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of the Ranstad Site

Title: On Decommissioning Costs of the Ranstad Site.
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This report concerns a study which has been conducted for the Swedish Radiation Safety Authority, SSM. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the SSM

Background

A demanding task for the present generation is to assure that appropriate financial resources are injected into the Swedish Nuclear Waste Fund. It will thereby be possible for coming generations to undertake efficient measures in the decommissioning and dismantling of older nuclear facilities. To undertake such measures in the context of Swedish as well as European environmental and health codes is essential.

Assuring that enough financial provisions are set aside to balance these future environmental liabilities is essential to demonstrate the sustainability and long term credibility of the financing system that underpins Sweden's nuclear waste liabilities.

A deficit situation must be avoided. Hence it is of utmost importance that cost estimates are prudent and made with a high level of precision. To secure this quality in the estimated costs for individual nuclear facilities that are candidates for decommissioning and dismantling, SSM is undertaking a systematic review of these estimates. Some of these reviews are made by external and independent resources, in order to enhance transparency and to introduce a spectrum of subjective judgement in areas of uncertainty.

Purpose of the project

The main objective of this study has been to extend the review of the future cost to decommission and dismantling the industrial area at the site of the old uranium mine at Ranstad in Sweden.

The feedback of experience and actual costs from a decommissioning project in the United Kingdom (A26 in Springfields) has been used to help in the assessment of the reasonableness of the estimated costs for decommissioning of the old uranium mine in Ranstad. A quantitative (albeit subjective) statement about the accuracy of the Ranstad cost estimate has been developed. Also, the factors relevant to the allocation of D&D costs between the Swedish state and the current owners of the old uranium mine site have been evaluated and presented.

Results

The study has developed the following main conclusions:

- The importance of thorough characterization/radiological mapping to the selection of the optimum decommissioning approach (technique) has been reinforced very strongly.
- Thorough characterization has the related consequence of being able to better define the costs of decommissioning, in terms of equipment needed, labour hours required and, importantly, the volumes of different categories of waste requiring different routes (and associated different unit costs) for ultimate disposition.
- Uncertainties in the Ranstad decommissioning cost estimate nevertheless remain, in particular relating to the viability of the proposed approach to dismantling and decontaminating the acid-proof bricks that line the pools in the Large Leaching Hall; a method that is acknowledged to be not proven. The outcome could have an impact on actual dismantling and decontamination costs, as well as on the costs of ultimate waste disposition. The KB2010 cost estimate report does not offer an alternative in the event that the base plan proves to be unfeasible.
- On balance it would appear that the continued presence of RMA at the Ranstad site ultimately will provide a net cost benefit to the D&D program. The extra costs that RMA operations may cause are assessed to be more than offset by the benefits of having a functioning RMA Leach Hall facility, as well as the historical benefits of general site management.

Continued work

There exists an ongoing need to acquire improved information about future decommissioning liabilities in order to enhance the reliability of related cost calculations. In this regard one important aspect identified in previous work is the value of developing a systematic approach to incorporating in a clear and transparent manner, in both cost studies and decommissioning plans, the conclusions from radiological mapping and facility characterization. Continued efforts in this research field are judged to be of value in order to improve our understanding of the quality of cost estimates. The inclusion of stake-holder perspectives provides another opportunity for strengthening the justification for estimated financial provisions, which in turn will be beneficial in terms of gaining the trust and support of public opinion.

Effects on SSM work

SSM will be able to use the study as supporting documentation in the review of the estimates given for the decommissioning costs of the nuclear facilities that are governed by the Studsvik Act. The findings in the report may also be of assistant to SSM when the appropriate fees according the Financing Act shall be calculated and fixed.

Project information

At SSM Staffan Lindskog has supervised and co-ordinated the project. Likewise, at NAC International Geoff Varley has performed the research task with determination and skill.

SSM reference: SSM 2009/2281

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1. Introduction

The Ranstad Industriecentrum AB (RIC) in Sweden hosts a range of facilities formerly used for the processing of natural uranium bearing alum shales mined from nearby deposits. Most of the facilities are no longer in use and some cleanup activities already have taken place. One of the facilities continues to be used actively by Ranstad Mineral AB (RMA), namely, a chemical processing facility for the recovery of uranium from wastes generated by nuclear fuel manufacturers. The recovery includes the handling of enriched uranium and is classified as a nuclear facility. RMA also makes use of space in older facilities for temporary storage of untreated wastes and processed wastes.

The longer term commercial future of RIC is most uncertain¹. Today the future of RMA also is uncertain – at least its continuity over the long term - because the workforce in total is very small and the management team comprises essentially just one person. SKI, now subsumed into SSM, therefore has taken a specific interest in the plans for and financing of the decommissioning liabilities associated with RIC and RMA. It is necessary to establish a reliable estimate of the cost for ultimate decommissioning and to establish a clear basis for the funding of such activities.

A report on the costs of decommissioning certain buildings and facilities at RIC, including an updated estimate of the total cost, was prepared in June 2008 by SKB International Consultants AB (SKB IC) – see reference 1 (hereinafter referred to as KB2008). SKB IC is a wholly owned subsidiary of the Swedish Nuclear Fuel and Waste Management Company, or Svensk Kärnbränslehantering AB (SKB). NAC International was commissioned by SKI to review this latest estimate and to provide an expert opinion on its reasonableness. In support of this task, a visit to the RIC site was made in July 2008 and all buildings included in the decommissioning estimate were inspected.

¹ Some of the costs associated with longer term management of the RIC site may be recovered via financial provisions made under the Studsvik Act.

A Part I report was prepared and delivered to SSM in August 2009, providing preliminary opinions on:

- The assumed overall logistics of the decommissioning effort, including the methodologies assumed to be applied and the extent to which these represent current/best practice
- Preliminary analysis of estimated costs for the various parts of the decommissioning program, including comparisons with relevant external decommissioning references to the extent possible.

The budget available for the Part I work necessarily constrained the level of detailed investigation and analysis possible at that stage.

This Part II report presents more detailed analysis, including:

- Comparison of parts of the Ranstad estimate with actual decommissioning costs at the A26 Facility on the Springfields Fuels Ltd site in the United Kingdom.
- Further discussion of the main factors driving the decommissioning cost
- Further discussion of uncertainties
- Discussion of the factors to consider in establishing an equitable allocation of decommissioning costs between the Swedish State and the current owners of RIC.

The main part of the report was completed in early June 2010. Subsequently NAC was asked to review and analyse new information that became available with the issue of an updated Ranstad Decommissioning Cost Estimate – see reference 2 (hereinafter referred to as KB2010). An Addendum to the Part II report has been added to present observations and conclusions resulting from review and analysis of the KB2010 information.

2. Description of A26 Facilities at the Springfields Fuels Site in the U.K.

2.1 *Background*

The Springfields site is located between Preston and Blackpool and has an area of 83 hectares. The site dates from the Second World War and has been variously owned by the Ministry of Defense (MoD), UKAEA, BNFL and now the Nuclear Decommissioning Authority (NDA) for whom it is operated by Westinghouse.

Following the war, the site became involved in the early stages of the UK military and civil nuclear programmes, providing the first fuels for both the Windscale Piles and the Calder Hall Magnox reactors.

The information relating to A26 that is presented in the remainder of this report is principally based on a visit to the Springfields site in November 2009 at which time it was possible to discuss the D&D program for this facility with the manager of those activities.

2.2 *Physical Description*

Building A26 at Springfields was used over many years principally as an oxide powder production plant. It was constructed of steel columns with brick in-fill panels and a steel sheet plus composite insulated roof. A majority of the building was single story but there was one tower constructed on four floors with a total floor area of about 800 m². Three basement areas covered an area of about 2,000 m². The building had an overall footprint of about 90 m x 120m and the maximum height is estimated at approximately 8 to 10 metres. The effective operating floor area has been quoted as about 7,500 m².

The facility included a Residues Recovery Plant (RRP), which was similar in scope and function to the RMA facility in Ranstad. Wet processes were used in the plant, including the ADU process for UO₂ powder production and many of the process areas had floors covered in acid proof tiles, as in RMA.

The facility was handed over to the decommissioning team around 1998. At handover to the D&D team some drawings of the facility were made available and some advice given on aspects of the plant condition, to help guide the team's efforts.

The overall project also included the dismantling of two local tank farm services areas.

2.3 **Initial Condition of the Facility/Characterisation**

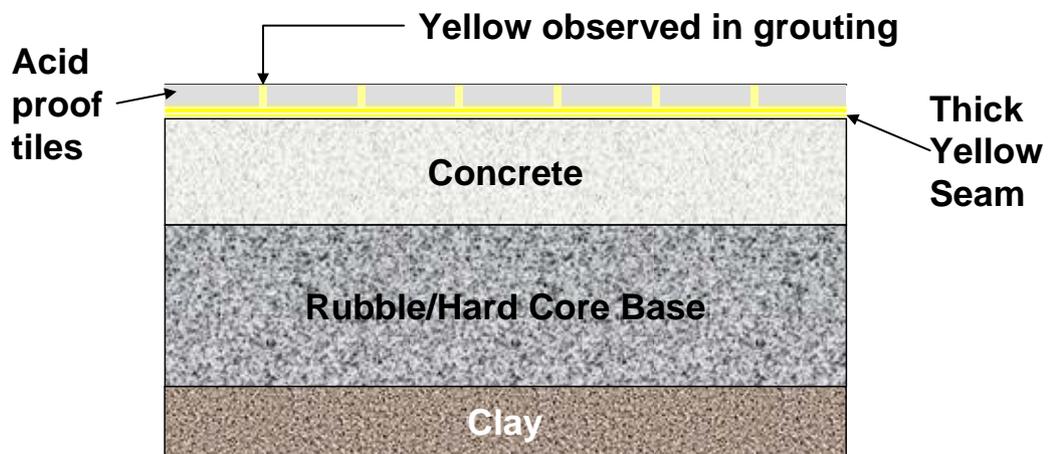
Some plant and equipment (P&E) had been removed prior to the commencement of the decommissioning project. As a result of this about 5 percent of the operating floor area was empty at the start of the project. This small benefit to the project cost is estimated to have been offset by the costs of decommissioning (without demolition) of the two local tank farm service areas.

In the RRP area of the plant a leak of Uranyl Nitrate occurred in the late 1970s. The leakage occurred adjacent to a building support column that was shrouded at its base with a steel surround that was covered in tiles. Due to cracking of the tiles, leakage to the ground underneath occurred for a some time (unspecified). Because enriched uranium was processed in the A26 facility, it was considered that pools of enriched uranium could have formed underground, representing a potential criticality hazard.

It was noted that a duct existed under the floor of the facility that in some way had been connected with munitions packaging activities in the past.

The typical floor structure in the facility was as shown in Figure 2.1. A layer of acid proof tiles were cemented and grouted on top of a concrete base, which in turn was formed on top of a hard core base and underneath that the natural ground was a layer of clay.

Figure 2.1 Typical Floor Structure in A26



Externally some yellow colouration of the grout between the tiles was observed, indicating the presence of uranium bearing material. Some tiles were lifted and, immediately underneath, there was a thick layer, or seam of yellow material. Core samples were taken below ground and the concrete layer was scabbled/milled to discover the extent of diffusion of radioactive contamination.

It was found that the first few mm of concrete were yellow (indicating presence of uranium) but below that, in general, only low levels of contamination were found. Some parts did exhibit contamination to greater depth.

The material including the tiles and down to the first few mm of the concrete base had an average activity content that exceeded the 100 Bq/g limit for disposal on a local landfill site. However, if mixed with all of the other waste volume below these first few layers, the average for the waste volumes was lower than the 100 Bq/g limit. This approach of dilution to facilitate disposal at a lower cost differs from the situation in Sweden where regulations forbid such an approach.

Extensive airborne contamination had spread from the dry processing area to the walls and floors of the building. The roof was found to be not a significant radiological problem as a result of having been replaced about 20 years prior to the start of decommissioning. Accordingly this was in the high volume – low activity (HVLA) category and disposal at a locally available public facility was possible at modest cost.

2.4 Project Approach and Implementation

The decommissioning project overall took about 6 years, with completion in January 2006. Most equipment (tanks and other process equipment) was cut up *in situ* and then packaged in boxes prior to removal for ultimate disposal.

Walls and floor areas required some localised paint stripping and surface scabbling. This applied to an approximate 15 percent of the total floor area. Walls were 100 percent dry-vacuumed and about 20 percent wet wiped.

An important part of the project was the construction of a decontamination facility within A26, in order to minimise the cost of waste disposal. Primary containment vessels required considerable surface decontamination, involving size reduction, jet-washing and chemical decontamination in this dedicated enriched uranium decontamination facility.

The decontamination facility included a 100mm deep pickling tank in which citric acid was used at 2 percent concentration and 55° Celsius for decontaminating mild steel components. For stainless steel the alternative was 5 percent nitric acid but it is understood that this was not used very much. It occupied about 12 percent of the floor area in the overall facility and was retained in operation throughout the project. A structure was completed around it and it remains available today. Indeed it is currently in use to support other work on site.

Waste with <100 Bq/g was allowed to be disposed of at the Clifton Marsh landfill site at a unit cost of about £30 per tonne. Waste with >100 Bq/g had to be sent to the Drigg LLW disposal site near to the Sellafield site in Cumbria. Any dismantling waste exceeding the 100 Bq/g limit was first sent to the decontamination unit to try and reduce it below the 100 Bq/g limit. If this was not possible then it would be committed to disposal in Drigg at a cost of about £2,000 to £3,000 per m³.

Wastes were monitored and, if necessary, sent for chemical decontamination. Otherwise, or subsequently, the waste was emplaced in 1 m³ boxes that had a lid fitted and then a band fitted to secure the lid.

The building did include some asbestos, which had to be dealt with using prudent procedures. Once all of this and the contaminated equipment and flooring material had been removed, the building was handed over to conventional demolition. Demolition was performed in two phases. This introduced extra costs for cladding to close up open faces at the end of the first phase of demolition and possibly also due to mobilisation of the demolition team twice rather than once.

2.4.1 Resources Needed

The available information on labour resources employed on the A26 decommissioning project are summarised in Table 2.1. The labour requirements summarised in Table 2.1 exclude activities to decontaminate and dismantle the dedicated decontamination baths that were installed inside A26 to support the overall project. A provision of between £1 and £1.5 million was made to account for the cost of completing this final piece of decommissioning. If 80 percent of this cost were associated with labour and if the ratio of supervisory labour to subcontractor labour were approximately the same as for the major

part of the project, the labour resources required to complete this activity would be approximately as shown in Table 2.2.

Table 2.1 Summary of A26 Decommissioning Labour Resources (excluding building demolition)

Labour Category	Number	Duration (yrs)	Rate (£/hr)	Total Cost
In-house staff				
Decommissioning Project Manager	1	6	Average of about £40 fully loaded	£1.75 million
Decommissioning Supervisor	1	6		
Assistant Engineering Support Manager	1	6		
Radiological protection Advisor	1	5		
Other internal cost/commercial control/oversight	–	–	N/A	£350k
External Resources				
Decontamination Construction	~ 20 to 25 man-years ^a		£17 to £18	£700k to £840k
Other Subcontractor workers - Decontamination	6 to 7	2 to 2.5	£17 to £18	£400k to £575k
Subcontractor – Dismantling/P&E removal	15 to 20 ^b	3 to 4	£17 to £18	£2 million
Total Labour Cost Estimate				£5.2 to £5.5 million

a. NAC estimate derived from assumption on total labour cost

b. NAC estimate based on overall cost estimate for removal of P&E and assuming 80 percent of cost was labour related

Table 2.2 Estimated Extra Labour Resources for Decommissioning the A26 Decontamination Baths

Assumed Cost	Estimated Labour Allocation		Approximate Implied Labour Hours	
	Supervisory	Subcontractors	Supervisory	Subcontractors
£1.0 million	£320k	£480k	8,000	27,500
£1.5 million	£480k	£720k	12,000	41,250

With a team of subcontractors similar in size to that used for the main decommissioning work, these estimates would imply a duration of 6 to 12 months to complete the complete removal of the decontamination baths and associated residual facilities.

On the basis described, the total supervisory effort would comprise of about 52,000 to 56,000 labour hours (27 to 29 man-years) and the subcontractor labour would amount to about 182,000 to 204,000 hours (95 to 106 man-years).

About 10 percent of the decommissioning project cost may be attributed to consumables i.e. approximately £1.3 million.

2.4.2 Dismantling Volumes/Wastes Disposed

The project to date i.e. excluding dismantling of the decontamination baths and associated facilities, has generated 16,000 tonnes of HVLA waste suitable for disposal at the Clifton Marsh facility at a cost of approximately £600,000.

LLW with residual activity >100 Bq/g was sentenced to disposal at the Drigg LLW facility near to Sellafield in Cumbria. The total cost was approximately £400,000 at a unit cost advised as £2,000 to £3,000 per m^3 . This implies a disposed volume of about 130 to 200 m^3 of LLW.

Final dismantling of the residual A26 decontamination facility can be expected to increase the volumes in each of these categories by up to approximately 10 percent based on a volume ratio of the remaining facilities. Using this assumption the project total waste volumes would be 17,600 m^3 in the HVLA category and 145 to 220 m^3 in the LLW category. The unit cost of disposing of waste in the HVLA category in the future is expected to be higher however, possibly by as much as a factor of five (approximately £200 per tonne).

2.5 A26 Decommissioning Cost

2.5.1 D&D Cost Breakdown

The overall project cost to date has been about £11.5 million, including between £1.5 million and £1.7 million for the dedicated decontamination facility that was built inside A26 to support decommissioning. The total will rise to between £12.5 and £13 million once the dedicated decontamination facility has been finally dismantled.

The current cost breakdown and a projected final cost breakdown are presented in Table 2.3. In this breakdown the cost of constructing the enriched uranium decontamination facility has been treated as a fixed external cost. The additional £1 million to £1.2 million under the *Decontamination Construction* category has been assumed to be approximately 30 percent materials/equipment and 70 percent labour. This is an NAC estimate only, because other details from the project are not available.

Table 2.3

A26 Project Cost Breakdowns: Current Actual and Estimated Final

Description	Sub-Category	Current Cost (£k)	Estimated Final Cost (£k)
Management and Supervision	Planning and Institutional	250	275
	Project Supervision	1,750	1,925
Decontamination Construction	Labour	750	825
	Other	350	385
	Decontamination Facility ^a	1,600	1,600
Decontamination and other Service-Enabling Works	Labour	1,000	1,100
	Other		
Decontamination Operating Costs, including Utilities	-	1,000	1,100
P&E Removal	Labour	2,000	2200
	Other	500	550
Demolition, including Service Terminations	External Contract	1,300	1,430
HVLA Waste Disposal	External Charge	600	920
LLW Disposal	External Charge	400	440
Totals		11,500	12,750

a. Mid-range of estimated £1.5 to £1.7 million provision

The relevant labour rates that applied during the A26 D&D project (during 2000 to 2006) are approximately as follows:

Contract labour rates	:	~£17.50 per hour (~£19 per hour time adjusted)
In-house management (fully loaded)	:	£40 per hour (~£44 per hour time adjusted)

These are much lower than the 2008 rates quoted in the Ranstad cost estimate, which are:

Miscellaneous labour	:	SEK 542 per hour (~ £47.50 per hour)
Project group	:	SEK 948 per hour (~ £83 per hour)

These rates however are representative of the current rates applicable in the Swedish nuclear industry.

2.5.2

A26 D&D Derived Benchmarks

The available details on the A26 decommissioning project are insufficient to derive more than two meaningful benchmarks, one concerning decontamination and one concerning demolition.

2.5.2.1 *Decontamination*

The costs associated with decontamination at A26 are as follows:

- £1.6 million for the enriched decontamination facility
- £1.2 million for other decontamination construction activity
- Up to £2.2 million for enabling works and operating costs

Embedded in these costs are utility costs and other enabling works that are not directly related to decontamination. The available information is not sufficient to provide an accurate basis to extract these from the total. Excluding the cost of constructing the decontamination facility the total is £3.4 million. The RMA facility effectively has the required decontamination facilities in place, so taking out this part of the A26 project makes sense for the purpose of comparison. The cost associated specifically with decontamination plausibly was not less than 70 percent of this, or £2.4 million.

The gross building floor area was 7,500 m², not all of which will have been contaminated. However, taking the gross area as denominator, the derived unit cost is about £320 per m². In practice the decontamination work included plant and equipment as well as surface area (walls as well as floors). The use of the gross floor area therefore is merely one simple proxy for comparison with other buildings of this type, housing various process equipment performing similar tasks.

An alternative would be to use building volume as the denominator. The detailed dimensions of A26 are not available but the effective floor area (assumed to exclude the basement areas) has been quoted as 7,500 m². Based on available photographic evidence, the average height of the building was not more than about 4m to 5 m. Using these estimates, the A26 building would have a volume of about 30,000 m³ to 37,500 m³. Using these estimates as denominator, the decontamination cost of £2.4 million translates to between £64 and £80 per m³.

2.5.2.2 *Demolition*

The A26 demolition cost, including a projected extra amount for the residual facility yet to be decontaminated, dismantled and demolished, is £1.43 million. Using gross floor area to derive a proxy for comparison with other facilities, the derived unit cost of demolition is about £190 per m², adjusted to about £210 in 2008 money values for comparison with the Ranstad estimate. Using the alternative of building volume to derive

a proxy, the derived unit cost of demolition is about £38 per m², adjusted to about £48 in 2008 money values

2.6 ***Experience Feedback from the A26 D&D Project***

A small number of important observations and conclusions were provided, based on the experience of D&D at A26, as follows:

- Washing of tiled floors with sulphuric acid was found to exacerbate contamination problems, depending on the concentration of the sulphuric acid used.
- Dry decontamination techniques are preferable, in order to minimize the amount of liquid effluent for treatment and disposal, as well as to control and limit the possibility of further migration of the radioactive contamination.
 - High pressure water jetting of solid surfaces can achieve some reduction in contamination but it also can result in pushing some of the contamination deeper into the material being decontaminated.
 - Self-contained grit blasting under vacuum can be more effective and avoids the creation of liquid effluents. Vacublast equipment supplied by Wheelabrator Group Ltd., was used at A26 to some degree. According to this company, the removal of surface contaminants from building blocks can be accomplished in a variety of ways, including environmentally responsible methods using either air blast or wheel blast technologies.
- The main drivers of D&D cost were described as:
 - Safety
 - Wastes (extent of decontamination possible to avoid expensive disposal in a radioactive waste disposal repository)

3. Observations on Ranstad Facilities

A selection of photographs showing parts of the RMA leaching hall and the large leaching hall pools was shown to the A26 D&D manager and his comments on the likely condition of the plant were solicited.

3.1 *RMA Facility*

The photographs of RMA that were inspected included those shown in Figure 3.1 through Figure 3.7.

Figure 3.1 Example of Acid Resistant Tiled Floors



Figure 3.2 Filter Press for Leaching Residues



Figure 3.3 Ammonium Di-Urinate (ADU) Precipitation Tanks (not in use)



Figure 3.4 Liquid-Liquid Extraction in Mixer-Settlers



Figure 3.5 Storage Tanks



Figure 3.6 Mid section of Percolation Leaching Vessels



Figure 3.7 Filter Press – Water Cleaning



Based on these photographs it was concluded that there was a strong likelihood of there being some open joints between the tiles (including but not necessarily restricted to areas shown in Figure 3.1 and Figure 3.7) and that seepage of uranium contaminated liquids beneath the tiles will have taken place. As stated, in addition to any spillages during routine operations, the practice of periodic washing with sulphuric acid may have increased the extent of such seepage.

It was recommended that some of the tiles in the areas where open joints are visible should be taken up to allow radioactive monitoring using a counter and also physical samples should be taken for analysis. In this way a better idea of the nature and extent of the contamination can be obtained.

3.1.1 *Large Leaching Hall Pools*

The photographs of the large leaching hall pools that were inspected included the one shown in Figure 3.8, Figure 3.9 and Figure 3.10. The pools, each about 25m x 25m in area and approximately 4 to 5m in depth are lined with acid-resistant brick. Sulphuric acid was used in the pools to leach uranium from the feedstock of prepared, alum shale.

Figure 3.8 One of Four 25m x 25m Large Leaching Hall Pools



Figure 3.9 View of Residual Uranium Contamination on Leaching Pool Wall



Figure 3.10 Close-up View of Residual contamination on Leaching Pool Wall



Based on this photographic evidence, the judgment of the A26 D&D manager was that the mortar between the bricks in the walls of the pools might be contaminated to a depth of about 25 mm. This may be compared with the approach to be adopted for decontamination of the large leaching pool walls, as indicated in appendix 2.5 of the Ranstad cost estimate report, where the removal of a 3mm surface layer was assumed to be necessary.

4. Review of the Ranstad KB2008 Decommissioning Cost Estimate

4.1 Cost Breakdown by Activity

To facilitate comparison with benchmark information from other sources, the KB2008 cost estimate for RIC and RMA decommissioning may be broken down into different categories of activity, approximately as shown in Table 4.1. The allocation of each line item to a broad category of activity is based on best judgement about the nature of the activity described. Where costs are related to more than one activity e.g. decontamination and dismantling, for the purposes of Table 4.1 the cost has been split 50:50 between the two activities. This is an approximation only.

Table 4.1 Approximate Breakdown of Cost Estimate by Category of Decommissioning Activity

Activity	Cost (MSEK)	% of Total	Remarks
Preparation and Institutional	23.2	12.3	-
Characterisation	5.6	3.0	Initial coarse mapping at about 50 percent level
Decontamination ^a	15.7	8.3	Includes decontamination of equipment in operational position as well as processing of some materials after removal from initial location e.g. concrete surface removed
Equipment Dismantling ^a	6.0	3.2	Mainly in RMA leaching hall
Support to Actual Decontamination and Dismantling Operations	9.7	5.1	Support across various activities
Conventional Building Demolition	70.7	37.3	May include some dismantling of non-contaminated equipment
Waste Disposal ^a	24.7	13.0	According to standard charges in Sweden
Final Clearance	33.8	17.8	Includes final detailed monitoring for declassification purpose
Totals	189.4	100	

- a. The costs associated with these scopes of work are the principal ones where the rationale for the allocation of costs needs to be analysed carefully.
 b. All costs include a 20% contingency

4.2 Principal Uncertainties

Decontamination work, dismantling work and the support work related to these activities are the main areas where it is most difficult to achieve good accuracy. A related

uncertainty is the volume of waste that has to be disposed of in a radioactive waste repository i.e. not suitable for landfill or free release, and the associated costs.

4.2.1 Characterisation

As stated in the Phase I report, one way to enhance the chance of good accuracy in the cost estimate is to do a good job of characterising the facility in advance. In the case of the facilities at RIC, based on a site inspection and the available written information, it appears that the main uncertainties correspond to the radioactive condition of the Large Leaching hall and the RMA Leaching Hall.

4.2.1.1 Large Leaching Hall Pools

Based on the available information, the characterisation of the large leaching hall pools appears to have been restricted to the monitoring of surface activity levels (radiation counters and smear tests), which probably is sufficient if, ultimately, a surface layer of no more than 3 mm needs to be removed in order to get rid of most of the radioactivity that has diffused into the acid resistant bricks and/or mortar that line the pools.

However, the feedback from the A26 project suggests that this assumption may not be valid. If, as suggested, radioactive contamination may be as deep as 25 mm into the mortar, the approach to decontamination and waste management might have to be different. Milling away this depth of material would not be practical or cost efficient. It therefore would seem to be a valuable, if not essential requirement to remove some of the acid proof bricks in the walls of the pools in order to determine with more certainty the extent and depth of radioactive contamination that is present. Depending on the results of such investigations, an alternative approach to this part of the decommissioning might have to be developed.

4.2.1.2 RMA Leaching Hall

The area of tiled flooring in the RMA Leaching Hall building is quite extensive and available documentation indicates an assumption that 50 percent of the gross area will be contaminated by uranium to a depth of 1 cm. Because this will be an important assumption in determining the volume of waste that needs to be processed (chemically decontaminated in the RMA facilities and/or disposed of in other than a public landfill site), it would appear to be worthwhile to take up tiles in various areas of the plant to

inspect the condition underneath, in order to either validate the current assumptions, or to provide a meaningful basis for an adjusted estimate.

4.2.2 **Decontamination**

The Ranstad estimate includes MSEK 4.6 to purchase equipment for decontamination of components (assumed mainly from the RMA Leaching hall) plus process equipment decontamination in the RMA Leaching hall. A further MSEK 4.4 is estimated for building surface milling, including the equipment for that activity. A large portion of that cost however will be related to facilities outside the RMA Leaching hall, principally the Large Leaching Hall. Backing out 85 percent of these two expenses from the total decontamination provision of MSEK 15.7 leaves a balance of approximately MSEK 8 that reasonably might be attributed to decontamination in the RMA Leaching Hall.

The benchmark for mixed decontamination (building plus plant and equipment) derived from actual experience at A26 in Springfields is £320 per m² of building floor area or alternatively £64 to £80 per m³ of building volume. Applying the A26 area benchmark to the 1615 m² of the main process areas in the RMA Leaching hall facility gives a total decontamination cost of about MSEK 6.5 after adjusting for the time value of money and converting at a rate of 11.4 SEK/£ (31 May 2010). Applying the A26 volume benchmark to the estimated 7,700 m³ volume of the RMA Leaching Hall building (4 floors x 1,100 m² per floor) gives a total decontamination cost of about MSEK 6.1 to MSEK 7.6 after adjusting for the time value of money and converting at a rate of 11.4 SEK/£.

In terms of absolute cost therefore the Ranstad estimate is probably no more than about 5 to 20 percent above the level predicted based on the proxy projections from A26.

However, given that the labour rates assumed in the Ranstad estimate are between 2 and 2.5 times higher than the time adjusted actual rates at A26 (see section 2.5.1), the underlying labour resources assumed to be needed for RMA are substantially lower than actually needed at A26. If the gross floor area for RMA were used (4,400 m²), the differential would be even greater. The relative effective working time efficiency factor for Sweden relative to the A26 example (potentially higher in Sweden) also could be a factor.

It is acknowledged that this quantified comparison is based on a relatively weak assumption for a meaningful proxy (cost per unit floor area or cost per unit building

volume). However, with such a large difference observed between two facilities of a broadly similar type, it would appear that some review of the decontamination estimate for the RMA Leaching Hall would be prudent.

4.2.3 Demolition

The RMA demolition is estimated to cost about MSEK 3.2 (2008 money value) for a building with a footprint of about 1,100 m² and four floors, for a total floor area of about 4,400 m². The unit cost accordingly is about SEK 725 per m². The derived A26 demolition cost benchmark (see section 2.5.2.2) is about £210 per m², or SEK 2,400 per m², a factor of 3.3 time higher. However, using a volume-based benchmark from A26, the projection for RMA would be about MSEK 3.3 to MSEK 4.2. Taking into account the difference in labour rates between the U.K. and Sweden, this implies that the Ranstad demolition would require less labour hours than actually needed at A26. Having said that, a large part of the cost may be related to demolition equipment rather than labour and the U.K. – Sweden labour cost differential would not be expected to be so great for equipment.

In any event, it is not surprising to see the Ranstad cost lower than at A26, in part due to economies of scale that would apply to the Ranstad site, in part because of a four storey building versus a mainly single storey building and also because demolition at the Springfield's site took place in a more physically constrained environment on an operational, nuclear licensed site. The Ranstad estimate was based on a quote from a commercial operator. The status of the quote is not known. If submitted purely for guidance without any commitment to honour the quotation, it could be considered as subject to uncertainty.

4.3 Review of the Overall Reasonableness of the Ranstad Cost Estimate

A summary of the Ranstad estimate cost breakdown and NAC observations on uncertainties is presented in Table 4.2.

Table 4.2 Summary of Ranstad Costs and Uncertainties

Description	Ranstad Estimate incl. 20% Contingency (MSEK)	Estimated Maximum Potential Extra Cost (MSEK)	Remarks
Preparation & Institutional	23.2	-	Relatively straightforward to define costs within an established system.
Characterisation	5.6	5.6	Additional investigations in the Large Leaching Hall and under the floors of the RMA Leach Hall may be justified.
Decontamination including allowance for Support Effort	22.7	20.0	Contamination may be present to a depth greater than assumed in pool walls and under tiled floors. Also a 50 percent upward adjustment based on A26 benchmark reference to correct for apparent Sweden-U.K. combined labour rate/efficiency differential
Dismantling including allowance for Support Effort	8.7	4.3	No obvious reason to challenge fundamentals of this part of the estimate. 50 percent upward adjustment based on A26 benchmark reference to correct for apparent Sweden-U.K. combined labour rate/efficiency differential
Conventional Demolition	70.7	-	Estimate is low relative to A26 experience but based on a commercial quotation. Represents 37% of the total cost so a new validation worthwhile.
Waste Disposal	24.7	3.5	Additional disposal costs could apply if the depth of contamination found is greater than currently assumed.
Final Clearance	33.8	-	No basis to challenge this number.
Totals	189.4	33.4	

Three main areas of uncertainty have been identified. A quantification of the uncertainty has been attempted, as explained earlier in this report. Such quantification in part is subjective. In total the uncertainty is judged to be at the level of about 20 percent of the base estimate (MSEK157.8). This excludes any uncertainty that may apply to the conventional demolition cost, which should be validated.

5. Rationale for Allocation of D&D Costs

How to determine an equitable division of the Ranstad D&D costs between the former owner, the Swedish State, and the current owner, Ranstad Mineral AB (RMA) is not straightforward. The following commentary provides information that is designed to help that decision process.

5.1 *Current Condition versus Condition at Handover*

The only facility where RMA has had any substantive impact on the condition of the facilities in respect of the eventual decommissioning, is in the leaching hall. The situation may be summarised according to a ‘traffic light’ categorisation, as shown in Table 5.1.

Table 5.1 Impact of RMA Operations on Condition of Leaching Hall

Item	Description	Impact
a)	Added some pieces of new equipment (pre-crusher for ashes, mill for ashes and drying equipment for leaching residues).	
b)	Continued chemical operations which, because of the inherent nature, inevitably result in some spillages of radioactive liquids internally in selected areas of the plant.	
c)	Performed periodic washing of the tiled floor areas with the objective to control surface activity and the related ambient radiation dose for the workers.	
d)	Performed some general tidying of the facilities.	
e)	Performed some monitoring and characterization work to support transparent dialogue on understanding of the radiological condition of the facilities.	
f)	Maintained a chemical processing capability that ultimately will be a useful support to the eventual decontamination and dismantling work.	
g)	Avoided the need for the Swedish State to mothball the site and incur costs associated with regular security, safety and general oversight.	

: Net increase of D&D cost
 : Impact not clear
 : Net saving to the overall D&D cost

Item a), the addition of extra equipment, clearly will result in some additional D&D effort and will increase the volume of wastes for disposal.

Item b) may have contributed to the overall inventory of radioactivity to be dealt with in the D&D of the RMA leaching hall but specific measurements would be needed before this could be judged correctly. For the moment therefore the actual impact on ultimate D&D cost, if any, remains unclear.

Item c), the periodic washing of the tiled floors with sulphuric acid, may or may not turn out to be a positive contribution. As noted in the feedback from A26 &D experience, such washing can result in a worsening of the situation regarding seepage of radioactive liquids underneath the tiles. It depends to some extent on how the job is done. If it was done with a vacuum machine the extent of any additional seepage is likely to have been much less, or not at all, in comparison with open washing that probably would have caused some extra seepage.

Other than these three items, all of the others would appear to be a clear, positive contribution to the overall situation *vis-à-vis* ultimate D&D.

5.2 Potential Actions to Clarify the Situation

The possible impact of items a) and d) theoretically might be clarified by conducting a sampling campaign. In practice, the results obtained may be far too complicated to interpret and therefore would be inconclusive. Acid proof tiles could be taken up and samples taken from underneath, including into the underlying base. Potentially there will be a radioactive isotope signature in the sampled material that could be attributed to the period of state operation and/or the period of RMA operation. The depth of penetration of various isotopes could be recorded. If there were any significant difference in the depth to which RMA contamination is present versus state contamination, there might be a case to adjust the allocation of waste disposal costs to the two parties. But distinguishing between RMA and State contamination may be impossible. For example, RMA may have processed natural uranium bearing materials, just like the state operations, as well as enriched uranium bearing materials. Also any leakage of RMA liquids and the periodic washing of the tiled floors, may have caused state contamination to have migrated along with the RMA contamination. In conclusion, it seems unlikely that much can be done to clarify this situation.

5.3 Balance of Cost Impacts from RMA Operations

5.3.1 RMA Additional Equipment

The additional equipment installed by RMA is shown in Figure 5.1, Figure 5.2 and Figure 5.3. The total tonnage of equipment to be dismantled from these three items is not known but can be estimated at just a few tonnes, representing no more than about 2 or 3 percent of the total amount of process equipment to be dismantled (159 tonnes).

Figure 5.1 Drying Equipment for Leaching Residues



Figure 5.2 Pre-Crusher for Ashes



Process equipment dismantling has been estimated to cost about MSEK6 and decontamination of the equipment an additional MSEK 1 (all including a 20 percent contingency). Even adding in the category of miscellaneous equipment decontamination, for a further MSEK 3.9, the total cost is not more than about MSEK 10. If the RMA additional equipment represents only 2 or 3 percent of the total, the cost reasonable attributable to RMA would be not more than about SEK 200,000 to SEK 300,000.

Figure 5.3 Mill for Ashes



Adding in the cost of extra waste disposal could increase this number but the available information makes it difficult to estimate an accurate amount. Even with rather pessimistic assumptions about the ability to decontaminate and allow free release, or disposal to landfill, it is difficult to see how the total cost could increase to more than about SEK 500,000.

5.3.2 ***Continuity of Oversight at Ranstad Site***

Had RMA not taken over the Ranstad site in 1988, the Swedish state would have continued to hold responsibility. As a minimum, in the absence of a decision to proceed with immediate decommissioning, they would have had to take steps to mothball the facilities in a safe condition and possibly would have felt it necessary to provide ongoing security and general surveillance over a period already of more than 20 years. Assuming just minimal security (3 shifts of one security person) and an hourly rate of SEK 300 would result in a cost of more than MSEK 50 over 20 years. The Swedish state potentially could have offset such costs by using the site for some other purpose at the same time, for example renting out land and/or building space for business use, much as has been done by the current owners. But this is just hypothetical and the reality is that it is difficult to derive a precise and meaningful estimate. Safe to say that some costs would have been incurred and most likely would have been substantially greater than the figure of SEK 500,000 potentially associated with dealing with the extra equipment installed by RMA.

5.3.3 *Availability of Facilities for Decontamination Work*

The ongoing RMA operations provide equipment that can be used in the decontamination stages of ultimate D&D. This is a valuable contribution. In the case of A26 in Springfields, the equivalent of about MSEK20 was spent on the construction of decontamination facilities to support the D&D work.

5.3.4 *Summary Remarks*

On balance it would appear that the continued presence of RMA at the Ranstad site ultimately will mitigate the costs of the D&D program.

6. Addendum Reviewing the Revised Ranstad Cost Estimate KB2010

6.1 *Project Activity mid-2008 to mid-2010*

Since the publication of the KB2008 report, various activities have taken place to improve the base of knowledge on selected facilities in Ranstad. Some of these activities have been aligned with recommendations made in NAC's Part I report and in the first phase of this Part II report that was issued in draft earlier.

In particular there has been a range of characterisation work done to provide a better knowledge of radioactive contamination in the various facilities. These results in turn have provided the basis for modifying the planned approach to decommissioning in certain parts of the site and in selected phases of the work.

6.2 *Main Differences between KB2010 and KB2008*

6.2.1 *Overview*

The cost schedules in KB2008 and in KB2010 suffer from a lack of easy interpretation. Some of the descriptions and the groupings of activities into a single line item make it difficult or impossible to separate out all activities associated with a specific category of activity. For example decontamination and dismantling activities in some instances are mixed together; 'project work' appears to include some actual decontamination activity; 'operations' includes some component decontamination.

A summary comparison based on the now available material in KB2008 and KB2010 is presented in Table 6.1. The KB2008 costs have been inflated by 4 percent (consistent with the KB2010 report assumption) in order to provide a constant money value comparison with KB2010 data. The comparison of individual group items in some cases is not a true comparison, because during 2009 and 2010 some of the work already has been completed (or will be completed by end of 2010) and the costs associated with this completed work have been taken out of the KB2010 individual group cost estimates. KB2010 estimates costs for 2011 through project completion. The groups affected in this way are highlighted in Table 6.1.

After adding back in the MSEK24 spent, or to be spent during 2009-2010, the KB2010 total cost excluding a contingency allowance for uncertainty is MSEK181.8, which is MSEK17.6 higher than the KB2008 estimate. However, the KB2010 estimate applies smaller contingency allowances on grounds of reduced uncertainty as a result of the works performed during 2009-2010. The net result is that the KB2010 total including allowance for uncertainty is only MSEK8.4 higher than the KB2008 estimate.

Table 6.1 Comparison of KB2008^a and KB2010^b Decommissioning Cost Estimate Breakdowns

Group	Cost Estimate Excluding Contingency			Cost Estimate Including Contingency		
	KB2008	KB2010	KB2010-KB2008	KB2008	KB2010	KB2010-KB2008
Preparations	7.00	4.05	-2.95	8.41	4.54	-3.87
Project work	31.37	35.23	3.86	37.64	40.52	2.88
Authorities	2.60	2.20	-0.40	3.12	2.64	-0.48
Rebuilding, temporary	3.64	5.20	1.56	4.37	5.98	1.61
System decontamination and local cleanup	8.11	9.13	1.02	9.73	10.95	1.22
Operation	4.58	3.20	-1.37	5.49	3.69	-1.80
Scanning building surfaces	14.66	10.12	-4.54	17.60	11.33	-6.26
Waste disposal	4.52	1.73	-2.79	5.43	1.94	-3.48
Interim storage	7.46	4.46	-3.00	8.95	5.36	-3.60
SFL	2.58	2.13	-0.45	3.09	2.56	-0.54
Transports	6.94	0.53	-6.41	8.32	0.63	-7.69
Dismantling; process, electrical and ventilation	9.43	22.86	13.44	11.31	27.44	16.13
Demolition of Buildings	61.27	56.98	-4.30	73.53	63.81	-9.72
Work completed 2009-10	-	24	24	-	24	24
Totals	164.2	181.8	17.6	197.0	205.4	8.4

- a. Estimated costs per group 2009 through project completion, inflated by 4 percent
- b. Estimated costs per group 2011 through project completion, net of MSEK24 spent in 2009-2010

- : No change - contingency allowance 20%
- : Contingency reduced from 20% to 15%
- : Contingency reduced from 20% to 12%
- : Groups where part of work completed since KB2008

The uncertainty estimates in the KB2010 report inevitably are subjective. The reductions relative to the KB2008 report result largely from the improved knowledge through radiological mapping, which in turn has enabled a clearer definition of approach that the preparers of the report have confidence in.

The assumed uncertainty on future characterisation needed has been reduced because much work already has been completed. Hence a 12 percent contingency in KB2010 versus 20 percent in KB2008.

The better (but not perfect) knowledge of radioactive contamination has provided a basis for a revised dismantling and decontamination sequence, notably for bricks lining the Large Leaching Hall pools, which in turn has led to a much reduced cost estimate for waste disposition. This reduction however is predicated on some major assumptions about the effectiveness of techniques, which the KB2010 acknowledges are not fully verified (ref 2, page 22). It is claimed however that a considerable surcharge has been included in the calculation value for this methodology, sufficient to cover the uncertainty. The extent of this surcharge is not readily visible.

The estimated nominal cost of conventional building demolition has been reduced because some of the buildings have been demonstrated to be completely clear of radioactive contamination.

The overall timescale for completion of the decommissioning project, specified as five years, appears to be reasonable. The A26 project in Springfields took about five to six years to accomplish a similar scope to that which will apply to the RMA Leaching Hall. A26 was bigger than the RMA building however. As long as the RMA leach hall does not represent a bottleneck in the program i.e. its throughput is compatible with the volumes of material from dismantling that has to be decontaminated in RMA, the execution of the overall program duration, with different buildings being dealt with in parallel, seems reasonable.

6.2.2 Characterisation

The characterisation work/radiomapping that has been conducted appears to have consisted mainly of smear tests and surface monitoring. There has been no evidence found in the KB2010 report that any bricks have been removed from the Large Leaching Hall pools to determine the depth of penetration of radioactivity. Nor is there any evidence that tiles have been lifted in the RMA Leach Hall to determine the extent of any radioactive penetration into the underlying concrete. Regarding the latter however the estimate has acknowledged the possible need to scabble away some of the underlying concrete, which is a wise and prudent assumption. More details as a result of such

additional investigation would have been beneficial but the absence of these details does not necessarily undermine the cost estimate because the associated uncertainty has been acknowledged and, it appears, taken into account.

The characterisation performed in late 2009 and into 2010 has provided a clearer picture of requirements at the Old Sorting Plant, where some relatively small areas of uranium contamination (penetration of concrete to a depth of 2 to 3 mm) has been discovered but that in turn has meant that the vast majority of the facility has been designated as clear.

Higher levels of activity than previously measured have been measured in the Large Leaching Hall and the RMA Hall (on bottom floor and around process equipment) but reportedly with no real hot spots to cause concern.

A final general observation regarding characterisation is that the radiological condition of a facility can be a powerful determinant of the decommissioning plan and the related cost estimate. The extent of radiological mapping conducted should be sufficient to provide a clear basis for developing a decommissioning plan. Surface monitoring and smear testing may be insufficient. Additional physical inspections and sampling may be necessary. All data gathered should be analysed in a way that provides a clear and full picture of the condition of the facility, in order to increase confidence in the cost of the decommissioning plan. The importance of analysis and incorporation in the decommissioning plan of the deductions from the results cannot be overemphasised.

6.2.3 *Decontamination*

A major change from the KB2008 estimate is the decision to remove all the surface bricks and mortar from the Large Leaching hall pools and to process them in an industrial tumbler/washer. The base assumption is that this will remove the contaminated mortar and that it will clean up the surfaces of the acid-proof bricks. The assumption is that the latter will facilitate recycle of the acid-proof bricks.

These assumptions may prove to be valid but the KB2010 report does not say anything about an industrial reference for the assumed tumble/wash technique. The concept does seem realistic but, as stated, the KB2010 report acknowledges that it is not yet validated. Decontamination of the acid-proof bricks to the extent that they can be recycled is not proven. The extra financial provision to cover this uncertainty is not completely clear.

Increases for cost item A21.1 and the part of P7 related to building material decontamination might provide some indication but the descriptions of these items are not easily understood in terms of implied scope, nor are the descriptions consistent from KB2008 to KB2010. The KB2010 report does not offer any remarks on what the 'Plan B' might be if the currently proposed approach for any reason turns out to be not feasible.

The issue of rubber coated process equipment, the complications of which it is said were not dealt with in the KB2008 report, is raised in KB2010. A clear statement that this has been taken into account in the cost estimate has not been found but the report implies that KB2010 has done so.

6.2.4 ***Dismantling***

The amount of process, ventilation and electrical equipment to be dismantled has been increased by a factor of about 4.5 from 125 tonne in the KB2008 estimate to 560 tonne in the KB2010 estimate, as a result of improved information being available. A 20 percent contingency allowance for this item in the KB2008 estimate is mentioned as having covered this uncertainty but it is not immediately obvious how this would have covered a factor of 4.5 times difference in volumes. In any event the KB2010 estimate has taken this into account.

6.2.5 ***Building Demolition***

KB2010 includes a completely new estimate for building conventional demolition costs. Fixed installations that are not contaminated are to be left in place without further attention and dealt with in connection with the final conventional demolition phase. Radiation protection measures will not be needed.

Material will be recycled to the extent possible and economically motivated. Cavities below ground are to be filled with crushed concrete. There may also be a question of using crushed concrete to create hard ground surfaces as a basis for new buildings or roads.

The ground underneath the leaching facility has been identified as requiring inspection to identify if there are any traces of leakage that must be removed.

KB2010 acknowledges the point made in NAC's Part I report that the validity of the earlier building demolition cost estimate quote should be questioned. KB2010 notes that

commercial/market conditions at the time of contracting for such services will be a strong determinant of the eventual cost. It is a little puzzling therefore that the contingency allowance to reflect uncertainty for this item has been reduced from 20 percent to 12 percent.

6.2.6 Waste Volumes

A key assumption in the KB2010 estimate is the reduced volume of wastes to go to costly disposal, first in interim storage and later to a repository for long-lived radioactive waste. Because of the uncertainties associated with some of the decontamination methodology, this volume reduction for such hazardous waste is not yet proven. Overall a saving of more than MSEK12 on waste transport, interim storage and disposal is claimed in KB2010 versus KB2008.

6.3 Summary on Status of the KB2010 Decommissioning Cost Estimate

The work done on investigating the condition of the Ranstad facilities, in the period between the development of the KB2008 and KB2010 cost estimates, has made a helpful contribution to the definition of the projected cost for eventual decommissioning, including the associated uncertainty.

NAC's Part I report made the strong recommendation that further radioactive mapping work should be carried out, principally to better define the extent of penetration of radioactivity in selected areas (notably in the pools of the Large Leaching hall and under the tiled floors of the RMA Leach Hall). This in turn would indicate:

- a. If a change in the planned decontamination and dismantling approach might be needed
- b. If the volume of radioactive waste to be disposed of in a geological repository for long-lived radioactive waste might change significantly.

Both of these could have important impacts on the cost of decommissioning. Such work has been conducted and, indeed, has resulted in both items a) and b) being applied to the KB2010 cost estimate.

The improved understanding of the condition of the various facilities on the Ranstad site that has been gained undoubtedly has provided a basis for improved confidence in certain

aspects of the decommissioning program. However, some key assumptions remain to be validated.

- The proposed technique for decontamination of the Large Leaching Hall pool acid-proof bricks is not yet validated.
- The assumption that the acid-proof bricks can be cleared for recycle is not certain

The cost of waste disposition is dependent on these two assumptions. If they are incorrect, the cost of waste disposal could be higher.

The experience from decommissioning A26 in the U.K., taking account of apparent Sweden-U.K. labour rate/worker efficiency differentials, suggests that the labour hours estimated for the Ranstad decontamination and dismantling work might be underestimated. The available information makes it difficult to pick out exactly what the estimated remaining total base cost associated with these activities is but it could be in the order of MSEK50. If so, the possible labour rate factor therefore might add something like MSEK25.

The cost of conventional building demolition, which represents 35 percent of the estimated remaining total expenditure, is subject to the uncertainties of general economic cycles and the extent to which a competitive situation is created in the bidding for the work.

References

1. Calculation of costs for decommissioning and demolishing certain buildings and facilities belonging to Ranstad Industriecentrum AB, prepared by SKB International Consultants, June 2008
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