Part 5: General Alligator Rivers Region

Undertake an ecological risk assessment of Magela floodplain to differentiate mining and non-mining impacts

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Introduction

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

Two key results from the ecological risk assessment of the Magela floodplain reported at ARRTC 20 (October 2007) were that: (i) the overall findings of the landscape ecological risk assessment to date suggest strongly that non-mining landscape-scale risks to Magela floodplain should now receive the same level of scrutiny as that applied to uranium mining risks, including an assessment of what appropriate level of investment would be needed to manage these risks; and that (ii) of the landscape-scale ecological risks, damage from para grass > feral pigs > unmanaged fire. In this context it should be noted the current difference between non-mining and potential mining-related risk pathways may reduce when on-site water management systems at Ranger change in the transition between mine production and mine closure and rehabilitation. The transition between operations and closure requires a detailed and explicit risk assessment in itself.

Update: Fire and weed disturbance as landscape factors influencing vegetation development: implications for minesite revegetation

A key knowledge need identified by the Alligator Rivers Region Technical Committee (ARRTC) for rehabilitation of the final post-mining landform at Ranger is an understanding of the relationships between native vegetation communities and the physical environment. This knowledge is essential to identify revegetation management goals that optimise establishment of a sustainable vegetation community for rehabilitation of the site.

In this context, disturbance regimes (such as fire) are a key component of the physical environment affecting the development and composition of vegetation communities. Two landscape scale projects were undertaken during 2007–08 within Kakadu National Park (KNP) (including the Ranger Project Area) to: (i) assess the influence of fire on native vegetation

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communities; and (ii) to assess which environmental factors, including fire history, are significantly correlated with the distribution of two major grassy weeds, annual and perennial mission grass (*Pennisetum* spp). These two weed species are important because not only can they compete with native grasses and groundcover species but they can also increase fuel loads in areas in which they become established and hence increase the risk of high intensity fires.

The first study investigated the relationships between plant species diversity, ecological attributes of plants, and fire disturbance history (derived from Landsat satellite fire scar data) at 154 vegetation survey sites located through the Alligator Rivers Region (including the Ranger Project Area) and eastern Arnhem Land regions. The specific aims were to determine the relative importance of mean fire interval, late dry season fire frequency and early dry season fire frequency on the presence and absence of plant species. It was concluded that savannas are dynamic systems which are partially driven by variation in fire frequency and severity, thereby creating a mosaic of species that shift over time.

Sites with frequent fire, particularly late dry season (higher intensity) fire, were negatively related to species diversity. Furthermore, sites with longer mean intervals between burns were more likely to reflect a higher mix of species from different functional groups, such as ground cover species with a lifespan greater than 5 years. These findings are relevant to the management of the KNP region since changing disturbance regimes may alter the presence and diversity of different plant functional groups and species with differing life-histories. At the broader landscape scale, management incorporating a variety of fire regimes will promote biodiversity through the persistence of a savanna patch mosaic. The findings are also of relevance to minesite rehabilitation where an appropriate fire management strategy would be required during the early years following initial planting of vegetation. Exclusion of fire, especially higher intensity fire, for at least 5 years in the initial re-vegetation phase, will promote the establishment of ground and tree species that require fire-free intervals (of 5 to 10 years) to colonise and reproduce. Temporary fire exclusion may also aid in the establishment of deeper rooted perennial grasses that, compared to annual grass species, provide greater stability to soils and aid their biological development. After the vegetation establishment phase, fire frequency might be increased in line with the surrounding savanna woodlands in the Kakadu landscape. However, this would also need to assessed against other criteria used to measure the sucess of revegetation.

The second study used available spatial data on the distribution of annual and perennial mission grass in Kakadu and surrounds to assess the relationships with environmental factors such as fire history. Mission grass is commonly associated with disturbed areas, including minesites. As it is a potential threat to the successful rehabilitation of mine sites in the Alligator Rivers Region, it is important to understand the factors influencing the distribution of mission grass, as well as any potential ecological impact. A GIS approach has been used to discern broad scale factors that influence the distribution and fire behaviour of mission grass.

Results from the analysis indicate that mission grass can persist in a broad variety of vegetation communities, and that the strongest predictor of mission grass presence (apart from proximity to other patches of mission grass) is human activity (eg roads and settlements). This is likely due to a combination of the transportation of seed by vehicles, and increased disturbance near settled areas. Although cosmopolitan, the incidence of mission grass was reduced in areas of high overstory cover, prolonged seasonal inundation, or skeletal soils. Low lying, open habitats had the highest association with mission grass. Additionally a weak, yet significant, association was detected between fire and mission grass distribution in that lower fire frequency was associated with mission grass presence.

The findings support the current control regime, where eradication efforts focus on known colonies and new patches of mission grass as they appear, and controlling the spread of mission grass through human activity. Eradication and prevention of weed establishment is particularly important in areas of high local disturbance, such as the Ranger minesite and environs. Active weed control efforts, currently in place on the minesite, would in all likelihood be required to continue during the initial years following rehabilitation of the site, while the desired vegetation species are becoming established. This will also be important given the potential for the transport of seed from known weed colonies in the surrounding Park and on the mining lease.

Further investigation is warranted, particularly in regard to the fire management of mission grass affected areas. The more relevant questions regarding the interaction of fire and mission grass may be (i) what is the impact of mission grass on fire intensity rather than on frequency; and (ii) what is the impact of fire frequency on the spread of mission grass? Both of these would be best tested experimentally, although there may be some regions where the temporal record of mission grass distribution is sufficient to attempt such an analysis using the satellite record.

Definition of sediment sources and their effect on contemporary catchment erosion rates in the Alligator Rivers Region

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Introduction

The 2006–07 wet season was the wettest on record for Jabiru. A total of 2600 mm of rain was recorded. Most of this (1940 mm) fell in February and March 2007, with 737 mm over a three-day period between February 28 and March 2 (Moliere et al 2007). The most intense period of rainfall occurred during the morning of 1 March 2007. The rainfall and the associated flood event was greatly in excess of a 1 in 100 year occurrence and had widespread impacts across the East Alligator River catchment in both the Magela Creek and also the East Alligator River. Along the gorge parts of the East Alligator River, vegetation was removed and large amounts of sediment were redistributed along the channel (images shown in Appendix 1). The removal of vegetation and movement of sediment along the East Alligator River in response to large flood events has not been studied in detail.

Fourteen landslips occurred in the upper part of the Magela catchment during this large event (Figure 1). An additional 10 to 15 landslips occurred within the catchment of the East Alligator River. A 3-dimensional stereoscopic investigation of 1982 aerial photographs images (most recent) at a scale of 1:50 000 scale of the area did not show evidence of scars of existing landslips suggesting that the landslips had all been generated during the large event in 2007.

The landslips occurred on well-vegetated weathered Oenpelli dolerite, which occurs as intrusions in the surrounding Mamadwerre sandstone (previously called Kombolgie sandstone). The landslips in the upper Magela catchment are of particular interest to SSD because they are a potential source of fine sediment to Magela Creek and hence their influence on baseline sediment loads in the creek need to be clearly understood. It is important to be able to distinguish sediment coming from this source from that originating from the minesite, in the event that higher than usual turbidity values are recorded downstream of the minesite.

Methods

The area of the landslips was initially mapped using remote sensing imagery. A two-day fieldtrip was undertaken in August 2007 to obtain detailed on-ground measurements of selected landslips. This groundtruthing was undertaken to provide sufficient calibration data to convert the rest of the landslip dimensions inferred from the remote sensing image to actual dimensions. During the field trip the opportunity was taken to conduct an aerial photographic survey of the East Alligator River to collect data for a pre- and post-flood comparision of bed and bank changes (Appendix 1).

On-ground measurements were made of the physical characteristics (including length, width, height of scarp face and slope angle) of several of the Magela Creek landslips. Samples of the slumped material (visually characterised by its bright red colour as a result of high iron oxide content) were collected for physical (particle size analysis and bulk density) and chemical analysis. Initial particle size analysis results showed that landslip material consists of predominantly fine-grained material with more than 60% of the particles being less than 63 µm in diameter. Material of this size range is easily eroded and transported overland by flowing water. Initial chemical analysis has shown that it contains very low concentrations of uranium and other heavy metals and hence it not likely to impact water quality parameters other than turbidity.

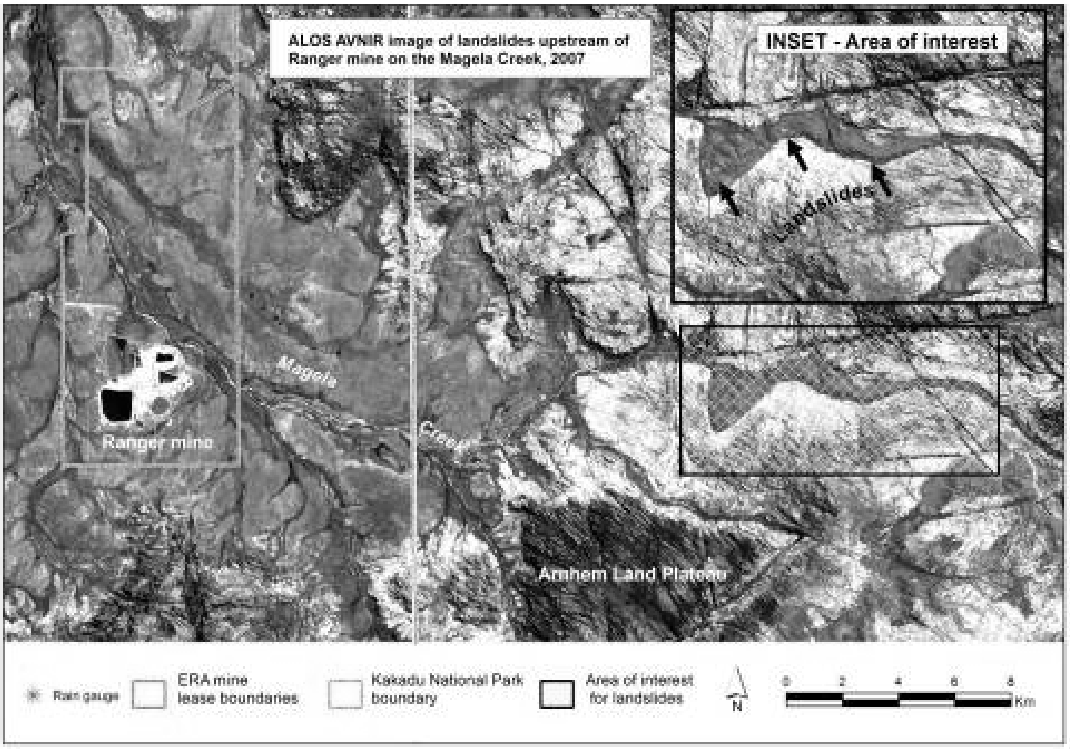

Figure 1 Location of the Landslips in the upper Magela Catchment in relation to Ranger mine

Results

The areas of the landslips measured on the ground are shown in Table 1. The slope angles ranged from 17° to 28° with an average of 21°. Areas derived from remotely sensed tended not to be able to distinguish between eroded material and deposited material and hence were approximately 1.3 larger than the field measured areas. This conversion factor was applied to all of the remotely identified landslips in the Upper Magela Catchment, to generate a total area of 0.3 km^2 (32 816 m^2) of sediment that was moved.

Although not all landslips were able to be measured in the field, the data that were acquired indicated an average depth of 2 m (Figure 2). Therefore the volume of the sediment that was moved during the landslip events was approximately 65 632 m^3. The average bulk density of the moved sediment was 1.19 t/m^3, which gives approximately 78 102 tonnes of sediment that was moved and potentially available for overland transport by future rainfall events.

Table 1 Landslip area comparisons generated by two different methodologies

Landslip no.	*Remotely sensed area (m²)*	*Measured areas (m²)*
1	5200	5630
2	530	250
3	840	250
8A	2720	1620
8B	7160	6420
9	16910	12220
Total	**33360**	**26390**

Figure 2 Field measurement of the one of the landslips in the Upper Magela Catchment. The approximate depth of the landslip at 2 m is illustrated.

Sediment dispersion in Magela Creek 2007–2008 wet season

During a routine field inspection of the SSD monitoring pontoons near the Ranger mine in January 2008 it was observed that the water was visibly red in colour (Figure 3). The source of this discoloration was traced by helicopter upstream to the vicinity of the landslips. With the landslips already being researched, and by tracing the source of the sediment back to these landslips, it was possible for timely and accurate information to be given to all stakeholders and other interested parties. In particular, the rapid conclusion that the source of the red water was not coming from Ranger mine provided assurance to local traditional owners that the source was natural.

During the 2007–08 wet season there were five occasions when the water in Magela Creek turned visibly red at the Magela Creek gauging station near Ranger mine (G8210009). In all cases when the river turned red there was a pronounced turbidity spike recorded at the Magela Creek pontoons. However, the water level did not exhibit the usual rise (Figure 4) that historically has been associated with higher turbidity levels in Magela Creek, indicating that the rainfall that triggered the events was localised in the vicinity of the landslips rather than being catchment wide. That the total area of the landslips is only 0.3 km^2, compared with the 605 km^2 catchment area of Magela Creek at the G8210009 monitoring point downstream of the mine, shows how much this highly erodible material can contribute to turbidity levels in Magela Creek. Indeed it is estimated that the landslips contributed approximately 50% of the total load of fine suspended sediment in Magela Creek for the 2007–08 wet season.

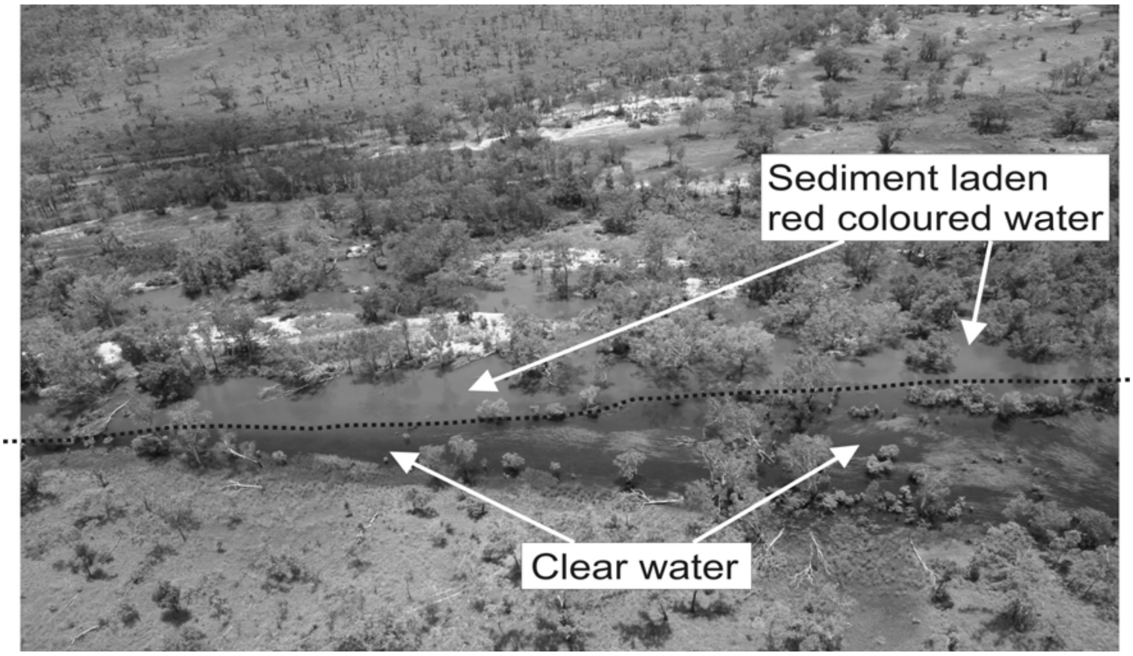

Figure 3 Red coloured sediment laden plume in Magela Creek downstream of G8210009 on 5 February 2008

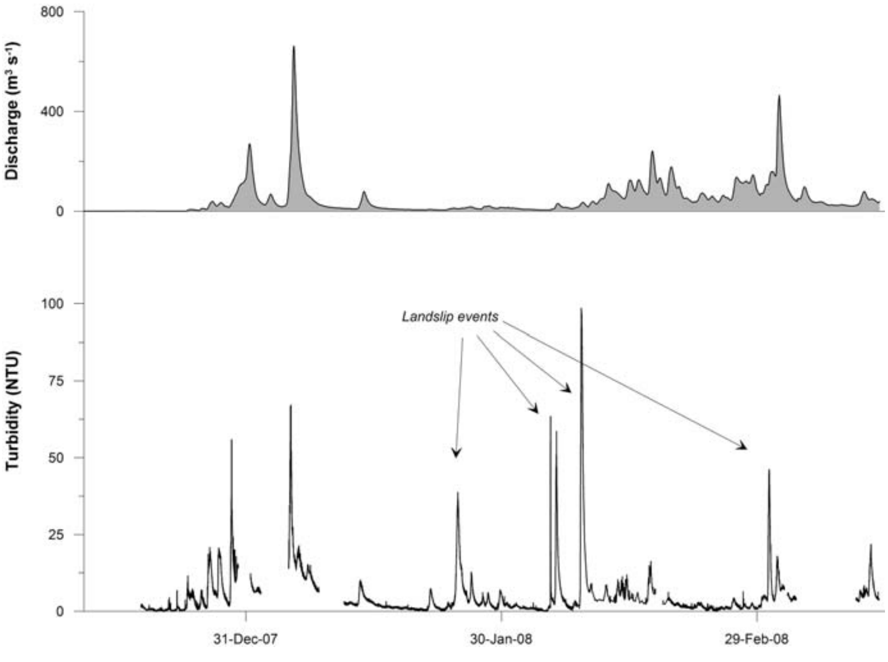

Figure 4 Wet season hydrograph for Magela Creek, showing high turbidity levels with low discharges

Rain gauge installation

An electronic rain gauge was installed on one of the hills above the landslips in late February 2008 to provide an early warning of the likely occurrence of turbidity pulses from the landslips. The rain gauge is able to be accessed by dial-in telemetry. The Bureau of Meteorology radar archive is also being investigated to see if it can be used to identify local weather systems that are likely to produce rain of sufficient intensity to mobilise the landslip material. The real time output of the rain gauge near the landslip may be able to be used to calibrate the radar images. If this technique proves to be successful, weather radar could possibly be used to obtain quantitative measurements of rainfall intensity generated by localised storm cells across the landscape.

Movement of sediment in the East Alligator River

During the large flood event large amounts of sediment were deposited in the river channel downstream of the lower gorge, approximately 1 km upstream of Cahills Crossing. In this context ***eriss*** was asked to comment on the deposition of sediment along the river section upstream of Cahill's Crossing which reduced the distance upstream that boat tour operators could negotiate (Figures 5 & 6). The advice provided was that this was the result of a natural process (ie a pulse of bedload moving through the catchment) and that it would clear in time (at least several wet seasons) as it had in the past. Dreging of the material was not recommended as a solution. It would be a long and inefficient processes as sediment would be distributed and re-deposited along the dredged sections.

Figure 5 East Alligator River upstream of Cahills Crossing in 2006 prior to the large movement of sediment. Points A, B, C are common points in both images.

Figure 6 East Alligator River upstream of Cahill's Crossing in 2007 after the large movement and deposition of sand during the flood

Further work

Further physical and chemical characterisation of the material from the landslips is underway to determine if there are any unique markers that can be used to distinguish landslip material from the fine sediment originating from the rest of the Magela catchment. The landslip sites also present an opportunity to track the natural re-establishment of vegetation. This is important in the context of reducing through time the contribution of the exposed landslip material to sediment load in Magela.

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Appendix 1

The following images illustrate changes that have taken place in the upper gorge section of the East Alligator River approximately 60 km upstream. The images were taken 8 months apart, before and after the flood event.

Upper section of the East Alligator River taken in July 2006

Same section of the East Alliator River as above, taken in April 2007 after the large rainfall event. River water level was similar at the time both of these photographs were taken. Note the removal of vegetation and the deposition of sand on both banks. The top of the right bank sand bar is estimated to be at least 10 m above baseflow conditions. Further upstream, on the left bank, bank scour is evident with removal of sand and vegetation. The level to which scour occurred is clearly seen.

Remediation of the remnants of past uranium mining activities in the South Alligator River Valley

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Introduction

In the 1950s and 60s the South Alligator River valley was prominent for its mineral and uranium mining activities. The main uranium deposits in the upper valley were characterised by high uranium contents with concentrations up to 2.5% U_3O_8. During peak activity, at least 16 different uranium ore bodies were discovered in the area, with 13 of them eventually mined (Waggit 2004). The South Alligator mill treated high-grade uranium ores from the Rockhole mine and the nearby O'Dwyers, Sterrets and Teague mines, which produced over 13 400 tons of very high grade uranium ore. This mill was located a few hundred metres east of Rockhole Mine Creek, near its confluence with the South Alligator River, and tailings were deposited on the ground with very little containment. When mining ceased in 1964 the minesites, mill and camps were abandoned and no substantial effort was made to rehabilitate or clean up the area.

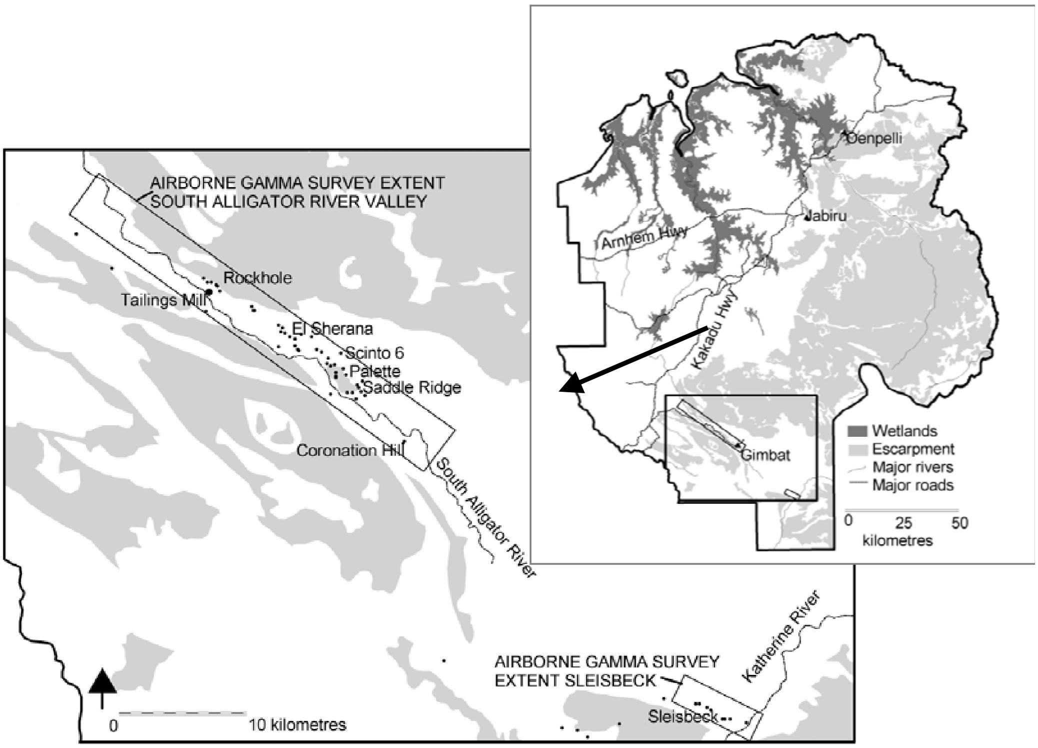

Figure 1 Alligator Rivers Region, with a detailed excerpt of the southern area showing the extent of two airborne gamma surveys conducted in 2000 and 2002, the location of known uranium anomalies (from MODAT database) and some historic mining and milling areas (Supervising Scientist 2003)

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Gamma surveys conducted by staff from SSD in 1984 confirmed the presence of radioactive tailings in the vicinity of the Rockhole mill. Most of the tailings present within the footprint of the original tailings deposition area were removed by Pacific Gold Mines NL between 1985 and 1986. In 1991, a routine survey revealed that residual tailings had become exposed in an erosion gully next to Gunlom Road directly opposite the old South Alligator mill tailings dam area. After the conclusion of this survey a program for rehabilitation of the abandoned mine sites was put into place and hazard reduction works were carried out in 1991 and 1992. During this period the South Alligator mill, surrounding buildings were demolished and the rubble and most of the remaining tailings waste were buried in trenches and covered with earth. Since completion of the hazard reduction works, routine bi-annual inspections of these sites are carried out by staff of SSD (Waggit 2003).

An airborne gamma survey was flown in 2000 to undertake precise mapping of the surface distribution of radiological material in the valley (Pfitzner & Martin 2000). The airborne gamma survey revealed that there was still some radiological contamination across the footprint of the original tailings area, extending to an area between the road and the South Alligator River (Pfitzner et al 2001). Groundtruthing was conducted in 2001. Dose estimate calculations made for three potentially affected classes of people – Park visitors, Rangers and local Aboriginal people – indicated that no further clean up action on radiological grounds alone (based on the most stringent International Atomic Energy Agency guidelines) was required (Bollhöfer et al 2002).

In 1996 land granted to the Gunlom Aboriginal Land Trust was leased to the Director of National Parks to be managed as part of Kakadu National Park. The lease agreement requires the Director to implement a plan of environmental rehabilitation of Guratba (Coronation Hill) and other mine sites and associated workings in the area so as to limit and where possible reverse the impact on the environment of any mining activities previously carried out. To that end, in May 2006, the Australian Government allocated $7.3 million over four years to the Director of National Parks.

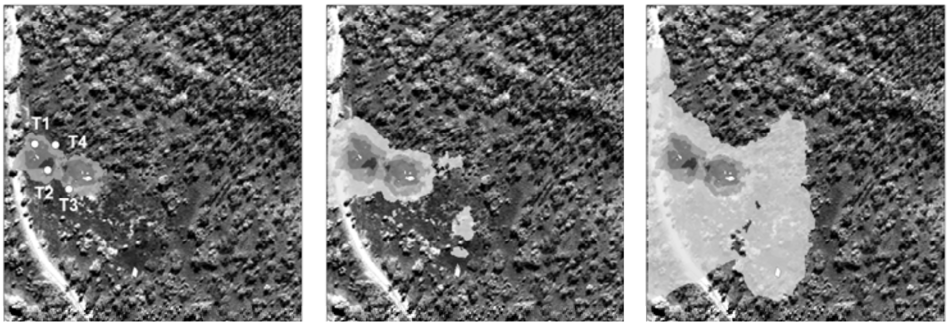
The rehabilitation program is being managed by Parks Australia, on behalf of the Director, and SSD is providing specialist assistance with the radiological assessment. The work is now well underway and includes: removal of residual physical hazards; remediation of non-radiologically contaminated areas; and cleanup of residual (radiological and non-radiological) mine-derived materials and ultimate burial of these latter materials in an engineered facility in the vicinity of the former El Sherana airstrip. Seasonal measurements of groundwater elevation, quality and baseline characterisation of radiological conditions of the soil profile are being done by SSD to provide input to the design process.

Results

Characterisation of contamination at the Rockhole residues site

A full characterisation of the tailings footprint area involved determining the areal extent of contamination, as well as the depth to which tailings-derived radiological material had penetrated into the soil profile beneath where the tailings were originally deposited. This survey was needed to quantify the volume of material to be removed to ensure effective remediation of the area, and hence to specifiy the design size of the engineered containment to hold it. In addition the data collected will provide the basis for deriving a radiological cleanup criterion, such that a clear distinction can be made between background and impacted material during the site excavation process.

A high resolution groundbased gamma survey was conducted in 2007 to determine the area of contamination at the former tailings dam footprint (Bollhöfer et al 2007). External gamma dose rate was measured at a spatial resolution of approximately 10 m using calibrated environmental dose rate meters. From the results, contour lines were produced which were overlaid on an Ikonos high resolution satellite image of the Rockhole residue area (Figure 2). An area between the road and the South Alligator River (to the top left edge of images in Figure 2) that contained some tailings derived material had been investigated in detail previously in 1999 (Tims et al 2000) and stabilised against erosion by covering it with rock. It is pending ultimate removal as part of the overall rehabilitation program.



1.2 μGy·hr^{-1} **0.9 μGy·hr^{-1}** **0.6 μGy·hr^{-1}**

Figure 2 Extent of the area at the original tailings dam footprint for various dose rate thresholds, and location of trenches 1 to 4 (T1–T4)

The gamma survey identified an area with elevated gamma dose rates of up to 3 micro grays per hour [μGy·hr^{-1}]. Several trenches were dug within this area with a backhoe to determine the depth of penetration of the radionuclides. Additional trenches were dug at the periphery of the area where dose rates had reduced to ~ 1 μGy·hr^{-1}. The walls of the trenches were sampled at a vertical resolution of 5 cm at the top 25–50 cm and at further 20 cm increments down to a total depth of 1–1.5 m.

The collected samples were measured for their activities of uranium and thorium series isotopes using high resolution gamma spectrometry in the ***eriss*** radioanalytical laboratories. The extent of penetration of radionuclides into the soil was found to be approximately 20 cm for Trenches 1–3 and approximately 1 m for Trench 4. The soil radionuclide activity concentrations (Bq·kg^{-1}) present in the respective layers were then converted to expected terrestrial gamma dose rates in air [μGy·hr^{-1}] using conversion factors recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2000). Results are shown in Figure 3.

These data will be used to derive radiological cutoff criteria to guide the contractors who will be carrying out the remedial works on site. These same criteria will be applied to the cleanup of the thin layer of radiological tailings-derived material lying between the road and the South Alligator River.

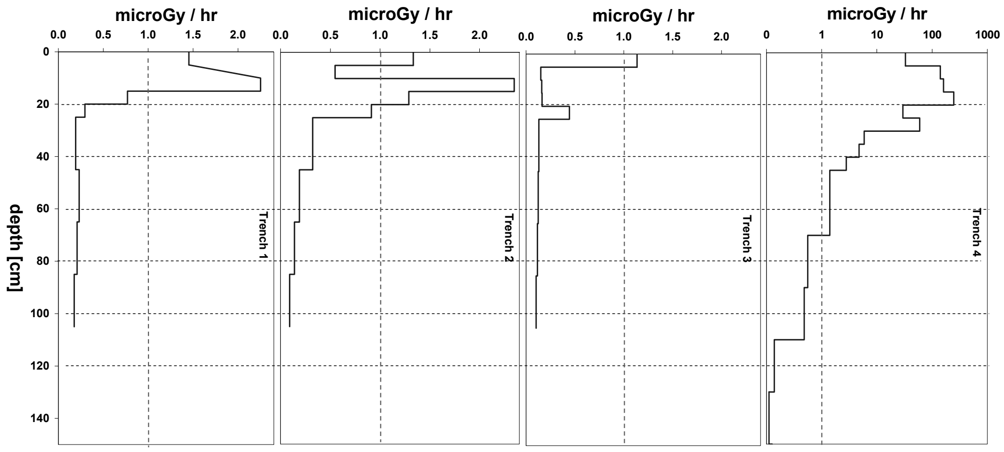


Figure 3 Terrestrial gamma dose rates calculated from radionuclide activity concentrations measured in trenches 1-4. The dashed vertical lines indicate a value of 1 µGy·hr^{-1}.

Assessment of the planned containment site

It is planned to build an appropriate capacity containment to bury the remnants of historic mining activities in the South Alligator River valley. Currently, a site located in the vicinity of the old El Sherana Airstrip close to the historic El Sherana mine is being assessed. A gamma radiation survey was conducted and Figure 4 shows that external gamma dose rates in the area average 0.13 µGy·h^{-1}, which is typical of the regional background including cosmic background.

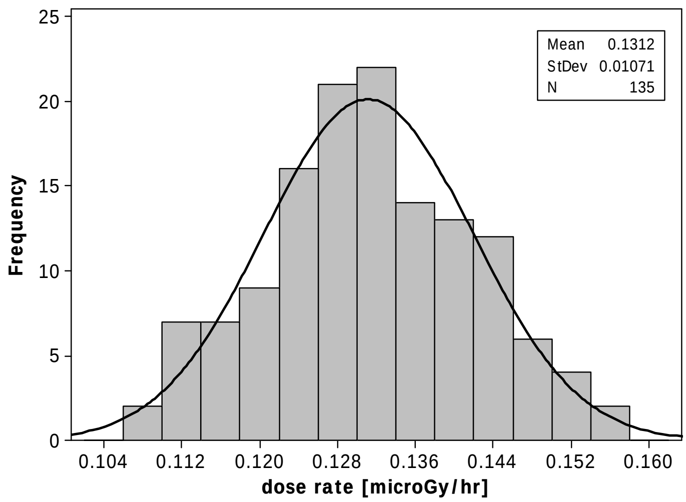


Figure 4 Histogram of γ-dose rates measured at the planned containment site at the El Sherana Airstrip

These measurements can be used to assess the performance of the containment after the placement of radioactive residues from the area and to demonstrate whether the containment meets the requirement to reduce the radiation levels at the surface to near background levels.

The final site selection for the containment also depends on a set of criteria related to potential for interaction with groundwater. In particular there should be sufficiently low hydraulic conductivity and the local water table should not rise to within 5 metres of the buried waste. ***eriss*** has been undertaking groundwater monitoring in the area of the proposed containment to assess seasonal variation in groundwater elevation and flow and to determine baseline groundwater quality. Figure 5 shows the location of the six groundwater monitoring bores that were installed in 2006. Continuous logging groundwater level monitoring sensors were placed in each bore in January 2007 and a permanent automated weather station was installed mid 2007.

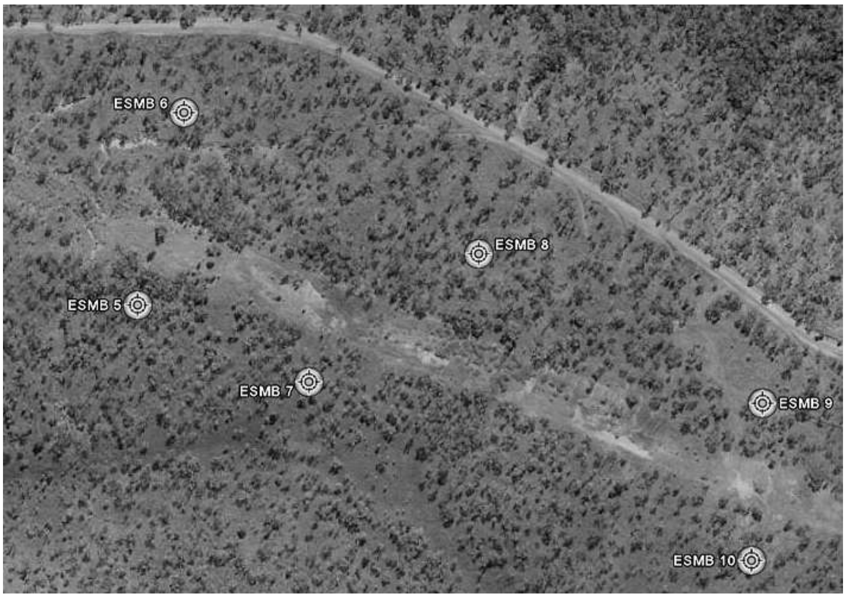


Figure 5 El Sherana airstrip groundwater monitoring bore locations

The depth of the bores range from 13.4 and 14.1 metres below ground surface for ESMB08 and ESMB09, respectively, to 20 metres for ESMB06 and ESMB07. Bores 8 and 9 have remained virtually dry, whereas the other four bores have water in them all year. The ground water levels range from 16 metres below the surface at the end of the wet season to more than 18 metres below the surface at the end of the dry season for ESMB06. This bore is situated at the furthermost upstream groundwater location and is at a higher elevation relative to the other bores. ESMB10 is the bore at the lowest relative elevation and at the furthermost groundwater downstream location. It exhibits groundwater levels of 7 metres below the surface at the end of the wet season and 12 metres below the surface at the end of the dry season. All bores show a slow and steady rise through the wet season and generally little or no response to individual storm events, with a slow lowering of groundwater levels during the almost rainless dry season. Further testing is under way to determine hydraulic conductivities in the area.

Acknowledgments

Thérèse Fox, Nadine Riethmuller and Rob Muller are thanked for support before and during the fieldwork.

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