A HISTORY OF URANIUM MILL TAILINGS MANAGEMENT IN NORTHERN AUSTRALIA

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ABSTRACT

Uranium mining in the northern part of Australia has been taking place more or less continuously since 1949. The long-term fate of uranium mill tailings has been a major environmental management issue for almost as long. As public awareness and the level of environmental concern have increased over the past 50 years or so, mining companies have had to improve the standards of environmental management, especially for matters of long-term waste management. The paper describes the transition from tailings mismanagement of the early days with uncontrolled heaps that discharged to the environment through early rehabilitation efforts and subsequent clean-up operations to modern systems incorporating the latest ideas and conforming to some of the world's highest environmental standards. The paper also looks to the future for some proposals for what could be the ultimate containment solution. The case histories discussed include the mining operations at Rum Jungle, South Alligator, Nabarlek and Ranger and show how the lessons of the past have led to the development of the systems in place today and potential improvements for the future.

INTRODUCTION

Uranium mining has been an activity in the "top end" of Australia's Northern Territory since 1949. At that time the exploitation of the Rum Jungle deposit began in earnest in association with the copper resource at the same site. As uranium was a metal of strategic significance the Australian Government had offered a substantial reward for the discovery of significant uranium deposits [1]. In a short time the deposits at Adelaide River and the uranium field of the South Alligator Valley had also been discovered and exploitation began. The mining operations were relatively small by today's standards, in some cases extremely small, and only three mills were operating, at Rum Jungle, Moline and South Alligator. In the campaigns of 60s the deposits of Koongarra, Nabarlek, Ranger and Jabiluka were discovered and mills were built at Nabarlek and Ranger. Today only Ranger is still operating and the deposits at Koongarra and Jabiluka await development. Another project in the sub-tropical zone of Australia was the Mary Kathleen uranium mine in Queensland. A brief overview of the history of tailings disposal at that site has also been included.

In respect of waste management, specifically uranium mill tailings management, the methods of the early days were not subject to environmental controls and the consequences of these uncontrolled practices have required intervention to achieve compliance with the environmental requirements of more recent times. In the study area (see Fig. 1) there have been three main interventions in relation to uranium mill tailings management: Rum Jungle in 1984, Moline and South Alligator in 1986 and South Alligator again in 1991 and 2001. The Nabarlek operation milled from 1980 until 1988 and Ranger commenced milling in 1981 and is still operating. The Jabiluka Project did commence some development work in 1999 but no milling took place. However, the issue of tailings management was a major topic in the updated Environmental Impact Statement (EIS) and a number of options were considered related to tailings management resulting in a proposal for a potential solution, which is considered to be unique.

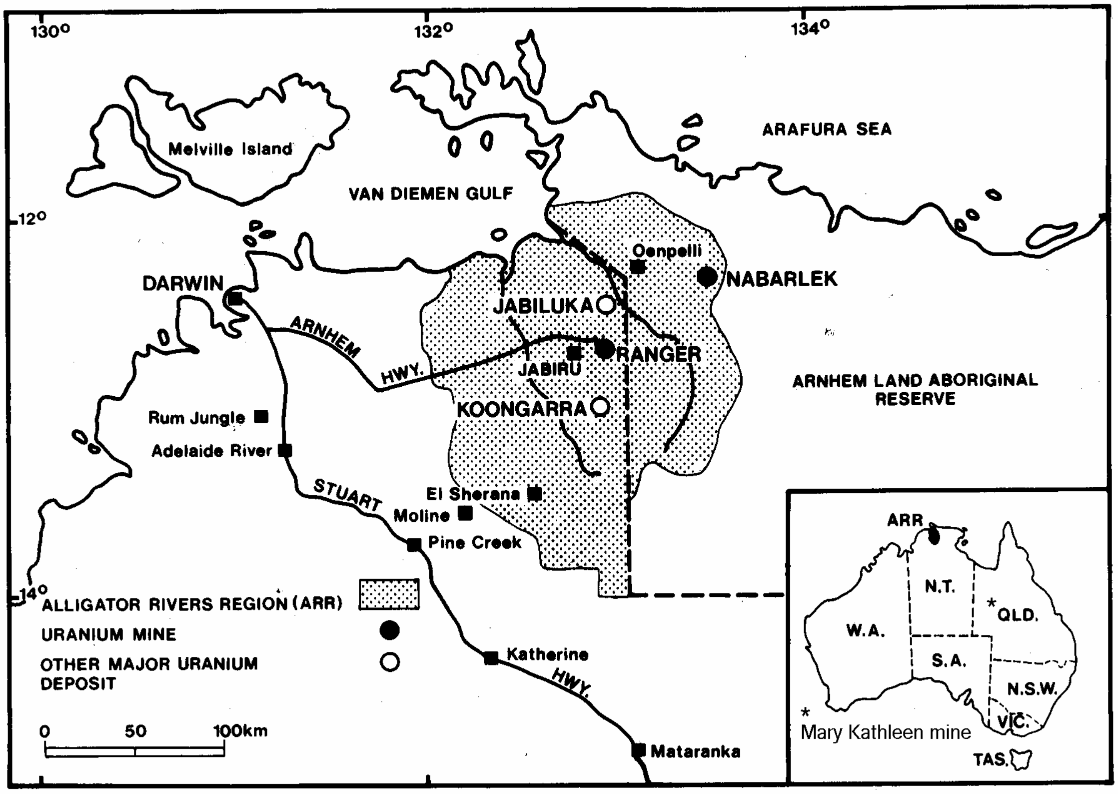

Fig. 1 Location map

CASE STUDIES

The study deals with the waste management aspects of the uranium mines of the "Top End". In context waste has been taken to mean uranium mill tailings but it should be remembered that waste rock either as overburden or with sub-economic grades of mineralisation may also represent substantial sources and volumes of waste associated with these mines [2]. Much of such materials may be classified as NORM (Naturally Occuring Radioactive Material) waste by current standards, and therefore requires to be managed appropriately as well as the tailings.

Rum Jungle

The Rum Jungle uranium deposit was first discovered in 1949, although there had been earlier reports of uranium minerals in the vicinity. The Rum Jungle area was highly mineralised and the mining of copper primarily, but also nickel and lead, in addition to uranium, continued from 1950 until 1965. The uranium mining and milling operations ran from 1950 until 1963 with four different open cuts being exploited at various times [3]. The total amount of uranium ore treated was 863,000 tonnes (1 tonne = 1Mg) in addition to a further 281,000 tonnes of uranium/copper ores, with a final production of 3,530 tonnes of U_3O_8. The mill also processed smaller quantities of ore from other sites including the nearby Adelaide River area and the Eva mine in Queensland [4].

In the early stages of milling the tailings were deposited in a shallow valley behind a low dam with dimensions of approximately 800m by 500m. The dam comprised a series of small impoundments and ultimately contained approximately 600,000 tonnes of tailings covering an area of about 31ha (0.31square km) [5]. This method continued from 1950 until 1954, when White's open cut was mined out and subsequently used as a tailings repository. The climate of northern Australia is marked by distinct wet and dry seasons, with an annual rainfall in this area of about 1,500mm, of which 95% falls between October and April. Under these conditions the vestigial tailings dam at Rum Jungle was frequently inundated and consequently overflowed with tailings flowing down the creek to discharge into the East Finnis River.

The ore materials mined at Rum Jungle contained high levels of sulfides. When these minerals oxidised in the tailings and waste rock dumps the sulfuric acid produced mobilised much of the residual heavy metals, especially copper, which then drained from the site by both surface and ground waters to pollute the downstream catchment. The impact on the East Finniss River was significant and resulted in an appreciable decline in fish diversity and abundance for at least 15 km downstream and a severe degradation of riparian and aquatic vegetation [6].

As part of an initial rehabilitation plan in 1986, all remaining tailings and contaminated soil were removed to the former Dyson's open cut, which was then capped and revegetated. There are no records of the pit being prepared in any special way, the tailings were placed in bulk, given one metre of rock cover, which was then covered with alternating layers of contaminated soil and copper heap leach waste, which were finally covered with soil before revegetation [5]. The rehabilitation work to cover the reactive waste rock dumps has recently been shown to be losing some effectiveness [7]. However, to date there have been no major problems reported with the final tailings disposal solution. No attempt was ever made to recover tailings from the Finniss River system and whilst the dispersed materials can be tracked radiologically there is no suggestion that they are causing any adverse environmental impacts. The problems in the river system were primarily attributed to the copper and other heavy metal pollution associated with the acid drainage.

Adelaide River

Between 1954 and 1957 ore from the Adelaide River deposits was processed at Rum Jungle and so no separate tailings disposal or storage facility was established. The process residues were incorporated into the tailings deposits at Rum Jungle. The nature of the operation meant that there were no significant waste rock stockpiles at the mines either.

South Alligator

There were two competing operations mining uranium in the South Alligator valley between 1953 and 1964. Initially United Uranium NL had a contract to supply customers in the USA and UK with pitchblende concentrates. The concentrates were produced at a gravity separation plant located some 2 km west of the El Sherana camp. The plant was opened in 1956. In addition to the concentrates these operations produced limited amounts of a tailings-like waste, which were sold onto the operations at Rum Jungle. Eventually, in about 1964, the processing site was simply abandoned and the residues remaining in the slimes of the ponds etc were not cleaned up until they formed a part of a hazard reduction program in 1991-92 [8]. The level of contamination was variable with some slimes areas giving gamma dose rates of between 3 and 14 $\mu G\ h^{-1}$ [9].

During the hazard reduction works program the pond walls and floors were bulldozed up into stockpiles to one side of the site. Two trenches were then dug approximately 5m wide by 80 m long by 4m deep across the site. The contaminated material was then placed in the bottom of the trench followed by contaminated scrap metal from other abandoned facilities at the site. A minimum cover of 1.5 metres of clean material was then used to fill in the trenches, which were reseeded. The site was landscaped to ensure that surface drainage was diverted away from and around the area of the containment. A radiological survey was undertaken over the whole site prior to completion of earthworks to ensure that the site clearance criterion ($<0.5\mu G\ h^{-1}$) had been achieved.

In the late 1950s a small mill was constructed by South Alligator Uranium NL which was located about 20 km downstream (east) of El Sherana alongside the road and between the base of the valley wall and the river bank. The mines serving this mill were known as the "Rockhole" mines. This mill was of only modest capacity but is claimed to have been the smallest solvent extraction process plant in Australia [10]. The tailings were simply piled at the lower end of the mill site, alongside the road. At times during the wet season, as a result of the river flooding, this area may be inundated to a depth of 4 metres or more and consequently some tailings were lost downstream. Today there is little trace of this series of events. The remaining tailings were left on site when the mill was abandoned in 1964, and in most years some tailings were continuing to be washed away by floods (R.Fry, first Supervising Scientist, pers.com).

However, in 1986 a small mining operator, Pacific Gold NL, offered to purchase the tailings and remove them to Moline, some 50km to the west, where they were treated to extract gold. Between June and November 1986 approximately 6,000 tonnes of tailings were removed from the "Rockhole" site and treated at Moline with the recovery of about 25 kg gold. The tailings at Moline were combined with the existing uranium tailings stock and the whole rehabilitated as one. This action was required as there had been a failure of the original tailings containment at Moline.

In 1991 a hazard reduction program carried out in the South Alligator valley included the demolition and burial of the mill and any residual tailings material [9]. The program was aimed at reducing radiological and physical hazards associated with mining in the valley, which had been gazetted as an established part of Kakadu National Park. In 1999 a routine monitoring survey of the former mill area discovered some additional uranium mill tailings, previously buried, had been exposed by road works. The plan to remediate these tailings and all associated, contaminated soil materials is currently underway as an integral part of the overall program to rehabilitate all former mining and milling sites in the area [11]. The proposal is for all the tailings and associated contaminated soil and other materials to be placed in a custom built containment within the valley. The containment would be built to modern standards.

Moline

The site of the former Northern Hercules mine and mill was renamed Moline by United Uranium NL when they acquired the site in 1958. This was a former gold mine site which was no longer economic. However, its location only about 50 km from the South Alligator valley uranium field made the acquisition of an operating mill an attractive alternative to building a new mill at El Sherana. Between 1959 and 1972 some 246000 tonnes of ore were milled at Moline, mainly from the uranium mines of the South Alligator valley. The tailings were deposited in a series of small dams, which were allowed to fail with each passing wet season. It was estimated that some 63,000 tonnes of tailings were allowed to erode away into the creek and thence to the Mary River system [12]. In 1986 the tailings were reprocessed to extract gold in conjunction with the transport and reprocessing of the 6,000 tonnes of South Alligator mill tailings. At the end of the extraction program all the remaining tailings were relocated to a custom built tailings storage facility designed to meet the requirements of the then newly revised Code of Practice for the management of uranium tailings. This required that uranium mill tailings stored above ground should remain contained for at least 1,000 years. To date the tailings repository has been performing in accordance with the design criteria.

Mary Kathleen

This facility had two phases of operational life, from 1958 to 1963, and 1976 to 1982. At the end of the first phase little attention was paid to rehabilitation. However, by the time the second phase ended some early Australian Government environmental protection legislation was in place and this required that the facility be rehabilitated. The total amount of tailings to be managed was estimated to be approximately 7 million tonnes spread over an area of about 28 ha.The coarse tailings fraction had been cycloned off during production and placed at the downstream toe of the main tailings dam. This area was leveled out during rehabilitation and given a cover of waste rock, which was 2 metres thick on the batter slope and 1 metre thick on the level areas, which had been graded to 0.5% slope to assist runoff. Finally a filter zone was created at the toe of the wall to trap any fine material eroding from the tailings area. This filter was itself protected by a 2 metre thick layer of waste rock covered with large rocks.

The majority of the tailings surfaces were graded to a 0.5% slope leading to drains at the perimeter of the site. 60% of the surface in the upper south part of the tailings area then had a 1 metre thickness of clean waste rock placed over it to act as a combination radon, radiation and erosion protection layer. The remainder of the tailings was given a 500 mm layer of clay and soil to control radon emanations which was also then covered with waste rock. The complete treatment was then applied retrospectively to the whole area. In the upper northern portion of the tailings area the surface was covered with a 500 mm layer of compacted contaminated soil, clay and evaporites obtained from cleaning the evaporation ponds. This was then treated, as in the other area, with a 500 mm soil and clay layer and 1 metre of waste rock. A final erosion protection layer of garnetite boulders was placed over the waste rock [13]. The work was completed in 1985 and the project received an environmental excellence award from the Institute of Engineers Australian in 1986.

Nabarlek

The Nabarlek mine operated from 1978 until 1988 with a number of features that are considered to be unique. The ore body was relatively small in size, containing approximately 606,700 tonnes of material containing about 12,000 tonnes of U_3O_8 at an average grade of 1.7wt% U_3O_8. This material was mined out in one campaign of 143 days duration in the dry season of 1979. The ore was stockpiled on a custom built impermeable pad and covered with concrete. The mill was built through the following wet season and milling commenced in 1980 [14].

The tailings were deposited directly into the mined out pit, initially as a sub-aqueous operation. In 1986 trials were undertaken to establish the feasibility and acceptability of a sub-aerial deposition method and this was successfully introduced in 1987. Milling ceased in 1988 with the final production volume being 10,800 tonnes of U_3O_8. The tailings were allowed to dry out at the surface and then a working platform was developed over the crusted surface. The platform comprised a geotextile layer followed by approximately one metre of graded waste rock. Once this was in place geotechnical wicks were inserted through the platform into the tailings to a maximum depth of 33m in a 3m by 3m grid pattern. These wicks immediately relieved excess pore water pressure and promoted the settlement of the tailings mass. In 1992 the evaporation ponds on site were allowed to dry out and were then scraped clean. The contaminated material was placed in the pit and the surcharge reactivated the wicks.

In 1995 the mining company was directed by the supervising authorities to decommission and rehabilitate the site. The pit was filled with the remnants of the mill that could not be sold or were uneconomic to clean as well as all remaining waste materials with the final layer comprising several metres of clean waste rock. The wicks reactivated and relieved pore water pressures and assisted drainage, and settlement was uniform across the site and within the limits predicted by the decommissioning engineers. Subsequent topographic surveys have shown that settlement has continued but at a much reduced rate and is still uniform across the site. Re-vegetation of the site is continuing, although discussion on the final criteria for release is also ongoing.

Ranger

The Ranger Uranium Mine is located about 200 km east of Darwin and has been in operation since 1980. The tailings are neutralised before deposition in a storage facility, the operator, Energy Resources of Australia (ERA), has tried a number of neutralants over the years including lime, cement and ground limestone. Currently the operation is using lime slurry to neutralise tailings to a pH of about 3.7.

Initially tailings were deposited in a custom-built dam approximately one kilometre square. This dam was built as a water retaining structure and has a rolled clay core keyed into the underlying rock. The reservoir was not lined at construction but a seepage collector system has been installed to trap the majority of the seepage through the floor of the structure. The method of disposal was sub-aqueous in the beginning as this was thought to offer the best reduction in radon emanations. However, the geotechnical properties of the tailings deposited by this method left much to be desired with lenses of both finer and coarser materials leading to extremes of density in the tailings mass. The method of deposition was changed to a sub-aerial system in 1986 after research had shown that radon emanations from damp, beached tailings were not a significant hazard. The deposition system employed a series of spigots at intervals around three sides of the dam's perimeter to create beaches. The resulting deposition was found to be more consistent in terms of settled density. In 1992-4 the deposition method was altered to adopt a single vertical spigot in the centre of the dam. This was based on the coning method suggested by Robinsky in 1979 [15], and was intended to further consolidate the tailings mass and reduce the presence of lenses of slimes. The central deposition spigot was relocated half way through this period.

The tailings dam was increased in height a number of times during its life finally reaching a crest level of RL 44m in 1989 with the completion of the fourth construction stage. All construction was by the downstream method so as to preserve the integrity of the core. The tailings dam was licensed to operate under conditions that stipulated maximum levels for both water and tailings.The tailings dam reached the authorised capacity limit in June 1996. In December 1994 ERA completed the mining of Pit #1 at the Ranger site and made plans to commence mining of the #3 ore body 1 km to the north. The final dimensions of the #1 pit were 750 m diameter and 175 m deep, bottoming out at RL –156m. In the next stage Pit #1 was prepared for use as a tailings repository with the installation of an under drain and connecting borehole to allow seepage waters to be pumped from beneath the tailings mass; a series of filter beds were installed in and around the base of the pit to assist in the collection of seepage and drainage from the tailings. Tailings deposition into Pit #1 commenced in August 1996. Initially the deposition was achieved by cascading tailings down the pit wall from a number of locations in sequence to establish an even cover over the base of the pit. However, this process was as found to encourage particle size separation and resulted in uneven deposition of the tailings.

Uranium mines in the Alligator Rivers Region are required, under Australian Government legislation, to place all tailings back into mined out pits at a level below sea level at the end of mining. Thus ERA staff were aware that they had to relocate the approximately 17 million tonnes of tailings from the tailings dam at the end of mining. In 1996 ERA had a rehabilitation plan, which called for the use of a dredge to effect this transfer. As a trial in 1997 ERA obtained authorisation to carry out trials and then transfer 1 million cubic metres of tailings from the dam to pit #1. The company purchased a suitable suction cutter dredge and the work was undertaken between September 1997 and May 1998 [16]. This task was completed satisfactorily from a mechanical point of view with a total of 1.8 million tones being transferred. However, it was considered that the settled density of the tailings after the transfer was below what had been anticipated. ERA staff are required to maintain a minimum average settled density for tailings in pit#1 of 1.2 t/cu.m. Whilst the company has been able to meet this requirement it has been a struggle at times. In the early days the deposition was sub-aerial with beaches forming at locations around the perimeter of the tailings mass. A succession of above average wet seasons between 1994 and 2001 had resulted in an increase in process water inventory at the mine, which may be stored only in the tailings dam or Pit #1.

This had turned the tailings deposition into a sub-aqueous situation and had a deleterious impact on tailings settlement. ERA staff relocated the discharge point for tailings to a floating central pipe in 2000 in an attempt to assist self-consolidation of the tailings mass.

ERA have recently changed their relocation plan for the tailings from dredging to "truck and shovel" following a successful transfer of tailings by this method at the Woodcutters Mine which is located 60 km south of Darwin. The methodology is straightforward and ERA staff believe they will be able to complete the task in the time available in one dry season. The operation could be carried out using existing mine plant and personnel. As a consequence the dredge has been sold.

At the time of writing the level of tailings in the Ranger has reached approximately RL -20 m with approximately 15 m of water cover. The average settled density of tailings has been calculated to be 1.38 t/cu.m. ERA staff have also investigated the introduction of thickened tailings but whilst trials have been impressive the technical challenges of introducing the system on a field scale have proven too difficult to implement economically. ERA staff have also investigated the installation of geotechnical wicks into the tailings to aid rapid consolidation but this too has been proven to be possible only on a pilot scale until later in the project.

Jabiluka

The Jabiluka project was first identified in 1971 by Pancontinental mining at a location some 20 km north of the Ranger site. This is a significant deposit in world terms with the Jabiluka 2 deposit estimated to contain reserves of more than 160,000 tonnes of U_3O_8 with ore grades averaging around 0.5%. After the successful assessment of an EIS the development of the project was suspended in 1983 as a consequence of political changes in Australia. The deposit was acquired by ERA, operators of the Ranger mine, in 1991. ERA commissioned a new feasibility study in 1993 and revised the project from an underground mine to one where ore would be trucked 22 km to Ranger for milling. Thus tailings would be disposed of at Ranger, being placed in the mined out pits together with the Ranger process residues.

In 1996 there was a change of government in Australia. The obstacle to uranium mine development was removed by the incoming government doing away with the former government's "three mine policy". ERA commenced a new program and a new EIS was prepared with three options: the original Pancontinental proposal (which already had an approved EIS), the project to mill at Ranger (Ranger Mill Alternative-RMA) with tailings placed in the existing Ranger mine pits, and an option to mill at Jabiluka (Jabiluka Mill Alternative-JMA). For this last proposal (JMA) an alternative tailings management strategy had to be devised. Pancontinental had proposed building a dam, similar to ERA's Ranger tailings dam, at a site a few kilometres from the mine. This was in addition to using some portion of the tailings as backfill in the stopes. However, the geotechnical properties of the site were considered not to meet modern environmental standards. The proposal put forward by ERA was to create two pits in the floor of the valley below Jabiluka and place the tailings in these, possibly as cemented paste. These tailings would be the portion in excess of what was required for stope backfilling. The limited amount of hydrogeologcial information available for the proposed sites was insufficient for the supervising authorities to be confident that the plan would provide the required degree of environmental protection. This proposal was therefore rejected. Thus the final solution proposed by ERA was to place the "excess" tailings in vertical shafts mined into the upper Kombolgie sandstone which overlies the ore body, again as a thickened deposit, most probably as a cemented paste. The cost of this proposal was significant but was submitted by ERA and is part of the JMA proposal, which at the present time has authority to proceed, subject to the agreement of the Traditional Owners.

After receiving approval from the supervising authorities ERA proceeded with Phase 1 of the development, which was common to both the JMA and RMA development options. This comprised some building of some surface infrastructure items, including an Interim Water Management Pond and developing an 1,100 m decline and about 900m of underground workings. The development was stalled at this point with various issues relating to the concerns of the Aboriginal Landowners remaining unresolved. In the event ERA chose, in 2003, to place the Jabiluka project in a long term care and maintenance mode which has included returning all the materials mined in Phase 1 to the underground workings to the greatest extent practicable and sealing the decline. The re-opening of the mine will be subject to completion of mining at Ranger (currently scheduled for 2009) as well as the resolution of issues with the Aboriginal landowners.

CONCLUSIONS

Uranium mill tailings management in northern Australia has developed in less than 50 years from relatively uncontrolled processes with little account being taken of the potential or actual environmental impacts involved, to a series of systems that are aimed at reducing environmental impact and risk of damage to the absolute minimum. In terms of best environmental management practice the tailings management solutions at Ranger and Jabiluka seem to offer the optimum solution with containment of tailings effectively guaranteed for significant periods of time, arguably even geological periods. The uranium mines of the Alligator Rivers Region have, we believe, the best tailings management regimes available.

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