Uranium and Manganese in Surface Water — Rehabilitation Standard for the Ranger uranium mine

Water and sediment theme

# Preface

The Supervising Scientist developed this Rehabilitation Standard to describe the requirements to protect aquatic ecosystems outside of the Ranger Project Area in the Alligator Rivers Region of the Northern Territory from the effects of uranium and manganese in surface water.

This document is part of a series of Rehabilitation Standards for the Ranger uranium mine. It may be updated as additional relevant knowledge becomes available.

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# General elements

## Scope

1.1 The Rehabilitation Standards for the Ranger uranium mine have been developed in accordance with section 5c of the *Environment Protection (Alligator Rivers Region) Act 1978* and are advisory only.

1.2 The *Environmental requirements of the Commonwealth of Australia for the operation of the Ranger uranium mine* (Environmental Requirements) (Australian Government 1999) specify the environmental objectives for the rehabilitation of the Ranger uranium mine*.*

1.3 The Supervising Scientist's Rehabilitation Standards quantify the rehabilitation objectives and recommend specific values based on the best available science that will ensure a high level of environmental protection. These values can be used to assess the achievement of, or progress towards, the rehabilitation objectives, some of which may not be reached for a significant period of time.

1.4 Until it can be determined that the rehabilitation objectives have or will be reached, there will be an ongoing need to ensure environmental protection during and after rehabilitation, through continued water quality monitoring, including the comparison of water quality data with relevant water quality limits.

## Objective

1.5 There is currently no agreed acceptable level of effect to the environment surrounding the Ranger Project Area. In the absence of agreement, the Rehabilitation Standard for uranium and manganese in surface water aims to protect the biodiversity and health of aquatic ecosystems outside of the Ranger Project Area. This includes ecosystems upstream of the mine given that poor water quality within the Ranger Project Area could form a barrier to the movement of aquatic organisms. If an acceptable level of effect is agreed, this standard will be updated accordingly.

## Application

1.6 This Rehabilitation Standard should be applied in Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream from the Ranger uranium mine.

1.7 Given the potentially long time frame between the completion of rehabilitation and the peak delivery of contaminants to surface water, this Rehabilitation Standard will most likely be used to assess predicted uranium and manganese concentrations from modelled scenarios. Ongoing surface water and groundwater monitoring will be required after rehabilitation to continue to ensure the environment is being protected, and validate and assess confidence in the models.

# Relevant requirements

## Environmental Requirements

2.1 The primary environmental objectives in the Environmental Requirements require that surface waters or groundwater arising from the Ranger uranium mine do not result in any detrimental change to biodiversity or impairment of ecosystem health outside of the Ranger Project Area, including during or following rehabilitation. This Rehabilitation Standard is relevant to the Environmental Requirements listed in Box 1.

## Aspirations of Traditional Owners

2.2 The Mirarr Traditional Owners desire that operations at the Ranger uranium mine should not result in anychange to the natural water quality of surface waters outside of the Ranger Project Area (Iles 2004). Specifically, as stated in Garde (2013):

…the waters contained within all riparian corridors, (i.e. rivers and billabongs), must be of a quality that is commensurate with non-affected riverine systems and health standards. The principle of ‘as low as reasonably achievable’ should not apply to these areas. Instead, the standard of rehabilitation must be as high as is technically possible and level of contamination must be as low as technically possible.

**Box 1: Ranger Environmental Requirements relevant to the Uranium and Manganese Rehabilitation Standard**

**1 Environmental protection**

1.1 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 (i.e. the wetlands within Stages I and II of Kakadu National Park)

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

1.2 In particular, the company must ensure that operations at Ranger do not result in:

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

(b) damage to the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (i.e. the wetlands within Stages I and II of Kakadu National Park)

(d) change to biodiversity, or impairment of ecosystem health, outside of the Ranger Project Area. Such change is to be different and detrimental from that expected from natural biophysical or biological processes operating in the Alligator Rivers Region.

**3 Water quality**

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

# Recommended values for uranium and manganese in surface water

3.1 To protect the aquatic ecosystems outside the Ranger Project Area in accordance with the rehabilitation objectives, predicted water quality at the boundary of the Ranger Project area, reported as 72-hour moving averages, should not exceed the recommended values for the parameters shown in Table 1. Additionally, uranium concentrations in surface water should not lead to an exceedance of the uranium sediment guideline value (a separate standard).

**Table 1 Rehabilitation standards for uranium and manganese in surface water**

| **Parameter** | **Location** | **Rehabilitation standard** |
| --- | --- | --- |
| Dissolved uranium | In Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream of the Ranger uranium mine | 2.8 µg/L |
| Dissolved manganese | In Magela and Gulungul creeks at the boundary of the Ranger Project Area, downstream of the Ranger uranium mine | 75 µg/L |

3.2 From the predictive relationship developed for local waterbodies between U in surface water and U in sediments (see section 4.8), it has been determined that if U in surface waters was held at the value of the U rehabilitation standard (2.8 µg/L), U in sediments would not accumulate to a level of concern. Hence, adherence to this Rehabilitation Standard will also ensure the protection of benthic communities. The level of concern referred to is addressed in a separate sediment Rehabilitation Standard, which specifies the U guideline value protective of sediment-dwelling communities.

# Scientific basis

## Guidelines and standards used to develop the recommended values

4.1 The rehabilitation standards for uranium and manganese are based on the site-specific guideline values derived from laboratory-based effects data, using the majority of procedures recommended in the previous and current Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000, ANZG 2018) and associated methods subsequently revised by Batley et al. (2014) and Warne et al. (2018). No local field effects data are available for these standards.

4.2 Given the ecological importance of the region surrounding the Ranger uranium mine, the uranium and manganese rehabilitation standards have been derived to provide the highest level of protection: at least 99% of species according to the national water quality guidelines (ANZECC & ARMCANZ 2000, ANZG 2018).

## Scientific evidence summary

4.3 Uranium and manganese are present in the Ranger ore and waste rock at various concentrations. The main source of manganese, however, is from an introduced processing chemical (pyrolusite) used in milling. Uranium and manganese both pose a risk to the aquatic environment surrounding the Ranger uranium mine because they will be present at high concentrations in tailings and concentrated brine that will be disposed of in the mine pit voids. These metals may be mobilised under certain conditions and leach from the buried tailings and brine, and the waste rock landform, and enter surrounding surface through groundwater egress after rehabilitation. The bioavailability and toxicity of metals may be higher in the low pH soft receiving waters surrounding the Ranger Project Area than in most other freshwater ecosystems.

### Uranium (U)

4.4 The ANZECC & ARMCANZ (2000) default guideline value for uranium in freshwater was 0.5 µg/L. However, this was a low reliability guideline value based on very few data and is not appropriate to apply to this local situation.

4.5 The Supervising Scientist has studied the effects of uranium on local aquatic species in the laboratory for approximately 30 years. Sixteen studies involved the completion of more than 60 toxicity experiments using seven local species, focusing on the chronic (long-term) toxicity of uranium. The results of these studies were summarised in van Dam et al. (2012) and van Dam et al. (2017).

4.6 Other studies examined the effects of key environmental factors that might influence the toxicity of uranium in freshwater, summarised in van Dam et al. (2013). These factors included water hardness (Riethmuller et al. 2000, Charles et al. 2002, Markich 2013), alkalinity (Riethmuller et al. 2000), pH (Franklin et al. 2000, Cheng et al. 2010) and dissolved organic carbon (DOC) (Trenfield et al. 2011a, b). Extensive research on the effect of DOC on uranium toxicity showed that toxicity decreases as DOC increases. From this knowledge, equations were developed that allow uranium water quality guidelines to be adjusted based on DOC concentrations in the water (van Dam et al. 2012, van Dam et al. 2017).

4.7 The nationally-accepted species sensitivity distribution modelling approach for deriving water quality guideline values (ANZECC & ARMCANZ 2000) was used to derive a site-specific water quality guideline value for uranium that is predicted to protect 99% of species (van Dam et al. 2017). This site-specific guideline value was used to determine the current operational limit of 2.8 µg/L for uranium, which is applicable where the DOC concentration in creek water is 2 mg/L. This limit has been implemented in Magela and Gulungul creeks since 2016 (Turner et al. 2016). If necessary, the guideline value can be adjusted based on higher DOC concentrations using the van Dam et al. (2017) equation. The guideline value for uranium increases by approximately 10% for every 1 mg/L increase in DOC. The ability to adjust the uranium value depending on the DOC concentration may be of particular relevance to setting closure criteria for billabongs, as high DOC concentrations (> 10 mg/L) can occur in billabongs during the dry season.

4.8 Studies on the toxicity of U in sediments have shown that U is less toxic when bound to sediments. Freundlich isotherm modelling of U partitioning between water and sediment (McMaster et al 2020) estimates that 2.8 µg/L in the water column will equate to 48 mg/kg U in sediment, i.e. lower than the proposed sediment quality guideline value of 100 mg/kg. This provides assurance that a surface water guideline value of 2.8 mg/L U will not lead to a level of U accumulation in sediment that will impact benthic communities.

4.9 Based on the above evidence, the current operational limit of 2.8 µg/L is recommended as the rehabilitation standard for uranium. A correction of the uranium value based on DOC concentration would be appropriate if (i) predicted concentrations of uranium exceeded the rehabilitation standard, and (ii) DOC concentration could be reliably modelled.

### Manganese (Mn)

4.10 The ANZECC & ARMCANZ (2000) default guideline value for manganese in freshwater was 1,200 µg/L. However, research published since then, including that of the Supervising Scientist, has shown that this value is under-protective for many freshwater species and is not appropriate to apply to this situation.

4.11 The Supervising Scientist studied the effects of manganese on local aquatic species in the laboratory between 2012 and 2013. This project involved the completion of 21 toxicity tests using six different species. The results of these studies were published in Harford et al. (2014) and Harford et al. (2015). This testing indicated that the toxicity of manganese to local species in local water quality was typically higher than that reported in previous studies of other species and water types. A small number of international studies have reported the key environmental factors that may affect manganese uptake by organisms (i.e. bioavailability) and toxicity. These studies concurred with the observation that the soft waters of Magela and Gulungul creeks promote higher bioavailability and, potentially, greater toxicity (Peters et al. 2011).

4.12 More recently (late 2018 to early 2019), revisions have been made to two of the toxicity tests used in Harford et al. (2015) to bring these in line with new guideline derivation guidance (ANZG 2018, Warne et al. 2018).

1. The toxicity estimates arising from the fish species (*Mogurnda mogurnda*) acute 4-day toxicity test in Harford et al. (2015) were replaced using those from a chronic, sub-lethal 7-day toxicity test exposure (Pease et al. *in press*).
2. The 4-day toxicity test for the snail species described in Harford et al. (2015), which is considered an acute exposure (Warne et al. 2018), was extended to longer, chronic exposure periods (9-day and 14-day). However, the sensitivity of the snail remained greatest at the 4-day exposure and so these new 4-day data, together with the original data used in Harford et al. (2015), were used in guideline (re-)derivation.
3. Including the toxicity estimates from these additional laboratory studies to derive a new site-specific guideline value for manganese did not significantly change the guideline value. Thus, applying the nationally accepted species sensitivity distribution approach for deriving water quality guideline values (ANZG 2018) to the new dataset gave rise to a site-specific candidate guideline value of 80 µg/L. This value is comparable to the Harford et al., (2015) guideline value of 75 µg/L and supports the current magnesium Rehabilitation Standard. Importantly the current Standard is protective of the two species for which the new chronic toxicity data were considered.

4.13 To supplement the site-specific dataset, toxicity estimates were added from three international species (fish, alga, zooplankton) that had been tested in water conditions similar to Magela Creek water; that is, high bioavailability for manganese, low hardness and slightly acidic (Peters et al. 2011). This resulted in a toxicity dataset with nine species.

4.14 The nationally accepted species sensitivity distribution approach for deriving water quality guideline values (ANZECC & ARMCANZ 2000) was used to calculate a guideline value that aims to protect 99% of species in the environment. The water quality guideline value of 75 µg/L was considered site-specific and relevant to the water conditions of Magela and Gulungul creeks. This guideline value was implemented as a water quality limit for the operational phase of mining at the Ranger uranium mine (Turner et al. 2016).

4.15 Based on the above evidence, the current operational limit of 75 µg/L is recommended as the rehabilitation standard for manganese.

### Supporting evidence

4.16 Direct Toxicity Assessments (DTAs) of key Ranger mine-water types were conducted to determine if cumulative effects could be expected from mine-waters that contained various contaminant mixtures. This showed that Mg was the primary toxicant in contaminated shallow groundwaters and Mn was the primary contaminant in process waters, the two key mine-water types best representing sources of contaminants post-decommissioning. Antagonistic effects (i.e. lower than expected toxicity) were most common and cumulative effects (greater than expected toxicity) were rarely observed in the DTAs. Hence, the study concluded it would be suitable to use the single contaminant COPC guideline values to assess modelled outputs of the future surface water contaminant concentrations.

# Future knowledge needs

5.1 Rehabilitation planning can only be based on the best available information at a given time, but this should not preclude the continual improvement of the knowledge base and its subsequent application where directly relevant and possible.

5.2 The Supervising Scientist, through its Key Knowledge Needs, has identified the knowledge required to ensure appropriate management of the key risks to the environment from the rehabilitation of the Ranger uranium mine. For uranium and manganese, these knowledge needs are shown in Table 3.

5.3 The value(s) based on laboratory toxicity testing in this Standard were derived using the methodology prescribed in The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC & ARMCANZ 2000) and most of the recommendations from the recently revised Guidelines (ANZG 2018). In keeping with best practice, the current Standard will be reviewed in due course in line with further updated guidance from ANZG (2018).

**Table 3 Key Knowledge Needs for uranium and manganese in surface waters**

|  |  |  |
| --- | --- | --- |
| **ER Link** | **KKN Title** | **Questions** |
| Biodiversity and human health | WS7. Determining the impact of chemical contaminants on aquatic biodiversity and ecosystem health | WS7D. How do acidification events impact upon, or influence the toxicity of contaminants to, aquatic biota? |

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