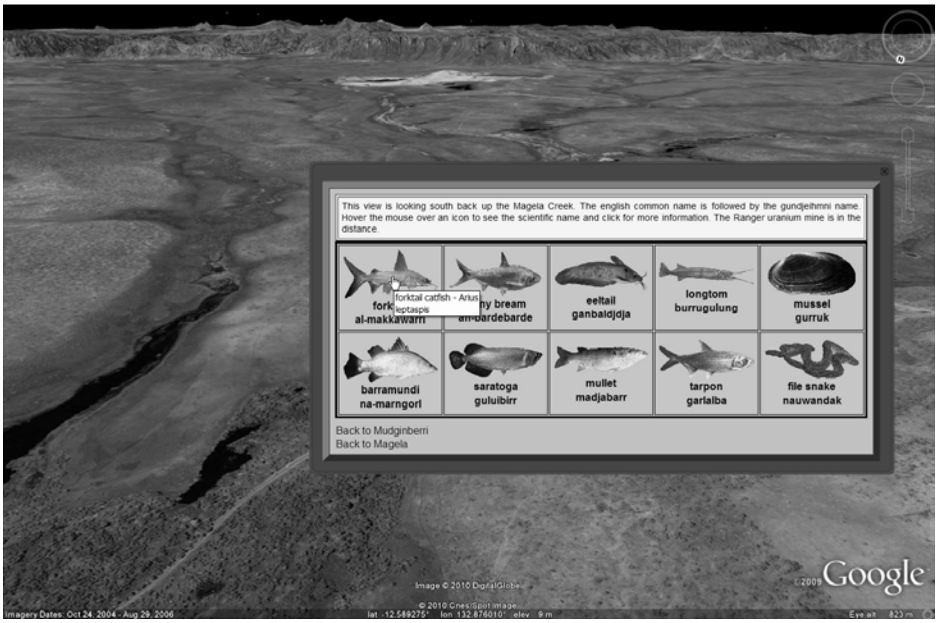

Figure 3.25 Another Google Earth snapshot showing a callout box with icons for the bushtucker species sampled at that site. In this Figure, Ranger uranium mine and Magela Creek are in the top centre.

3.10 Conceptual models of contaminant pathways for operational phase of Ranger uranium mine

Conceptual models of contaminant pathways associated with uranium mining in the Alligator Rivers Region (ARR) have been developed as part of the evolving ecological risk assessment framework being developed by the Supervising Scientist since the early 1980s. In response to recommendations by the World Heritage Commission Independent Scientific Panel and the Alligator Rivers Region Technical Committee (ARRTC), a specific project was initiated to produce an up-to-date comprehensive conceptual model of contaminant pathways associated with the operational phase of the Ranger uranium mine (RUM).

The new conceptual model framework was developed using an internal scientific expert panel approach involving senior ***eriss*** scientific staff to identify the main chemical, physico-chemical, biological and radiological contaminant types (stressors – see below) that could be potentially transported from the Ranger mine lease into the surrounding environment. For each contaminant class the source/s, potential transport mechanisms off-site, affected environmental compartments, receptor organisms, routes of exposure, types of effect (where known) and measures of effect (where available) were detailed. The conceptual model identified six main types of stressors and nine transport mechanisms associated with the operational phase of mining at Ranger (Table 3.9).

A diagram of the conceptual model elements was completed and validated by workshopping with external technical stakeholders in 2006. A sub-model diagram for the transport of inorganic toxicants via the surface water to surface water pathway was also completed to demonstrate the methodology that was being used. However, sub-model diagrams and narratives for the other potential contaminant pathways (up to 30) identified in the conceptual model were not developed at this time. Finalisation of the remaining contaminant pathway sub-models was identified as a priority by ARRTC during its most recent revision of the Key Knowledge Needs (KKN). Resources were allocated to progress the project in the second half of 2009.

A comprehensive review of the status of scientific knowledge regarding the various contaminants and pathways was undertaken and the content and structure of the conceptual model elements were revised as required. Draft sub-model diagrams for each of the potential contaminant pathways showing linkages between various model pathway elements (source, transport mechanisms, environmental compartments) and relevant measurement and assessment endpoints were also developed. The draft sub-models were revised following a technical workshop involving ***eriss*** Program Leaders and other senior scientific staff in September 2009. A report on progress was provided to ARRTC in November 2009. An example of the structure and content of the revised sub-models can be seen in the sub-model for the transport of inorganic toxicants via the surface water to surface water contaminant pathway (Figure 3.26). Supporting narratives for each of the sub-models were also drafted to provide explanatory information on the various pathway components, including spatial or temporal characteristics, the level of scientific knowledge and scientific certainty and any knowledge gaps. The narratives were refined with input from senior ***eriss*** scientific staff in early 2010.

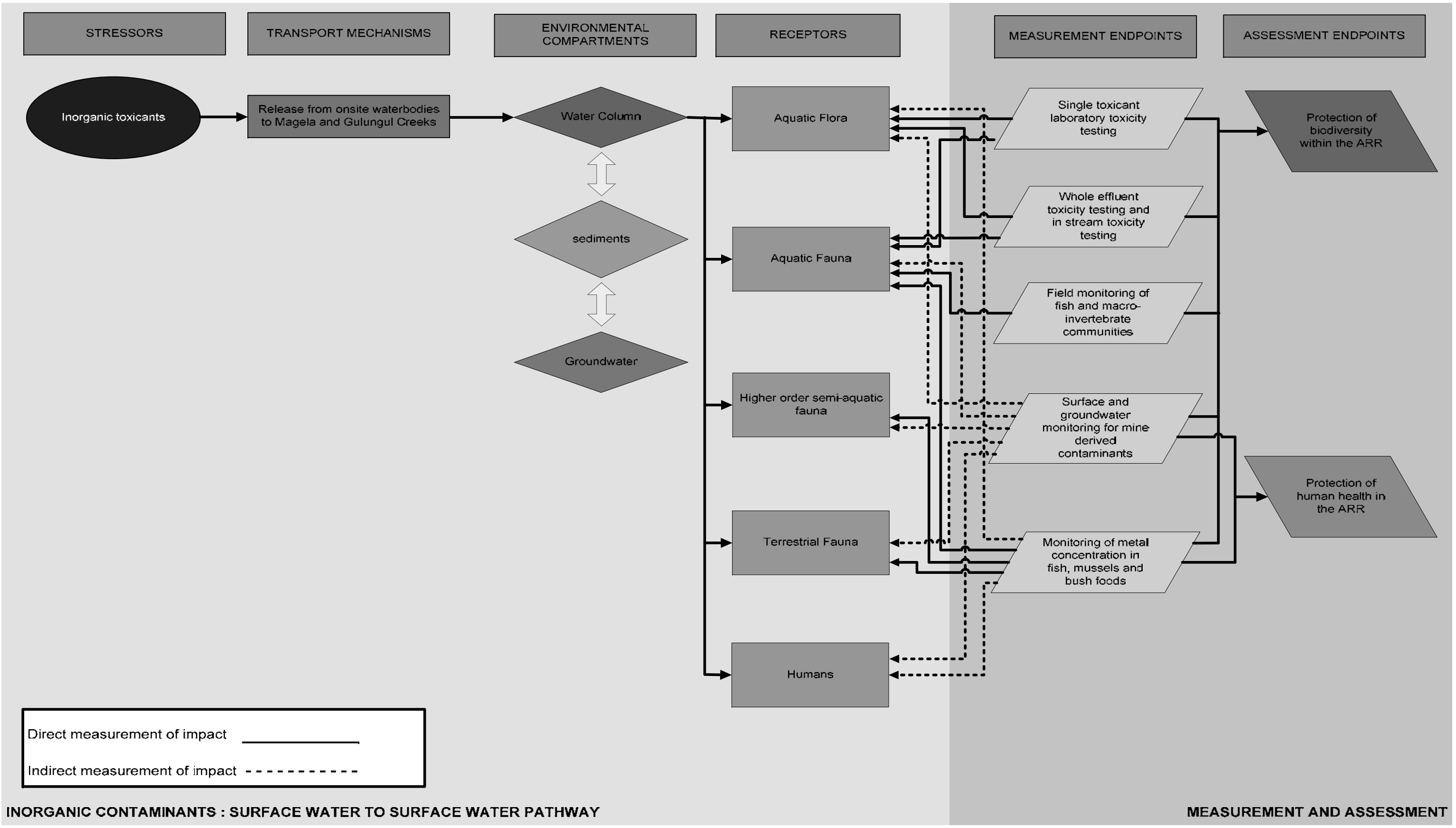

Figure 3.26 Conceptual model diagram for transport of inorganic toxicants from Ranger uranium mine via surface water to surface water pathway

TABLE 3.9 POTENTIAL STRESSORS AND TRANSPORT MECHANISMS ASSOCIATED WITH RANGER URANIUM MINE OPERATIONAL PHASE[2]

Potential stressors	**Inorganic toxicants** (eg uranium; magnesium; sulfate; manganese; ammonia) **Organic toxicants** (eg chlorinated aliphatic hydrocarbons, monocyclic aromatic hydrocarbons, polycyclic aromatic hydrocarbons, total petroleum hydrocarbons, organic sulfur compounds, volatile organic compounds) **Radionuclides** (eg Uranium – 238, 234, 235; Thorium-230; Radium-226; Lead-210; Polonium-210) **Radon-222 and its progeny** (eg Polonium-218, Lead-214, Bismuth-214, Polonium-214) **Weed propagules** (terrestrial and aquatic) **Suspended sediments** (<63 µm diameter)
Transport mechanisms	Release from mine site waterbodies direct to Magela and Gulungul Creeks Seepage from minesite waterbodies to groundwater and possible discharge to surface water systems Land application of mine water followed by (i) infiltration to groundwater and discharge to surface water and/or (ii) direct runoff to surface water Stormwater runoff from non-mine areas of lease Airborne dust and other particulates from mine site Airborne emissions from mill stacks and vehicles from mine lease Exhalation from mine lease Bioaccumulation and trophic transfer to mobile species visiting mine site waterbodies Human and non-human vectors (including vehicles)

1 Not all transport mechanisms are relevant to all stressors

2 from van Dam et al (2004)

The overall project approach and draft outputs were considered and endorsed by ARRTC in April 2010. Following this, it was decided that the importance of the contaminant pathways should be assessed in terms of their inherent potential to adversely impact on the environment within the ARR. In this context it should be noted that inherent potential does not equate to actual potential in the event of various management strategies (eg impounding of runoff followed by water treatment) being in place to provide mitigation.

A technical workshop involving senior ***eriss*** scientific staff was held in June 2010 in which each of the contaminant pathways were assessed based on the nature and size or generating capacity of the contaminant source, and the volume (and rate) of contaminants able to be transported off the mine lease via the pathway transport mechanisms. Project outcomes will be made available as a SSD Internal Report, in the Annual Research Summary and, eventually, a Supervising Scientist Report.

The content, design and functionality of various communication products arising from the project will be determined based on consultation with ARRTC members, traditional owners and other relevant stakeholders. This project will also contribute towards the future development of a risk-based framework, identified as a knowledge need by ARRTC, to support ***eriss*** research activities and scientific knowledge management.

4 STATUTORY COMMITTEES

4.1 Introduction

During 2009–10, the Supervising Scientist Division provided secretariat and administrative support to two statutory committees: the Alligator Rivers Region Advisory Committee and the Alligator Rivers Region Technical Committee.

These committees play important roles in facilitating discussion and information exchange between stakeholders in relation to the Division's environmental supervision and assessment activities, and facilitating peer review of associated scientific research activities.

4.2 Alligator Rivers Region Advisory Committee

The Alligator Rivers Region Advisory Committee (ARRAC) was established under the Commonwealth *Environment Protection (Alligator Rivers Region) Act 1978*. ARRAC facilitates communication between government, industry and community 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, and includes members representing the following stakeholder organisations:

- NT Department of Resources
- NT Department of Natural Resources, Environment, the Arts and Sport
- NT Department of Health and Families
- Office of the Administrator of the NT
- Australian Government Department of Resources, Energy and Tourism
- Australian Radiation Protection and Nuclear Safety Agency
- AREVA
- Energy Resources of Australia Ltd
- Cameco Australia
- Uranium Equities Ltd
- Koongarra Pty Ltd (a subsidiary of AREVA NC)
- Northern Land Council
- Gundjeihmi Aboriginal Corporation
- Environment Centre Northern Territory
- West Arnhem Shire Council
- Parks Australia, Australian Government Department of the Environment, Water, Heritage and the Arts
- Supervising Scientist Division, Australian Government Department of the Environment, Water, Heritage and the Arts

ARRAC offers a valuable forum for stakeholders to exchange views and information relating to the protection and rehabilitation of the Alligator Rivers Region environment from the effects of uranium mining. Public disclosure of environmental performance data through ARRAC is an important means of ensuring transparency and enhancing trust between the various stakeholder organisations.

At each ARRAC meeting, stakeholders present information reports to ensure transparency and enhance knowledge sharing. Information reports usually include a summary and interpretation of monitoring data and details of periodic environmental reports from mining companies. SSD provides a comprehensive report to each ARRAC meeting covering the outcomes of audit and assessment activities and environmental monitoring.

ARRAC met twice during 2009–10: in Jabiru in August 2009 and in Darwin in April 2010. Key issues considered by ARRAC at these meetings included:

- the status of mine operations, planning and development at Ranger;
- the results of chemical, biological and radiological monitoring for Ranger and Jabiluka;
- SSD communication and research activities;
- the outcomes of environmental audits and assessments of Ranger, Jabiluka and Nabarlek;
- the outcomes of Minesite Technical Committee (MTC) meetings and other regulatory processes;
- the status of mine rehabilitation projects in the South Alligator Valley;
- the Northern Land Council's work with the Alligator Rivers Region stakeholders and traditional owners.

ARRAC meeting minutes are available from the ARRAC web site at www.environment.gov.au/ssd/communication/committees/arrac/meeting.html.

4.3 Alligator Rivers Region Technical Committee

The Alligator Rivers Region Technical Committee (ARRTC) was established under the *Environment Protection (Alligator Rivers Region) Act 1978*.

ARRTC plays an important role in ensuring the scientific research conducted by ***eriss***, ERA, NT Government agencies and others into the protection of the environment from the impacts of uranium mining in the Alligator Rivers Region is appropriate and of the highest possible standard. ARRTC also reviews the quality of the science underpinning regulatory assessment and approval of proposals by uranium mining companies in the Alligator Rivers Region.

ARRTC reports openly, independently and without restriction.

Members of ARRTC are appointed by the Australian Government Minister for Environment Protection, Heritage and the Arts and include:

- an independent Chair (Mr Ray Evans)
- the Supervising Scientist
- a number of independent scientific members (including the Chair) with specific expertise nominated by the Federation of Australian Scientific and Technological Societies (FASTS)
- representatives from the Northern Land Council, the NT Department of Resources, Energy Resources of Australia Ltd (for Ranger and Jabiluka), Uranium Equities Ltd (for Nabarlek) and Parks Australia.

Dr Gavin Mudd was appointed to ARRTC as the environment NGO stakeholder in 2009.

ARRTC met twice in Darwin during 2009–10: in November 2009 and April 2010.

The key issues considered by ARRTC during these meetings included:

- current and proposed scientific research activities for ***eriss*** and ERA, in the context of the ARRTC Key Knowledge Needs;
- outcomes of chemical, biological and radiological research and monitoring being undertaken by DoR, ERA and SSD;
- scientific and technical issues relating to Ranger, Jabiluka and Nabarlek;
- the science underpinning Minesite Technical Committee (MTC) meetings and other regulatory decision making;
- the status of South Alligator Valley rehabilitation activities; and
- activity reports from the various stakeholder organisations.

During 2008–09 ARRTC undertook a gap analysis of its 2008–10 Key Knowledge Needs that was finalised in 2009. ARRTC provided advice to the Minister on its outcomes. The ARRTC 2008–10 Key Knowledge Needs are included in Appendix 1 of this Annual Report.

ARRTC meeting minutes are available on the ARRTC web site at www.environment.gov.au/ssd/communication/committees/arrtc/index.html.

5 COMMUNICATION AND LIAISON

5.1 Introduction

Effective communication with all stakeholders is an integral component of the Supervising Scientist Division's functions. Keeping traditional owners and other Aboriginal people living in the Alligator Rivers Region informed about SSD activities including the supervisory activities of the Office of the Supervising Scientist (***oss***) and the research and monitoring programs undertaken or managed by the Environmental Research Institute of the Supervising Scientist (***eriss***) is especially important. 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.

5.2 Research support and communication

SSD has been involved in community engagement activities such as festivals and school visits within local communities in Kakadu National Park and the Alligator Rivers Region. These activities strengthen SSD's relationship with local indigenous stakeholders, research organisations, non-governmental environmental groups and the general public.

General SSD communications activities are coordinated through the Business Support Unit and communication with indigenous stakeholders is managed by the Jabiru-based Community Liaison Officer (CLO) in conjunction with Jabiru Field Station and other SSD staff.

Events undertaken in the reporting period include community information, education and conference presentations. Specific and targeted liaison with traditional owners and other indigenous stakeholders continued to be a priority.

The 2009–10 program of community engagement activities included display booths at the Mahbilil Festival in Jabiru, interactive informal information sessions with local traditional owners and hosting visits at the Jabiru Field Station.

The SSD web site is another important means of raising community awareness of the work of the Division and providing public access to some of the Division's scientific data and reports such as the results of the SSD environmental monitoring program. Of note, all Supervising Scientist Reports, Research Reports and Technical Memoranda, and those Internal Reports that are not restricted or commercial-in-confidence, are now available online in PDF format.

5.2.1 Indigenous employment and consultation

Indigenous employment for activities such as field research projects gives SSD staff the opportunity to work alongside landowners on their country, sharing knowledge and gaining greater insight into traditional cultural values. It is also an opportunity for indigenous people to gain first hand knowledge and valuable technical skills and understanding of SSD's research and monitoring program.

Having applied for permission to research on Aboriginal land, engaged the help of residents in undertaking fieldwork and invited the local Aboriginal people to view the work done by SSD, we have a responsibility to follow up with results of these projects. We do this in a number of ways. For example, the same water chemistry control charts that are posted on the SSD web site are taken by the Community Liaison Officer (CLO) to Aboriginal communities in the Alligator Rivers Region to show the levels of uranium and other things we measure in the local creeks. Explanation of the significance of the levels and any variations is provided to local residents in a 'hands-on' practical manner. The results are also presented at local communities and are published in the local newsletter.

SSD has 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 – affording greater opportunity to communicate our role and function and helping us keep the local communities well informed about our monitoring and research programs. Informal contact has also 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.

SSD staff continued to collect bush tucker, complete permit applications and make regular contact with local Aboriginal organisations and communities.

The CLO liaises with stakeholders on a regular basis, including Energy Resources of Australia Ltd (ERA) community relations staff, Parks Australia staff, local Aboriginal corporations, the Northern Land Council and indigenous residents, to ensure there is a continuous flow of information on current SSD activities.

The SSD communications staff continue to make good use of the Jabiru Field Station mobile communications unit – an off-road trailer purchased to transport display materials to events and/or remote communities.

Regular meetings with the Gundjeihmi Aboriginal Corporation (GAC) have discussed matters such as employment, day labour payment details and updating of GAC's employment register. In the period, Mirrar people have worked 47 days on research and monitoring projects, including bush tucker collection and equipment maintenance and Jabiru Field Station ground and facilities maintenance.

Specific Aboriginal communications activities during the reporting period included:

- bush tucker collection with the women from Mudginberri (collected many fruits – yams, green plums and red and white apples);
- discussions about going out and collecting turtle meat (for the bioaccumulation project) with the Mudginberri women;
- continuing day labour on a regular basis;
- regular meetings between SSD staff and community members;

- permits for access to Aboriginal lands, such as Jabiluka permits, and other research work on Aboriginal lands continues with stakeholder and TO consultations.

Figure 5.1 SSD staff discuss research activities with local residents

An informal get-together was organised at Mudginberri Billabong for local residents to watch the Channel Billabong fish community survey. Lunch was provided and ***eriss*** staff provided information and answered questions. Residents viewed fish in their natural habitat through the ***eriss*** bubble boat. A similar activity was conducted at Sandy Billabong, with Parks staff and local indigenous people. A barbeque set the scene for inter-divisional interaction and discussion of ***eriss*** projects covered in the Parks-***eriss*** protocols.

A number of school tours of the Jabiru facility were organised with presentations on the role of ***eriss*** and its research activities. These included hosting a school group from West Arnhem College and the Junior Ranger program. The presentations were interactive and were tailored to the students' curriculum programs.

Figure 5.2 Schoolchildren from West Arnhem College attending a presentation on ecosystem protection at Jabiru Field Station

Figure 5.3 The Kakadu Junior Ranger program visits Jabiru Field Station

5.2.2 Research protocols for Kakadu National Park

Details of proposed 2010–11 SSD research and monitoring activities within Kakadu National Park were circulated to relevant stakeholders in April 2010, as required under the revised protocols agreed by the Director of National Parks and the Supervising Scientist in 2008.

The protocols define working arrangements for effective and timely communication between ***eriss*** and Parks Australia staff, the Kakadu Board of Management and traditional owners in relation to ***eriss*** research and monitoring activities within Kakadu National Park.

5.2.3 Internal communication

The Division supports effective internal communication between staff of all levels through regular staff and section meetings. Various working groups (eg Monitoring Support, Spatial Users and Technical Data Management) are convened as required to address important strategic business issues within the Division.

IiP (Investor in People) activities undertaken during 2009–2010 are described in Chapter 6.

SSD's internal newsletter *Newsbrief* is produced fortnightly and is available on the Intranet. It provides information on current Divisional activities in the Darwin and Jabiru offices, including articles on research, conferences attended, field trips and communication activities. Each SSD program reports on a selection of activities every sixth issue.

SSD continues to make extensive use of the Intranet. More than half the staff have received intranet training, and sections manage their own uploads and edits. The Intranet is used for new staff inductions and for important internal announcements. A review of the Division's Intranet site was undertaken during the 09–10 year.

The Spatial Sciences and Data Integration Group uses the Intranet to share its map collection with SSD staff. In addition, we now have continuous monitoring data from our telemetered stations in the Magela Creek catchment on the SSD intranet and available for staff to access as required. The data (which include EC, pH, turbidity, stage height, discharge and rainfall) are presented in the form of time-series plots enabling visual assessment of each parameter. The data are presented as reports and graphs accessible by clicking a station's name on a schematic map of the area around the minesite, and are updated daily after they have been downloaded from the stations.

5.2.4 Communication with technical stakeholders and the general community

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

The Alligator Rivers Region Advisory Committee (ARRAC) and the Alligator Rivers Region Technical Committee (ARRTC) both held two meetings during the period. Further information on ARRAC and ARRTC activities is provided in Chapter 4 of this report.

Indigenous stakeholders and the traditional owners of Kakadu National Park are also kept informed on SSD activities through their involvement in these committees. Gundjeihmi Aboriginal Corporation (GAC) and the Northern Land Council (NLC) are both members of ARRAC. The Director of ***eriss*** is a member of the Kakadu Research Advisory Committee.

SSD hosted a display booth at Mahbilil (Jabiru Wind Festival) in September 2009 with a comprehensive collection of publications, posters, macroinvertebrates and microscopes (see photos on right).

The ‘Friends of Fogg Dam’ Field Day event provided an opportunity for staff from the Aquatic Ecosystem Protection program to present a macroinvertebrate display and answer questions from the community.

Figure 5.4 (above) Macroinvertebrate display at the ‘Friends of Fogg Dam’ Field Day. **Figure 5.5** SSD staff at Mahbilil.

These activities served to enhance awareness and understanding of the work and role of the Division and to raise SSD’s profile within the local and wider community. These events also enabled SSD staff to provide information to local residents in a ‘hands-on’ practical manner.

5.2.5 Australia Day awards

Three Australia Day awards were made to SSD this year: The Landform Team for outstanding dedication by team members over a period of eighteen months to bring the monitoring system for the rehabilitation trial landform at the Ranger mine to operational completion, often under very challenging physical conditions; Ian Furner for outstanding service to the Supervising Scientist Division, the department and elsewhere in the Australian Public Service over a career of 30 years in both military and civilian areas; and Kim Cheng for exceptional performance and invaluable contribution to SSD’s Ecotoxicology Program and outstanding commitment to development of the Ecotoxicology Laboratory Manager role.

5.3 National and international environmental protection activities

5.3.1 Revision of National Water Quality Guidelines

Two ***eriss*** research scientists, Dr Rick van Dam and Dr Chris Humphrey, are providing the technical coordination for the current revision of the *2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (the Guidelines). The Guidelines, which constitute Guideline 4 of the National Water Quality Management Strategy, represent a key source document in Australia and New Zealand for managing natural water quality and protecting aquatic ecosystems. Six Working Groups have been established to oversee revisions to specific parts of the Guidelines. By July 2010, all Working Groups had met to determine initial revision tasks for 2010 and scope larger revisions for commencement in 2011. The technical coordination role primarily involves ensuring cross-cutting issues are addressed and integrated across the activities of the Working Groups. Drs van Dam and Humphrey also are members of four of the six Working Groups. ***eriss*** will continue to work with the Water Reform Division during 2010–11 on this project.

5.3.2 Basslink

SSD staff, as Australian Government representatives on the Gordon River Scientific Reference Committee, provided comment on the 2006–09 Basslink Review Report, a report evaluating the Gordon River Basslink Monitoring Program after three years of Basslink operations.

5.3.3 Northern Australian Water Futures Assessment (NAWFA)

The Northern Australia Water Futures Assessment is a multidisciplinary program being managed by the Environmental Water and Natural Resources Branch within DEWHA. The objective is to provide an enduring knowledge base to inform development of northern Australia's water resources, so that development proceeds in an ecologically, culturally and economically sustainable manner.

During 2009–2010, staff from ***eriss*** assisted the Department in two working groups convened to address the priority areas being covered by the Assessment. The names of the working groups and the respective ***eriss*** representatives are Dr Rick van Dam (Ecology) and Dr Renée Bartolo (Knowledge Base).

Each of these groups has:

- developed a work plan for acquisition of required new information;
- provided advice on existing information, knowledge and research;
- identified linkages with other Assessment Programs and relevant activities; and
- provided advice on new research/knowledge needs and made recommendations on priorities for future research.

More information about the NAWFA and the products that are being produced by the program can be found at www.environment.gov.au/water/policy-programs/northern-australia/index.html.

5.3.4 Tropical Rivers and Coastal Knowledge (TRaCK) Research Program

The TRaCK research hub headquartered at Charles Darwin University in Darwin is one of the major components of the CERF program being managed by DEWHA. Staff from ***eriss*** contributed to two of the research theme areas in the past year:

- Theme 4: Material Budgets. ***eriss*** is a collaborator in Project 4.1: Catchment water budgets and water resource assessment. The specific engagement is with Task 3 that involves flood inundation mapping for the Mitchell and Daly River catchments using a combination of radar and optical satellite imagery analysis. Landsat 5 TM and ALOS-PALSAR satellite imagery were acquired for the 2009 wet season to represent the maximum extent of inundation ('wettest' wet year).
- Theme 5: Biodiversity and High Conservation Value Aquatic Ecosystems (HCVAE). ***eriss*** is contributing to Project 5.8: Bioregionalisation conservation priorities and predictive models of aquatic biodiversity. The work involves contributing information and biological samples that will be used to identify areas or regions of high biodiversity and biological uniqueness.

  In May, ***eriss*** staff collected vegetation and biomass data for the Magela floodplain to provide mapping products that can be used for a project examining food webs on the Magela floodplain.

More information about TRACK can be found at www.track.gov.au/

5.3.5 Kakadu Research Advisory Committee

Dr David Jones and Dr Renée Bartolo were appointed as members of the reconstituted Kakadu Research Advisory Committee (KRAC). KRAC is a committee appointed by the Kakadu National Park Board of Management that advises the Board and Director of National Parks on science research issues in the Park. The first meeting of the new committee was held on 3–4 June 2010 at the Bowali Visitors Centre at Jabiru. The agenda comprised finalising the terms of reference defining the scope of the committee's remit, initiating the development of a framework for identifying and prioritising key research needs for the Park, and reviewing changes proposed for the assessment and approvals process for applications to conduct research in the Park. It was agreed that at least one (and usually two) meeting of the committee be held each year.

5.3.6 Special Feature in the *Journal of Spatial Science*

eriss Research Scientist, Dr Renée Bartolo, along with Dr Kasper Johansen from the University of Queensland, compiled and edited a Special Feature for the *Journal of Spatial Science* focused on Geographic Object-Based Image Analysis (GEOBIA). The Special

Feature includes eight articles from around the world focused on the theory and applications of GEOBIA in the field of remote sensing analysis and was published in June 2010.

5.3.7 EPBC compliance audits

oss staff provided assistance to the Approvals and Wildlife Division of the Department in the conduct of compliance audits against approval conditions issued under the *Environment Protection and Biodiversity Conservation Act*, including leading an audit of the McArthur River Mine in April 2010.

5.3.8 Rum Jungle collaboration

The Rum Jungle legacy uranium and copper mine site is located close to the town of Batchelor, approximately 80 km south of Darwin. Rehabilitation work was initially undertaken between 1982 and 1986. However, the site has remained an ongoing source of metal load to the Finniss River, as well as being in a state that is not currently suitable for return to the local traditional owners. In 2008, the Rum Jungle Technical Working Group (RJTWG) was formed to progress and implement:

- environmental maintenance activities;
- continuation of appropriate environmental monitoring programs;
- development of contemporary site rehabilitation strategies for the site.

The group consists of representatives from the Supervising Scientist Division (SSD), NT Department of Resources (formerly Department of Regional Development, Primary Industry, Fisheries and Resources), NT Department of Natural Resources, Environment, the Arts and Sport (NRETAS), Australian Government Department of Resources, Energy and Tourism (DRET) and the Northern Land Council (NLC). Mr Alan Hughes (Supervising Scientist) and Dr David Jones (Director ***eriss***) are the SSD representatives.

In the 2009 federal budget an allocation of $7 M of special purpose funds was made to progress assessment of the site over a period of four years, with the objective of developing a costed rehabilitation plan consistent with contemporary best practice. The program is being managed by the NT Government Department of Resources (DoR) under the terms of a 'National Partnership Agreement (NPA) on the management of the former Rum Jungle mine site' between DoR and the Australian Government Department of Resources Energy and Tourism. The RJTWG will continue to provide technical advice and oversight of the projects that will be commissioned that address the terms of the NPA.

During 2009–10, SSD produced reports on two projects (described in the 2008–09 Annual Report) that had previously been commissioned by DRET to define the current state of surface and groundwater quality on the Rum Jungle site. The information contained in these reports will provide the basis for ongoing work by consultants engaged to develop a groundwater transport model for the site and to calculate loads of metals that are currently being exported from the site during the wet season.

5.3.9 Other contributions

Dr David Jones was a member of the panel of experts that reviewed the CSIRO Water for a Healthy Country Flagship program in October 2009. He also provided independent review of the inland acid sulfate soils characterisation reference document being developed by the Murray Darling Basin Authority.

Supervising Scientist Mr Alan Hughes is a member of the Mt Todd Minesite Rehabilitation Reference Group that has been established by the Northern Territory Department of Resources. The Supervising Scientist provides an independent scientific perspective to the group which is a community consultative forum for discussing environmental management issues at the Mt Todd minesite near Katherine. Meetings of this group are typically held annually following the wet season.

Mr Hughes has been appointed by the Northern Territory Minister for Natural Resources, Environment and Heritage as a member of the Water Resources Review Panel, under the NT *Water Act* as the representative under the category of Mining. The Review Panel is required to advise the Controller of Water Resources and the Minister in assessing the number of appeals regarding licensing decisions against Water Allocation Plans and Bore Construction Permit refusals in the Northern Territory. The panel has not been convened to consider any relevant issues since Mr Hughes appointment to the panel.

In January 2010, SSD hosted two IAEA delegates from Mongolian Nuclear Energy Agency as part of a program to assist them in gaining an understanding of how the uranium mining industry operates and is regulated in Australia. Visits were scheduled for different operations in both the Northern Territory and South Australia. SSD hosted the NT portion of the visit while the SA government hosted their visit to SA. In the NT the delegates were shown around SSD facilities in Darwin where they held discussions with key staff before heading out to field visits of Ranger Mine and the Jabiru Field Station (JFS) to gain an understanding of operational mining issues from ERA and to observe the monitoring programs undertaken by SSD.

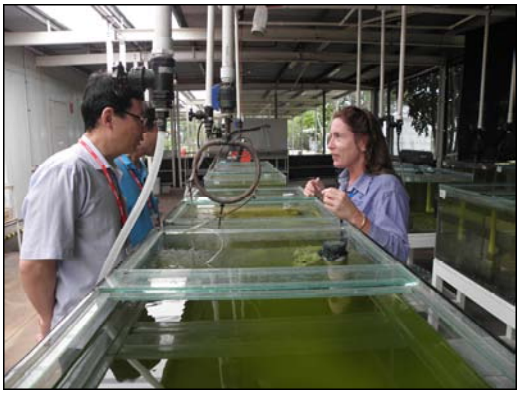

Figure 5.6 JFS Manager Wendy Murray shows the IAEA delegates around the Jabiru Field Station

5.4 Science communication (including conferences)

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 journals and conference papers, and in a range of in-house journals and reports including the Supervising Scientist and Internal Report series – for detailed reporting on scientific projects – and the Supervising Scientist Note series used to showcase specific projects to a wider audience. Other media such as posters and educational or promotional materials are also produced to suit specific requirements or events.

In addition, a number of the Division's staff contribute to external scientific, technical and other professional organisations, including various editorial boards and panels.

The complete Supervising Scientist Report series is available in PDF format on the SSD web site – the move towards electronic distribution supports the Department's policy of reducing its environmental footprint.

A review of the web site is conducted annually so that all information remains current and relevant. The web site subscription facility – incorporating an automatic email notification when a new SSD publication is released – continues to improve the level of service to our stakeholders.

SSD staff presented papers at a number of important national and international conferences during the reporting period:

- 5 papers at the 13th Australasian Society for Ecotoxicology Conference, University of Adelaide, September 2009
- 1 paper at the Combined Australian Entomological Society's 40th AGM & Scientific Conference and Society of Australian Systematic Biologists & 9th Invertebrate Biodiversity and Conservation Conference, Darwin, September 2009
- 1 paper at the 4th International Mine Closure Conference, Perth, September 2009
- 3 papers at the Australian Society for Limnology, Alice Springs Convention Centre, September/October 2009
- 1 paper at the Surveying and Spatial Sciences Institute Biennial International Conference, Adelaide, September/October 2009
- 1 paper at the International Minewater Conference, Pretoria, South Africa, October 2009
- 2 papers at the Australasian Radiation Protection Society Conference, Fremantle, October 2009
- 2 papers at the AusIMM International Uranium Conference. Adelaide, June 2010

SSD staff attended the 11th International Minewater Conference held in Pretoria in October 2009 and the Processing of Low Grade Uranium Ores workshop hosted by the International Atomic Energy Agency in Vienna in March 2010. Participation in international events allows staff to share their knowledge and expertise with peers and maintain awareness of international best practice in relevant areas. Participation is also seen as important in allowing the Supervising Scientist Division to maintain its profile as a part of the broader scientific and technical community.

eriss has continued to contribute to the Kakadu National Park Landscape Change Symposia series being run by Parks Australia. The aims of the symposia are to serve as a forum for knowledge exchange between stakeholders in the Kakadu region, including identifying management issues, emerging threats, knowledge gaps and research needs pertaining to landscape management at local, regional and national scales.

Publications Manager Ann Webb, in conjunction with Steve Winderlich, SallyAnn Atkins and Mim Jambrecina of Parks Operations and Tourism Branch, Kakadu National Park, prepared three more reports in the Kakadu National Park Landscape Symposia Series 2007–2009 for publication in the SSD Internal Report series and also on the SSD web site (www.environment.gov.au/ssd/publications/ir/index.html). Reports on weed management, climate change and fire management have now been completed – they are Internal Reports (IR) 565, 567 and 566 respectively. A report on management of feral animals is forthcoming.

A full list of papers and reports published during 2009–10 is provided in Appendix 2. Papers presented at national and international conferences are listed in Appendix 3.

SSD hosts researchers and visitors from other organisations to undertake collaborative funded projects, for sabbatical periods, or to present seminars or training workshops (Table 5.1).

TABLE 5.1 RESEARCHERS AND OTHER VISITORS, 2009–10

Activity	Visitor/organisation	Date
Field sediment uranium toxicity project	Dr Stuart Simpson, CSIRO Centre for Environmental Contaminants Research	December 2009
Impact of extreme rainfall events on stability of the rehabilitated Ranger landform using the CAESAR Landform Evolution Model	Professor Tom Coulthard, University of Hull	12–24 October 2009
Impact of extreme rainfall events on rehabilitated landform – application of CAESAR to mine-impacted catchments and erosion monitoring/modelling activities (Tin Camp Creek)	Associate Professor Greg Hancock, The University of Newcastle NSW	19–23 October 2009; 10–14 May 2010
Bedload fluxes in Ngarradj Creek catchment Geomorphic characterisation of Gulungul Creek catchment Geoecologic impacts of Cyclone Monica on *Allosyncarpia ternata* rainforest in Ngarradj Creek catchment Extreme event Impacts on the island anabranching East Alligator River	Professor Wayne Erskine, The University of Newcastle NSW, Ourimbah Campus	1 January – 30 June 2010
Workshop on Bayesian methods for determining hazardous concentration in ecotoxicology	Dr David Fox, Director, Australian Centre for Environmetrics, The University of Melbourne	December 2009
Seminar on Radiological protection of the environment: concepts, approaches, and work towards national guidance	Dr Che Doering, Australian Radiation Protection and Nuclear Safety Agency	February 2010

In 2009–10, ***eriss*** staff supervised three post-graduate research projects:

- The influence of dissolved organic carbon on the bioavailability and toxicity of metals to tropical freshwater biota (PhD, The University of Queensland)
- An evaluation of image and field data for vegetation community mapping in tropical savannas (PhD, The University of Queensland)
- Metal resistance in bacteria (PhD, Charles Darwin University)

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*.

Mr Alan Hughes was appointed to the position in December 2005.

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.

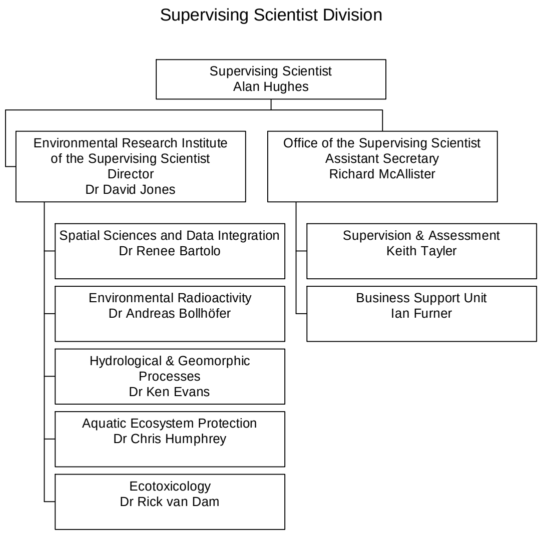

Figure 6.1 Organisational structure of the Supervising Scientist Division (as at 30 June 2010)

The Office of the Supervising Scientist (***oss***) is responsible for supervision, assessment, policy, information management and corporate support activities. Mr Richard McAllister, Assistant Secretary, is the ***oss*** Branch Head.

The Environmental Research Institute of the Supervising Scientist (***eriss***), managed by Dr David Jones, is responsible for scientific research and monitoring activities.

Staffing numbers as at 30 June 2009 and 30 June 2010 are given in Table 6.1.

TABLE 6.1 STAFFING NUMBERS (1) AND LOCATIONS

	2008–2009	2009–2010
Darwin	44	43.0
Jabiru	6	7.5
Total	50	50.5

(1) Average full time equivalent from 1 July to 30 June

6.1.3 Investors in People

The Supervising Scientist Division (SSD) has actively supported and promoted Investors in People initiatives through embedding the framework within strategies, policies and procedures implemented in the workplace. In February 2010 the Department was audited against the Investors in People (IiP) standard and was successful in achieving reaccreditation.

The SSD IiP program is led through a representative Action Group with participation from management and staff from each work program. The group meets regularly to discuss human resource issues with the aim of developing and promoting new initiatives and strategies that contribute to improved performance and workforce capability.

Facilitation of continuous improvement is achieved through the implementation of periodic staff surveys enabling the Department and each Division within the portfolio to gain insight into staff perceptions on the Department's performance against indicators within the IiP framework. SSD has addressed staff concerns through development and implementation of a Divisional Improvement Plan that incorporated strategies to

- improve communication and respect in the workplace
- promote health, wellbeing and work life balance initiatives
- encourage effective performance management
- recognise staff contribution

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. There has also been a significant investment in leadership training and development for all executive level staff. Through the Performance Development Scheme, staff identify training requirements to help deliver their work plan outcomes. SSD staff have access to Canberra-based seminars and information sessions. Locally hosted seminars, in addition to the SSD Internal Seminar Series, provide staff with 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 staff newsletter, *Newsbrief*, that attracts a wide range of internal contributors and readership. Management and staff participate in regular structured meetings that ensure 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.

During 2009–10, the health and wellbeing program offered staff access to health screenings, vaccinations for influenza, hepatitis and tetanus, exercise classes and a team pedometer challenge, quiz events, and internal health and wellbeing seminars on back care, work-life balance, heat stress and hydration, and dealing with the 'challenges of Christmas'.

6.1.4 Occupational Health and Safety

SSD has continued to maintain a strong commitment to occupational health and safety (OH&S) during 2009–10 with a focus on risk management and prevention to reduce workplace hazards. This has been achieved through an education program and encouraging staff to report incidents and near misses not just injuries. As a consequence, there has been an increase in incident reporting with 68% of reports related to a hazard or near miss and 32% related to an injury. Injury reports resulted in three claims being accepted by Comcare.

The Occupational Health and Safety Committee (OHSC) met regularly and was responsible for reviewing and updating a number of OH&S guidelines and procedures related to safety clothing, road travel, risk assessment, incident/hazard reporting, emergency response, emergency evacuation, special vehicle operations and establishment of the Terms of Reference for the Emergency Control Committee (ECC).

All OH&S risks related to SSD operations have been identified and given a risk rating. The risk register has been reviewed by senior management and further controls have been applied to reduce or eliminate high or extreme risks. Road travel and remote field work were identified as specific high level risks for SSD and consequently additional safety measures are being trialled including GPS satellite tracking (with added features of roll over activation and duress alarm) that will allow a vehicle to be located almost immediately in the event of an emergency.

SSD is currently procuring new chemical management software that will enable greater control of the chemicals on site. Chemical audits have been undertaken to ensure compliance with the new ***eriss*** substance labelling/storage protocols.

In 2009–10 there was an emphasis on safety education for staff with seminars on:

- Heat stress and hydration
- Manual handling and back care
- Health and wellbeing examinations
- Fire extinguisher usage
- Warden training
- Respect and courtesy workshops
- 4WD training
- First aid and remote first aid training

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) issues a license to SSD that permits the holding of certain radioactive and non-ionising radiation sources. These sources and general control, safety and management plans are included in the Radiation Source Control Plan of SSD.

6.2 Finance

The Supervising Scientist Division is part of the Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) and full financial statements for the Department are contained in the Department's Annual Report (www.environment.gov.au/about/publications/annual-report/index.html)

A summary of the actual expenses of the Supervising Scientist against the Department's outputs are provided in Table 6.2.

TABLE 6.2 SUMMARY OF DIRECT PROGRAM EXPENSES

PBS Outcome 1	2008–2009	2009–2010*
Program 1.2 – Environmental Regulation, Information and Research	Not applicable	$8 412 344
Output 1.5 – Response to the impacts of human settlements		
Sub-output 1.5.3 – Supervision of uranium mines	No longer reported at sub-output level	Not applicable
Output 1.2 – Conservation of the land and inland waters		
Sub-output 1.2.4 – Tropical wetlands research	No longer reported at sub-output level	Not applicable
Total**	$8 193 605	$8 412 344

* PBS reporting structure changed in 2009–10 with Supervising Scientist Division reporting all activity against Program 1.2 instead of Output 1.5 and Output 1.2.

** Excludes departmental corporate overheads of $3 460 343 in 08–09 and $4 007 235 in 09–10.

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, Water, Heritage and the Arts Darwin facility adjacent to the Darwin International Airport. This facility consists of office accommodation and laboratories. During the year no major works were commissioned, however there are still ongoing problems with air-conditioning and moisture intrusion into the laboratories that are yet to be rectified.

The office space, library and amenities are shared with Parks Australia, which is also part of the Department of the Environment, Water, Heritage and the Arts.

6.3.2 Jabiru Field Station

A Field Station at Jabiru is maintained to support the activities of the Supervising Scientist Division. The staff consists of the monitoring team that carry out the Supervising Scientist's environmental monitoring program, an employee who is responsible for delivering the Supervising Scientist's community liaison program 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.

Figure 6.2 JFS aquaculture facility after installation of new roof and snail tubs

Following demolition or relocation of unused buildings all underground utilities have been removed or decommissioned and reinstatement of the vacant area has commenced. Works have also been undertaken at the Field Station to repair the administrative building and a project is underway to upgrade the aquaculture facility and equipment that supports the snail breeding program.

6.4 Information management

Information management activities provide support to staff based in Darwin and the Jabiru Field Station through library services and the co-ordination of records management activities.

During this period 289 new files were created and 300 files were destroyed under the *Archives Act 1983* and other relevant legislation. The Division's file titling thesaurus has been updated. Efforts to transfer files to the Australian National Archives have stalled and will be recommenced once a new Records Disposal Authority has been developed and approved.

The library continued to provide services to staff including loans, reference services, reader education, and inter-library loans. Integration of the SSD collection into the Department's catalogue has begun. During the reporting period, 209 new items were added to the collection.

In 2010, SSD successfully transitioned from an Oracle-based to a Microsoft-based platform for its electronic document management system. In addition to these activities, a new data structure is being developed to better organise the documents stored in the system.

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 2009–10.

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 2009–10.

6.7 Environmental performance

The Supervising Scientist Division contributes to the department's sustainability objectives through a range of measures aimed at continuously improving the environmental performance of our business operations and minimising any associated environmental impacts. The Division reports on its environmental performance in the Department's 2009–10 Annual Report.

6.7.1 Environmental Management System

The Department has committed to extend the scope of its Environmental Management System (EMS) and associated certification to SSD in the future. In the interim, SSD's operations are conducted in a manner consistent with the Department's aim to minimise the ecological footprint on the environment. This involves a range of strategies including complying with legal and other agreements, actively promoting sustainable work practices, preventing pollution as result of work practices, focus on continuous improvement, public reporting of environmental performance as part of the Department's Annual Report and procurement and use of sustainable goods and services.

6.8 Animal experimentation ethics approvals

eriss seeks the approval of Charles Darwin University's Animal Ethics Committee (AEC) to undertake scientific experiments involving vertebrate animals. Additionally, the Animal Welfare Branch of the Northern Territory Government grants the ***eriss*** premises a licence to use animals for research purposes. This licence includes the laboratories in Darwin and Jabiru, as well as field work conducted in the Alligator Rivers Region.

A final report for the project ‘Larval fish for toxicity tests at ***eriss***’ (ref no 97016) was submitted to the CDU AEC and approved on 18 June 2010. An application for renewal of this project was approved until June 2012. No fish were collected for the project ‘Monitoring mining impact using the structure of fish communities in shallow billabongs’ (ref no A09001) as this survey is conducted bi-annually. This project is due for renewal in February 2011.

The number of fish used in toxicity tests at ***eriss*** was reported in July 2010 to the Northern Territory Government, as part of our licence requirements granted by them permitting the use of animals for research purposes.

Table 6.3 provides information on new applications, renewals of approvals and approval expiries for projects during 2008–09.

TABLE 6.3 ANIMAL EXPERIMENTATION ETHICS APPROVALS

Project title	Ref no	Initial submission	Approval/latest renewal	Expiry
Larval fish toxicity testing at ***eriss***	97016	26 May 1997	18 June 2010	18 June 2012
Monitoring mining impact using the structure of fish communities in shallow billabongs	A00028/ A09001	25 Sep 2000	8 Mar 2009	27 Feb 2011

APPENDIX 1 ARRTC KEY KNOWLEDGE NEEDS 2008–2010: URANIUM MINING IN THE ALLIGATOR RIVERS REGION

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 2012. This will be followed by milling until about 2020 and final rehabilitation expected to be completed by about 2026;
- 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 may provide valuable data for consideration in the design and implementation of rehabilitation at Ranger;
- Jabiluka will remain in a care and maintenance condition for some years. ERA, the project owner, has stated that further mining will not occur without the agreement of the traditional owners; and
- grant of an exploration title at Koongarra is required under the terms of the *Aboriginal Land Rights (Northern Territory) Act 1976* before the mining company can apply for a mining title. As such, any future activity at Koongarra is subject to the agreement of the traditional owners and the Northern Land Council.

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 ensure the research and monitoring strategy is flexible enough to accommodate any new knowledge needs.

The Australian 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 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.

A secondary environmental objective applies to water quality and is linked to the primary ERs. This ER states:

> The company must not allow either surface or ground waters arising or discharging from the Ranger Project Area during its operation, or during or following rehabilitation, to compromise the achievement of the primary environmental objectives.

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

'Key Knowledge Needs 2008–2010: Uranium mining in the Alligator Rivers Region' is based on and supersedes a predecessor document, 'Key Knowledge Needs 2004–2006: Uranium mining in the Alligator Rivers Region'. KKNs 2004–2006 remained the operative set during their review and the development of KKNs 2008–2010.

While some KKNs remain essentially unchanged, others contain revised elements or are new in their entirety. Care should be exercised if using KKN numbers alone as a reference because some continuing KKNs have changed numbers in the revised document.

1 Ranger – Current operations

1.1 Reassess existing threats

1.1.1 Surface water transport of radionuclides

Using existing data, assess the present and future risks of increased radiation doses to the Aboriginal population eating bush tucker potentially contaminated by the mining operations bearing in mind that the current traditional owners derive a significant proportion of their food from bush tucker.

1.1.2 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

1.2.1 Ecological risks via the surface water pathway

Off-site contamination during mine operation (and subsequent to decommissioning – refer KKN 2.6.1) should be placed in a risk-based context. A conceptual model of the introduction, movement and distribution of contaminants, and the resultant biotic exposure (human and non-human) has been developed, and the ecological risks (ie probability of occurrence x severity of consequence) of some of the contaminant/pathway sub-models have been estimated. This process should be completed for all the contaminant/pathway sub-models, noting, however, that the level of effort for each needs to be proportionate to the level of concern of the issue~~.~~ It is critical that robust risk assessment methodologies are used, and that they explicitly incorporate uncertainty in both the assessment and subsequent decision making processes. Where ecological risk is significant, additional information may be required (eg. mass-balance and concentration dynamics, consideration of possible interactive effects, field data). Further, knowledge gaps preventing reasonable estimation of potential risks (ie with unacceptable uncertainty) must be filled.

The Magela floodplain risk assessment framework developed to estimate and compare mining and non-mining impacts should be revisited periodically, and updated to the current risk profile. It should be revised in the event that either **(i)** the annual monitoring program or other sources indicate that the inputs from mining have significantly increased relative to the situation in 2005, or **(ii)** an additional significant contaminant transport pathway from the minesite is identified, or **(iii)** there is a change in external stressors that could result in a significant increase in likelihood of impacts from the site.

1.2.2 Land irrigation

Investigations are required into the storage and transport of contaminants in the land irrigation areas particularly subsequent to decommissioning. Contaminants of interest/concern in addition to radionuclides are magnesium, sulfate and manganese. Results from these investigations should be sufficient to quantify the role of irrigation areas as part of satisfying KKN 1.2.1, and form the basis for risk management into the future.

1.2.3 Wetland filters

The key research issue associated with wetland filters in relation to ongoing operations is to determine whether their capacity to remove contaminants from the water column will continue to meet the needs of the water management system in order to ensure protection of the downstream environment. Aspects of contaminant removal capacity include (i) instantaneous rates of removal, (ii) temporal performance – including time to saturation, and (iii) behaviour under ‘breakdown’ conditions – including future stability after closure. Related to this is a reconciliation of the solute mass balance particularly for the Corridor Creek System (see KKN 1.2.5).

1.2.4 Ecotoxicology

Past laboratory studies provide a significant bank of knowledge regarding the toxicity of two of the major contaminants, uranium and magnesium, associated with uranium mining in the ARR. Further studies are scheduled to assess (i) the toxicity of manganese and, potentially, ammonia (in the event that permeate produced by process water treatment will contain potentially toxic ammonia concentrations), and (ii) the relationship between dissolved organic matter and uranium toxicity. This knowledge should continue to be synthesised and interpreted, within the existing risk assessment framework (refer KKN 1.2.1), as it comes to hand.

An additional issue that needs to be addressed is the direct and indirect effects on aquatic biota of sediment arising from the mine site. In the first instance, a conceptual model needs to be developed (building on the relevant components of the conceptual model developed under KKN 1.2.1) that describes the movement of sediment within the creek system, including the associated metal-sediment interactions and biological implications. Studies likely to arise from the outcomes of the conceptual model include:

- the effects of suspended sediment on aquatic biota;
- the relationship between suspended sediment and key metals, and how this affects their bioavailability and toxicity; and
- the effects of sediment-bound metals to benthic biota, including, initially, a review of existing information on uranium concentrations in sediments of waterbodies both on- and off the Ranger site, and uranium sediment toxicity to freshwater biota.

Whilst of relevance at present, the above issues will be of additional importance as Ranger progresses towards closure and rehabilitation (refer KKN 2.6.1). Finally, the need for studies to assess the toxicity of various mine waters (treated and untreated) in response to specific supervisory/regulatory or operational requirements is likely to continue.

1.2.5 Mass balances and annual load limits

With the expansion of land application areas and the increase in stockpile sheeting that has occurred in concert with the expansion of the footprints of the waste rock dumps and low grade ore stockpiles, it is becoming increasingly important to develop a solute mass balance for the site – such that the behaviour of major solute source terms and the spatial and temporal contribution of these sources to water quality in Magela Creek can be clearly understood. Validated grab sample and continuous data records are needed to construct a high reliability solute mass balance model.

Related to mass balance is the issue of specifying allowable annual load limits from the site – as part of the site's regulatory requirements. The technical basis for these load limits needs to be reviewed since they were originally developed decades ago. There has since been significantly increased knowledge of the environmental geochemistry of the site, a quantum increase in knowledge about ecotoxicological sensitivity of the aquatic systems and updated data on the diet profile of traditional owners.

1.3 Monitoring

1.3.1 Surface water, groundwater, chemical, biological, sediment, radiological monitoring

Routine and project-based chemical, biological, radiological and sediment monitoring should continue, together with associated research of an investigative nature or necessary to refine existing, or develop new (promising) techniques and models. A review of current water quality objectives for Ranger should be conducted to determine if they are adequate for future water management options for the whole-of-site, including the closure and rehabilitation phase (KKN 2.2.1 and KKN 2.2.2).

ARRTC supports the design and implementation of a risk-based radiological monitoring program based on a robust statistical analysis of the data collected over the life of Ranger necessary to provide assurance for Aboriginal people who source food items from the Magela Creek system downstream of Ranger.

2 Ranger – Rehabilitation

2.1 Reference state and baseline data

2.1.1 Defining the reference state and baseline data

There is a requirement to define the baseline data/reference state that existed at the Ranger site prior to development. This will inform the process of the development of closure criteria which is compatible with the Environmental Requirements. The knowledge need is to develop and perform analysis to generate agreed reference data that cover the range of pre-mining and operational periods.

2.2 Landform

2.2.1 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 programs listed below.

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

2.2.2 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 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.

2.2.3 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.

There is a need to develop and analyse conceptual models of mine related turbidity and salinity impacts following closure. These models could be analysed in a variety of ways as a precursor to the development of a quantitative model of potential turbidity and salinity impacts offsite caused by surface and subsurface water flow off the rehabilitated mine site. This analysis should explicitly acknowledge knowledge uncertainty (eg plausible alternative conceptual models) and variability (eg potential for Mg/Ca ratio variations in water flowing off the site) and explore the potential ramifications for the off-site impacts. (see also KKN 2.6.1)

2.2.4 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.

2.2.5 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 exhalation 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 use of potential analogue sites for establishing pre-mining radiological conditions at Ranger should be further investigated to provide information on parameters such as pre-mining gamma dose rates, radon exhalation rates, and levels of radioactivity in dust. This information is needed to enable estimates to be made of the likely change in radiation exposure when accessing the rehabilitated site compared to pre-mining conditions.

2.3 Groundwater dispersion

2.3.1 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 and transfer (including TD to Pit #3) 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.

2.3.2 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.

There is a specific need to address the existence of groundwater 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. 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.

2.3.3 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.

2.3.4 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

2.4.1 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. A priority should be evaluation of the potential impact of treatment sludge and brine streams on long term tailings chemistry in the context of closure planning and potential post closure impacts on water quality.

2.4.2 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. Research is needed to establish the effect of wet-dry seasonal cycling on contaminant retention and release, since this aspect will influence design criteria and whether such wetlands should be maintained as ephemeral or perennial waterbodies There is also the need to assess the long-term behaviour of the physical and biotic components of the wetlands, their ecological health, and the extent of contaminant accumulation (both metals and radionuclides) in the context of potential human exposure routes.

2.5 Ecosystem establishment

2.5.1 Development and agreement of closure criteria from ecosystem establishment perspective

Closure criteria need to be established for a range of ecosystem components including surface water quality, flora and fauna. The environmental requirements provide some guidance but characterisation of the analogue ecosystems will be an important step in the process. Consultation on closure criteria with the traditional owners has commenced and it is important that this process continues as more definitive criteria are developed.

2.5.2 Characterisation of terrestrial and aquatic ecosystem types at analogue sites

Identification and characterisation of analogue ecosystems (target habitats) can assist in defining the rehabilitation objective and developing robust, measurable and ecologically-based closure criteria. The concept of using analogue ecosystems for this purpose has been accepted by ARRTC and the traditional owners. Substantial work has been undertaken on the Georgetown terrestrial analogue ecosystem while there is also a large body of information available on aquatic analogues, including streams and billabongs. Future work on the terrestrial analogue needs to address water and nutrient dynamics, while work on the aquatic analogue will include the development of strategies for restoration of degraded or removed natural waterbodies, Coonjimba and Djalkmara, on site.

2.5.3 Establishment and sustainability of ecosystems on mine landform

Research on how the landform, terrestrial and aquatic vegetation, fauna, fauna habitat, and surface hydrology pathways will be reconstructed to address the Environmental Requirements for rehabilitation of the disturbed areas at Ranger is essential. Trial rehabilitation research sites should be established that demonstrate an ability by the mine operator to be able to reconstruct terrestrial and aquatic ecosystems, even if this is at a relatively small scale. Rehabilitation establishment issues that need to be addressed include species selection; seed collection, germination and storage; direct seeding techniques; propagation of species for planting; fertiliser strategies and weathering properties of waste rock. Rehabilitation management issues requiring investigation include the stabilisation of the land surface to erosion by establishment of vegetation, return of fauna; the exclusion of weeds; fire management and the re-establishment of nutrient cycles. The sustainable establishment and efficiency of constructed wetland filters, reinstated waterbodies (eg Djalkmara Billabong) and reconstructed waterways also needs to be considered (see KKN 2.3.2).

2.5.4 Radiation exposure pathways associated with ecosystem re-establishment

Radionuclide uptake by terrestrial plants and animals on the rehabilitated ecosystem may have a profound influence on the potential utilisation of the land by the traditional owners. Significant work has been completed on aquatic pathways, particularly the role of freshwater mussels, and this now forms part of the annual monitoring program. The focus is now on the terrestrial pathways and deriving concentration factors for Bushtucker such as wallabies, fruits and yams. A project investigating the contemporary diet of traditional owners has commenced and needs to be completed. Models need to be developed that allow exposure pathways to be ranked for currently proposed and future identified land uses, so that identified potentially significant impacts via these pathways can be limited through appropriate design of the rehabilitation process.

2.6 Monitoring

2.6.1 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. The monitoring regime should address the key issues identified by the ecological risk assessment of the rehabilitation phase (KKN 2.7.1).

2.6.2 Off-site monitoring during and following rehabilitation

Building upon the program developed and implemented for the operational phase of mining, a monitoring regime is also required to assess rehabilitation success with respect to protection of potentially impacted ecosystems and environmental values. This program should address the dispersion of contaminants by surface water, ground water and via the atmosphere. The monitoring regime should address the key issues identified by the ecological risk assessment of the rehabilitation phase (KKN 2.7.1).

2.7 Risk assessment

2.7.1 Ecological risk assessments of the rehabilitation and post rehabilitation phases

In order to place potentially adverse on-site and off-site issues at Ranger during the rehabilitation phase within a risk management context, it is critical that a robust risk assessment framework be developed with stakeholders. The greatest risk is likely to occur in the transition to the rehabilitation phase, when active operational environmental management systems are being progressively replaced by passive management systems. A conceptual model of transport/exposure pathways should be developed for rehabilitation and post rehabilitation regimes and the model should recognise the potential that some environmental stressors from the mine site could affect the park and vice versa. Implicit in this process should be consideration of the effects of extreme events and climate change.

Conceptual modelling should be followed by a screening process to identify and prioritise key risks for further qualitative and/or quantitative assessments. The conceptual model should be linked to closure criteria and post-rehabilitation monitoring programs, and be continually tested and improved. Where appropriate, risk assessments should be incorporated into decision making processes for the closure plan. Outputs and all uncertainties from this risk assessment process should be effectively communicated to stakeholders.

2.8 Stewardship

The concept of Stewardship (including ownership and caring for the land) is somewhat broader and applies to all phases of, in this case, uranium mining. In this context it is considered to be the post closure phase of management of the site, ie after relinquishment of the lease. If the rehabilitation phase is successful in meeting all objectives then this stewardship will effectively comprise an appropriate level of ongoing monitoring to confirm this. Should divergence from acceptable environmental outcomes be detected then some form of intervention is likely to be required. The nature, responsibility for, and duration of, the monitoring and any necessary intervention work remains to be determined.

3 Jabiluka

3.1 Monitoring

3.1.1 Monitoring during the care and maintenance phase

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

3.2 Research

3.2.1 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 radiological data, 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

4.1 Success of revegetation

4.1.1 Revegetation assessment

Several assessments of the revegetation at Nabarlek have been undertaken; the most recent being completed by ***eriss***. There is now general agreement that the rehabilitated areas require further work. Revised closure criteria are currently being developed through the mine-site technical committee and these should be reviewed by relevant stakeholders, including ARRTC. The required works should then be completed on site with further monitoring leading to the relinquishment of the lease.

4.1.2 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 in comparison to ground survey methods should continue. The outcomes of this research will be very relevant to Ranger.

4.2 Assessment of radiological, chemical and geomorphic success of rehabilitation

4.2.1 Overall assessment of rehabilitation success at Nabarlek

The current program 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 significant radiological exposure pathways should be identified and a comprehensive radiation dose model developed. Additional monitoring of ground water plumes is required to allow assessment of potential future groundwater surface water interaction and possible environmental effects.

5 General Alligator Rivers Region

5.1 Landscape scale analysis of impact

5.1.1 Develop a landscape-scale ecological risk assessment framework for the Magela catchment that incorporates, and places into context, uranium mining activities and relevant regional landscape processes and threats, and that builds on previous work for the Magela floodplain

Ecological risks associated with uranium mining activities in the ARR, such as current operations (Ranger) and rehabilitation (Nabarlek, Jabiluka, future Ranger, South Alligator Valley), should be assessed within a landscape analysis framework to provide context in relation to more diffuse threats associated with large-scale ecological disturbances, such as invasive species, unmanaged fire, cyclones and climate change. Most key landscape processes occur at regional scales, however the focus will be on the Magela catchment encompassing the RPA. A conceptual model should first be developed to capture links and interactions between multiple risks and assets at multiple scales within the Magela catchment, with risks associated with Ranger mining activities made explicit. The spatially explicit Relative Risk Model will be used to prioritise multiple risks for further qualitative and/or quantitative assessments. The conceptual model and risk assessment framework should be continually tested and improved as part of Best Practice. Where appropriate, risk assessments should be incorporated into decision making processes using advanced risk assessment frameworks such as Bayesian Networks, and all uncertainties made explicit. This risk assessment process should integrate outputs from KKN 1.2.1 (risks from the surface water pathway – Ranger current operations) and the new KKN 2.6.1 (risks associated with rehabilitation) to provide a landscape-scale context for the rehabilitation of Ranger into Kakadu National Park, and should be communicated to stakeholders.

5.2 South Alligator River valley rehabilitation

5.2.1 Assessment of past mining and milling 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 program and conducts a low level radiological monitoring program. This work should continue.

5.3 Develop monitoring program related to West Arnhem Land exploration activities

5.3.1 Baseline studies for biological assessment in West Arnhem Land

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 in areas where advanced exploration or proposed mining projects are identified and in line with the current approvals process under the Aboriginal Land Rights Act**.**

5.4 Koongarra

5.4.1 Baseline monitoring program for Koongarra

In line with the current approvals process under the Aboriginal Land Rights Act, a low level monitoring program should be developed for Koongarra to provide baseline data in advance of any possible future development at the site. Data from this program could also have some relevance as a control system for comparison to Ranger, Jabiluka and Nabarlek.

Appendix 2 Publications for 2009–2010

Published[6]

Bartolo R, van Dam R & Bayliss P 2010. Regional ecological risk assessment for Australia's tropical rivers: Application of the Relative Risk Model. *Human and Ecological Risk Assessment.* (in press)

Bayliss P, van Dam R & Bartolo R 2010. Quantitative ecological risk assessment of Magela Creek floodplain on Kakadu National Park: comparing point source risks from Ranger uranium mine to diffuse landscape-scale risks. *Human and Ecological Risk Assessment.* (in press)

Bollhöfer A, Brazier J, Humphrey C, Ryan B & Esparon A 2010. A study of radium bioaccumulation in freshwater mussels, *Velesunio angasi*, in the Magela Creek catchment, Northern Territory, Australia. *Journal of Environmental Radioactivity*: In Press, Available online 28 April 2010 doi:10.1016/j.jenvrad.2010.04.001.

Cheng KL, Parry DL, Hogan AC, Markich SJ, Harford AJ & van Dam RA 2010. Uranium toxicity and speciation following chronic exposure to the tropical freshwater fish, *Mogurnda mogurnda*. *Aquatic Toxicology* 79(5), 547–554.

Frostick A, Bollhöfer A & Parry D (in press). A study of radionuclides, metals and stable lead isotope ratios in sediments and soils in the vicinity of natural U-mineralisation areas in the Northern Territory, Australia. *Journal of Environmental Radioactivity* (2010), doi:10.1016/j.jenvrad.2010.04.003.

Hancock, GR, Lowry JBC, Coulthard TJ, Evans KG & Moliere DR 2010. A catchment scale evaluation of the SIBERIA and CAESAR landscape evolution models. *Earth Surface Processes and Landforms* 35(8), 863–876.

Hogan AC, van Dam RA, Houston MA, Harford AJ & Nou S 2010. Uranium exposure to the tropical duckweed, *Lemna aequinoctialis*, and pulmonate snail, *Amerianna cumingi*: fate and toxicity. *Archives of Environmental Contamination and Toxicology* 59, 204–215.

Jones DR & Webb A (eds) 2010. ***eriss*** *research summary 2008–2009*. Supervising Scientist Report 201, Supervising Scientist, Darwin NT.

Jones DR, Humphrey C, van Dam R, Harford A, Turner K & Bollhöfer A 2009. Integrated chemical, radiological and biological monitoring for an Australian uranium mine: a best practice case study. In *Proceedings International Mine Water Conference*, 19–23 October, Pretoria, South Africa, Water Institute of South Africa, ISBN 978-0-9802623-5-3, 95–104.

6 Includes presentations to conferences and symposia that have been externally published in 2009–10.

Lowry JBC, Evans KG, Coulthard TJ, Hancock GR & Moliere DR 2009. Assessing the impact of extreme rainfall events on the geomorphic stability of a conceptual rehabilitated landform in the Northern Territory of Australia. In *Mine Closure 2009. Proceedings of the Fourth International Conference on Mine Closure*, 9–11 September 2009, Perth, Australia, eds A Fourie & M Tibbett, 203–212.

Lowry J, Hess L & Rosenqvist A 2009. Mapping and monitoring wetlands around the world using ALOS PALSAR: the ALOS Kyoto and Carbon Initiative wetland products. In *Lecture Notes in Geoinformation and Cartography - Innovations in Remote Sensing and Photogrammetry,* eds. S Jones & K Reinke. Springer-Verlag, Berlin, 105-120.

Moliere DR & Evans KG 2010. Development of trigger levels to assess catchment disturbance on stream suspended sediment loads in the Magela Creek, Northern Territory, Australia. *Geographical Research*, Article first published online 24 Feb 2010, DOI: 10.1111/j.1745-5871.2010.00641.x

van Dam RA, Harford AJ, Houston MA, Hogan AC & Negri AP 2008. Tropical marine toxicity testing in Australia: A review and recommendations. *Australasian Journal of Ecotoxicology* 14(2/3), 55–88. (published December 2009)

van Dam RA, McCullough CD, Hogan AC, Houston MA, Harford AJ & Humphrey CL 2010. Aquatic toxicity of magnesium sulphate, and the influence of calcium, in very low ionic concentration water. *Environmental Toxicology & Chemistry* 29(2), 410–421.

Warne M & van Dam R 2008. NOEC and LOEC data should no longer be generated or used. *Australasian Journal of Ecotoxicology* 14(1), 1–5. (published October 2009)

Unpublished papers and reports

Alligator Rivers Region Advisory Committee 2010. Alligator Rivers Region Advisory Committee 31st Meeting, April 2009, Darwin, Meeting papers. Internal Report 572, March, Supervising Scientist, Darwin. Unpublished paper.

Atkins S & Winderlich S (ed) 2010. Kakadu National Park Landscape Symposia Series 2007–2009. Symposium 3: Fire management, 23–24 April 2008, Aurora Kakadu (South Alligator), Kakadu National Park. Internal Report 566, February, Supervising Scientist, Darwin.

Buckle D, Storey A, Humphrey C & Chandler L 2010. Fish and macroinvertebrate assemblages of the upper Ord River catchment. Internal Report 559, January, Supervising Scientist, Darwin.

Harford AJ, Hogan AC & van Dam RA 2010. Ecotoxicological assessment of a polyelectrolyte flocculant. Internal Report 575, June, Supervising Scientist, Darwin.

Jambrecina M & Winderlich S 2010. Feral animal management workshop, IR568

Jones D (ed) 2010. ***eriss*** Strategic Planning and Evaluation Workshop, August 2009. Internal Report 564, January, Supervising Scientist, Darwin. Unpublished Paper.

Jones DR & Turner K 2010. Surface water quality monitoring at the Rum Jungle Mine Site, 2008–09 wet season. Internal Report 578, June, Supervising Scientist, Darwin.

Jones DR (ed) 2010. ***eriss*** communication and planning workshop – 09/10 workplan and proposed 10/11 directions. Internal Report 569, May, Supervising Scientist, Darwin. Unpublished paper.

Madon E 2009. Potential impacts of ammonia on the natural environment from the land application of effluent water at the Ranger mine. Internal Report 562, November, Supervising Scientist, Darwin. Unpublished Paper.

McAllister R & Tayler K 2010. Operation of the INB heap leach facility at Caetité, Bahia State, Brazil. Internal Report 577, June, Supervising Scientist, Darwin. Unpublished paper.

Medley P 2009. A review of chemical storage and handling protocols in the Environmental Radioactivity laboratories of ***eriss***. Internal Report 548, September, Supervising Scientist, Darwin. Unpublished Paper

Medley P 2010. Barium sulphate method for consecutive determination of radium-226 and radium-228 on the same source. Internal Report 544, April, Supervising Scientist, Darwin.

Ryan B & Bradley F 2010. Preliminary report into the characterisation of groundwater at the Rum Jungle mine site: Consultancy report for Department of Resources, Energy and Tourism. Internal Report 570, February, Supervising Scientist, Darwin. Unpublished paper.

Ryan B, Bradley F & Bollhöfer A 2010. Final report into the characterisation of groundwater at the Rum Jungle mine site: Consultancy report for Department of Resources, Energy and Tourism. Internal Report 571, February, Supervising Scientist, Darwin. Unpublished paper.

Saynor M, Houghton R, Erskine W, Smith B & Crisp E 2010. Cross section, scour chain and particle size data for Gulungul and Ngarradj Creeks: 2006 to 2009. Internal Report 574, April, Supervising Scientist, Darwin.

Supervising Scientist 2010. Rehabilitation of Rockhole Mine Creek: Report to NT World Heritage Ministerial Council, December 1999. Internal Report 537, March, Supervising Scientist, Darwin. Unpublished paper.

Winderlich S (ed) 2010. Kakadu National Park Landscape Symposia Series 2007–2009. Symposium 2: Weeds management. 27–28 November 2007, Jabiru Field Station, Supervising Scientist Division, Kakadu National Park. Internal Report 565, January, Supervising Scientist, Darwin.

Winderlich S (ed) 2010. Kakadu National Park Landscape Symposia Series 2007–2009. Symposium 4: Climate change. 6–7 August 2008, Gagudju Crocodile Holiday Inn, Kakadu National Park. Internal Report 567, January, Supervising Scientist, Darwin.

Consultancy reports

Boyden J 2010. Waterbirds data and related environmental datasets collated by SSD for the Northern Australia Water Futures Assessment (Ecological assets sub-project). March 2010.

Jones, DR, Humphrey C & van Dam R 2010. Review of water, sediment and biota data for Page and Lawn Hill Creeks. Commercial-in-Confidence Report for Metals and Mining Group – Century, February 2010.

Ryan B & Bradley F 2010. Preliminary report into the characterisation of groundwater at the Rum Jungle mine site: Consultancy report for Department of Resources, Energy and Tourism. Supervising Scientist, Darwin.

Ryan B, Bradley F & Bollhöfer A 2010. Final report into the characterisation of groundwater at the Rum Jungle mine site: Consultancy report for Department of Resources, Energy and Tourism. Supervising Scientist, Darwin.

APPENDIX 3 PRESENTATIONS TO CONFERENCES AND SYMPOSIA, 2009–2010[7]

Akber R, Lu P & Bollhöfer A 2009. Uranium series disequilibrium in soils in areas used for water disposal through spray irrigation at ERA Ranger Uranium Mine. Paper presented at 2009 Australasian Radiation Protection Society (ARPS) Conference, Fremantle 26–28 October 2009.

Bollhöfer A, Esparon A, Ryan B & Pfitzner K 2009. Investigating a pre-mining radiological analogue for Ranger Uranium mine, Northern Territory, Australia. Paper presented at 2009 Australasian Radiation Protection Society (ARPS) Conference, Fremantle 26–28 October 2009.

Buckle D, Humphrey C & Davies C 2009. *Fish community monitoring in tropical shallow billabongs and the influence of aquatic vegetation*. Paper presented at Australian Society for Limnology, Alice Springs Convention Centre, 28 September – 2nd October 2009.

Cheng K, Parry D, Hogan A, Markich S & van Dam R 2009. Uranium speciation and toxicity following chronic exposure to the tropical freshwater fish, *Mogurnda mogurnda*. Paper presented at the 13th Australasian Society for Ecotoxicology Conference, 20–23 September 2009, University of Adelaide, Adelaide.

Harford A, Saynor M, Hogan A, Cheng K, White D & van Dam R 2009. The development of water quality guidelines for suspended sediments in Magela Creek. Paper presented at the 13th Australasian Society for Ecotoxicology Conference, 20–23 September 2009, University of Adelaide, Adelaide.

Hogan A, van Dam R, Harford A, Cheng K & Turner K 2009. Effects of Mg pulse exposures on tropical freshwater Australian species. Paper presented at the 13th Australasian Society for Ecotoxicology Conference, 20–23 September 2009, University of Adelaide, Adelaide.

Houston M, Ng J, Noller B, Markich S & van Dam R 2009. Amelioration of uranium toxicity by dissolved organic carbon from a tropical Australian billabong. Paper presented at the 13th Australasian Society for Ecotoxicology Conference, 20–23 September 2009, University of Adelaide, Adelaide.

Humphrey C & Chandler L 2009. Taxonomic resolution for biological assessment of mining impacts in tropical streams of the Northern Territory. Paper presented at the Combined Australian Entomological Society's 40th AGM & Scientific Conference and Society of Australian Systematic Biologists and 9th Invertebrate Biodiversity & Conservation Conference, 25–28 September 2009, Darwin.

7 Presentations to conferences and symposia that have been externally published in 2009–10 are included in Appendix 2.

Humphrey C, Davies C, Buckle D & McGuinness K 2009. *Development of cost-effective, ‘early warning’ techniques to monitor and assess changes in water quality*. Paper presented at Australian Society for Limnology, Alice Springs Convention Centre, 28 September – 2nd October 2009.

Humphrey C, McGuinness K & Douglas M 2009. *Experimental design considerations for monitoring of macroinvertebrate communities in tropical seasonally-flowing streams*. Paper presented at Australian Society for Limnology, Alice Springs Convention Centre, 28 September – 2nd October 2009.

Jones D, Humphrey C, van Dam R, Harford A, Turner K & Bollhöfer A 2009. Integrated chemical, radiological and biological monitoring for an Australian uranium mine – a best practice case study. Paper presented at International Minewater Conference, Pretoria, October 2009.

Staben G, Saynor M & Lowry J 2009. Mapping landslides in northern Australia using object based classification techniques. Paper presented at Surveying and Spatial Sciences Institute Biennial International Conference, 28 September – 2 October 2009, Adelaide Convention Centre, Adelaide, Australia.

Tayler K & Bush M 2010. Stakeholder cooperation: Regulating a uranium mine with multiple statutory approvals. Paper presented at 2010 AUSIMM Uranium Conference, Adelaide, 16–17 June 2010.

Warne M StJ & van Dam R 2009. 101 reasons to stop generating and using hypothesis based toxicity estimates – NOECs and LOECs should be banned. Paper presented at the 13th Australasian Society for Ecotoxicology Conference, 20–23 September 2009, University of Adelaide, Adelaide.

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Feedback on the Supervising Scientist 2009–10 Annual Report

We hope we have presented a comprehensive and informative account of the activities of the Supervising Scientist Division during 2009–2010.

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 Sustainability, Environment, Water, Population and Communities web site:

www.environment.gov.au/about/publications/annual-report/

More Information

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

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

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