Review of Water Management at Jabiluka :

Environmental Issues and Recommendations

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Executive Summary

- Water management at Jabiluka has historically – and currently – been promoted as a 'no-release' operation, but due to unnecessary project risks taken by current owner ERA, the Jabiluka project is facing a continually escalating water management crisis;

- The use of "Best Practicable Technology" (BPT), as practised by ERA, fails to account for the legitimate concerns of the Mirrar, generally being an exercise in assuring approvals of the lowest cost option;

- The Mirrar and their representatives from Gundjehmi Aboriginal Corporation have not been adequately informed and consulted about water management issues at Jabiluka, especially prior to approvals;

- Groundwater behaviour around and discharge into the decline is still poorly understood and analysed, despite this being the major contaminant source for water management at Jabiluka;

- Inadequate reporting of critical water management aspects by ERA, OSS and NT authorities, especially :
    - water level and quantity over time of the IWMP;
    - Reverse Osmosis treatment quality and irrigation quantities (and performance of Jabiluka soils from this irrigation);
    - groundwater sources, both quantity and quality, remain poorly reported.

- The Northern Land Council (NLC) and Office of the Supervising Scientist (OSS) need to pro-actively support the legitimate concerns of the traditional owners, the Mirrar, and argue for active rehabilitation over 2002 and 2003 to alleviate water management strains;

- Water treatment should be continued on-site at Jabiluka in the short-term to ensure that contamination levels are not further increased in areas outside of the IWMP.

1 Introduction

The proposed uranium mining project at Jabiluka has been consistently opposed by the region's traditional owners the Mirrar since its discovery in the early 1970s. In mid 1998, current owner Energy Resources of Australia Ltd (ERA) began construction of mining and associated facilities at the Jabiluka site, with the intention of mining ore at Jabiluka and trucking it 22 km south to their Ranger mill for processing – despite the clear opposition from the Mirrar. The facilities built and operated between June 1998 and September 1999 are :

- an underground decline for access, mine development and exploration;
- office and workshop facilities, including diesel storage tanks;
- an 'Interim Water Management Pond', intended for 1-2 wet seasons until permission could be sought to truck Jabiluka ore to Ranger;
- a 'mineralised' stockpile, which includes uranium ore ≥0.02% U_3O_8 and potentially acid-forming rock (contains reactive sulfide minerals);
- an inert or 'non-mineralised' stockpile (ie. below the mineralised criteria);
- ventilation shaft (for the underground decline);
- sediment traps for erosion and drainage control.

All development and exploration work ceased at the site in September 1999. A current site map is shown in Figure 1. By November 2001, the 'interim' pond has been subjected to 3 heavy wet seasons and is facing its fourth. This report briefly examines the history of water management at Jabiluka, and examines current management practices being used by ERA to try and minimise unacceptable environmental impacts. Based on this analysis, options and recommendations for water management at Jabiluka are presented to help achieve the best possible environmental and community outcomes for the Mirrar.

2 Climate and Hydrology

The first measurements of rainfall and evaporation at Jabiluka were taken in the early 1970s, although monitoring has not been continuous since. The climate varies between a monsoonal wet season from November to April and a dry season between May and October. A compilation of the available climate data is presented in Table 1, including nearby Jabiru East (airstrip) and Gunbalanya (Oenpelli) for comparison. The rainfall over the past three wet seasons has been well above average, amongst the highest recorded rainfall for the East Alligator region over the past 30 years whilst evaporation has been considerably lower than average (see Appendix 1 for data).

Table 1 – Rainfall and Evaporation Data (mm)

	Jabiluka		**Jabiru East**		**Gunbalanya**	
	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation
30 Year Average (1)	NA	NA	1,483 (1)	NA	1,500 (1)	NA
May 1998 – April 1999	1,915	1,266 (2)	1,893	2,307	NA	NA
May 1999 – April 2000	1,862.2	1,935.8	1,917	2,301	NA	NA
May 2000 – April 2001	1,953.6	1,980.4	1,946	2,270	NA	NA

(1) - data from September 1971 to August 1998; (2) - data for Sept. 1, 1998 to April 1, 1999 only.

References : NTSA (various); NTS (1999); Johnston & Prendergast (1999), ERA (2000 & 2001).

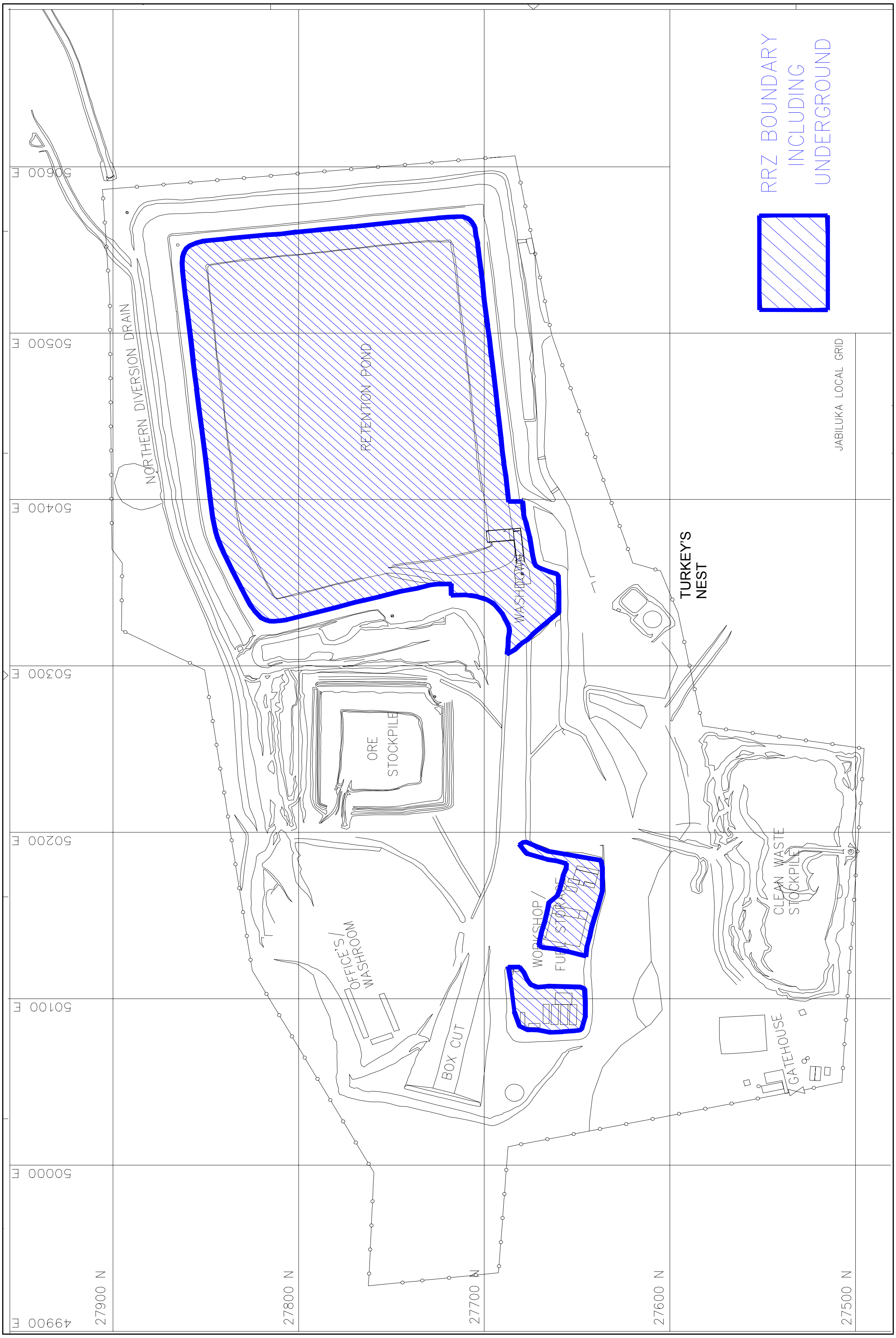


Figure 1 – Site Layout of Jabiluka Facilities, November 2001 (ERA, 2001)

3 Water Management at Jabiluka

3.1 History of Water Management Proposals

In the 1970s, Pancontinental Mining Ltd presented two major proposals for the development of the Jabiluka project. The first proposal, as outlined in the Draft Environmental Impact Statement (EIS) (Pancon, 1977), included a water management regime which allowed the controlled release of contaminated mine waters through dilution with clean water. This was contrary to the recommendations of the Ranger Uranium Environmental Inquiry (Fox *et al.*, 1977), which argued against water release and urged the adoption of a 'no-release' water management system for all proposed uranium mines of the Alligator Rivers Region. In July 1979, Pancontinental presented the second proposal for Jabiluka, a major overhaul of the earlier Draft EIS, which, as well as shifting from an open cut to an underground mine, included the adoption of a 'no-release' water management system (Pancon, 1979).

After failing to develop the Jabiluka project in the 1980s [1], Pancontinental were forced into selling Jabiluka to Energy Resources of Australia Ltd (ERA) in August 1991. ERA, who operated the Ranger uranium project to the south, went about re-designing the entire Jabiluka project. Under a deed of transfer agreed to and signed on December 24, 1991, ERA and the Northern Land Council (NLC) agreed that in order for Jabiluka ore to be milled at Ranger, the consent of the NLC shall be required, which may be refused or given subject to conditions. With the election of the Howard Coalition Government in March 1996, the previous restriction on uranium mine development was lifted and ERA began a new environmental impact assessment process to develop Jabiluka (ie. Kinhill, 1996 & 1997).

The key change in concept was to operate a 'small' underground mine and truck the ore for milling at Ranger - the 'Ranger Mill Alternative' (RMA). The RMA was to maintain a 'Total Containment Zone' for water management at Jabiluka, essentially a different wording of no-release. The Commonwealth and Northern Territory (NT) approvals for development of the RMA option were given by late 1997. As per the 91 deed of transfer, this change in mine plan required the express consent NLC and therefore the traditional owners. Since the Mirrar have continued to clearly oppose any development at Jabiluka, this consent has never been given.

After belated recognition of Mirrar opposition, ERA was forced to reconsider their development options for Jabiluka and were then required to undertake a lower level of environmental assessment, a Public Environment Report (PER), on the potential for a major uranium mill onsite at Jabiluka (in addition to the underground mine facilities) (ie. Kinhill, 1998). This was due to serious deficiencies identified in the Draft EIS and Supplement concerning ERA's contingency for a milling operation at Jabiluka. The new proposal was taking advantage of the earlier Pancontinental agreement with the traditional owners [2] for a mill onsite at Jabiluka – and hence is known as the 'Jabiluka Mill Alternative' (JMA). The draft guidelines for the PER were released in May 1998, with the final guidelines adopted on June 3, 1998 – though not publicly acknowldged until June 9 - the same day the JMA PER was released.

[1] - due to the Hawke Labour Government's 'Three Uranium Mines Policy' from 1983 to 1996, which recognised community and traditional owner opposition to uranium mining, especially in Kakadu National Park.

[2] - the Mirrar have always maintained this agreement was negotiated under extreme duress.

Despite the significant uncertainties surrounding the Jabiluka project by mid-1998 (namely where to mill the ore and the impending federal election in October), ERA sought and (eventually) won court approval for construction of facilities in June 1998 which were 'common' to both the RMA and JMA – principally the decline and an 'interim water management pond' (IWMP). The PER did not gain federal approval until late August 1998. Further to this, there was no discussion of staged construction in the Draft EIS (Sections 4.3.4 and 4.9.3) or the Supplement (Section 5.4). The (later) approved PER [3] proposes a schedule whereby construction of water management facilities would start in July 1998 and be completed by November 1998 (pp 4-11, Kinhill, 1998).The original JMA proposal in the Draft EIS included a 'raw water pond' of 4.0 ha, however, this was excluded in the JMA as proposed in the PER in favour of using the tailings pits as part of the water management system (pp 4-8, Kinhill, 1998). For comparison, the RMA water management pond was proposed to be 9.0 ha in the Draft EIS (pp 4-67, Kinhill, 1996). It is generally assumed that the IWMP was to last for one wet season until the RMA could proceed in 1999 [4].

It is curious that NTSA (1999) states that the IWMP "… will be incorporated into the WMS [water management system] constructed for the production phase" (pp 61).

Given that approval of the RMA included a specific recommendation [5] that the design of the water management pond obtain the approval of the Supervising Scientist before proceeding, it would seem that ERA were keen to proceed with the risks of construction at Jabiluka with no clearly defined project future. This leaves a limited scientific or engineering basis upon which to design the pond and encourages little confidence in ERA's approach to water management.

Development of the underground decline and further exploration drilling continued at Jabiluka until September 1999. Since this time the site has been on an 'environmental management and standby phase', until such time as ERA and/or its latest parent company Rio Tinto Ltd either proceed with the JMA, abandon the entire Jabiluka project as wished by the Mirrar, or seek to renegotiate from January 2005 for the potential milling of Jabiluka ore at Ranger.

A chronology of water management proposals is compiled in Box 1.

3.2 Water Management Regime – Late 1998 to Early 2000

As part of the various approvals and conditions from both the Commonwealth and Northern Territory governments, ERA was committed to a 'Total Containment Zone' for water management at Jabiluka. As shown in Figure 1, the main features of the facilities, as constructed, are supposedly common to both the RMA and JMA proposals, although the actual basis for this appears slight at best. The excavation for the IWMP was completed in August 1998 and the pond liner system installed in September (concurrently with work starting on the decline) (OSS, 1998).

[3] - no date for completion of the water management pond at Jabiluka is given in NTS (1999).
[4] - eg. talk by Brendan Lewis, NLC, at Gundjehmi Governing Committee, April 10, 2001 (NLC, 2001a).
[5] - Recommendation 28, Minister for the Environment, August 1997 (see pp 82, EA, 1997).

Box 1 : Chronology of Water Management Proposals for Jabiluka

May 1977	• Ranger Uranium Environmental Inquiry (Fox Inquiry) recommends that all proposed uranium mines in the Alligator Rivers Region adopt a 'no-release' water management regime.
Dec. 1977	• Pancontinental Mining Ltd releases its Draft EIS, proposing release of contaminated minesite waters diluted with clean waters.
July 1979	• Pancontinental Mining Ltd releases its Final EIS, proposing a 'no-release' water management system.
Aug. 1991	• Energy Resources of Australia Ltd (ERA) gain ownership of Jabiluka, and redesign the entire Jabiluka Project.
Oct. 1996	• ERA releases its Draft EIS for a completely new Jabiluka proposal, presenting a 'Total Containment Zone (TCZ)' for the underground mine infrastructure (ore would be trucked to ERA's Ranger mill for processing). Pond size is 9.0 ha.
June 1997	• ERA release their Supplementary EIS, with no change to water management.
Oct. 1997	• Commonwealth government gives final approvals to ERA's development of the Ranger Mill Alternative (RMA) for Jabiluka.
May 1998	• After steadfast opposition from the Mirrar, ERA is forced to undertake a Public Environment Report (PER) for developing a mill at Jabiluka ('JMA').
June 2, 1998	• NT approval to start construction, the Mirrar block with court action.
June 3, 1998	• PER guidelines finalised but not released - PER already sent for printing.
June 9, 1998	• ERA release the PER on the revised JMA. No retention ponds included in project design, instead using tailings pits.
June 15, 1998	• ERA win court approval to begin construction of 'common elements' to both the RMA and revised JMA, despite no approval for the revised JMA and no mention of 'staged' construction in the RMA. The Mirrar remain opposed.

By the start of the Jabiluka site's first wet season in November 1998, the major water management features were (totalling about 8 ha in area [6]) :

- an underground mine decline and groundwater collection system;
- the 'Interim Water Management Pond' (IWMP);
- a 'non-mineralised' stockpile;
- sediment traps for erosion and drainage control.

As noted, the IWMP was apparently built to approximately the RMA design and function, although the construction was staged to allow time for the gaining of consent from the Mirrar for this proposal. The IWMP covered an area of 3.27 ha and collected all water from the working areas of the Jabiluka site (about 8 ha [7]), mainly the underground decline, workshops, pond and mineralised stockpile. Although the authorisation which allowed ERA to proceed in June 1998 did not allow the release of water [8], a 'Restricted Release Zone' (RRZ) was not declared until 'mineralised' rock (see below) was encountered in the construction of the underground decline on April 26, 1999 (OSS, 1999a). On this date the RRZ was officially declared [9].

There is no discussion of this detail in NTS (1999), despite it being absolutely pivotal in water management at Jabiluka. It would also seem that the phrase of 'Total Containment Zone' was no longer preferred, although OSS (2001a) maintains that the RRZ is still a TCZ (pp 25 & 29).

[6] - based on Restricted Release Zone as outlined in Map 3 in NTS (1999); map dated April 1999.
[7] - total site area is about 17 ha, courtesy of ERA, www.energyres.com.au, printed November 25, 2001.
[8] - Item 6.3, Schedule 6, Jabiluka Authorisation 98/2 (Appendix G), NTS (1999).
[9] - see Figure Map 3, NTS (1999). OSS (1999b) states approval of the RRZ as May 10, 1999.

The principal change to occur after the 1998-99 wet season was that construction and development work in the underground decline encountered 'mineralised' material on April 26, 1999, introducing contaminated rock into the surface environment at Jabiluka. It should be noted that the first annual environmental report for Jabiluka (ie. NTS, 1999), did not mention this development although it was within its reporting period. Mineralised material is classified as rock which contains ≥0.02% U_3O_8 (low grade uranium ore) and/or sulfidic minerals [10] and was stockpiled on a separate pad with a double-layered impermeable liner. The total quantity of mineralised material placed on the pad was 47,000 tonnes [11], after a further expansion in late June 1999 to accommodate the extra material encountered (OSS, 1999a). Based on criteria for assessing the sulfides in extracted material, the mineralised rock was classified as non-sulfidic since the average sulfide concentration was 0.12% S, with the maximum sulfur grade being 0.48% S. The average uranium grade is 0.123% U_3O_8, including 10,000 t at 0.27% U_3O_8.

If exposed to excessive rainfall and infiltration, this could lead to significant leaching of contaminants from the mineralised rock into the water management system. The principal contaminants were considered to be uranium (U), lead (Pb), magnesium (Mg), manganese (Mn), radium-226 (^{226}Ra) and sulfate (SO_4). All drainage through this stockpile goes to the IWMP. It is worth noting that there was about 150 mm of rainfall in April 1999 (NTS, 1999), although the timing of this rainfall is not clear from avaliable reports.

All development and underground exploration work ceased at Jabiluka in September 1999, with the site converting to an 'environmental management and standby phase'. In November 1999, a tarpaulin was placed and weighed down over the mineralised stockpile to prevent infiltration and also to excise this area from the RRZ (down to 4.95 ha; ERA, 2001), thereby reducing the flow of contaminated water into the pond (approved on December 14, 1999). The IWMP was maintained for the 1999-2000 wet season, which was again a near-record at 1,862 mm of rainfall.

3.3 Water Management Regime – Mid 2000 to Late 2001

By early 2000, there was serious concern that the IWMP would be retaining too much water which could not be lost through evaporation before the 2000-01 wet season. Under the various approvals, ERA is required to maintain enough capacity in the IWMP to hold a 1-in-10,000 year wet season of about 2,460 mm [12].

A 'Best Practicable Technology' (BPT) process was initiated in late March 2000 (NLC, 2000a) which investigated numerous options for treatment and/or disposal of the excess contaminated water. The outcome of the BPT assessment, undertaken by ERA and then presented to regulators and the NLC [13] at an informal meeting on March 29, pointed to two prime options for water treatment – land application and reverse osmosis treatment (or RO, followed by land application or direct discharge).

[10] - based on ≥0.5% sulfides, Net Acid Producing Potential of 20 kg H_2SO_4 per tonne and Net Acid Generation pH <4 (pp 23, NTS, 1999). The Jazbiluka authorisation was changed on February 27, 2001, to alter the criteria for sulfide mineralisation (reasons unknown) (see OSS, 2001a).

[11] - Fax from Allan Wade, ERA, to Geff Cramb, NLC, November 27, 2001, 1 p.

[12] - using the recommended figure of Johnston & Prendergast (1999).

[13] - who are statutorily required to represent the interests of the traditional owners, the Mirrar.

A BPT assessment has to take into account age and effectiveness of equipment, location, environmental benefits and risks, social factors and cost [14]. Since land application scored marginally higher than RO, combined with the fact that it was considerably cheaper, land application (ie. direct irrigation) was ERA's preferred choice. This indicates that social concerns, particularly the legitimate concerns of traditional owners, are not adequately considered by ERA into its BPT assessments.

When water management options were discussed at an informal Jabiluka Minesite Technical Committee (JMTC) on March 29, 2000, ERA argued strongly for land application, however, the NLC and Office of the Supervising Scientist (OSS) argued convincingly for RO followed by land application of the treated water within the Jabiluka site (ie. no external release as per the approvals). ERA established and ran a series of apparently successful RO laboratory trials at Ranger, which were discussed at a further informal JMTC meeting held on July 19.

Following JMTC support for RO from this meeting, ERA applied to the NT Minister for Mines and Energy to install and operate an RO water treatment system followed by land application over 3.76 ha. The irrigation was to provide an extra buffer (through contaminants, primarily uranium, being retained within soils) should the quality of the RO output vary over time, as argued by the NLC and others. The Minister's approval was given on August 17, 2000, with the approval amended on August 24 for irrigation limits. The water quality limits set for irrigation were required to be met for samples taken from the 'Turkey's Nest' (see Figure 1), a small pond in the southern part of the site where RO output water would be temporarily stored until irrigated.

The first RO unit began operation followed by irrigation on August 28, 2000 [15], with a second unit arriving in October but wasn't commissioned until late November 2000 due to delays in the delivery of the microfiltration membranes (ERA, 2001). The cost of the RO system was apparently in the order of some $500,000 (NLC, 2001a). The units were supplied by O'Donnell Griffin [16] but their performance has been much less than satisfactory, however, with problems including biological fouling of the membranes, chemical compatibility (requiring the dosing of input water with sulfuric acid) and questionable quality in the supplied equipment and its operation. A compilation of the performance of the RO units is presented in Section 6.

Further drainage modifcations were made in late 2000 to further reduce the RRZ area, to allow clean runoff to be diverted and the quantity of inflow to the IWMP. The reduced RRZ of 4.1 ha was approved in January 2001 (see Figure 1) (ERA, 2001).

In December 2000, ERA claimed that they were able to meet the 1-in-10,000 year rainfall contingency for the 2000-01 wet season [17], although this included storage in the decline (not preferred but seen as safe). The near-record rainfall of 1,954 mm led to emergency pumping of IWMP water into the underground decline on February 13, 2001 (ERA, 2001). From 11:00 on February 13 to 14:00 on February 15, approximately 12 million litres (ML [18]) was pumped from the IWMP into the decline. This reduced the level of water in the IWMP sufficiently not to require further underground storage for the remainder of the wet season.

[14] - see clause 12 of the Environmental Requirements for the Ranger uranium mine (in Appendix 2).
[15] - NTSA, 2000b, Report N0. 40.
[16] - NLC, 2001a2-&&&.
[17] - see minutes from the Alligator Rivers Region Advisory Committee meeting, December 2000.
[18] - 1 million litres = 10^6 L = 1 ML = 1,000 m^3 (1 m^3 = 1,000 L).

By March 22, 2001, the quantity of water stored in the decline was 17.7 ML, including groundwater inflow, with up to 30 ML expected to be stored by the mid dry season when pumping out of the decline was to commence (NLC, 2001b). The dewatering of the decline, totalling approximately 20 ML, commenced in early May 2001 and was completed on June 19, 2001 (OSS, 2001a).

By mid 2001, it was apparent that the RO units were not maintaining performance expectations (0.4 ML per day), and would not be likely to last until the end of the 2001-02 wet season. Before consultation and formal meetings between the NTDME, NLC and OSS, ERA applied on September 20, 2001, for an expanded irrigation area with increased load limits (ie. IWMP water). At an informal JMTC meeting on October 1, 2001, it was agreed that land application was needed on a larger scale than currently being practiced (NLC, 2001c). ERA subsequently sought approval for a modified water management regime at Jabiluka, including combined irrigation of RO-IWMP water and direct irrigation of IWMP water during the dry season. Approvals were forthcoming on October 11, 2001, only specifying load limits and concentrations for Mg, SO_4 and U. This approval did not specify whether the irrigated water would be RO, IWMP or mixed, nor did it differentiate between irrigation during the wet and dry season. Critically, the OSS was not party to the derivation of these criteria, although they appear to reluctantly accept that their appropriateness (OSS, 2001c).

It would appear that some debate followed this approval, as a further informal Jabiluka MTC was held in late October 2001 to address the deficiencies in the approval criteria from the NT authorities. As the NT approval also stated that any further directions from the JMTC would apply, it is disappointing that the meeting was only an informal meeting (meaning its enforcement is perhaps questionable). Following this meeting, ERA agreed that only RO treated water could be irrigated during the wet season but that mixed RO-IWMP water could be irrigated for the subsequent dry season. Other conditions included no visible run-off, stopping irrigation after enough capacity in the IWMP has been reached for the 1-in-10,000 year rainfall (including an appropriate buffer), meeting water quality criteria for Swift Creek downstream and an overall review of water management at Jabiluka starting in February 2002. The available area for irrigation was increased to 6.34 ha. Given the timing of these events, it is likely that the refusal to inspect Jabiluka on October 30 was in part due to this lack of formal clarity for water management criteria.

The approved limits for irrigation, such as flow rate, load and concentrations, were based on a 3-tiered approach for the monitoring of Swift Creek, as discussed and agreed to by stakeholders at the September 21, 2001, Jabiluka MTC meeting. Three separate trigger values were set, based on statitsical analyses of background data : focus, action and limit. An analysis of these trigger values and comparisons to the natural water quality variation within Swift Creek will be presented in Section 7.

Although ERA apparently started combined RO-IWMP water irrigation by the end of October, neither the OSS nor NLC were informed, which subsequently led to the incorrect advice provided to Gundjehmi Aboriginal Corporation by the OSS on October 30, 2001 [19] (cf. OSS, 2001b). Another feature of current operations is the use of 'enhanced evaporation' by spray irrigation on the sides of the IWMP, although it is unclear when this practice began [20]. A chronology of recent water management issues is given in Box 2. Recent aerial photos are shown in Box 3.

[19] - this advice was corrected by OSS on November 14, 2001 (OSS, 2001c).
[20] - see for example OSS (2001c).

Box 2 : Recent Chronology of Water Management at Jabiluka

June 15, 1998	• Start of construction for infrastructure 'common' to the RMA or JMA. Pond designed as an 'Interim Water Management Pond' (3.27 ha).
August 1998	• Excavation work completed for the IWMP.
Sept. 1998	• IWMP liner installed, work on decline commences.
Wet 1998-99	• Wet season rainfall of 1,915 mm.
April 26, 1999	• Mineralised material (≥0.02% U_3O_8) encountered within the decline, stored on specialised pad, not classified as sulfidic rock (<0.5% S). Restricted Release Zone (RRZ) declared, totalling about 8 ha.
Sept. 14, 1999	• Construction of 'Stage I' completed, site enters 'Environmental Management and Standby' phase.
Dec. 14, 1999	• Mineralised stockpile excised from RRZ.
Wet 1999-00	• Wet season rainfall of 1,862 mm, evaporation of 1,936 mm.
March 2000	• ERA, realising that the IWMP would not maintain enough storage for 1-in-10,000 year rainfall in the next 2000-01 wet season, begin a process of identifying options for dry season treatment of IWMP water.
March 29, 2000	• Jabiluka Minsite Technical Committee (informal meeting) considers urgent need for intervention, with ERA pushing for land application though OSS and NLC argue for Reverse Osmosis (RO) treatment.
July 19, 2000	• Jabiluka Minsite Technical Committee (informal meeting) considers lab scale results from RO tests at Ranger. ERA then aaply for RO units at Jabiluka, followed by land application.
Aug. 17, 2000	• RO treatment approved by NT Minister for Mines & Energy, the treated water from the RO plant was to be irrigated within the Jabiluka site.
Aug. 24, 2000	• Irrigations loads and limits amended NT Minister for Mines & Energy. Area of irrigation 3.76 ha.
Aug. 28, 2000	• RO treatment begins followed by irrigation within the Jabiluka site.
Late Oct. 2000	• Second RO unit arrives at Jabiluka, not installed due to delays in some parts arriving.
Late Nov. 2000	• Second RO unit commissioned.
Wet 2000-01	• Wet season rainfall of 1,954 mm, evaporation of 1,980 mm.
Jan. 2001	• Restricted Restricted Release Zone reduced to 4.1 ha, following further modifications to drainage patterns on-site.
Feb. 13, 2001	• Maximum Operating Level (wet season) reached in IWMP (RL 25.23 m), pumping to decline initiated at 11:00, continuing until 14:00 February 15, 2001. Total of 12 ML stored in decline).
March 22, 2001	• Decline storing about 17.7 ML.
Early May 2001	• Dewatering of the decline begins, pumping water back to the IWMP.
June 19, 2001	• Decline emptied of excess water, total pumped about 20 ML (including groundwater inflow)
Sept. 20, 2001	• ERA apply for direct irrigation of IWMP water.
Oct. 1, 2001	• Land application of direct IWMP water considered at an (informal) Jabiluka Minsite Technical Committee, as well as the continued use of RO treatment.
Oct. 11, 2001	• Approval given for enlarged irrigation including IWMP water. Limits set by NTDME without input from the OSS. Area of irrigation increased to 6.34 ha.
Late Oct. 2001	• After an informal Jabiluka MTC, further conditions agreed to, including mixed RO-IWMP water for remainder of 2001 dry season, irrigation of RO water only during 2001-02 wet season and no runoff. A major Best Practice Technology (BPT) review of water management is scheduled for February 2002.
Late Oct. 2001	• ERA begin combined RO-IWMP land application. RO unit expected to fail by mid-December 2001.
Oct. 30, 2001	• Representatives of the Mirrar and environment groups denied access to visit Jabiluka and witness the RO-IWMP water management regime.
Nov. 16, 2001	• Representatives of the Mirrar and environment groups visit Jabiluka and witness the RO-IWMP water management regime.

Box 3 : Recent Aerial Photos of the Jabiluka Site

(courtesy of ERA's website, www.energyres.com.au)

(author, July 2001)

(author, July 2001)

3.4 Water Management – Summary

Water manegement for the Jabiluka project has been based, for more than 20 years, on the principle of 'no-release'. Current approvals continue to enforce this, however, due to unnecessary risks taken by current owner ERA, acute water management problems have developed. Despite the acknowledged seriousness of the water management problems at Jabiluka, ERA is now able to operate the site without *"stringent operational criteria"* [21], providing that there is no direct water release off-site and that the end environmental result dopwnstream in Swift Creek is acceptable to regulators. The Mirrar have had no direct rights or participation in this process. Thus, some impacts on the Jabiluka site – above pre-mining levels – are therefore considered acceptable by ERA, OSS and the NLC, providing there is no impact downstream. The critical concern is that by the time monitoring detects potential impacts downstream in Swift Creek it will be too late. This will be further discussed in Section 7.

4 Water Quantity – IWMP & Groundwater

4.1 Interim Water Management Pond (IWMP)

The 'Interim Water Management Pond' first began receiving water in late 1998, and by November 16 contained about 20,000 litres (0.02 ML), presumably derived from groundwater inflows from the decline and initial wet season rains. A compilation of the water levels and contained volumes within the IWMP for the three wet seasons to date is given in Table 2, including maximum operating levels (MOL) and volumes for the wet and dry seasons. Although not acknowledged elsewhere, the MOL is currently stated by ERA as 25.36 m for a contained volume of 167.0 ML [22].

The first use of IWMP water began in late December 1998 for underground drilling and decline development work (NTS, 1999). There was no further use of IWMP water beyond September 1999, until RO treatment began in mid 2000 followed by combined RO treatment and direct IWMP irrigation in late 2001.

Overall, due to the three heavy wet seasons to date, the capacity of the IWMP has been streteched to its absolute limit, though ERA has managed to avoid overtopping or overflowing of the IWMP. As noted in Section 3.3, the wet season MOL was reached on February 13, 2001, which led to pumping of 12 ML of IWMP water into the decline for temporary storage, as shown in Figure 2.

[21] - emphasis added, minutes of the Jabiluka Minesite Technical Committee, September 21, 2001 (pp 3).
[22] - Fax from Allan K Wade, ERA, November 27, 2001, 1 p.

Table 2 – IWMP Water Levels and Contained Volumes

	Water Level – RL (1)	**Contained Volume**
Dry Season MOL	25.40 m	168.339 ML
Wet Season MOL	25.23 m (25.36 m ? (2))	162.658 ML (167 ML? (2))
IWMP Maximum (3)	25.90 m	185.378 ML

	Minimum – Wet Season				**Maximum – Wet Season**		
Date	RL (m)	Vol. (ML)	%WMOL	Date	RL (m)	Vol. (ML)	%WMOL
Nov. 16, 1998	19.96	0.020	0.012%	April 14, 1999	19.96	83.769	51.5%
Oct. 21, 1999	22.19	67.515	41.5%	April 27, 2000	25.00	154.976	95.3%
Nov. 16, 2000	24.215	129.423	79.6%	Feb. 13, 2001 #	25.23	162.658	100%
				Feb. 15, 2001 D	-	12 ML D	~20% D (4)
Nov. 16, 2001 (2)	23.20	97.5					

– pumping to decline initiated (incl. date pumping finished), pond level not reached again; D – decline.

(1) - RL is 'relative level', and is referenced to sea level at 0 m;
(2) - Fax from Allan K Wade, ERA, November 27, 2001, 1 page;
(3) - level of overflow or overtopping of the walls of the IWMP;
(4) - assuming total capacity of decline at 61 ML; agreed storage capacity below the unconformity is 25 ML.

References : NTS (1999); ERA (2000 & 2001).

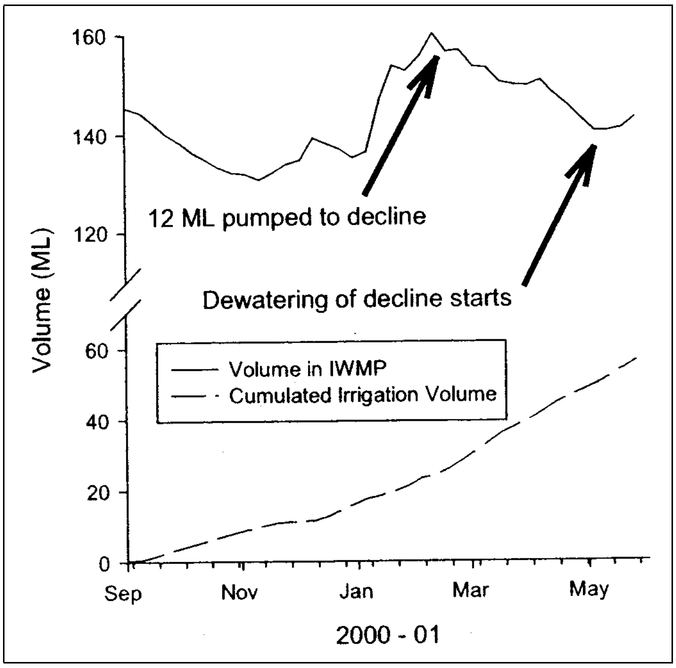


Figure 2 – Water Volume in the IWMP for the 2000-01 Wet Season (OSS, 2001a)

4.2 Groundwater Inflow

The second major source of water at the Jabiluka site is groundwater inflow to the decline. A simplified geological cross-section showing the major sources of groundwater is shown in Figure 4. Although further detailed groundwater studies were a major recommendation from the Minister for the Environment's approval of the Jabiluka Project (the Draft EIS, Supplement and PER) as well as a legal requirement from the Minister for Resources' development approvals [23], the majority of this additional baseline groundwater research has yet to be completed or even initiated [24]. Thus, the understanding of groundwater behaviour, and therefore existing and potential impacts from the Jabiluka project to date, is difficult to estimate accurately.

In general, a simplified interpretation has been adopted whereby groundwater is considered to be derived from two main aquifer systems – shallow and deep. The shallow aquifers include surficial soils, sands and the Kombolgie sandstones, while the deeper aquifers mainly consist of the Cahill Formation fractured rock sequence, which also contains the uranium orebody, though the Kombolgie at depth can also be included as part of the deep aquifer.

Based on recent information, groundwater inflows to the decline have been lower than that predicted for the environmental assessment process, although there have been times during construction of the decline that significant quantities of groundwater were required to be pumped out until an aquifer was pumped dry (eg. NTS, 1999). The average inflows during the wet and dry seasons is about 1.5 and 0.75 litres per second (0.13 and 0.065 ML/day; 32 ML per year in total), respectively (NLC, 2001c).

Although these flow rates are not large *per se* for an underground decline of the size of Jabiluka, it does illustrate some degree of response to infiltration of rainfall with higher inflows in the wet season compared to the dry season. This could be related to old exploration bores (many of which have been recently capped by ERA), disturbance from blasting and excavation works during decline construction or existing connections between the deep and shallow aquifers. The annual environmental reports by ERA (NTS, 1999; ERA, 2000 & 2001) do not adequately address physical factors controlling groundwater flows around the decline area and therefore the respective contaminant loads from the shallow and deep aquifers. Thus a high degree of caution is still required in interpreting groundwater data for the decline.

[23] - see EA, 1997 & 1998.
[24] - NLC at Gundjehmi Governing Committee, March 27, 2001.

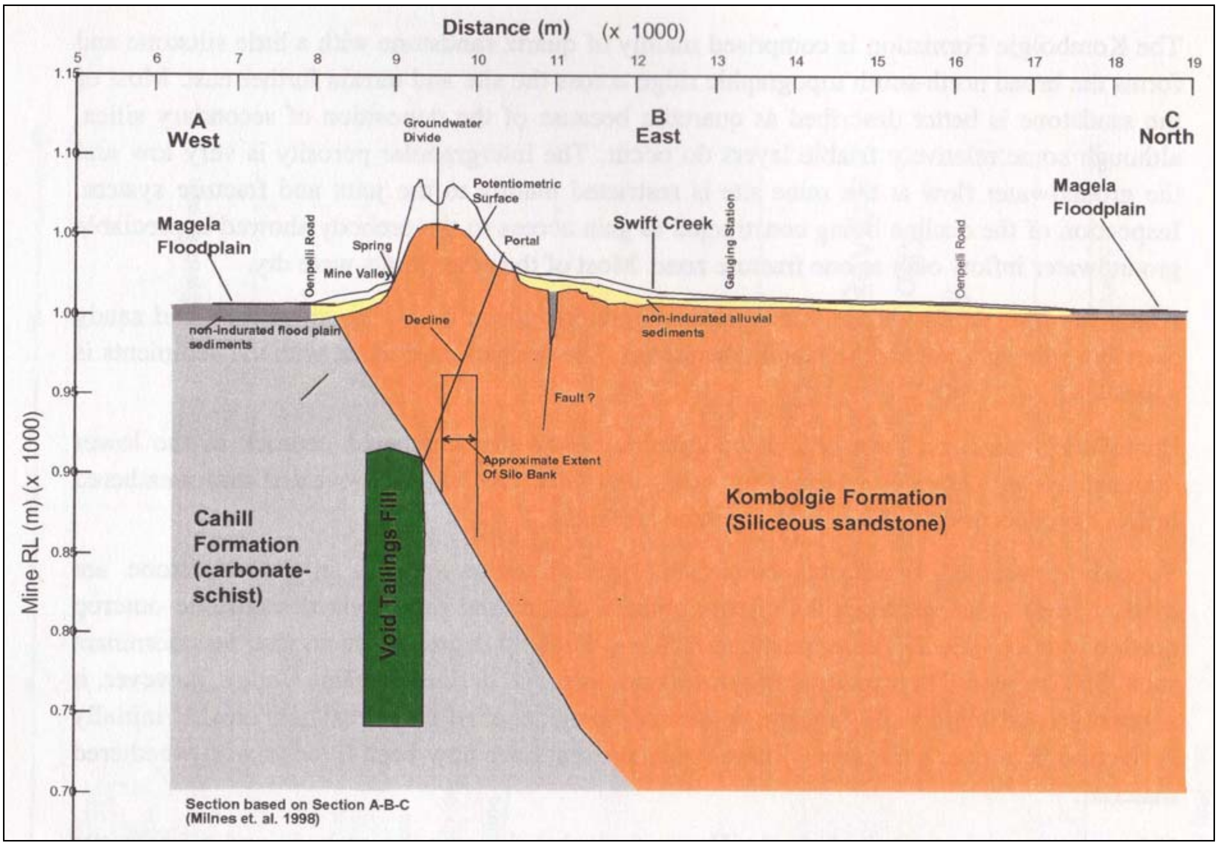


Figure 4 – Geological Cross-Section for Groundwater Sources
(from Kalf & Dudgeon, 1999)

5 Water Quality – IWMP, Groundwater and Mineralised Stockpile

One of the most critical issues in water management at Jabiluka is the quality of the water stored within the Interim Water Management Pond. There are three major sources of solutes entering the IWMP :

- surface runoff (derived from rainfall and its interaction with surface sediments);
- decline (especially groundwater inflows from the deep aquifer hosting the orebody);
- seepage from the mineralised stockpile (slightly sulfidic, low grade uranium ore).

Due to the nature of the Jabiluka site at present, the water quality in the IWMP is generally of a low salinity but it does contain very high uranium concentrations. The quantity of water in the IWMP is chiefly derived from rainfall and surface runoff, while the uranium and solute loads are largely derived from the inflow of groundwater to the decline (a minor portion of solutes also derive from the mineralised stockpile). A compilation of the water quality of the IWMP is shown in Table 3, with a graph in Figure 5. The water quality of groundwater inflow to the decline and seepage from the mineralised stockpile is presented in Table 4.

From the various tables and graphs, the major events in the history of Jabiluka to date can be discerned. For example, the intersection of mineralised material in April 1999 led to a very significant increase in uranium concentrations in the IWMP, with another major increase in June 2001 following the pumping out of the water stored in the decline from earlier in the year.

Overall, the monitoring does seem to be adequately covering the main contaminants present and potentially present in site waters due to operations. There remains, however, some points of concern about the water quality data, as presented by ERA, NTDME and OSS in their respective reports (eg. NTS, 1999; ERA, 2000 & 2001; OSS, 2001a & c; NTSA, various) :

- the mineralised stockpile contains 47,000 t of low grade uranium ore (and low sulfur grades) – this will remain a pollution source as long as it is above ground. Importantly, the stockpile is already being noted as a source of acidic drainage (eg. NLC, 2001d);
- based on single samples each year collected in April and analysed in detail (ERA, 2000 & 2001 [25]), heavy metal concentrations in the IWMP appear low (except U);
- most contaminants are in a dissolved form;
- salinity has steadily increased due to reverse osmosis treatment [26], continuing inputs of solutes and evaporation, though not dramatically;
- radium (^{226}Ra) is only analysed quarterly but shows significant activities (up to 1,000 mBq/L) and is often late in being reported – as a major component of radioactive risk, it should be routinely monitored in IWMP and other waters (preferrably fortnightly);
- radon (^{222}Rn) does not appear to be analysed at all – since radon is often present in groundwater from uranium orebodies in much higher activities than its parent radium, real data is needed to substantiate low radon levels;
- quality control issues are not sufficiently highlighted and investigated (eg. uranium in sediments [27]). This prevents full confidence in the monitoring data presented by ERA;
- if RO treatment is continued, this will lead to higher salinity and uranium concentrations over time but the rate of this increase is difficult to predict

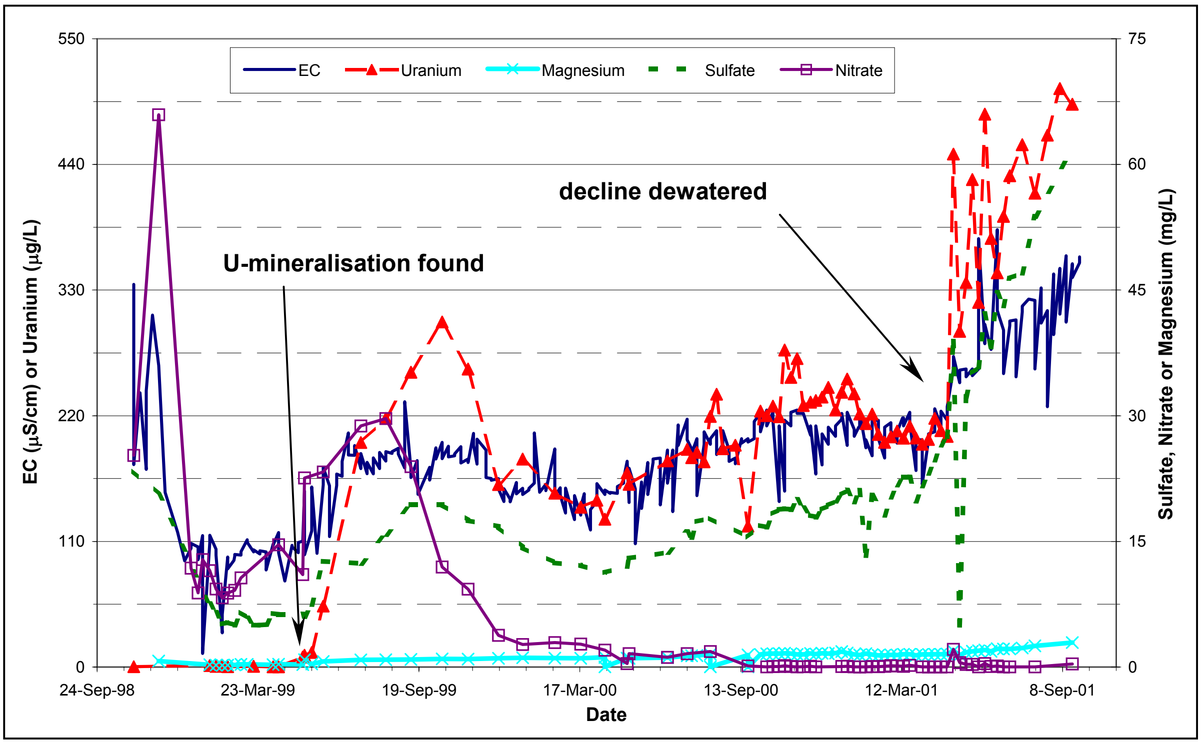


Figure 5 – IWMP Water Quality Over Time

[25] - no full analyses of heavy metals in IWMP water appears in the 1999 report (NTS, 1999).
[26] - reverse osmosis produces a high quality treated water output as well as a degraded, more saline output (or brine) which is discharged back to the IWMP.
[27] - pp 27-28, ERA (2001) and pp 28, ERA (2000), for significant differences between tested and expected uranium concentrations from analytical standard samples.

Table 3 – IWMP Water Quality Over Time

10th Percentile - Mean - 90th Percentile

	pH	**EC** (µS/cm)	**SS** (mg/L)	**Turb.** (NTU)
May 1998 – April 1999 (1)	5.7 - 8.5 - 9.7	70 - 115 - 335	38 - 102 - 235	1.1 - 119 - 546
1999 Dry	8.8 - 9.2 - 9.7	100 - 170 - 190	NA	NA
May 1999 – April 2000	8.5 - 9.0 - 9.5	140 - 160 - 190	3 - 19 - 46	3 - 14 - 34
2000 Dry	8.8 - 9.2 - 9.5	150 - 180 - 200	NA	NA
May 2000 – April 2001	8.3 - 8.6 - 9.0	180 - 200 - 220	3 - 10 - 11	2 - 4 - 5
2001 Dry	7.7 - 8.4 - 8.7	210 - 290 - 350	NA	NA

EC – Electrical Conductivity; SS – Suspended Solids; Turb. - Turbidity.

	Ca (mg/L)	**Mg** (mg/L)	**SO_4** (mg/L)	**NO_3** (mg/L)
May 1998 – April 1999 (1)	NA	1.6 - 1.9 - 3.3	5.0 - 5.6 - 19	8.8 – 16 - 25 (2)
1999 Dry	NA	2.3 - 5.0 - 6.6	12 - 16 - 18	12 - 23 - 29
May 1999 – April 2000	12 - 15 - 17	5.3 - 6.8 - 8.0	8.2 - 14 - 19	2.7 - 3.4 – 11
2000 Dry	NA	0.12 - 8.4 - 10	12 - 15 - 17	0.30 - 1.6 – 1.9
May 2000 – April 2001	19 - 20 - 22	10 - 11 - 12	16 - 19 - 23	<0.023 - 0.063 - 0.15
2001 Dry	NA	11 - 14 - 17	23 - 37 - 49	<0.023 - <0.023 - 0.46

	Cu (µg/L)	**Mn** (µg/L)	**Pb** (µg/L)	**U** (µg/L)	**^{226}Ra** (mBq/L)
May 1998 – April 1999 (1)	<2 - <2 - 2	<1.0 - 2.3 - 5.1	0.17 - 0.22 - 0.28	<0.1 - 0.4 - 1.6	16 - 17 - 18
1999 Dry	<2 - <2 -2	<1.0 - 1.1 – 5	0.14 - <1.0 - 1.0	0.21 - 13 - 226	38 - 192 (3)
May 1999 – April 2000	0.69 - 0.98 - 1.9	<1 - <1 - 2.4	0.035 - 0.095 - 0.16	29 - 170 - 280	68 - 82 (3)
2000 Dry	0.81 - 1.5 - 1.9	<1 - 0.80 - 2.9	<0.05 - <0.05 - 0.14	130 - 180 - 212	175 (3)
May 2000 – April 2001	1.8 - 3.6 - 4.8	0.40 - 1.3 - 3.2	<0.05 - <0.05 - 0.16	190 - 220 - 240	<2 - 9 - 248 (3)
2001 Dry	2.3 - 6.7 - 11	0.44 - 0.9 - 5.4	<0.05 - 0.08 - 0.16	200 - 385 - 485	190 (3)

(all µg/L)	**Al**	**Fe**	**Cu**	**Mn**	**Pb**	**Zn**	**U**	**^{226}Ra #**
Feb. 2000	865	320	4.0	9.5	0.5	13.5	206	900
Oct. 18, 2000	-	-	-	-	-	-	-	250 [a]
Dec. 5, 2000	-	-	-	-	-	-	-	240 [b]
April 17, 2001	-	-	-	-	-	-	-	190 [c]
April 20, 2001	-	-	-	-	-	-	-	193 [d]
Sep. 18, 2001	-	-	-	-	-	-	490 [e]	-

[#] – units mBq/L; [a] – residue 13 mBq/L; [b] – residue 88 mBq/L; [c] – residue 19 mBq/L; [d] – residue 19 mBq/L; [e] – residue 1 µg/L.

Note : dissolved concentrations unless specified; (1) – median not mean. NA – not available; (2) –maximum NO_3 was 66 mg/L; (3) – insufficient number of analyses for statistical analyses.

References : NTS (1999); ERA (2000 & 2001); NTSA (various); NLC (2000a & b, 2001a to e).

Table 4 - Water Quality in the Jabiluka Decline and Mineralised Stockpile
(ERA, 2001)

Decline	%10^TH	Mean	%90^TH
pH	8.0	8.4	9.0
EC (μS/cm)	280	360	530
SO_4 (mg/L)	26	47	75
NO_3 (mg/L)	0.59	2.7	4.2
Mg (mg/L)	18	26	30
U (μg/L)	360	800	1,400

Stockpile	Min.	Mean	Max.
pH	3.5	3.8	4.5
EC (μS/cm)	5,100	6,400	7,200
SO_4 (mg/L)	530	800	1,400
NO_3 (mg/L)	950	2,500	4,100
Mg (mg/L)	380	450	510
U (μg/L)	4.0	6.3	9.0

6 Performance of the Reverse Osmosis Units at Jabiluka

As noted previously, the Reverse Osmosis water treatment plants that have been installed and operated at Jabiluka have been far less than satisfactory, mainly from a volume and commercial basis. There has been some periods where the regulatory criteria for water quality have failed to be met, with the water subsequently pumped back into the IWMP. For example, during the 2001 dry season, the electrical conductivity (or EC, a measure of salinity) of RO output was satisfactory with calcium and uranium “occassionally exceeding instantaneous targets” (pp 71, NTSA, 2001b). A compilation of RO performance is presented in Tables 5 and 6 and Figure 6.

According to NTSA (2001b), 48 ML was irrigated from RO treated water in the six months to the end of September 2001. The quantity of uranium was 0.156 kg (pp 71), giving an average uranium concentration in the irrigated water of 3.25 μg/L. This represented some 70% of the authorised load limits (ie. the load limit must be about 0.225 kg for the 3.76 ha area under irrigation). Other metals in RO output were less than 10% of their authorised irrigation load limits. Based on single samples from each RO unit in April 2001 and presented in Table 32 of ERA (2001), the concentration of most heavy metals in RO output appears to be low. The actual water quality limits set by the regulators (NT Department of Mines & Energy, NTDME) for operation of the RO units from August 2000 till October 2001 have still not been released.

As discussed earlier, ERA began irrigation of mixed RO-IWMP water from late October 2001. The maximum daily volume of mixed RO-IWMP water allowed to be irrigated is 0.6 ML, which equates to 9.5 mm per day. The basis for this appears to be irrigation rates at Ranger, which are of a similar daily quantity. Based on analyses of daily evaporation versus infiltration rates at Ranger (eg. Akber *et al.*, 1991) and, it can be expected that the majority of irrigated water will infiltrate the soils at Jabiluka. Given the lower salinity of IWMP water, however, this is not likely to lead to significant salt impacts, as the case has been at Ranger’s land application areas, where salts have migrated to the banks of the Magela Creek (see Mudd, 2001).

The initial load and concentration limits were derived and approved through the NTDME without input from the OSS, and are shown in Table 7. These limits were further refined by the JMTC in late October, with the main changes being that the use of RO water only was clarified for the 2001-02 wet season and criteria to determine when the wet season ‘proper’ is considered to have started [28]. This was mainly to minimise the risk of irrigated water becoming runoff and entering Swift Creek.

[28] - eg. wet season has started when 24 hours of continuous rainfall or 7 consecutive days of rainfall occurs.

Table 5 – Reverse Osmosis Treated Water Quality : May 2000 – April 2001

(based on Jabiluka water quality database in ERA, 2001)

	Min.	Mean	Max.
pH	5.27	6.21	8.74
EC (μS/cm)	2	11.25	42
Ca (mg/L)	<0.1	0.51	1.3
Mg (mg/L)	<0.1	0.36	0.8
Cl (mg/L)	0.1	0.32	1.9
SO_4 (mg/L)	<0.1	0.66	1.8
NO_3 (mg/L)	<0.022	0.19	0.99

	Min.	Mean	Max.
Al (μg/L)	<0.1	1.74	8.0
Cu (μg/L)	<0.05	1.45	5.84
Fe (μg/L)	<20	<20	20
Mn (μg/L)	0.05	0.26	2.51
Pb (μg/L)	<0.05	0.34	0.77
^{226}Ra (mBq/L)	<2 #	<2 #	17 #
U (μg/L)	0.15	2.60	10.87
Zn (μg/L)	<0.5	4.69	21.4

Note : mean excludes values below detection. # - only four samples analysed for ^{226}Ra, three were <2 mBq/L.

Table 6 – Performance Over Time of the RO Units and Irrigated Volumes

Period	Daily RO Volume Treated	Total RO Volume	Irrigated IWMP	Total Area
August 28 to Sept. 30, 2000	up to 0.150 ML/day	3.9 ML	0	3.27 ha
Nov. 22 to Dec. 4, 2000	0 (breakdown)	0	0	3.27 ha
January 2001	~0.199 ML/day		0	3.27 ha
February 2001	~0.262 ML/day		0	3.27 ha
Oct. 1, 2000 to March 31, 2001	up to 0.377 ML/day (average 0.2 ML/day)	36 ML	0	3.27 ha
April 1 to September 30, 2001	up to 0.330 ML/day	48 ML	0	3.27 ha
Early October 2001	~0.22 ML/day		0	3.27 ha
October 2001	0.20 to 0.25 ML/day		??	6.34 ha
Late October to November 12, 2001		3.2 ML	0.3 ML	6.34 ha
November 16, 2001	~0.05 ML/day	0.05 ML	~0.15 ML	6.34 ha
November 2001 - planned #		1.5 ML	6 ML	6.34 ha
December 2001 - planned #		1.5 ML	9 ML	6.34 ha
	Total (to end 2001)	~94 ML	~16.5 ML	

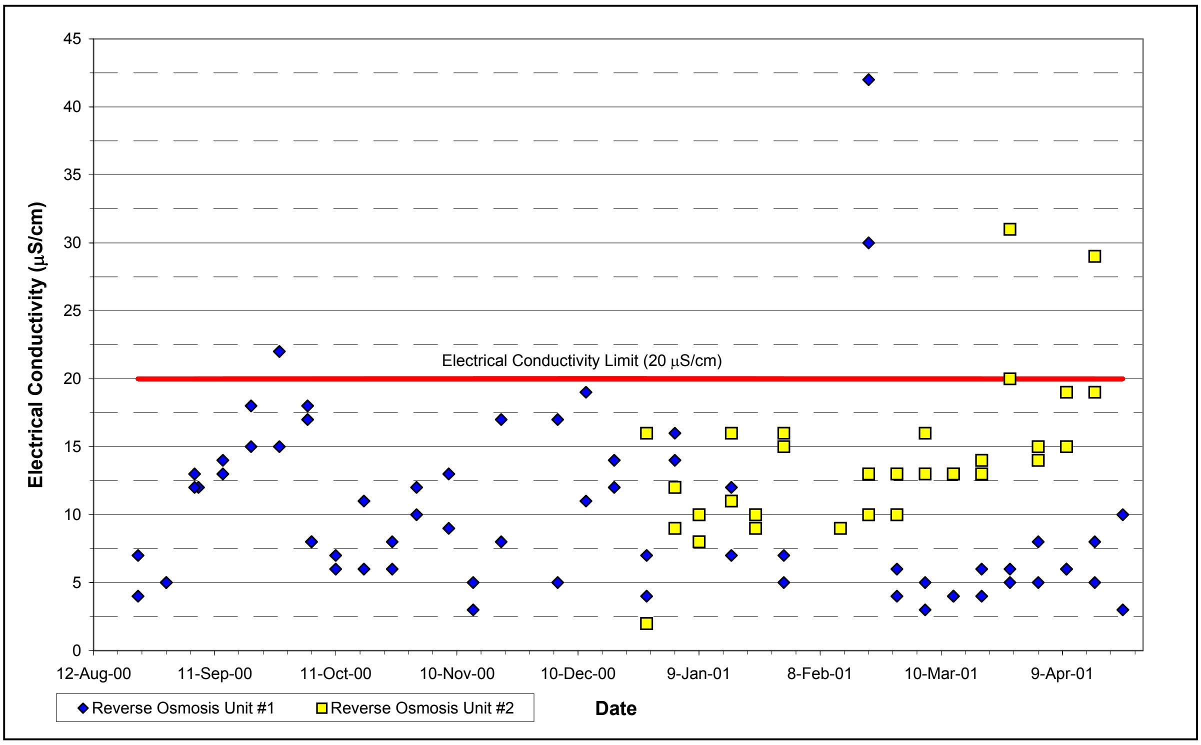
- over 15 days each period, assuming RO output of 0.05 ML/day.

References : NTSA (various); OSS (2001a & 2001c), ERA (2001).

Table 7 – Regulatory Limits for Irrigation From Late October 2001 [29]

	EC	Mg	SO_4	U
Maximum Concentrations	600 μS/cm	40 mg/L	80 mg/L	1,000 μg/L
Maximum Monthly Loads	-	700 kg	1,400 kg	40 kg
Maximum Yearly Loads	-	4,200 kg	8,400 kg	240 kg
IWMP (Sept. 2001)	360 μS/cm		60 mg/L	500 μg/L

[29] - Letter from Minister for Resources Development, Hon. Paul Henderson MLA, to R Weston (ERA), Oct. 11, 2001, 2 p.



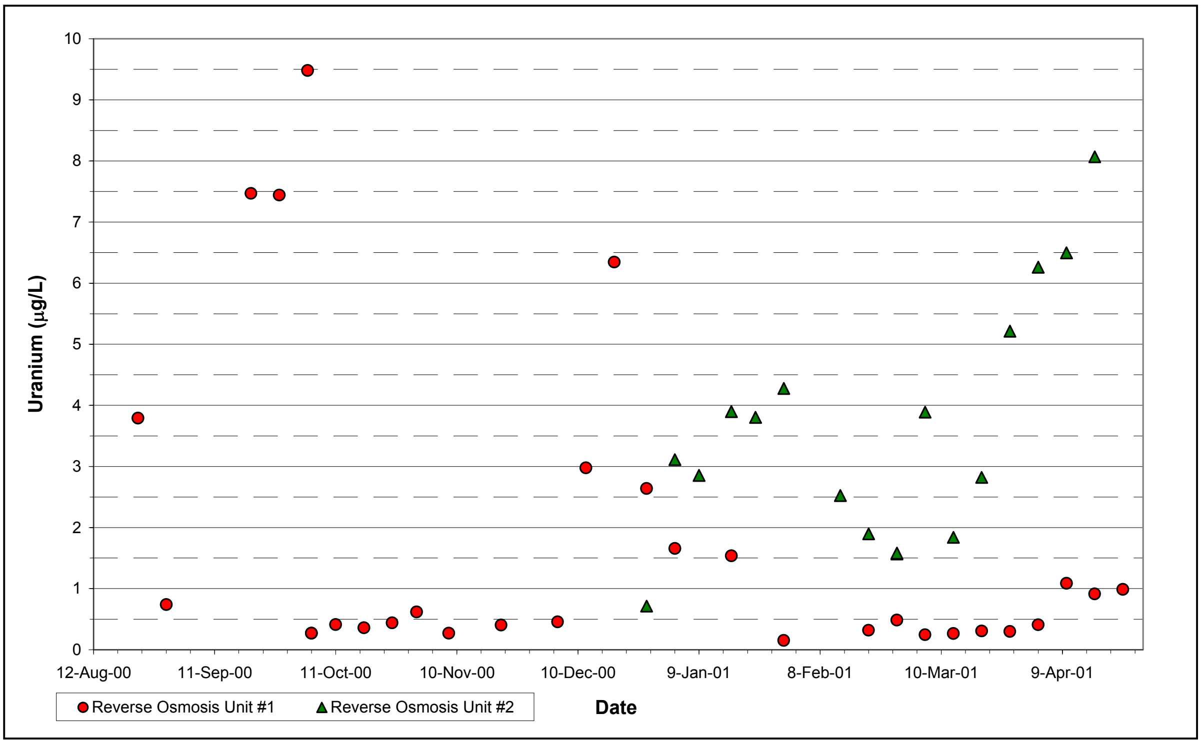


Figure 6 - Trends of Electrical Conductivity and Uranium in RO Treated Water
(data adpated from ERA, 2001)

A map of the enlarged irrigation areas (now 6.34 ha) within the Jabiluka site area is shown in Figure 7, including the 8 points for visual monitoring of runoff [30]. A number of points need to be made concerning irrigation areas :

- there is no future room for expansion if current loads are found to be excessive and irrigation loads need to be diluted;
- the basis for suitability of irrigation has been its extensive use at Ranger, which has been irrigating contaminated Retention Pond 2 (RP2) water on an area adjacent to the Ranger mill (also adjacent to Magela Creek) since 1985 – there have been no studies conducted on the contaminant retention characteristics of Jabiluka's sandier soils (which would likely have a lower ability to retain uranium), as well as potential rates of infiltration;
- the previous irrigation of RO-treated water should have been investigated for the U-retention capabilities to provide a more scientific basis for the current, increased loadings now approved;
- the uranium loadings, initially about 0.06 kg per hectare from RO treated water, have now been increased to 37.9 kg/ha – compared to average annual uranium loadings at Ranger of about 11.3 kg/ha, with the cumulative to date about 169 kg/ha [31] (a total of 6,722 kg over 53 ha).

The average uranium concentration in the earth's crust is about 2.7 parts per million (ppm or mg/kg) (eg. Langmuir, 1997; Mudd, 2001). The soils in the vicinity of the Jabiluka site are generally well below this value, varying from <0.10 to 0.5 mg/kg (eg. Kinhill, 1998; Hollingsworth *et al.*, 1998; NTS, 1999; ERA, 2000 & 2001). It is rare for soils to exceed 20 mg/kg uranium in the region [32], with most generally less than 5 mg/kg (see Mudd, 2001). According to Hollingsworth *et al.* (1998), the average uranium concentration around the Jabiluka site is 0.2 mg/kg (Appendix 2).

It is often claimed that irrigation is environmentally acceptable since the uranium (and radium-226) are retained or 'sorbed' onto the upper 5 cm of soil (eg. Akber *et al.*, 1991) and this will not lead to uranium concentrations which are significantly above background. No data is presented publicly by ERA, such as iron, clay or organic content in Jabiluka soils, to substantiate claims that such behaviour could be reasonably expected at Jabiluka.

Based on these claims, it is possible to calculate the increase in uranium concentrations expected from the high uranium loading rates approved at Jabiluka, assuming some average properties for a sandy soil :

- dry density of 1,800 kg/m^3 (porosity about 0.32)
- soil thickness of 5 cm (or 0.05 m)
- irrigation area 6.34 ha (or 63,400 m^2)

  $\Rightarrow$ gives mass of dry soil of 1,800 x 0.05 x 63,400 = 5,706,000 kg (or 5,706 t)

- based on 240 kg U :

  $\Rightarrow$ gives increase in concentration as 240,000,000 / 5,706,000 = 42 mg/kg

30 - adapted from irrigation map supplied by ERA to NLC and Gundjehmi, November 27, 2001.
31 - based on preliminary data in Mudd, G M, 2001, Ranger Research Report, due for release in early 2002.
32 - upstream in Swift Creek often has uranium between 2.5 and 16 mg/kg (see above references).

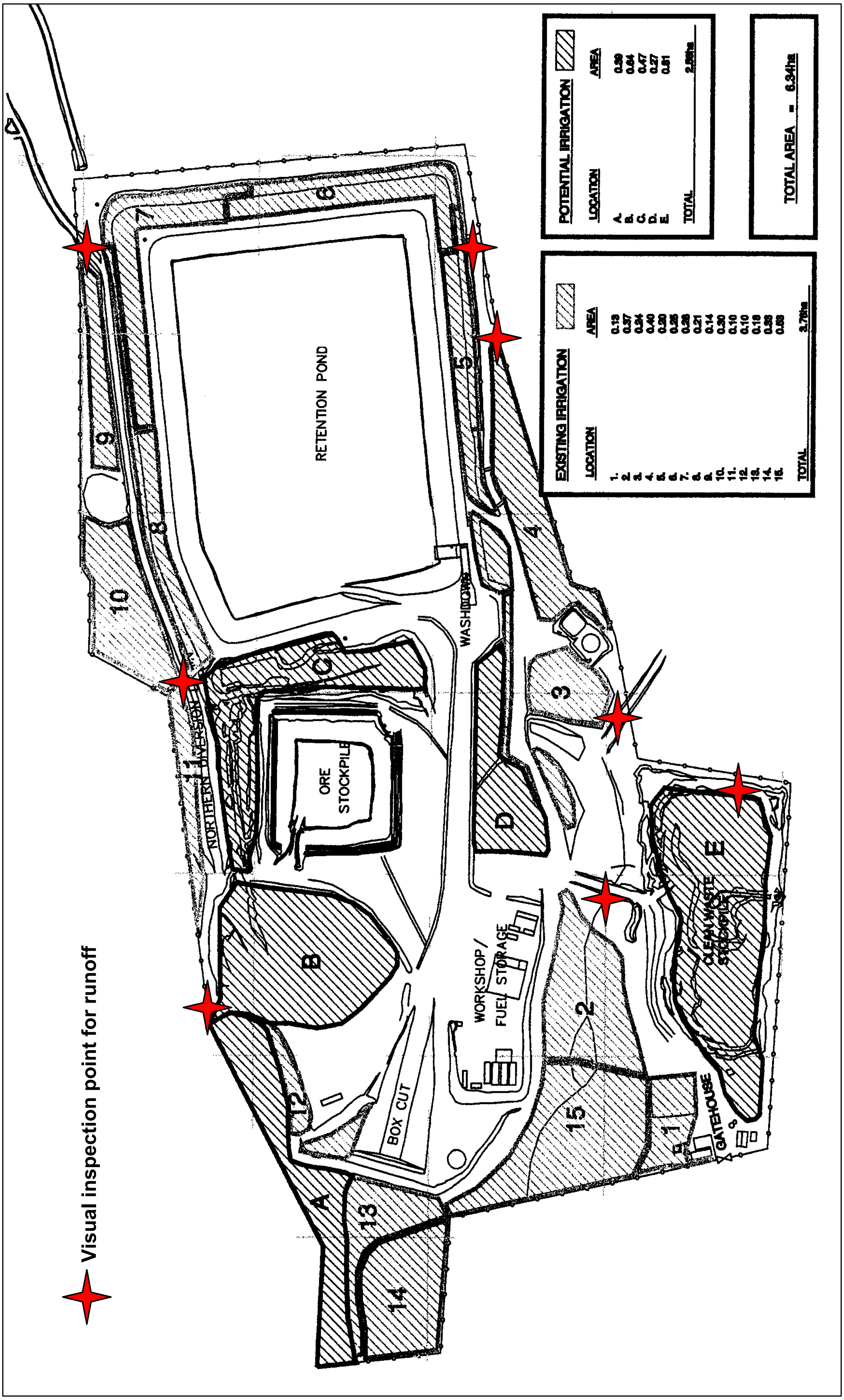


Figure 7 – Location of Irrigation Areas and Visual Monitoring Points for Runoff

If one assumes that all of the IWMP water (about 168.339 ML) is to be irrigated at the maximum uranium concentration (1,000 μg/L), this equates to some 168.339 kg U over the 6.34 ha or 26.6 kg/ha. Alternatively, if one assumes the 240 kg U limit, then this allows the uranium concentration to reach 1,425 μg/L (assuming the entire IWMP is to be irrigated). As noted for Ranger's land application, the uranium loadings are cumulative, with the annual average and cumulative uranium loadings being about 11.3 and 169 kg/ha, respectively. These figures can be compared with some realistic estimates for Jabiluka.

The maximum daily application rate is 0.6 ML, equivalent to 9.5 mm per day (which does not appear to be based on evaporation or infiltration rates of Jabiluka soil). This flow rate also allows the entire IWMP to be irrigated in one year – 168.4 ML in 365 days. If it is assumed that current IWMP water is irrigated at the approved rate, this gives rise to 0.6 kg per day, 219 kg in a full year or 34.5 kg/ha (remembering that irrigation of direct IWMP water will not be taking place during the wet season 'proper', and this figure is therefore likely to be less over a year).

Assuming the current uranium concentration in the IWMP (~500 μg/L) and only eight months irrigation (dry season), this gives an annual figure of 73 kg uranium irrigated or 11.5 kg/ha. The increase in uranium concentrations in Jabiluka site soils can be estimated as 12.8 mg/kg. Compared to natural uranium concentrations of 0.2 mg/kg, this represents a 64-fold increase compared to pre-mining conditions. For 0.4 ML per day of IWMP water over eight months, this gives a load of 49 kg of uranium and a concentration increase of 8.5 mg/kg (43-fold increase). If only RO water is irrigated (using the original 3.76 ha), this would represent an increase of just 0.05 mg/kg, or well within the range of natural concentrations on the Jabiluka site. A compilation of the various load estimates, including those for Mg and SO_4, is presented in Table 8. The quality of irrigated RP2 water from Ranger is also shown.

Table 8 – Estimates of Annual Mg, SO_4 and U Loads in Irrigation at Jabiluka

	Mg			**SO_4**			**U**		
	mg/L	kg	kg/ha	mg/L	kg	kg/ha	μg/L	kg	kg/ha
Approved Limits	40	4,200	662	80	8,400	1,325	1,000	240	37.8
Current IWMP (1)	21	3,066	484	62	9,052	1,428	~500	73	11.5
Current IWMP (2)	21	1,533	242	62	4,526	714	~500	36.5	5.8
Typical RO	0.36	-	-	0.66	-	-	2.6	-	-
Ranger RP2 (3)	88	133 t	2,515	437	2,315 t	43,680	1,500	6,722	169

(1) – based on 8 months irrigation at 0.6 ML per day (or 146 ML per year), concentration data from NTSA (2001b) (based on electronic data provided by Gretel Parker, NTDME);
(2) – based on 8 months irrigation at 0.3 ML per day (or 73 ML per year), concentration data from NTSA (2001b);
(3) – average concentrations and cumulative loads to date (15 years) over 53 ha (Mudd, 2001).

The above estimates are somewhat speculative without access to actual irrigation data, that is – the water quality and respective quantities of RO and IWMP waters. Depending on the extent of RO treatment during late 2001, the actual increase in uranium in Jabiluka soils could be lower, but if higher proportions of IWMP water are used (which is considered likely), then the increase may be even higher than 64-fold. It is clear that current irrigation practices and approvals allow for significant increases in uranium concentrations in soils far in excess of pre-mining concentrations.

The irrigation concentration and load limits therefore appear designed to ensure that irrigation at Jabiluka can proceed without "stringent operational criteria" since the current loads and concentrations of Mg, SO_4 and U are such that the IWMP should not reach values approaching the load and concentration limits. However, given recent increases in contaminant concentrations, this may not hold true if several years are allowed to pass and both ERA and NT regulators would be forced to reconsider load limits accordingly.

7 Water Quality Issues for Swift Creek

As alluded to earlier in Section 3.3, the three trigger levels or water quality criteria that ERA are required to meet downstream in Swift Creek were based on statistical analyses of background concentrations. The methodology was based on the recently released National Water Quality Management Strategy guidelines [33], which allow for site-specific data to be set based on local toxicity data and statistical analysis techniques (ANZECC & ARMCANZ, 2000). During the site visit on November 16, 2001, ERA and OSS were claiming that this is probably the first application of the new guidelines in Australia, or at the very least for the mining industry. However, the suitability of the derived values for Jabiluka do require comparison to the new recommended guideline values, plus the typical background values in Swift Creek, as compiled in Table 9.

Table 9 – Trigger Levels for Water Quality Criteria in Swift Creek

	Focus	Action	Limit	NWMQS	Swift Creek (1)	
					Upstream	Downstream
EC (μS/cm)	15	18	21	20 – 250 (2)	9 – 17	7.4 – 17
pH	4.61 – 5.31	4.27 – 5.65	3.92 – 6.00	6.0 – 8.0 (3)	4.5 – 6.4	5.2 – 6.0
Mg (mg/L)	0.37	0.50	0.76	no data	<0.1 – 0.56	<0.1 – 0.65
NO_3 (mg/L)	0.30	0.63	1.26	0.005 (3)	<0.022 – 0.034	<0.022 – 0.05 (4)
SO_4 (mg/L)	0.60	0.91	1.50	no data	<0.1 – 0.60	<0.1 – 0.74
U (μg/L)	0.02	0.03	5.8	0.5 (5)	<0.005 – 0.015	<0.005 – 0.017

Notes :
- Focus – mean plus 1 standard deviation (80th percentile) [34];
- Action – mean plus 2 standard deviations (95th percentile);
- Focus – mean plus 3 standard deviations (99.7th percentile) or the 'No Observable Effect Concentration' (NOEC) [35].

(1) – based on 10TH and 90TH percentiles in NTSA (2001b) (based on NTS, 1999; ERA, 2000 & 2001);
(2) – recommended values for 'slightly disturbed' NT tropical upland and lowland rivers;
(3) – recommended values for 'slightly disturbed' NT tropical wetlands, freshwater lakes and reservoirs, and lowland rivers (though pH is clearly not applicable to Swift Creek);
(4) – some potential impacts from blast residues (high in nitrate) leaching from non-mineralised waste rock (values over 0.35 mg/L were observed);
(5) – considered a 'low reliability' toxicity-based guideline.

References : ANZECC & ARMCANZ (2000); NTSA (2001b); OSS (2001c).

33 - developed by the Australian & New Zealand Environment & Conservation Council (ANZECC) and the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ). (see www.ea.gov.au/water/quality/nwqms/) [ERISS/OSS had significant input into these guidelines.]
34 - a standard deviation and percentile are measures of the statistical variation in a data set.
35 - when no toxic effects are observed in biological tests on various organisms at this concentration.

As can be seen, the natural water quality of Swift Creek is quite pure and of very high quality with low salinity (such as Mg and SO_4) and extremely low uranium [36]. Compared to the new NWQMS guidelines, the trigger values are generally low and reasonable from a ecotoxicity or environmental risk – except uranium. The 'limit' of 5.8 μg/L is some 12 times higher than the NWQMS value, although the data used to derive this figure is considered of low reliability. This also compares to the proposed World Health Orgtanisation guideline of 2 μg/L, the USA and Canadian guidelines of 20 μg/L [37]. Based on these figures, the limit value of 5.8 μg/L is therefore in the lower range of global guideline values, but is still about 580 times higher than the typical median values in Swift Creek of 0.01 μg/L (see NTSA, 2001b).

The 5.8 μg/L limit for uranium allows significantly increased loads to be discharged through the Swift Creek before ERA could be considered to have potentially breached the Environmental Requirements for the Jabiluka project. It is perhaps academic whether or not the concentrations are sufficient to induce toxic responses in various organisms, as this represents a demonstrable environmental impact if it is indeed reached. If this value is reached, there would be serious risk of further increases, since it would suggest the failure of irrigation and uranium being retained by soils, as well as other management regimes at the Jabiluka site.

For NO_3, the amount of non-mineralised rock on the surface exposed to weathering and leaching has not increased since late 1999. This should see a decrease in the NO_3 being leached into the tributaries of Swift Creek over time, as can be seen in the North Tributary over the past three wet seasons (which was mainly impacted by NO_3 in the 1998-99 wet season). The Central Tributary, on the other hand, experienced an increase in NO_3 in the 1999-2000 and 2000-01 wet seasons, indicating a slower leaching due to flow through the stockpile attenuating diretc discharge into the creeks. Over time NO_3 would be expected to return to background levels, however, the trigger levels for NO_3 do allow for substantial increases (which would likely require further mining and placing of waste rock on the surface). As a major component of nutrients in aquatic ecosystems, sustained increases in NO_3 are of concern.

The basis for trigger values for Swift Creek for EC, pH, Mg and SO_4, as variation from background, should not see noticeable effects in the aquatic ecosystems. The main concern is that such increases could point to failure of management regimes at Jabiluka and the potential for increases in uranium associated with such failures. Given that experience at Ranger shows that Mg and SO_4 in irrigated RP2 water is not retained by soils (and has been shown to migrate to Magela Creek), the irrigation of IWMP water at Jabiluka is likely to lead to an increase in Mg and SO_4 in Swift Creek, though small in magnitude. Prolonged irrigation of IWMP could lead to the trigger levels being approached, though how many wet seasons this might take is unclear and speculative.

[36] - such low concentrations of uranium have only become analytically detectable in recent times.
[37] - see www.antenna.nl/wise/uranium/utox.html

In summary, the trigger values set for downstream water quality in Swift Creek are mostly conservative and should not see significant environmental effects arise, however the values for nitrate and uranium do allow substantial increases over background concentrations. A further concern is that by the time monitoring detects these impacts in Swift Creek, a significant quantity of contaminants would already have been leached or flushed from the Jabiluka site and therefore not amenable to remediation through management changes at Jabiluka. Assuming that appropriate changes are made promptly on-site, this would mean that over the next few wet seasons, this load of contaminants would be flushed through the system, leading to slow decreases in concentrations in Swift Creek [38].

8 Summary and Recommendations

Water management at proposed and operating uranium mines in the Alligator Rivers Region has always been a contentious indigenous, public and scientific issue. The various regimes approved for water management have always been on the basis of ‘no-release’ of contaminated mine site waters. When current owner of the Jabiluka site, Energy Resources of Australia Ltd, began construction – against the wishes of the traditional owners – they clearly took the risk of building staged facilities that support the Ranger Mill Alternative (RMA) (trucking Jabiluka ore to Ranger for processing). The subsequent veto over this proposal has seen Jabiluka stalled and the small ‘Interim Water Management Pond’ (IWMP) being forced to operate as a medium-term solution, contrary to its design and function. The IWMP has now been through 3 heavy wet seasons and is now preparing for its fourth.

From mid-2000 to late 2001, emergency action saw two Reverse Osmosis (RO) water treatment units installed but they have failed to meet performance expectations (mainly on a volume basis, although some water quality targets, such as EC, were being occassionally exceeded).

In late 2001 ERA sought and received approval for direct irrigation of IWMP water, with loads which will significantly increase the uranium concentrations around the Jabiluka site. The loads approved for magnesium and sulfate are already close to beign exceeded, though they are still much lower than those used in irrigation at Ranger.

The trigger levels for water quality downstream in Swift Creek should not lead to any significant environmental effects, although the maximum ‘limit’ value does allow substantive increases in uranium and nitrate. If the highest trigger limits are exceeded, it is likely that it will take a period of time to recover typical background concentrations.

There are still several unknowns in quantifying the medium- to long-term effects, as this would depend on the actual quantity and quality of RO and IWMP waters irrigated by the end of 2001, the nature of the 2001-02 wet season and the contribution from the decline.

[38] - eg. uranium contamination in RP1 at Ranger, once occurred, has taken three wet seasons to flush through, despite active changes in the catchment for uranium sources (low grade ore). After the third wet season, the uranium concentrations are still above those prior to the start of the contamination.

A detailed review of water management is scheduled to begin in February 2002, which should lead to consideration of future options at Jabiluka. There are two clear options shown by this to be preferrable – continued use of active water treatment (such as RO or a functionally equivalent technology like ion exchange columns) and action to reduce inflow from the decline (the major source of uranium contamination).

In the short-term, RO treatment capacity (or equivalent) needs to be maintained on-site at Jabiluka to minimise the increasing spread of contaminants through irrigation and help to manage the water balance and quality within the IWMP. However, it is clear that the use and need for such options would be negated if the principal source of uranium – decline inflow – was rehabilitated in a fashion which stops the need for dewatering. This would involve the placement of most of the mineralised stockpile back into the decline with appropriate lining or sealing. The major difficulties or uncertainties in this approach relate to the small quantity of mineralised material which would not fit into the decline plus the poorly understood groundwater behaviour in this region. Further work is needed to more clearly refine understanding of these uncertainties.

Water management at Jabiluka has clearly not been systematically planned, and is now regularly disposing of excess contaminated water outside of the 'Restricted Release Zone' (though this is still within the current footprint of the site). If the past four years is a guide to the future directions of ERA's management of the site, the current difficulties are not likely to be overcome to the satisfaction of the traditional owners.

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10 Chronology of Jabiluka Minesite Technical Committee Meetings

• May 6, 1998 • May 19, 1998 • June 17, 1998 • August 26, 1998 • October 8, 1998 • November 24, 1998	• January 20, 1999 • March 3, 1999 • May 21, 1999 • September 10, 1999 • November 3, 1999	• Febuary 3, 2000 • March 19, 2000 # • July 19, 2000 # • January 23, 2001 • September 7, 2001 • September 21, 2001 • October 1, 2001 # • October (late), 2001 #

- informal meeting only.

11 Common Acronyms & Units

EIS	Environmental Impact Statement
ERA	Energy Resources of Australia Ltd
ERISS	Environmental Research Institute of the Supervising Scientist
IWMP	Interim Water Management Pond
JMA	Jabiluka Mill Alternative
MOL	Maximum Operating Level
MTC	Minesite Technical Committee
NLC	Northern Land Council
NTDME	Northern Territory Department of Mines and Energy
NTS	North Technical Services (division of North Ltd)
NTSA	Northern Territory Supervising Authorities (part of NTDME)
OSS	Office of the Supervising Scientist
RMA	Ranger Mill Alternative
RO	Reverse Osmosis
RRZ	Restricted Release Zone
TCZ	Total Containment Zone

12 Abbreviations for Elements, Chemical Units & Measurements

EC	Electrical Conductivity (measured in ‘μS/cm’)
g	gram (1 kg = 10^3 or 1,000 g)
ha	hectares (100x100 metres, or 10,000 m^2)
L	litre (mass of 1 kg)
mg/L	milligrams per litre (or parts per million, ppm)
ML	mega litre (1,000,000 litres or 10^6 L)
mm	millimetres (10^{-3} metres)
SS	Suspended Solids (measured in ‘mg/L’)
Turb.	Turbidity (measured in ‘NTU’)
t	tonnes (1,000 kg)
U_3O_8	Uranium Oxide (‘Yellowcake’)
μg/L	micrograms per litre (or parts per billion, ppb)

Al	Aluminium	Pb	Lead
Ca	Calcium	pH	acidity / alkalinity
Cu	Copper	^{226}Ra	Radium-226
Fe	Iron	^{222}Rn	Radon-222
Mg	Magnesium	SO_4	Sulfate
Mn	Manganese	U	Uranium
NO_3	Nitrate	Zn	Zinc

Appendix 1 – Monthly Rainfall and Evaporation at Jabiluka (mm)

	Rainfall	Evap'n	Rainfall	Evap'n	Rainfall	Evap'n	Rainfall	Evap'n
	1998	1998	1999	1999	2000	2000	2001	2001
January			388	145	202.2	143.2	626.4	161.6
February			344	109	396.2	116.6	518.8	110.2
March			363	144	403.8	136.2	263.8	130.4
April					224.0	117.4	102.8	150.6
May			0.0	166.0	30.2	172.2	0.0	178
June			0.4	167.0	0.0	159.4	0.0	163
July			0.0	189.0	0.0	165.6	0.0	181
August			0.0	192.4	0.0	183.6	0.0	191
September			0.0	184.0	0.0	212.0	0.0	210
October	167	218	83.2	200.8	50.4	206.6		
November	121	161	225.6	165.8	149.2	194.6		
December	388	135	326.8	157.4	212.0	133.6		

Rainfall	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Minimum	405.5	419.7	343.5	163.4	10.1	0.1	0.0	0.0	0.0	100.2	165.3	308.9
Average	202.2	344.0	263.8	102.8	0.0	0.0	0.0	0.0	0.0	50.4	121.0	212.0
Maximum	626.4	518.8	403.8	224.0	30.2	0.4	0.0	0.0	0.0	167.0	225.6	388.0

Evap'n	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Minimum	149.9	111.9	136.9	134.0	172.1	163.1	178.5	189.0	202.0	208.5	173.8	142.0
Average	143.2	109.0	130.4	117.4	166.0	159.4	165.6	183.6	184.0	200.8	161.0	133.6
Maximum	161.6	116.6	144.0	150.6	178.0	167.0	189.0	192.4	212.0	218.0	194.6	157.4

Appendix 2 – Definition of 'Best Practicable Technology' (BPT)

From OSS (1999b)

12. BEST PRACTICABLE TECHNOLOGY

12.1 All aspects of the Ranger Environmental Requirements must be implemented in accordance with BPT.

12.2 Where there is unanimous agreement between the major stakeholders that the primary environmental objectives can be best achieved by the adoption of a proposed action which is contrary to the Environmental Requirements, and which has been determined in accordance with BPT, that proposed action should be adopted. Where agreement can not be reached the Minister will make a determination with the advice of the Supervising Scientist.

12.3 All environmental matters not covered by these Environmental Requirements must be dealt with by the application of BPT.

12.4 BPT is defined as : That technology from time to time relevant to the Ranger Project which produces the maximum environmental benefit that can be reasonably achieved having regard to all relevant matters including :

a) the environmental standards achieved by uranium operations elsewhere in the world with respect to :
i) level of effluent control achieved; and
ii) the extent to which environmental degradation is prevented;
b) the level of environmental protection to be achieved by the application or adoption of the technology and the resources required to apply or adopt the technology so as to achieve the maximum environmental benefit from the available resources;
c) evidence of detriment, or lack of detriment, to the environment;
d) the physical location of the Ranger Project;
e) the age of equipment and facilities in use on the Ranger Project and their relative effectiveness in reducing environmental pollution and degradation; and
f) social factors including the views of the regional community and possible adverse effects of introducing alternative technology.

12.5 Proposals to amend or introduce operational approaches, procedures or mechanisms must be supported by a BPT analysis. The rigour of the BPT analysis must be commensurate with the potential environmental significance of the proposal.The BPT analysis must involve consultation with and having regard to the views of the major stakeholders and copies of the BPT analysis must be provided to each of the major stakeholders.

12.6 A precautionary approach is to be exercised in the application of BPT in order to achieve outcomes consistent with the primary environmental objectives.