

APPENDIX 1 ARRTC KEY KNOWLEDGE NEEDS

As noted in the introduction to Chapter 3 of this report, as a result of the extension in mine life and the conduct of a further three years of research since the original key knowledge needs (KKNs) and timeline priorities were established, it was judged by the Alligator Rivers Region Technical Committee (ARRTC) that a revision of the KKNs should be conducted in 2007–08. This was done and a revised list of KKNs approved by the committee. Both the original (2004–2006) KKNs and the new (2008–2010) KKNs are listed in this appendix so that the updates that have been made can be clearly identified. Appendix 1A contains the 2004–2006 KKNs; Appendix 1B contains the 2008–2010 KKNs.

Appendix 1A Alligator Rivers Region Technical Committee Key Knowledge Needs 2004–2006: 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 2008. This will be followed by milling until about 2011 [revised to 2014 during 05/06] and final rehabilitation expected to be completed by about 2016 [revised to 2019 during 05/06].
- Nabarlek is decommissioned but has not reached a status where the NT Government will agree to issue a Revegetation Certificate to the mine operator. Assessment of the success of rehabilitation at Nabarlek is ongoing and is being used as an analogue for rehabilitation at Ranger.
- Jabiluka will remain in a care and maintenance condition for some years, at least until mining ceases at Ranger.
- It is unlikely that any proposal will be brought forward for mining at Koongarra in the foreseeable future.

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

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

Specifically, under the Ranger Environmental Requirements (ERs):

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

- (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list;
- (b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (ie the wetlands within Stages I and II of Kakadu National Park);
- (c) protect the health of Aboriginals and other members of the regional community; and
- (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.

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

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

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

- (a) revegetation of the disturbed sites of the Ranger project area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long-term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park;
- (b) stable radiological conditions on areas impacted by mining so that, the health risk to members of the public, including traditional Aboriginal owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restrictions on the use of the area;
- (c) erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas.

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

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

1 Ranger – current operations

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

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

1.1 Reassess existing threats

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

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

1.2 Ongoing operational issues

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

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

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

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

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

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

1.3 Monitoring

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

2 Ranger – rehabilitation

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

2.1 Landform design

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

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

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

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

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

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

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

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

2.2 Ecosystem establishment

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

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

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

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

2.3 Groundwater dispersion

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

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

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

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

2.4 Water treatment

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

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

2.5 Monitoring

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

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

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

3 Jabiluka

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

3.1 Monitoring

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

3.2 Research

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

4 Nabarlek

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

4.1 Success of revegetation

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

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

4.2 Assessment of radiological, chemical and geomorphic success of rehabilitation

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

5 General Alligator Rivers Region

5.1 Landscape scale analysis of impact

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

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

5.2 South Alligator River valley rehabilitation

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

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

5.3 Develop monitoring programme related to West Arnhem Land exploration activities

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

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

5.4 Koongarra

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

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

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

6 Knowledge management and communication

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

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

6.1 Integrated framework

Development of an integrated framework: This has already commenced within a landscape analysis framework and is linked with the development of conceptual models of the ARR

recommended above. Such an integrated framework will assist with the communication where the scientific information is relevant, and how it informs on the various risks to the system and its people from the uranium mines.

6.2 Uncertainty analysis

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

6.3 Effective communication channels between research providers

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

6.4 Effective communication to stakeholders

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

Appendix 1B Alligator Rivers Region Technical Committee 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; and
- 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 cause 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 gully 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, sedimentological 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.