Radioactive Waste Safety Appraisal

An International Peer Review of the Licence Application for the Australian Near Surface Radioactive Waste Disposal Facility

Report of the IAEA International Review Team

IAEA
International Atomic Energy Agency

RADIOACTIVE WASTE SAFETY APPRAISAL

AN INTERNATIONAL PEER REVIEW OF THE LICENCE APPLICATION FOR THE AUSTRALIAN NEAR SURFACE RADIOACTIVE WASTE DISPOSAL FACILITY

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

The Australian government has decided to develop a near surface radioactive waste disposal facility for low level and short lived intermediate level waste that is currently stored in over one hundred locations throughout Australia. The Department of Education, Science and Training (DEST) is the authority responsible for the development of this facility. A site selection process was undertaken and an Environmental Impact Statement (EIS) report was prepared and approved for the designated site. The DEST submitted an application to the national nuclear regulatory authority, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), for a licence that would authorize DEST to prepare a site to construct and operate the proposed facility. The Chief Executive Officer of ARPANSA requested the IAEA, on the basis of the IAEA's statutory mandate to establish standards of safety and to provide for their application, to undertake an international peer review of the licence application and to advise him accordingly. In carrying out the review and examining the documentation in support of the application for the licence, the International Review Team have taken into consideration currently prevailing international best practice.

Peer reviews are increasingly being acknowledged as an important component in building broader stakeholder confidence in the safety of facilities. For this reason, an increase in their number and frequency is anticipated. The coming into force of the Joint Convention has also focused attention on the demonstration of waste management facilities. This report presents the consensus view of the international group of experts convened by the IAEA for carrying out the review.

The present publication will be of interest to organizations responsible for the development and operation of facilities for the disposal of radioactive waste, to regulatory bodies responsible for regulating their safety, technical support organizations and the broader range of stakeholders interested or affected by the development of such facilities.

EDITORIAL NOTE

CONTENTS

SUMMARY AND CONCLUSIONS 1

BACKGROUND 1
APPROACH TO THE REVIEW 2
CONCLUSIONS 3
Regulatory framework 3
Approach to safety assessment and documentation 4
Step by step approach 4
Safety case development and documentation 5
Management systems 5
Post-closure safety assessment 6
Assessment context 6
System description 7
Scenario development 8
Model development and justification 8
Surveillance and monitoring 8
Operational safety assessment 9
Transport safety assessment 10
OVERALL CONCLUSION 10

1. INTRODUCTION 11

BACKGROUND 11
TERMS OF REFERENCE 17
REVIEW PROCEDURE 19
STRUCTURE OF THE REPORT 20

2. REGULATORY FRAMEWORK 21

International best practice 21
Observations 22
Conclusions 23

3. APPROACH TO SAFETY ASSESSMENT AND DOCUMENTATION 25

STEP BY STEP APPROACH 25
Internatitonal best practice 25
Observations 26

Conclusions 28
SAFETY CASE DEVELOPMENT AND DOCUMENTATION 28
International best practice 28
Observations 31
Conclusions 34
MANAGEMENT SYSTEMS 35
International best practice 35
Observations 36
Conclusions 38

4. POST-CLOSURE SAFETY ASSESSMENT 40

BACKGROUND 40
ASSESSMENT CONTEXT 41
International best practice 41
Observations 42
Conclusions 44
SYSTEM DESCRIPTION — ENGINEERED BARRIERS 45
International best practice 45
Observations 46
Conclusions 48
SYSTEM DESCRIPTION — NATURAL BARRIERS 48
International best practice 48
Observations 49
Conclusions 53
SCENARIO DEVELOPMENT 53
International best practice 53
Observations 54
Conclusions 55
MODEL DEVELOPMENT AND JUSTIFICATION 55
International best practice 55
Observations 56
Conclusions 57
RESULTS AND CONFIDENCE BUILDING 57
International best practice 57
Observations 58
Conclusions 58
SURVEILLANCE AND MONITORING 59
International best practice 59
Observations 60

Conclusions 61
5. OPERATIONAL SAFETY ASSESSMENT 62

International best practice 62
Observations 64
Conclusions 65

6. TRANSPORT SAFETY ASSESSMENT 66

International best practice 66
Observations 66
Conclusions 66

REFERENCES 67

BIBLIOGRAPHY 70

MEMBERS OF THE INTERNATIONAL REVIEW TEAM 73

SUMMARY AND CONCLUSIONS

BACKGROUND

S01. Radioactive waste has been generated in Australia for a number of decades, the waste having arisen from the production and use of radioactive materials in medicine and industry, from the processing of various minerals containing natural radionuclides and from various research activities. The waste is stored at over one hundred locations throughout Australia and it has been decided in the interests of long term safety and security to develop a radioactive waste disposal facility to accommodate the low level and short lived intermediate level waste, which make up the bulk of the stored waste, other than mining and minerals processing residues. The responsibility for developing and operating the facility has been vested in the Department of Education Science and Training (DEST). A site selection process has been undertaken and Environmental Impact Statement (EIS) report prepared and approved. A Licence Application has been submitted by DEST to the national nuclear regulatory authority, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) for a facility licence authorising the applicant to prepare a site to construct and operate the proposed facility.

S02. In making a decision on whether to issue a facility licence, the *Australian Radiation Protection and Nuclear Safety Act 1998* and Australian Radiation Protection and Nuclear Safety Regulations 1999 require the Chief Executive Officer (CEO) of ARPANSA to take account, of inter alia:

- International best practice in relation to radiation protection and nuclear safety;
- Whether the application establishes that the ‘proposed conduct’ can be carried out without undue risk to the health and safety of the people, and to the environment;
- Whether the applicant has shown that there is a net benefit from carrying out the ‘conduct’ relating to the controlled disposal facility;
- Whether the applicant has shown compliance with dose limits and the magnitude of individual doses, the number of people exposed, and the likelihood that exposures that will happen, are as low as reasonably achievable, having regard to economic and social factors.

S03. In order to assist the CEO of ARPANSA in his deliberations, he has requested the IAEA, in terms of its statutory mandate to establish standards of safety and to provide for their application, to undertake an international peer review of the Licence Application and to advise him in respect of:

— International best practice in radiation protection and nuclear safety for the disposal of low level and short lived intermediate level waste;

— Whether the characteristics of the proposed site and the design, construction and operation of the proposed repository are adequately addressed and would be amenable to the protection of people and the environment in accordance with international best practice in radiation protection and nuclear safety;

— The suitability and adequacy of proposed waste acceptance and conditioning criteria for the purpose of disposing of the radioactive waste in the repository;

— Whether the proposed environmental monitoring and auditing programme is suitable and adequate;

— Transport practices of conditioned waste to the repository.

APPROACH TO THE REVIEW

S04. In response to the request, the IAEA assembled an International Review Team (IRT) of suitably qualified experts in the safety and licensing of radioactive waste disposal facilities, who have undertaken the review as requested. The review entailed consideration of the documentation submitted in support of the Licence Application, a series of meetings and discussions with representatives of DEST and their contractors, with staff members of ARPANSA and a visit to the site of the proposed disposal facility.

S05. As a basis for the review process, the IRT adopted as its point of reference for "international best practice" the articles of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, the corpus of international radioactive waste safety standards and the documented outcomes of activities supporting their development and use, such as the co-ordinated research projects on development and application of safety assessment methodology. The IRT also made use of prevailing national practices it considered compliant with the above.

S06. In fulfilling its mandate, the IRT reviewed the existing regulatory framework, the approach being adopted to achieve safety, the documents submitted in support of the licence application, the management systems for the project and the safety assessment. In presenting the findings of the IRT for each area of work this report describes what the IRT considers to be international best practice; this is followed by the observations of the IRT about the project; and, finally, by a number of conclusions identifying (a) a number of aspects where the project meets *international best practice*; (b) *recommendations* on aspects where, in the opinion of the IRT, improvements are needed to meet the requirements for safety, and (c) *suggestions* for improvement, that should be considered by the Applicant (DEST), the Regulatory Body (ARPANSA), or both.

CONCLUSIONS

S07. The conclusions referred to in S06 are presented in the following sections. The main body of the report presents what the IRT considered to be international best practice, its observations and the conclusions for each aspect reviewed.

Regulatory framework

S08. Good Practice: Australia is a Contracting Party to the Joint Convention and has met its primary obligations under the convention by compiling a national report explaining how it is complying with the articles of the Convention, and submitting this for peer review by the Contracting Parties to the Convention. Also by having in place a legal and regulatory infrastructure and clearly allocating responsibilities, and by adopting and applying safety standards to waste management activities that are compatible with internationally recognized standards. With regard to legal and regulatory aspects the EPBC and ARPANS Acts [2, 3] provide an appropriate legal basis and ARPANSA is the nominated Regulatory Body. Responsibility for development and operation of the disposal facility has been allocated to DEST (§210).

S09. Recommendation: the Australian national regulatory guidance made as subsidiary documents to the legislative framework is largely focused on reactor safety and pre-dates a number of significant developments in waste safety. This highlights the need for dialogue between the Regulatory Body (ARPANSA) and the Applicant (DEST) to develop a mutual understanding of the regulatory requirements and of the arrangements necessary to ensure compliance with them. The IRT recommends that a process be established to identify key regulatory issues in the licensing of the facility and to track their resolution (§211).

S10. Recommendation: because the existing regulatory guidance is not designed for the licensing of radioactive waste repositories, the IRT recommends that the Regulatory Body should develop a guidance document specifically for radioactive waste disposal (§212).

S11. Suggestion: the Joint Convention makes explicit reference to the need for both the operating organization and the Regulatory Body to be provided with adequate resources to undertake their respective responsibilities. The responsibility for development and operation of the repository rests clearly with the Applicant who, with a limited number of dedicated staff, appears to rely heavily on contractors. This makes it difficult to deliver an integrated programme (given the wide range of scientific and technical disciplines involved) and to provide the continuity needed later when the facility will be operated on a campaign basis. The IRT suggests that the Applicant should consider retaining more of the functional responsibilities for development and operation of the repository within DEST. The IRT suggests that the Regulatory Body should also review its staffing and training to ensure that adequate resources are allocated to the waste management area (§213).

Approach to safety assessment and documentation

Step by step approach

S12. Good Practice: with respect to the process of site selection, the IRT was impressed by the work that had been carried out to identify, through three phases, a shortlist of three sites from eight large arid regions located throughout Australia. The transparency of the process and the arrangements for consultation with the public and other interested parties are in accord with international best practice (§309).

S13. Good Practice: the EIS is clearly written and presented and represents a significant milestone in the repository development project. The IRT considers that the EIS demonstrates that there are good prospects that the envisaged disposal system will be capable of meeting internationally endorsed safety objectives and criteria, and that there is a ‘net benefit’ to be gained from the disposal of radioactive waste at the proposed site (§310).

S14. Recommendation: the application for siting, design, construction and operation of the facility in a single step overlooks the step by step approach that is now considered to be international best practice. A single step approach precludes the iteration considered to be necessary to achieve, demonstrate and develop confidence in the safety of the facility. It is recommended that alternatives be explored to take the licensing process forward in a more step by step manner (§311).

Safety case development and documentation

S15. Recommendation: the Applicant appears to have been late to recognize the value of a high-level, well-referenced synthesis document as a vehicle for controlling, developing, maintaining and presenting the safety case for the repository. Appendix H of the Supplementary Information for ARPANSA goes part way towards realising such a document but more needs to be done to make it comprehensive and to provide accurate and relevant cross-referencing to the key components of the safety case. The IRT therefore recommends that the Applicant should improve the coherency, consistency and presentation of the safety case by developing such a document, which should show the hierarchical structure of the safety case, the underlying safety assessments and the limits, controls, conditions (e.g. waste acceptance criteria) and procedures necessary to deliver safety (§329).

S16. Suggestion: the IRT suggests that site-based experiments be conducted to demonstrate the feasibility of creating the necessary structures and repository barriers and to build confidence in their performance (§330).

S17. Suggestion: the IRT suggests that the Licence Application would be improved by a more systematic and transparent approach to organising the documents. In particular, the page numbering system should be improved so that readers can more easily find their way through the documents (§331).

Management systems

S18. Good Practice: the IRT notes that the Management System is clearly designed to be compliant with ISO 9001:2000 and this gives confidence that the activities covered by the Management System will be fit for purpose. In this respect the Management System accords with international best practice (§345).

S19. However, the documentation is difficult to navigate and, when the appropriate section is found, many of the procedures are present as drafts or missing entirely. In addition, two issues that might have been expected to be addressed, design control and independent peer review, appear to be absent. Recommendation: the IRT recommends that these omissions be rectified (§346).

S20. Recommendation: the exclusion of the pre-receipt activities from the Management System will increase the difficulty of ensuring that waste packages conform to the waste acceptance criteria and considerable reliance will need to be placed on the auditing of the pre-receipt activities, the at-repository inspection and, in the final resort, on the contract between the Applicant and the waste owner. Such reliance on contractual terms may give rise to logistical difficulties and produce litigation. In these respects the IRT recommends that the Applicant should prepare more detailed descriptions of (i) how pre-receipt activities are to be audited and (ii) post-receipt inspections, including a description of the location and nature of the inspection facility (§347).

S21. Recommendation: the IRT recommends that the Applicant should provide a description of the information that is to be archived for the benefit of future generations and explain how this is to be carried out (§348).

Post-closure safety assessment

Assessment context

S22. Good Practice: the choice of 200 years active institutional control is within the range of values commonly used in North America and Europe (100–300 years). Given Australia's history and culture, it seems to be an adequately conservative estimate of the amount of time during which institutional control may be relied upon to inhibit potential inadvertent human intrusion. The use of this value is therefore consistent with international best practice (§412).

S23. Recommendation: the IRT recommends further dialogue between the Applicant and the Regulatory Body to agree upon the radiological protection limits, constraints and levels to be applied to normal evolution and human intrusion situations for the post-closure period. The IRT suggests that the most recent recommendations of the International Commission on Radiological Protection on radioactive waste management should be used as a basis for establishing of these criteria (§413).

S24. Recommendation: application of probabilities to human intrusion scenarios is not in line with current recommendations of the ICRP, which has explicitly developed its recommendations to avoid such approaches. The IRT recommends that consideration be given to using the approach developed in ICRP 81 in consideration of human intrusion (§414).

S25. Suggestion: the IRT suggests that additional clarity is needed in the applied time frame for the long term. It is currently unclear whether the 10 000 year limit is used as a cut-off for evaluations, and if waste acceptance criteria are developed based on dose or risk projections at longer times (§415).

S26. Suggestion: the IRT suggests that the Applicant should produce a clear statement of the assessment philosophy (as elaborated in the IAEA ISAM Project) that has been adopted. It should describe how this has influenced the selection of scenarios, models, and parameter values and the extent to which it has biased the model results toward conservatism (§416).

System description

S27. Recommendation: as part of the safety case and in relation to the defence-in-depth principle, the IRT recommends that the Applicant should clearly identify the safety functions of the various components of the repository design (including both the engineered and natural barriers), and provide confidence, by demonstrations or otherwise, that each component will perform effectively (§425).

S28. Good Practice: the IRT notes that the Applicant has adequately characterized the site at both the regional and the local scale and that this aspect is in line with international best practice (§445).

S29. Recommendation: at the same time the regional to local scale correlation is not well described in the documentation and the IRT recommends that this should be given more prominence to better support the safety case (§446).

S30. Recommendation: the IRT recommends that the disposal zone (within the inner fence) should be characterized (borehole and/or pits) to confirm the geological, hydrogeological and geochemical characteristics of the disposal zone (§447).

S31. Recommendation: the IRT recommends further study of the faults and fractures on the site (as already requested by Environment Australia) to evaluate their potential influence on groundwater movement and allow, if necessary, their effect to be incorporated into safety assessments (§448).

S32. Suggestion: the IRT suggests that the Applicant should conduct a more extensive study of the geomorphology of the site. This should aim to explain how the site has evolved to the present day so that its future evolution, as expressed in the safety case, can be fully justified (§449).

Scenario development

S33. Recommendation: the IRT recommends that scenarios should be developed based on a formal consideration of all site-specific features, events, and processes (FEPs) that could affect the disposal facility. Reasons should be given when FEPs are excluded from further consideration. The scenarios, which should be both traceable and justified, should consider all relevant exposure pathways and justify any exclusions. Appropriate attention should be given to both trenches and boreholes and the potential influence of different combination of the two in the site configuration adopted (§456).

Model development and justification

S34. Recommendation: the IRT recommends that the Applicant should put greater emphasis on demonstrating that models and data used in safety assessment are both traceable and justified. All parameters need to be justified but special care is needed when simple but potentially non-conservative models (e.g. dilution factors) are used to approximate more complex behaviour (§464).

S35. Recommendation: the IRT recommends that a clear and consistent strategy should be applied to the selection of the level of conservatism used in the analysis. This strategy should be derived from the assessment philosophy established in the assessment context. The strategy may or may not include formal uncertainty and sensitivity analysis methods (§465).

Surveillance and monitoring

S36. Recommendation: the IRT recommends that the Applicant should direct the monitoring plan towards supporting the safety of the facility by monitoring parameters relevant to the performance of all the repository barriers that are important to the safety of the repository. The dynamics of the repository system and the nature of the safety function should determine the frequency and the sensitivity of the monitoring measurements (§478).

S37. Recommendation: the IRT recommends that the Applicant should prepare a plan to identify the actions that would be taken if the monitoring programme were to produce an unexpected observation. This plan needs to be based on an understanding of the implications for safety of various levels of radionuclide concentrations if detected in the media being monitored (§479).

S38. Suggestion: the environmental monitoring plan deals with both the operational and post closure phases and proposes to monitor a wide range of environmental media, including fauna and flora. The IRT suggests that it should be extended to include site meteorological data (§480).

Operational safety assessment

S39. Recommendation: the IRT recommends that the Applicant should now develop a repository reference design that includes construction means and methods for both trenches and boreholes and submit these for licensing (§510).

S40. Recommendation: the IRT recommends that the Applicant should detail the safety relevant limits, controls, conditions and procedures to be used for the construction and operation of the repository (both boreholes and trenches), including the arrangements for dealing with emergencies. These will allow the assessment and the demonstration of radiological safety during repository operation. If the complete set of procedures, limits, controls and conditions is not reviewed and approved by the Regulatory Body, then the arrangements for their control (approval, modification etc.) should be agreed with the Regulatory Body, preferably in advance. In any event, sufficient information should be presented to the Regulatory Body to allow it to make an independent assessment of safety (§511).

S41. Recommendation: the IRT recommends that, once the reference design has been developed, the Applicant should consider the limits, controls and conditions that are necessary to ensure that the repository attributes that are necessary for post-closure safety are both delivered and preserved during the operational phase. (§512).

Transport safety assessment

S42. Good Practice: the IAEA Transport Regulations have been adopted into the Australian regulatory framework and so the framework is consistent with international best practice (§603).

S43. Recommendation: the IRT recommends that, if waste is to be transported without an overpack, then the restrictions on waste loading should be incorporated into the Waste Acceptance Criteria. However, if the Applicant is to make other arrangements (e.g. an overpack), then the design should be specified and described to enable regulatory review (§604).

OVERALL CONCLUSION

S44. The IRT has concluded that the process of site selection has been thorough and that the site selected offers good prospects of meeting internationally endorsed safety objectives and criteria. However, further work is necessary to demonstrate safety before regulatory approval of construction and operation of the facility.

1. INTRODUCTION

BACKGROUND

101. During the past 100 years, radioactive materials have come to be used in Australia in a wide range of medical, industrial, agricultural and environmental applications. These activities have given rise to the generation of a certain amount of radioactive waste, in total around 3 700 m^3 (see Fig. 1). This waste is classified according to the scheme set out in the 1992 National Health and Medical Research Council (NHMRC) Code of Practice [1], falling into the categories of low and intermediate level waste. Of the waste generated to date 2 010 m^3 is slightly contaminated soil stored near Woomera, which arose from

Inventory of Existing Waste

Australia has accumulated about 3 700 m^3 of radioactive waste from over 40 years of research, medical and industrial uses of radioactive material. Of this total 2 010 m^3 is slightly contaminated soil stored near, Woomera, which arose from Commonwealth Scientific and Industrial Research Organization (CSIRO) research into the processing of radioactive ores during the 1950s and 1960s. Another major component is 1 320 m^3 of ANSTO operational waste, including clothing, paper and glassware, stored at Lucas Heights near Sydney. The Department of Defence (Defence) has 210 m^3, including contaminated soils from land remediation, sealed sources, gauges, electron tubes and other equipment, held at a number of locations around the country. The remaining waste — approximately 160 m^3 (conditioned volume), comprises spent sealed sources and miscellaneous laboratory waste from hospitals, universities, industrial activities and other ‘small users’, and is distributed throughout the country. A summary of existing waste is provided in the Table below. Of the total inventory of 3 700 m^3, 2 228 m^3 (60%) is held in South Australia and, of that, 2 010 m^3 is contaminated soil stored at Woomera.

State	Estimated volume
South Australia	2 228 $m^{3(1)}$
Victoria	33 m^3
New South Wales	1335 m^3
Queensland	45 m^3
Tasmania	15 m^3
Australian Capital Territory	8 m^3
Northern Territory	16 m^3
Western Australia	All historical and current waste in WA is disposed of at the Mount Walton East facility
Total	3 700 m^3

(1) includes 2 010 m^3 of contaminated soil stored near Woomera

FIG. 1. Extract from the Draft EIS Main Report [5] describing the existing radioactive waste inventory in Australia.

research into the processing of radioactive ores during the 1950s and 1960s. Another major component is 1 320 m^3 of Australian Nuclear Science and Technology Organization (ANSTO) operational waste, including clothing, paper and glassware, stored at Lucas Heights near Sydney. The Department of Defence has 210 m^3, including contaminated soils from land remediation, sealed sources, gauges, electron tubes and other equipment, held at a number of locations around the country. The remaining waste, approximately 160 m^3 (conditioned volume), is comprised of spent sealed sources and miscellaneous laboratory waste from hospitals, universities, industrial activities and other ‘small users’, and is distributed throughout the country. It is expected that about 40 m^3 of low level and short-lived intermediate level waste (conditioned volume) will be routinely generated per year in the future (see Fig. 2), plus there will be other volumes from reactor decommissioning. In addition to the radioactive waste arising from these various activities, uranium and other mining and minerals processing activities have given rise to the generation of radioactive waste containing naturally occurring radionuclides.

Future Waste Generation

Recycling of disused sources of radioactive materials used in medicine, industry or research is now extensively practised, and consequently estimated future waste quantities are relatively small. It is expected that about 40 m^3 of routine low level and short-lived intermediate level waste (conditioned volume) will be generated per year in the future, plus there will be other volumes from reactor decommissioning. The estimated future low level and short-lived intermediate level waste arisings are summarized in the table below.

Compared with the amounts of similar wastes disposed of in countries with nuclear power programs, the accumulated and expected future amounts of this waste are quite small. For example, the Centre de la Manche repository in France accepted about 525 000 m^3 of radioactive waste from 1969 to 1994.

The repository would be designed to take about 10 000 m^3 of low level and short-lived intermediate level waste (although the limit would be set in terms of total activity of various radionuclide groups).

Location and nature of waste	Estimated volume when packaged/conditioned
ANSTO (HIFAR and replacement research reactor)	30 m^3/yr
Nationwide, other sources Up to	10 m^3/yr
Moata research reactor (shut down in 1995)	55 m^3
Lucas Heights HIFAR research reactor decommissioning	500–2 500 m^3
Lucas Heights replacement research reactor decommissioning	Expected to be similar to HIFAR

FIG. 2. Extract from the Draft EIS Main Report [5] describing future waste generation in Australia.

102. The low level and short-lived intermediate level radioactive waste is temporarily stored at more than 100 locations across Australia, largely in buildings that were neither designed nor located for the long-term storage of radioactive material. In order to reduce the cumulative risks associated with managing numerous waste storage areas, the Commonwealth of Australia proposes to construct and operate a national near surface repository for the disposal of Australian low level and short-lived intermediate level waste. Such a repository has been determined to represent the most effective option for Australia to manage this type of waste. The repository would be designed to accommodate about 10 000 m^3 of low level and short-lived intermediate level waste and be located approximately 20 kilometres east of Woomera in South Australia (see Figs 3 and 4(a,b)). The facility is not intended for the disposal of radioactive ores from mining, and radioactive waste generated overseas will not be accepted for disposal in the repository. The Commonwealth is in the process of identifying a site for a national store for long-lived intermediate level waste produced by Commonwealth agencies, which will not be located in South Australia.

103. It is proposed to use two basic forms of disposal structure for shallow waste burial at the facility. These are disposal trenches and large diameter boreholes. Disposal trenches (see Fig. 5) will be utilized for disposal campaigns where there is a substantial quantity of waste for disposal. This will be the case for the first campaign that will dispose of the current waste inventory of around 3 700 cubic metres in volume. Boreholes (see Fig. 6) will be utilized for disposal campaigns where the quantity of waste is relatively small with a view to making a cost effective system. It is envisaged that this may be the situation for later

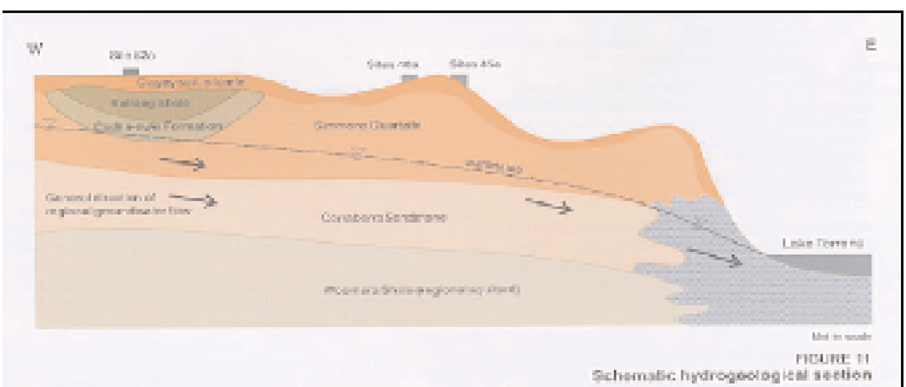

FIG. 3. Schematic hydrogeological section [5].

FIG. 4(a). The site location.

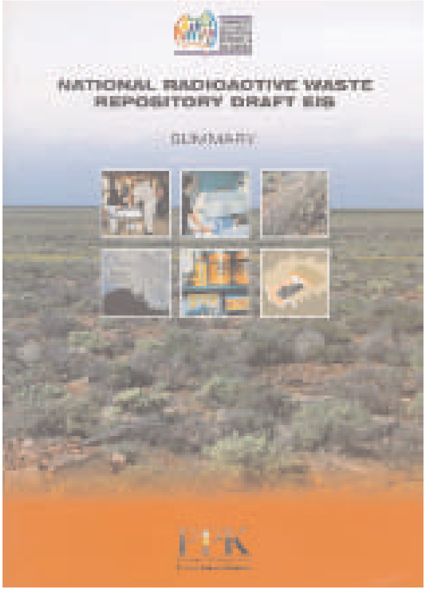

FIG. 4(b). Draft of EIS report summary [5].

campaigns where the waste volume may not exceed 200 cubic metres in volume.

The general dimensions of the disposal structures envisaged based on practical considerations are proposed:

Trench:

- Maximum depth to base of 15 to 20 metres
- Width at the base of about 12 metres
- Side walls at stable batters slopes for the in-situ material

Borehole:

- Depth to base of 15 to 20 metres

104. In terms of Commonwealth legislation, a radioactive waste disposal facility is deemed to be a nuclear activity and requires approval under the Environment Protection and Biodiversity Conservation (EBPC) Act 1999 [2] so as to ensure that matters potentially and significantly affecting the environment are fully examined and taken into account in decisions made by the Commonwealth Government. The repository is also a nuclear installation

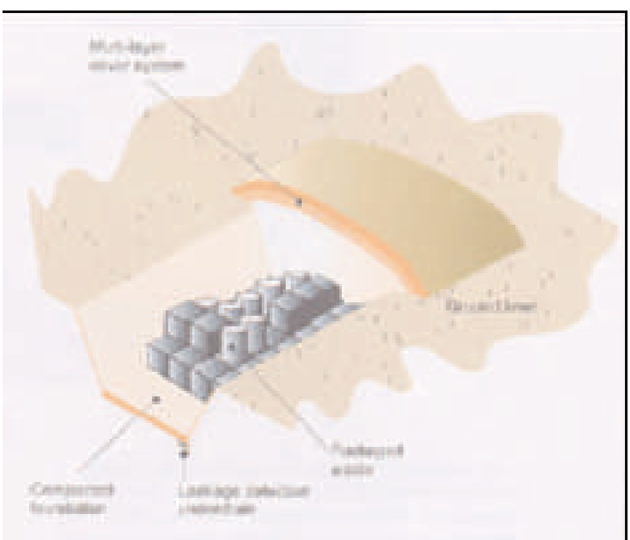

FIG. 5. Disposal trench [5].

under the Australian Radiation Protection and Nuclear Safety (ARPANS) Act [3] which requires the proponent, the Department of Education Science and Training (DEST), to obtain a facility licence from the CEO of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) authorising DEST to prepare a site for, construct and operate the facility. And subsequently would require an application for a licence to decommission, dispose or abandon the facility.

105. To satisfy the requirements of the EPBC Act DEST prepared and submitted an Environmental Impact Statement [4–7] for the proposed national repository. The Minister of Environment and Heritage under the EPBC Act approved two of the three shortlisted sites in May 2003.

106. A Licence Application to prepare a site for, construct and operate the repository was submitted to the CEO of ARPANSA in August 2003 [8–10]. At

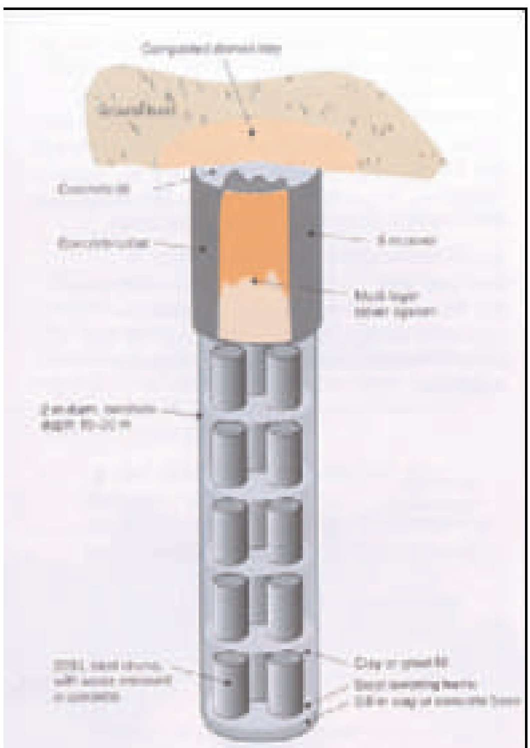

FIG. 6. Disposal borehole [5].

the request of the CEO of ARPANSA, the information contained in the Licence Application was subsequently supplemented by an additional volume [11].

107. In order to assist the CEO of ARPANSA with his deliberations, he has requested the International Atomic Energy Agency, in the context of its statutory responsibility for establishing international standards of safety and providing for their application, to undertake an international peer review of the Licence Application.

TERMS OF REFERENCE

108. In making a decision whether to issue a licence, the ARPANS Act [3] and Regulations require the CEO of ARPANSA to take account of inter alia:

— International best practice in relation to radiation protection and nuclear safety;

— Whether the application establishes that the proposed conduct can be carried out without undue risk to the health and safety of the people, and to the environment;

— Whether the applicant has shown that there is a net benefit from carrying out the conduct relating to the controlled facility;

— Whether the applicant has shown compliance with dose limits and the magnitude of individual doses, the number of people exposed, and the likelihood that exposure that will happen, are as low as reasonably achievable, having regard to economic and social factors.

109. As such, the review was to be undertaken by a team of experts that will advise the CEO in respect of:

— International best practice in radiation protection and nuclear safety for the disposal of low level and short lived intermediate level waste;

— Whether the characteristics of the proposed site and the design, construction and operation of the proposed repository are adequately addressed and would be amenable to the protection of people and the environment in accordance with international best practice in radiation protection and nuclear safety;

— The suitability and adequacy of proposed waste acceptance and conditioning criteria for the purpose of disposing of the radioactive waste in the repository;

— Whether the proposed environmental monitoring and auditing programme is suitable and adequate;

— Transport practices of conditioned waste to the repository.

110. The primary documents against which the review has been carried out are listed in Fig. 7.

Licence Application submitted by DEST:

National Radioactive Waste Repository: Draft EIS Summary, (May 2002).

National Radioactive Waste Repository: Draft EIS Main Report, (May 2002).

National Radioactive Waste Repository: Draft EIS Appendices, (May 2002).

National Radioactive Waste Repository: Supplement to the Draft EIS, (January 2003).

National Radioactive Waste Repository: Application for a Licence to Site, Construct and Operate the Repository; Volume I, (Aug 2003).

National Radioactive Waste Repository: Application for a Licence to Site, Construct and Operate the Repository; Volume II, Repository Management System, (Aug 2003).

National Radioactive Waste Repository: Application for a Licence to Site, Construct and Operate the Repository Volume III, Supporting Documents, (Aug 2003).

National Radioactive Waste Repository: Application for a Licence to Site, Construct and Operate the Repository; Supplementary Information for ARPANSA, (Dec 2003).

Other Documents Relevant to the Licence Application:

ENVIRONMENT AUSTRALIA, Environment Assessment Report, Proposed National Radioactive Waste Repository, (Mar 2003).

COMMONWEALTH OF AUSTRALIA, Radioactive Waste Repository for Australia, Site Selection Study, Phase 3, A Report of Public Comment, (Jun 1997).

COMMONWEALTH OF AUSTRALIA, A Radioactive Waste Repository for Australia, Site Selection Study – Phase 3. Regional Assessment, A Public Discussion Paper, (Nov 1997).

Australian Regulatory Documents:

NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL (NHMRC), Code of practice for the near-surface disposal of radioactive waste in Australia, (1992).

AUSTRALIAN RADIATION PROTECTION AND NUCLEAR SAFETY AGENCY, Regulatory Assessment Principles for Controlled Facilities RB-STD-42-00 Rev 1 Regulatory Branch, October (2001).

FIG. 7. Main documents considered by the review.

REVIEW PROCEDURE

111. The review was undertaken by a five-member International Review Team (IRT) assembled by the IAEA (see page 73), the review process being carried out according to the terms of reference. Documentation that had been initially provided in support of the Licence Application in August 2003 was made available to members of the IRT together with supplementary information submitted in December 2003. A series of meetings took place in Sydney, Australia during the period 18– 27 January at which the Applicant and their Contractors made presentations on the Licence Application and responded to the questions of the IRT were discussed. A visit was made to the repository site on 22 January.

FIG. 8. The site visit.

112. The findings of the review were presented to the Applicant orally on 27 January and to the CEO of ARPANSA on 28 January. A written summary, which included a list of draft conclusions, was also presented to the CEO of ARPANSA on 28 January. No substantive changes were made to the summary as a result of these presentations and discussions. The full report was reviewed by ARPANSA for factual accuracy prior to its finalisation for publication.

STRUCTURE OF THE REPORT

113. This section of the report presents the background to the review and the terms of reference and provides a description of the review process. Section 2 addresses the regulatory framework for the project. Section 3 deals with the approach to safety, its documentation and its presentation and the management systems employed. Section 4 covers post-closure safety assessment, Section 5 operational safety assessment and Section 6 transport safety assessment.

114. In presenting the findings of the IRT for each area of work this report describes what the IRT considers to be international best practice; this is followed by the observations of the IRT about the project; and, finally, by a number of conclusions identifying (a) a number of aspects where the project meets international best practice; (b) recommendations on aspects where, in the opinion of the IRT, improvements are needed to meet the requirements for safety, and (c) suggestions for improvement, that should be considered by the Applicant (DEST), the Regulatory Body (ARPANSA), or both.

2. REGULATORY FRAMEWORK

INTERNATIONAL BEST PRACTICE

201. The concept of a global safety regime has emerged in recent years in respect of nuclear, radiation and radioactive waste safety. The regime is made up of binding international conventions, internationally agreed safety standards which support national legal and regulatory infrastructures. In respect of radioactive waste management, the Joint Convention on the Safety of Spent Nuclear Fuel and the Safety of Radioactive Waste Management (the Joint Convention [12]) is the relevant convention. The IAEA corpus of radioactive waste safety standards makes up the applicable international standards and a number of and supporting activities and documents provide for their use and application.

202. The Joint Convention requires the establishment and maintenance of a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management that must provide for:

— the establishment of applicable national safety requirements and regulations;

— a system of licensing and regulatory control;

— appropriate institutional control;

— a clear allocation of responsibilities of the bodies involved in the different steps of radioactive waste management.

203. The prime responsibility for safety must rest with the holder of the relevant licence. A Regulatory Body, with sufficient independence, must be entrusted with the implementation of the legislative and regulatory framework, and provided with adequate authority, competence and financial and human resources to fulfil its assigned responsibilities.

204. A number of international safety standards are relevant and are listed in the bibliography (see page 70). Of prime consideration are the:

— IAEA Radioactive Waste Safety Fundamentals [13];

— IAEA Safety Requirements for Near Surface Disposal of Radioactive Waste [14];

— IAEA Safety Requirements for the Legal and Governmental Infrastructure [15];

— IAEA Transport Regulations [16];

— IAEA Safety Guide for Safety Assessment of Near Surface Disposal [17];

— IAEA Safety Series on Siting of Near Surface Disposal Facilities [18].

Also of relevance are the most recent recommendations from the International Commission on Radiological Protection (ICRP) on disposal of solid radioactive waste [19].

205. There have also been a number of international collaborative projects on the safety of near surface radioactive waste disposal facilities in recent years whose outcomes point to an emerging consensus on international best practice in this area. In this respect the ISAM [20] and the ongoing ASAM projects are relevant.

206. These various standards, recommendations and related projects cover radiation protection objectives and criteria, siting, design and operational aspects of facilities, licensing and demonstration of safety and management systems. Recent international developments have seen consensus emerging in a number of areas, which are of particular interest to this project. These concern the structure and content of safety cases for near surface disposal facilities, the systematic structuring and presentation of supporting safety assessments and the step by step approach to facility development. Collectively, all these elements have been used by the IRT as measures of international best practice.

OBSERVATIONS

207. Australia is a Contracting Party to the Joint Convention and has met its primary obligations under the convention by compiling a national report explaining how it is complying with the articles of the Convention, and submitting this for peer review by the Contracting Parties to the Convention. Also by having in place a legal and regulatory infrastructure and clearly allocating responsibilities, and by adopting and applying safety standards to

waste management activities that are compatible with internationally recognized standards. With regard to legal and regulatory aspects the EPBC and ARPANS Acts [2, 3] provide an appropriate legal basis and ARPANSA is the nominated Regulatory Body. Responsibility for development and operation of the disposal facility has been allocated to DEST.

208. Regarding national safety standards and regulations, the licensing requirements are set out in the ARPANS Act [3], and ARPANSA has informed DEST that safety of the facility and its operation should be compared against the National Health And Medical Research Council (NHMRC) Code of Practice [1]. Further regulatory guidance is available in three other documents 21–23]. Transport of radioactive material in Australia is regulated by State and Commonwealth authorities against a code of practice for the safe transport of radioactive material [24]. ARPANSA has also indicated that international best practice in radiation protection and nuclear safety should be identified in the Licence Application because the ARPANS Act [3] requires the CEO of ARPANSA to take this into consideration in his deliberations on whether to issue a facility licence.

209. It is noted that the regulatory guidance in place is largely based on reactor safety considerations and needs interpretation in its application to waste management facilities. Furthermore, a number of developments have taken place in safety standards and practice in radioactive waste safety since the 1992 NHMRC Code of Practice [1] was issued, and which are not fully reflected in the Licence Application. These relate to the step by step approach to facility development, the structuring and presentation of the safety case and the systematic approach to safety assessment. These aspects are discussed in later sections.

CONCLUSIONS

210. Good Practice: the fact that Australia is a Contracting Party to the Joint Convention and is generally compliant with all the obligations placed on Contracting Parties by the articles of that Convention is considered by the IRT to represent international best practice. The flexibility inherent in the regulatory legislation to take account of international best practice is considered to be particularly useful. The fact that Australia has called for international peer review of the Licence Application for the repository is also deemed to be consistent with international best practice in respect of developing confidence in the safety of waste disposal facilities.

211. Recommendation: the Australian national regulatory guidance made as subsidiary documents to the legislative framework is largely focused on reactor safety and pre-dates a number of significant developments in waste safety. This highlights the need for dialogue between the Regulatory Body (ARPANSA) and the Applicant (DEST) to develop a mutual understanding of the regulatory requirements and of the arrangements necessary to ensure compliance with them. The IRT recommends that a process be established to identify key regulatory issues in the licensing of the facility and to track their resolution.

212. Recommendation: because the existing regulatory guidance is not designed for the licensing of radioactive waste repositories, the IRT recommends that the Regulatory Body should develop a guidance document specifically for radioactive waste disposal.

213. Suggestion: the Joint Convention makes explicit reference to the need for both the operating organization and the Regulatory Body to be provided with adequate resources to undertake their respective responsibilities. The responsibility for development and operation of the repository rests clearly with the Applicant who, with a limited number of dedicated staff, appears to rely heavily on contractors. This makes it difficult to deliver an integrated programme (given the wide range of scientific and technical disciplines involved) and to provide the continuity needed later when the facility will be operated on a campaign basis. The IRT suggests that the Applicant should consider retaining more of the functional responsibilities for development and operation of the repository within DEST. The IRT suggests that the Regulatory Body should also review its staffing and training to ensure that adequate resources are allocated to the waste management area.

3. APPROACH TO SAFETY ASSESSMENT AND DOCUMENTATION

STEP BY STEP APPROACH

International best practice

301. The internationally accepted framework for the development of a radioactive waste disposal facility is a step by step approach that, through all stages of the project, is supported by iterative evaluations of the design and management options, system performance and overall safety. The step by step approach, first used for reactor licensing and more recently applied to deep geological disposal projects [25, 26], has come to be accepted as best practice for most nuclear projects. The step by step approach aims to enhance the quality of the technical programme and technical decision-making by providing a framework in which confidence in feasibility and safety is progressively developed as the project moves forward. The framework needs to allow sufficient time and opportunities for the collection and interpretation of the relevant scientific and technical data, the development of designs and operational plans, and the development of a safety case that gives reasonable assurance of transport, operational and post-closure safety.

302. The step by step approach also allows opportunities for independent technical reviews, and political, public and other stakeholder involvement. Important steps in the development of a near surface repository might be:

— Identification, characterization and prioritization of sources and other waste;

— Conceptual design of the disposal facility;

— Identification of an appropriate disposal site;

— Characterization of the site environment;

— Site-specific design of the disposal facility;

— Conditioning and packaging of sources for disposal;

— Operation (including facility construction, waste emplacement and backfilling);

— Closure of the disposal facility as a whole;

— Post closure institutional control.

303. At all steps the Applicant should aim to update the various safety assessments so as to provide confidence that all subsequent steps can be carried out safely. An Applicant seeking approval for a specific step (site approval, for instance) should provide sufficient information about the future steps to give reasonable assurance that the facility as a whole is capable of being safely constructed, operated and closed. This is achieved through progressive development of the safety case, as explained in paras 312 and following.

Observations

304. With regard to the step by step approach, it is noted that the Licence Application submitted by the Applicant (DEST) covers siting, design, construction and operation. Each of these would generally be considered as an individual licensing step. Whilst there may be legal and financial reasons to prefer an approach requesting licensing authorization for all the steps together, safety considerations need to be given pre-eminence. The importance of this approach to safety has been recognized in developments regarding geological disposal facilities, but its utility is increasingly seen for any type of disposal facility. The regulatory authority needs to develop sufficient confidence that the site will provide the attributes necessary for safety and that sufficient assessment and supporting evidence have been undertaken. Design options need to be considered and a demonstration made that safety has been optimized in the section of the preferred option. Aspects of construction important to realising and preserving the features important to safety need to be identified and subject to regulatory authorization and finally the operational programmes that will ensure and assure safety need to be established and put into place.

305. Paraphrasing the draft safety standards on geological disposal [26], such an approach is needed

— to ensure the quality of the technical programme and associated decision-making;

— to provide a framework in which confidence in technical feasibility and safety can be progressively developed through iterative design and safety studies as the project progresses;

— to provide opportunities for independent technical reviews, regulatory reviews, and political and public involvement.

306. The Licence Application is the culmination of more than 10 years' work to identify a suitable site for disposal of Australia's low- and short-lived-intermediate-level radioactive wastes. Beginning with eight large arid regions located throughout Australia, thirteen site selection criteria listed in the NHMRC Code of Practice [1] were used to arrive at the shortlist of three sites described in the EIS [5]. These three sites were reduced to two by the Minister for the Environment and Heritage and the site finally chosen, Site 40a, 20 km east of Woomera, was decided upon by the Minister for Science in May 2003.

307. With regard to other steps in the repository development programme, the ARPANSA Regulatory Principles document [21] does not explicitly require a step by step approach. However, para. 4.5 states that:

> *To facilitate reference to two important versions of the SAR [Safety Assessment Report], the term 'preliminary SAR' (PSAR) is used for the version of the SAR that is first submitted to ARPANSA with an application for a licence to construct a facility. The term 'final SAR' (FSAR) is used for the updated version of the SAR that is submitted to ARPANSA with an application for a licence to operate a facility. 'PSAR' and 'FSAR' are thus progressive versions of the one SAR. The SAR is a living document that is updated as appropriate throughout the life of the facility (including the decommissioning stage) to reflect its current state.*

This two-step approach is very much in keeping with existing practice for the licensing of nuclear reactors, an area that has, in the past, been the main focus of ARPANSA's activities and an area that reflects ARPANSA's main area of expertise. The wording does, nonetheless, highlight the importance of a step by step approach necessary for licensing of the disposal facility.

308. In the event, the Applicant's submission to the Regulatory Body is for approval to "site, construct and operate the repository" and, indeed, because of the nature of the operations, the application should be construed as including closure also. Amalgamating the various steps in this way is, the Applicant

argues, necessary because the periodic operation of the facility makes it difficult to separate one activity from another as there will be concurrent construction and operational activities and possibly design activities.

Conclusions

309. Good Practice: with respect to the process of site selection, the IRT was impressed by the work that had been carried out to identify, through three phases, a shortlist of three sites from eight large arid regions located throughout Australia. The transparency of the process and the arrangements for consultation with the public and other interested parties are in accord with international best practice.

310. Good Practice: the EIS is clearly written and presented and represents a significant milestone in the repository development project. The IRT considers that the EIS demonstrates that there are good prospects that the envisaged disposal system will be capable of meeting internationally endorsed safety objectives and criteria, and that there is a 'net benefit' to be gained from the disposal of radioactive waste at the proposed site.

311. Recommendation: the application for siting, design, construction and operation of the facility in a single step overlooks the step by step approach that is now considered to be international best practice. A single step approach precludes the iteration considered to be necessary to achieve, demonstrate and develop confidence in the safety of the facility. It is recommended that alternatives be explored to take the licensing process forward in a more step by step manner.

SAFETY CASE DEVELOPMENT AND DOCUMENTATION

International best practice

312. An important component of a repository development programme is the safety case, described as "the collection of arguments and evidence that describe, quantify and substantiate the safety, and the level of confidence in safety, of a radioactive waste disposal facility" [27]. The safety case will contain a post-closure safety assessment together with supporting information and reasoning on the robustness and reliability of the safety assessment and the underlying assumptions. The safety case is an essential input to all the

important decisions and authorizations that concern the facility. Coherency and consistency are aided if the safety case contains a high level synthesis that presents, amongst other things, a description of the engineered and natural barriers and their safety functions, (perhaps in relation to the various radionuclides in the waste). This document should then reference the more detailed information contained in the various safety assessments. Consensus on the nature of safety cases for radioactive waste disposal facilities, in terms of scope, structure and content is evolving and useful guidance can be found in the working papers of the ASAM project and in the draft document of the NEA "The Nature and Purpose of the Post-Closure Safety Case in Geological Disposal" [28].

313. The expectation is that a safety case will be progressively refined as a repository project proceeds, making it a living document i.e. one that develops alongside the repository project itself. The construction of a coherent and persuasive safety case is primarily the responsibility of the Applicant. Some of the information in the safety case, specifically, that which is concerned with the design and the future safety of the facility, will need to be preserved for the benefit of future generations. This information should be defined, compiled and placed in suitable storage (e.g. a national archive).

314. The safety case should describe the design of the disposal facility, its location and how the waste is to be transported there, how the facility is to be operated and, finally, how it is to be closed and managed during any period of post-closure institutional control. To this end, the safety case will need to make use of information about the inventory, the design of equipment, the facility design, the geology of the site, its future evolution, and more. The volume of information and the degree of uncertainty associated with it will change as the repository development programme moves forward but, overall, the safety case should be sufficiently detailed and comprehensive to provide the necessary technical input to inform the decisions needed at each step and provide enough justification and traceability to allow independent review. The safety case should also identify key areas of uncertainty i.e. those most in need of additional information, as the repository programme is developed. In sum, the safety case may be seen as an 'information platform' that facilitates decision making at the technical, regulatory, societal and political levels.

315. In addressing post-closure safety, the safety case and its supporting assessment should consider both the normal (or expected) evolution of the facility over time, less likely alternative evolutions, and the potential impacts of relevant natural disruptive events, such as floods or earthquakes. The safety

case should also consider the impact of possible future human activities (human intrusion), which could give rise to additional exposures or change the normal evolution of the facility or its vulnerability to disruptive events. Where a safety case takes credit for active controls exercised during the post-closure period (as is the case with the Licence Application), these controls and the period of time for which they are assumed to be effective need to be specified as conditions of the relevant licence or authorization [14].

316. A safety case needs to be 'written to be understood' by the audiences to whom it is addressed. A crucial issue here is clarity. Beyond this, the safety case should be sufficiently detailed and comprehensive to provide the necessary technical input to inform whatever decisions are needed, and be of sufficient quality to allow independent review and assessment by the Regulatory Body.

317. In considering a safety case submitted by an Applicant, the Regulatory Body needs to be able to judge (in the context of the stage that the facility development programme has reached)

— whether the safety case contains sufficient detail (to allow independent review, for example);

— whether the data and information presented are sufficiently accurate;

— whether the safety case demonstrates that the design has been optimized and that, with reasonable assurance, the safety objectives and criteria will be met;

— whether the quality management system is adequate;

— whether the arrangements proposed for the preservation of records are adequate;

— whether unresolved issues have been adequately identified.

318. The amount of detail necessary to provide the appropriate level of confidence will increase as the project moves through successive steps. The documentation provided in support of an application for a licence to construct and operate a repository, for instance, should contain certain key components:

— a complete and fully detailed set of the construction and operational procedures;

— the disposal plan (i.e. schedule);

— the radiological protection plan;

— the waste acceptance plan (including the waste acceptance criteria);

— the surveillance and monitoring plan;

— the post-closure plan i.e. the arrangements for institutional control.

319. Where procedures are not to be submitted for regulatory approval, this should be justified and agreed (if possible) in advance by the Regulatory Body.

Observations

320. In the context of DEST's Licence Application, the safety case may be considered to be made up of the various documents that have been submitted. However, the IRT found it difficult to identify a single high level document that provided a synthesis or 'route map' of the safety case i.e. one that explains the contributions of the various components of the safety case and integrates them into the overall argument. Appendix H of the Supplementary Information for ARPANSA [11] had been developed to provide a linkage between the various documents submitted in the Licence Application. This is a document based on NUREG 1199 [29], a document of the US Nuclear Regulatory Commission that serves as a checklist of issues that must be addressed in such licensing applications. While Appendix H is not itself a synthesis of the safety case, it does provide some helpful summaries and useful cross-references to the various sections of the EIS and the Licence Application to explain where the relevant information can be found. Appendix H also usefully directs the reader to Section 6 of [11], where a high level description of the engineered and natural barriers and their safety functions can be found.

321. If Appendix H is taken to be definitive, then the information supplied there does much to resolve many of the inconsistencies that occur elsewhere in the documentation — especially between the EIS and Volume III of the later Licence Application [10]. However, a few of the cross-references are incorrect, many are imprecise, and some seem not to fully substantiate the statements

made in Appendix H. Three examples will be provided here. First, with respect to mineral resources, in Section 2.12 (para. 2) of Appendix H it is stated that:

> *There are no natural resources at the site of the repository with economic values, which if exploited at some future date, would affect the operation[1] of the repository.*

322. For further information the reader is directed to the EIS Main Report [5] Section 10.4, which is concerned with Land Use and Demographics. This section contains no discussion of mineral resources other than noting (Section 10.4.1) that there are mining centres to the north (Andamooka and Olympic Dam) and south (Mount Gunson). Mining resources are briefly discussed in Section 10.6.5 where it is stated that:

> *The region is recognized as an area with high potential for mining activity*

and, a little later, that:

> *making predictions about future land use and activity [is] very difficult*

which do not support the statement quoted in §321 that "there are no natural resources…".

323. Second, under the heading of Geotechnical Characteristics – Field and Laboratory Testing and Engineering Properties (Section 2.10.1 para. 1), Appendix H reports the tests designed to characterize the soils that would be used to cap the trenches. Some of these soils were taken from Site 40a (from the boreholes in fact) and the reader is referred to the EIS Appendix C4 [6] that does, indeed, contain the relevant information. However, it also concludes that:

> *Additional sampling and analysis would be required to confirm the distribution and geotechnical properties of the sandy clay material [found at site 40a].*

[1] It was assumed that 'operation' here means the future performance of the repository, not the operational phase.

If such unresolved issues are to be resolved, it is important for them to be identified and placed on the future project plan which is itself an important part of the safety case. Such a plan could not be found in the Applicant's documentation.

324. Thirdly, with respect to the cement backfill, Appendix H (final para. of Section 3.5.9) states that:

> *"Flowable" fill shall be used to encase the waste layer and be applied around all waste packages placed within boreholes and trenches. The reason for using "flowable" fill is to:*
>
> - *Provide a compacted material surrounding the waste packaging in order to limit the flow of moisture from upper layers to the underlying rock formations, and*
>
> - *Reduce the likelihood and severity of settlement of the engineered barriers due to a possible future failure of the original waste packaging (mild steel drums) by providing a layer that will not settle over time.*
>
> *The flowable fill is a weak concrete, consisting of a mixture of sand, cement and water, with a design strength of 8 MPa. The mixture shall be designed to be a free flowing liquid which is easily worked and which has self-compacting properties.*

325. For further information, the reader is directed to the Operations Manual (Section 5 of [9]). Contradicting Appendix H, this states the flowable fill as being composed of "a mixture of sand, cement fly ash and water". The quotation above points to the flowable fill having two safety functions. But the high level description of the engineered and natural barriers and their safety functions (Section 6 of the [11]) maintains that the backfill will also have the ability to "control the corrosion rate of waste canisters" and "act as a sorption matrix". More significantly, there appears to be no discussion of how the various safety functions and operational requirements (for strength, flowability and workability, for instance) of the flowable fill are to be achieved through its specification.

326. Design issues such as waste handling, soil properties, flowable fill properties and waste drum corrosion are issues in which confidence can be

developed through practical demonstrations. It would have been useful, for instance, to conduct on-site or near-site experiments in which simulated waste drums were monitored during exposure to relevant environmental conditions for a period of a perhaps a year or more. No such experiments appear to have been carried out or proposed.

327. Regarding the synthesis of the safety arguments, this should aim to (i) draw upon the three safety assessment areas (transport, operational and post-closure) to describe the safety functions required of the various engineered and natural barriers and (ii), by reference to limits, controls and conditions (including waste acceptance criteria) and supporting procedures, to show how these functions are to be realized. Much of the information on safety functions is contained in Section 6 of [11], but without the necessary links to the safety assessments, the operational procedures and the limits, controls and conditions derived from them.

328. In the absence of a high level synthesis of the safety arguments, the IRT found that it was difficult to navigate a way through the Licence Application. This was especially the case for Parts II and III and the Supplementary Information for ARPANSA, all of which contained many separate reports and appendices, each with its own page numbering system.

Conclusions

329. Recommendation: the Applicant appears to have been late to recognize the value of a high-level, well-referenced synthesis document as a vehicle for controlling, developing, maintaining and presenting the safety case for the repository. Appendix H of the Supplementary Information for ARPANSA [11] goes part way towards realising such a document but more needs to be done to make it comprehensive and to provide accurate and relevant cross-referencing to the key components of the safety case. The IRT therefore recommends that the Applicant should improve the coherency, consistency and presentation of the safety case by developing such a document, which should show the hierarchical structure of the safety case, the underlying safety assessments and the limits, controls, conditions (e.g. waste acceptance criteria) and procedures necessary to deliver safety.

330. Suggestion: the IRT suggests that site-based experiments be conducted to demonstrate the feasibility of creating the necessary structures and repository barriers and to build confidence in their performance.

331. Suggestion: the IRT suggests that the Licence Application would be improved by a more systematic and transparent approach to organising the documents. In particular, the page numbering system should be improved so that readers can more easily find their way through the documents.

MANAGEMENT SYSTEMS

International best practice

332. The IAEA is currently developing a safety guide to the management systems required for the safety of radioactive waste disposal facilities [30]. This draws on the international standard set by ISO 9001:2000 [31] and states that:

> *Quality management is a term used to describe the process of ensuring that an organization achieves its stated goals efficiently and effectively. Two important components of quality management are Quality Assurance (QA) and Quality Control (QC). QA is an interdisciplinary management tool that provides a means for ensuring that all work is adequately planned, correctly performed and assessed whilst QC is a means of ensuring, usually by measurement during an inspection and/or test, that a product or service meets the required specification.*

333. Quality management systems are applicable to any organization but, in the context of radioactive waste management, they apply most acutely to the Licence Holder or would-be Licence Holder (i.e. the Applicant). Formal recognition of an organization's commitment to quality management is usually achieved by gaining accreditation to ISO 9001:2000 (or its national equivalent). Although accreditation is valuable, it is not essential to quality management, nor will it automatically lead to compliance with the relevant quality standards for radioactive waste disposal.

334. The first requirement for the establishment of a quality management system is the formal endorsement of such a system at the highest level of management of an organization together with a commitment to ensuring that the system is fully implemented throughout the organization. It follows that an organization's goals must be the focal point of its quality management system.

335. With clearly stated goals, a Quality Management System can be put in place to promote their achievement. This is often achieved by breaking down the goals in a hierarchical way - into "activities" and "tasks" for instance — and structuring the organization to reflect this breakdown. This means that organizational structure and job descriptions form part of the quality management system. How the goals/activities/tasks are to be performed and by whom is documented in policies, procedures, work instructions, quality plans and so on. By ensuring that compliance with the relevant safety requirements and criteria forms part of the Applicant's goals/activities/tasks, a quality management system can contribute to delivering compliance and, through the associated documentation, provide evidence for this.

336. The quality management system should apply to all the work of an organization and extend beyond its doors to suppliers and contractors who should also be expected to work to agreed procedures. In this context, nationally and internationally recognized codes, regulations and standards provide practical, widely understood benchmarks and should be used whenever possible. In the case of an Applicant, the quality management system should extend to the waste producers who might have their waste packaging arrangements audited by the Applicant. In turn, the Regulatory Body should approve the Applicant's quality management system.

Observations

337. Volume II of the Licence Application [9] describes the repository management system. It is sub-divided into five parts:

(i) an Overview,

(ii) a Management and Quality Manual;

(iii) Safety Management Manual;

(iv) an Environmental Management and Monitoring Manual;

(v) an Operations Manual.

338. Section 2.1 of the Overview makes it clear that "the owner of the repository, the Department of Education, Science and Training (DEST) must design and implement a management system that is compliant with AS 9001:2000 Quality Management Systems — Requirements". Accordingly, the

contractors used in the preparation of the Licence Application are accredited to ISO 9001:2000 [31].

339. In Section 3.2 (“Scope”) of the Overview it is stated that:

— *The management system applies to all activities associated with the repository with the exclusion of:*

— *waste generation;*

— *waste identification and checking against waste acceptance criteria;*

— *waste packaging;*

— *waste conditioning;*

— *labelling of waste.*

> *These activities, while being the responsibility of other parties, are not covered by the management system. However, the processes involved in preparing waste for acceptance by the repository will be audited in accordance with the Audit procedures contained in the management system.*

340. The “other parties” mentioned here are primarily the waste owners that could number more than 100 organizations. The location of the audit procedures is not specified in the Overview but can be found in the Appendix to the Management and Quality Manual in [9]. The audit procedures there are of a general nature i.e. they are not specific to the pre-receipt activities. This Appendix also makes it clear that some management and quality procedures, including Maintenance of a Waste Inventory, have yet to be written.

341. Application of the Management System to the design of a disposal facility is important if the design is to be developed in a controlled and systematic way. According to Section 2.9 of the Management and Quality Manual [9], “planning for the design and operation of the facility is described in the Operations Manual” (also to be found in [9]). However, the section of this document that deals with the design of the disposal system (Section 9) reads more like a specification than a management system document in that it focuses more on *what* is to be designed rather than how it is to be designed. There is, for example, no discussion of *how* the management system has been

applied to the creation of the repository design, nor how future changes to the design are to be managed. In a similar vein, there appears to be no mention of arrangements for the checking of results through independent peer review.

342. An important element of the strategy for waste receipt is transfer of ownership to DEST. As outlined in Section 8 of the Operations Manual [9], this will occur once the waste has been accepted and loaded for transport to the repository by the transport contractor. Once the waste has reached the repository it will be unloaded and checked for integrity and compliance with the Waste Acceptance Criteria as specified in the Waste Acceptance Plan (WAP). The WAP (Section 2 of [10]) specifies three levels of at-repository waste inspection. The most intensive level includes intrusive sampling and analysis i.e. sampling and assay of the drum contents. The WAP does not say where these activities would be carried out, nor do inspection facilities appear in the repository conceptual design.

343. If waste packages are found to be non-conforming, ownership of the waste reverts to the previous waste owner — a condition to be specified in the contracts between DEST and the waste owners. The non-conforming waste will either be collected by the (previous) waste owner or alternatively the repository operator may treat the waste to make it conform at the expense of the (previous) waste owner. Again, the Licence Application gives no indication of where, and under what conditions, such treatment would be carried out.

344. The IRT was unable to locate any description relating to the archiving of information for the benefit of future generations.

Conclusions

345. Good Practice: the IRT notes that the Management System is clearly designed to be compliant with ISO 9001:2000 and this gives confidence that the activities covered by the Management System will be fit for purpose. In this respect the Management System accords with international best practice.

346. However, the documentation is difficult to navigate and, when the appropriate section is found, many of the procedures are present as drafts or missing entirely. In addition, two issues that might have been expected to be addressed, design control and independent peer review, appear to be absent. Recommendation: the IRT recommends that these omissions be rectified.

347. Recommendation: The exclusion of the pre-receipt activities from the

Management System will increase the difficulty of ensuring that waste packages conform to the waste acceptance criteria and considerable reliance will need to be placed on the auditing of the pre-receipt activities, the at-repository inspection and, in the final resort, on the contract between the Applicant and the waste owner. Such reliance on contractual terms may give rise to logistical difficulties and produce litigation. In these respects the IRT recommends that the Applicant should prepare more detailed descriptions of (i) how pre-receipt activities are to be audited and (ii) post-receipt inspections, including a description of the location and nature of the inspection facility.

348. Recommendation: The IRT recommends that the Applicant should provide a description of the information that is to be archived for the benefit of future generations and explain how this is to be carried out.

4. POST-CLOSURE SAFETY ASSESSMENT

BACKGROUND

401. International best practice in safety assessment for near surface disposal is represented by the approaches and concepts presented in the ISAM programme [20]. The ISAM methodology represents a generalization and elaboration of extensive prior experience in safety assessment for near surface disposal facilities, as well as an international extension of national safety assessment methodologies developed in the 1980s to 1990s [32]. The general framework of the ISAM methodology provides a systematic and structured development of the safety assessment, including the various components as shown in Fig. 9. The emphasis is on a clear elaboration of the analysis at each

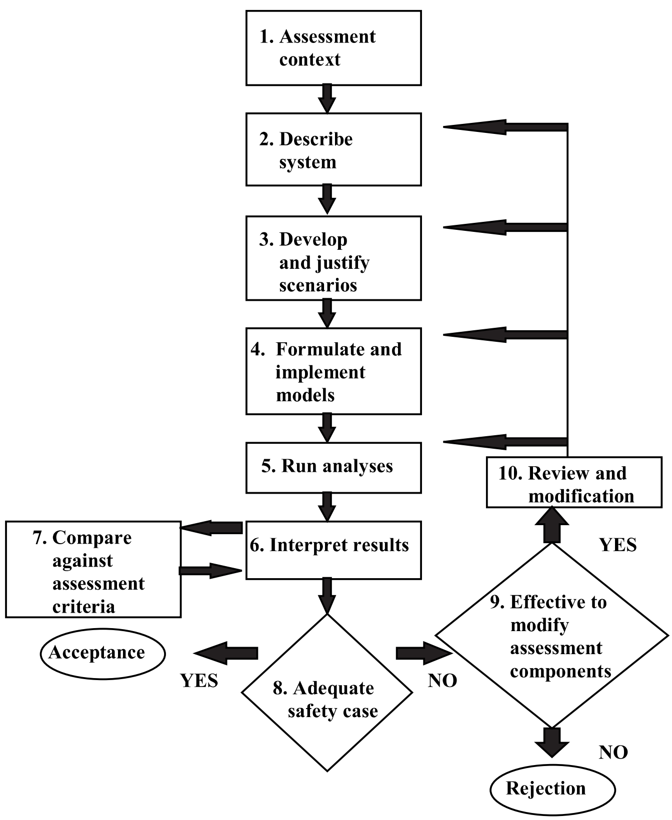

FIG. 9. The ISAM safety assessment methodology.

stage, which allows focus and clarity in subsequent stages. It also allows for a natural sequence in the presentation of ideas. Finally, the methodology recognizes the importance of a progressively increasing knowledge base (influenced, for example, by external reviews, independent evaluations, and parallel investigations) by explicitly acknowledging the iterative nature of safety assessment. That is, it is natural for the assessment to evolve from less complex to more complex, and from broad in scope to more detailed, as the work programme progresses. The ISAM methodology provides a 'model' approach, which countries can use as a basic point of reference.

402. During oral presentations, DEST stated that they were aware of the ISAM project, and the Licence Application refers to part of the ISAM documentation.[2] However, the DEST safety assessment, as a whole, follows a different structure. Nevertheless, the remainder of this section represents an examination of the DEST safety assessment in relationship to the key categories in the ISAM methodology.

ASSESSMENT CONTEXT

International best practice

403. The ISAM report [20] states that:

> *The safety assessment context is intended to clarify what is going to be assessed and why is it going to be assessed. In addressing the assessment context, information should be provided concerning the following key aspects that need to be considered at the start of the safety assessment: purpose; regulatory framework; assessment end-points; assessment philosophy; disposal system characteristics; and time frames. It should be noted that many components of the assessment context are inter-related, and that decisions relating to one component can influence other components. For example, the end-points assessed should be appropriate for the timeframes considered in the assessment.*

[2] This is not a criticism of the DEST analysis, but simply an observation.

404. International best practice in these areas is relatively complex to describe. The most important aspects for discussion here may be summarized as follows:

— For assessment endpoints, consider the radiation protection principles for waste management currently recommended by ICRP. Among these recommendations are the use of dose constraints for normal evolution and dose reference levels for human intrusion, and the recommendation not to include the probability of events dependent on human activities. This reflects difficulties experienced by some national programs in attempting such approaches [33, 34]. Where risk-based regulatory criteria are used, these are not applied to human intrusion [35, 36].

— For short to medium term time frames, a period of active institutional control may be relied upon to ensure that inadvertent human intrusion does not occur. The duration of the period is variable, and is dependent on many societal influences. Typical values in North America and Europe are 100–300 years.

— The assessment philosophy[3] can have a significant influence on the selection of scenarios, models and parameters used in the analysis.

Observations

405. Explicit dose constraints are not established by ARPANSA in a legally binding document. Instead, the NHMRC Code of Practice [1] is used to establish dose limits, and the Applicant is expected to propose appropriate constraints. DEST has approached this issue by proposing to use the international system of radiation protection for waste management recommended by ICRP [37]. In doing so, they have proposed multiple constraints. In the case of normal evolution, DEST proposes 10 percent of the annual public dose limit of 1mSv, as well as a 10^{-6} y^{-1} individual risk. In the case of inadvertent human intrusion, a dose value of 100 mSv y^{-1} and a risk value of 10^{-6} y^{-1} are applied.

[3] The assessment philosophy is an expression of the extent to which the assessment is designed to provide a "realistic" estimate of potential impacts for comparison with the assessment end-points, or whether more cautious, or pessimistic assumptions should be adopted for the purposes of demonstrating compliance with safety requirements.

406. ARPANSA has identified the importance of the Regulatory Assessment Principles in establishing dose constraints [21] and states that "Dose constraints for each source are chosen by the operating organization and agreed with ARPANSA, and must be no greater than the relevant dose limit."

407. Similarly, remaining elements of the assessment context have not been specified in regulations and need to be addressed. In particular, time frames associated with the evaluation have been proposed by the Applicant, who states in [10] that:

> *In undertaking numerical calculations, the focus is on the period until 10,000 years after closure. Where appropriate, discussion is provided of potential repository performance in later timeframes.*

408. As a practical matter, the post-closure risk assessment in [10] makes little distinction between doses in the 10 000 year time frame and those calculated to occur later. In the evaluation of effects from radon gas, a third time period (100 000 years) is introduced.

409. The Licence Application also states that "an institutional control period of 200 years will be adopted to ensure ongoing public safety and environmental protection" (Section 4.5 of [10]). During oral presentations to the IRT, it was not clear whether the 200-year institutional control was intended to represent an actual operating limit (i.e. an intention to release the site at the end of institutional control), or whether it is simply an assumption made for the purposes of safety assessment (i.e., the maximum time for which credit can be given for institutional control). Nor could the IRT resolve this by reference to the text of the Licence Application.

410. The Applicant has applied probabilities of occurrence to scenarios, so that the risk is calculated as the product of a calculated dose times the ICRP-recommended dose-to-risk conversion, times the probability of occurrence of the scenario. A number of the scenarios are conservatively assumed by the Applicant to occur with a probability of unity, whereas for other scenarios a small probability of occurrence is applied, intending to reflect the remoteness of the site. Scenario probabilities are applied to all of the scenarios for inadvertent human intrusion.

411. The safety assessment philosophy is unclear. In oral presentations to the IRT, one of the Applicant's contractors indicated that the overall analyses were intended to represent a conservative bound to the potential doses that

might occur at the site. Using this approach, it was argued that statements associated with safety of the site relative to dose constraints are very robust.

Conclusions

412. Good Practice: the choice of 200 years active institutional control is within the range of values commonly used in North America and Europe (100–300 years). Given Australia's history and culture, it seems to be an adequately conservative estimate of the amount of time during which institutional control may be relied upon to inhibit potential inadvertent human intrusion. The use of this value is therefore consistent with international best practice.

413. Recommendation: the IRT recommends further dialogue between the Applicant and the Regulatory Body to agree upon the radiological protection limits, constraints and levels to be applied to normal evolution and human intrusion situations for the post-closure period. The IRT suggests that the most recent recommendations of the International Commission on Radiological Protection on radioactive waste management should be used as a basis for establishing of these criteria.

414. Recommendation: application of probabilities to human intrusion scenarios is not in line with current recommendations of the ICRP, which has explicitly developed its recommendations to avoid such approaches. The IRT recommends that consideration be given to using the approach developed in ICRP 81 in consideration of human intrusion.

415. Suggestion: the IRT suggests that additional clarity is needed in the applied time frame for the long term. It is currently unclear whether the 10 000 year limit is used as a cut-off for evaluations, and if waste acceptance criteria are developed based on dose or risk projections at longer times.

416. Suggestion: the IRT suggests that the Applicant should produce a clear statement of the assessment philosophy (as elaborated in the IAEA ISAM Project) that has been adopted. It should describe how this has influenced the selection of scenarios, models, and parameter values and the extent to which it has biased the model results toward conservatism.

SYSTEM DESCRIPTION – ENGINEERED BARRIERS

International best practice

417. According to the IAEA near surface requirements, (para. 7.1) [14]

> *The repository shall be designed to provide adequate isolation of disposed waste for the required period of time, with account taken of the waste characteristics, the characteristics of the site and the safety requirements applicable to the repository.*

418. International best practice, as expressed in existing and draft IAEA documents, recognizes that the development of a radioactive waste disposal facility is an integrated and long-term process. To achieve the required level of safety, decisions made at every step of the development need to take due account of all the following steps and activities. Licensing of the site can be based on a conceptual design, which allows various alternatives to be assessed. But before approving construction and/or operation of a facility, most regulatory regimes require detailed plans to have been prepared. The conceptual design stage may be followed by other design stages, e.g. a Reference (sometimes called a Basic) Design, then a Detailed Design, and finally an "as Built" Design. The Reference Design will be based on firm decisions about the system components, and the ways in which they contribute to the safety of the facility.

419. In near surface disposal systems, a number of engineered barriers will be employed. As expressed in the Safety Requirements document [14], (para. 7.3):

> *Near surface disposal facilities may include engineered barriers, which, together with emplacement medium and its surroundings, isolate the waste from humans and the environment. The engineered barriers include the waste package and other human made features such as vaults, covers, linings, grouts and backfills, which are intended to prevent or delay radionuclide migration from the repository to the surroundings;*

and, (Paragraph 12.2),

> *The elements of the quality assurance programme shall take account of the potential effects of activities, structures, systems and components on the safety of the repository and shall be designed accordingly. Activities,*

structures, systems and components important to safe operation and disposal shall be identified on the basis of results of a systematic safety assessment of the operational and post closure phases of the repository.

420. To achieve the latter requirement, the components of the disposal system and human activities during construction and operation need to be categorized into safety-related and non-safety-related classes (further sub-classes may also be helpful). This will allow, for instance, appropriate quality standards to be applied. Such categorization is essential to the design basis and will be documented as part of the Reference Design. Usually, control standards appropriate to good industrial and construction practice are applied to non-safety related components and activities. But for safety-related components and practices higher standards will usually apply. In deriving the design basis, consideration will need to be given to any safety timescales imposed by the Regulatory Body, the longevity of the radioactivity in the waste, required and credible containment periods, the occurrence and likely magnitude of disruptive events, etc.

Observations

421. The Licence Application is based on the conceptual design of the National Radioactive Waste Repository (NRWR) described in the EIS Main Report [5] with further details in the Disposal Structure Design Concepts Report [10]. The NRWR is a trench and borehole type disposal facility located inside a large buffer/protective zone. The site area is 1.5×1.5 km^2, containing a 150×150 m^2 disposal area in the middle. The site dimensions have been chosen appropriately. A large buffer zone and a large controlled area will allow extension of the facility or, should more detailed considerations of the design and construction so indicate, a less dense placement of the waste.

422. Trenches will be 12 m deep and the waste packages will be stacked so that there will be at least 5 m between the top of the waste and the ground surface. This solution allows emplacement of waste drums in 8–9 layers. The size of the trenches will vary depending on the waste quantities to be disposed of in each campaign. Individual campaigns are likely to occur every 2–5 years and will include construction of the necessary disposal structures (trench and/or borehole), waste disposal operations, and closure of the filled up trench or borehole. The minimum trench area, set by technical and economic factors, is 12×12 m^2 at the base of the trench. Where the waste arisings are too small to

make trench construction economic, 2 m diameter boreholes, drilled to a depth of 20 m could be used. In this way a single borehole could be sufficient to dispose of Australia's annual radioactive waste production. The borehole conceptual design includes concrete rings to line the walls.

423. The trenches are covered with a cap that has a multi-layer design consisting of soil, clay and a high density polyethylene membrane; this will be used to close the disposal unit. The thickness of the cap is 5 m with a slightly elevated centre that allows surface water to be directed to an evaporation pond via surface drains. Site preparation will include levelling, fencing and construction of separate surface drainage systems for the controlled and non-controlled areas. Temporary internal drainage of the trenches during waste campaigns (i.e. before capping) is foreseen but not yet designed (consideration could be given to temporary coverage during operations).

424. The present conceptual design contains a range of options for the required multi barrier approach, stating that the final detailed design will be produced by the contractor/operator responsible for construction, operation and closure of each campaign. As outlined in Section 6 of [11], for the trench design the principal barriers are:

First Barrier

— the 205-litre steel drum

— the concrete waste form

Second Barrier

— surface drainage

— engineered cover

— backfill between the waste packages

— the clay layer at the base of the trench

Third Barrier

— the natural geological conditions

The first and second barriers constitute the engineered barriers but the above may not be a complete list because elsewhere (e.g. Table 2 of the Disposal Structure Design Concepts Report [10]), the security fence and trench wall linings are also cited as engineered barriers. In any event, even for those engineered barriers that have been unambiguously identified, the design basis (e.g. performance requirements) has yet to be specified and the performance of the barriers has yet to be demonstrated.

Conclusions

425. Recommendation: as part of the safety case and in relation to the defence-in-depth principle, the IRT recommends that the Applicant should clearly identify the safety functions of the various components of the repository design (including both the engineered and natural barriers), and provide confidence, by demonstrations or otherwise, that each component will perform effectively.

SYSTEM DESCRIPTION – NATURAL BARRIERS

International best practice

426. Reference [18] suggests that four stages can be considered for the siting of a near surface disposal facility:

— Conceptual and planning stage

— Area survey stage

— Site characterization stage

— Site confirmation stage

427. During the conceptual and planning stage, potentially important factors are identified, potential host rock(s) and possible siting area(s) are identified, and investigation objectives and identification programmes are defined. In the area survey stage, a broad region is examined to identify one or more potential sites for further investigations. These sites are studied during the site characterization stage to identify the preferred site for confirmation. Finally, during the site confirmation stage, the preferred site should be characterized through detailed subsurface studies to determine acceptability from the safety point of view.

428. The site characterization stage requires site-specific information to establish the characteristics and the range of parameters with respect to the location of the intended disposal facility. This will require site reconnaissance and investigations to obtain evidence on actual geological, hydrological and environmental conditions on the site. This involves on-site surface and subsurface geological investigations supplemented by laboratory work.

429. The purpose of the site confirmation stage is to conduct detailed investigation at the preferred site to:

— Support or confirm the selection of the preferred site,

— Provide additional site-specific information required for detailed design, safety analysis, environmental impact assessment and for licensing.

430. Finally, Ref. [18] gives guidelines on the expected data necessary to characterize the site from the point of view of geology, hydrogeology, geochemistry, tectonics and seismicity, as well as surface processes and meteorology.

431. Reference [17] indicates that a conceptual model must be developed in order to provide a framework that will permit judgments to be made about the behaviour of the total disposal system.

432. The development of this conceptual model should include characterization of the disposal site with respect to (amongst others) geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, ecology and distribution of local populations and their social and economic practices. This information is needed to define pathways and receptors and thus to develop conceptual physical, chemical and biological models of the site.

Observations

433. Meteorology assessments indicate that the site is located in an arid area (Section 8.6.1 of [5]). The mean annual rainfall is less than 0.2 m at Woomera while the mean annual evaporation is more than three metres. Rainfall is irregular and heavy rainfall events can occur in any month. The annual mean wind speed is 17.9 km/h.

434. According to CSIRO (Section 8.6.2 of [5]), an increase in surface temperatures of around 4°C is predicted by the end of the century along with a small increase in rainfall. An increased frequency of more intense rainfall events is also predicted.

435. The geomorphology of the site is described in the EIS main report (Section 8.2 of [5]) with a summary in Section 3.1.2.1 of [11]. Site 40a is the highest in elevation (189m) of the three sites, with a maximum relief of 4m over the 0.5 km inner square. This site has the greatest relief of the three sites. Significant features with respect to waste management are the drainage features, which may result in some surface flow being directed toward the nominated storage area. The geomorphological description contains no description of the evolution of the site to the present day. An erosion rate of 0.17 mm per year is indicated; this figure is derived from estimates for the region. The extent to which this is influenced by extreme rainfall events is unclear.

436. A description of the site geology is provided in Chapter 8 of the EIS Main Report [5] and in Section 8, Appendix B of Volume III of the Licence Application [10]. A “generalized geology”, i.e. a detailed description of all the geological units found at the three sites (as collected from on-site borehole data), is provided in EIS Appendix C5 [6]. Stratigraphic sections across the site are reported in Appendix C1 [6]. A table showing the depth of the various geological units in the eight inner boreholes at Site 40a is provided in Appendix B of the Disposal Structure Design Concepts Report in Volume III of the Licence Application [10]. Finally, a brief description of the site is also given in the Safety Analysis Report, again in Volume III of the Licence Application [10].

437. Overall, the documents do provide an adequate description of the geology of the site and its context with respect to the surrounding region. However, as indicated by the previous paragraph, the information is difficult to find, being spread among a number of documents. The presentation would also have been much improved by additional illustrations, particularly the addition of geological maps and cross-sections at different scales.

438. Characterization of the site was stopped at the edge of the disposal zone (i.e. at the inner security fence), no boreholes having been drilled within the disposal zone. Observations from additional boreholes or pits in the disposal zone would have allowed the interpolations made between the outer boreholes to be confirmed. The use of additional characterization techniques, especially X-ray diffraction, on a few borehole samples would also have

increased confidence in the site characterization by, for instance, determining the type of clay on site and establishing the nature of the alteration of the quartzite unit. The mineralogy and physico-chemical properties (types of clay mineral, chemistry, exchange capacities, sorption properties etc) of the different formations on the selected site need to be determined and included in the application documents.

439. Appendix C5 of the EIS [6] indicates the presence of minor brittle fractures perpendicular to the bedding in the quartzite at Site 40a. With the results obtained to date, it is difficult to eliminate the possibility of connected fractures at the site, which could have a potential influence on radionuclide transport under wetter climate conditions. A description and a mapping of the faults and fractures at the site, designed to allow their potential influence on groundwater movement to be evaluated, would enable their effect may be incorporated into safety assessments.

440. The hydrogeological characterization of the site is presented at scales ranging from the regional to that of the inner fence. As with the geological information, this is spread over a number of documents. Good descriptions of the regional, sub-regional and site hydrogeology are provided in the EIS Main Report, Section 8.5 [5]. With the exception of chloride levels, however, the documents contain relatively little information on groundwater chemistry. Regarding the site hydrogeology, Section 8.5.2 of the EIS Main Report [5] indicates that "slug tests" were used to evaluate the hydraulic conductivities of the different sites. However the same section indicates that "slug tests typically underestimate hydraulic conductivity, and results should be considered indicative only". This suggests that additional hydraulic conductivity determinations should be considered. It would also be useful to extend the hydrogeological characterization into the disposal zone.

441. Solute and water transport in the unsaturated zone below the repository has been assessed using the Chemflo Model (Appendix C5 in [6]) applied to Site 52a. The calculations include both averaged yearly rainfall and storm events. The model assumes that rainwater percolates quickly through the waste to reach the repository base and then diffuses down through the clay base and the underlying geology. The calculations indicate that under averaged rainfall conditions no water reaches the water table. The storm calculation shows that water reaches no further than 1 m into the underlying geology. But this calculation appears to assume that the clay layer at the base of the trench retains a low hydraulic conductivity (i.e. that it does not crack), that water cannot escape from the trench by flowing out via the (possibly unlined) trench

wall, and that there are no connected fractures in the underlying geology — any of which circumstances could invalidate the calculation. Furthermore, it would have been helpful to include fuller descriptions and justifications for the sorptive properties (i.e. diffusion coefficients) for the different units. Similarly, for the magnitude of the storm event.

442. Concerning seismicity, Ref. [10] indicates that major faults are located 80–100 km west of the site and that no earthquakes of magnitude (ML) 6 or greater have been recorded within the Adelaide geosyncline. Volume III of the Licence Application (Section 5.4.4 of [10]) states that “activity in the area of site 40a ranges from ML 1 to 2” and Appendix C concludes that:

> *Given the relatively stiff soil profile and seismicity of the region, the repository could be satisfactorily designed in accordance with AS1170.4 to meet any stringent “serviceability limit state” (safety, limited non structural damage and continued performance of the facility during and after an earthquake) and also the “ultimate limit state” (no collapse nor loss of life during the maximum probable earthquake).*

443. But the “design earthquake” considered by AS1170.4 (The Standards Association of Australia, AS1170.4 “Minimum Design Loads on Structures, Part 4 Earthquake Loads”) is one that has a 90% probability of not being exceeded in a 50 year period. Given the 200 year institutional control period, a longer time frame could be appropriate. Furthermore, for the post-closure period, one might expect an even larger earthquake – perhaps one closer to the highest recorded within the geological region – to be considered and to have been submitted as part of the Licence Application. In such an assessment, consideration would be given the influence of such an event on the fractures located on the site as well as on the groundwater direction(s) (described as SW to NE) and the position of the discharge point(s).

444. The biological environment of the site is described in the EIS main report [5], with further detail in EIS Appendix D [6]. Good descriptions are provided of the flora and fauna at both regional and local scale and the assessment of the impact of the construction and operation of the disposal facility on the flora and fauna is well done. Little consideration is given, however, to radioactivity transfer through biological chains. It is also worth noting that the assessment of the impact of burrowing animals on post-closure safety seems to assume the continued existence (and therefore maintenance) of an animal-proof fence beyond the 200 year institutional control period (see Disposal Structure Design Concepts report in [10]).

Conclusions

445. Good Practice: the IRT notes that the Applicant has adequately characterized the site at both the regional and the local scale and that this aspect is in line with international best practice.

446. Recommendation: at the same time the regional to local scale correlation is not well described in the documentation and the IRT recommends that this should be given more prominence to better support the safety case.

447. Recommendation: the IRT recommends that the disposal zone (within the inner fence) should be characterized (borehole and/or pits) to confirm the geological, hydrogeological and geochemical characteristics of the disposal zone.

448. Recommendation: the IRT recommends further study of the faults and fractures on the site (as already requested by Environment Australia) to evaluate their potential influence on groundwater movement and allow, if necessary, their effect to be incorporated into safety assessments.

449. Suggestion: the IRT suggests that the Applicant should conduct a more extensive study of the geomorphology of the site. This should aim to explain how the site has evolved to the present day so that its future evolution, as expressed in the safety case, can be fully justified.

SCENARIO DEVELOPMENT

International best practice

450. Formal scenario development procedures for radioactive waste disposal have been the subject of many studies over the past few decades, and they have been considered an integral part of near surface disposal facility safety assessments for nearly a decade. To this end, in 1996 IAEA began to develop an international FEPs (Features, Events, and Processes) list for use in near surface waste disposal assessments [38]. The IAEA has described a procedure for the use of the international FEPs list in the derivation of activity limits for near surface disposal facilities [39]. Similar approaches are being used in a number of countries for safety assessments of national or regional disposal facilities [e.g. 35, 36, 40], leading to a broadening consensus on the general applicability of both the approach and the FEPs list.

451. A primary use of the generic FEP list is in the safety assessment for near surface disposal facilities and in particular in the development and justification of scenarios. Two main applications can be defined:

— use of the FEP list in the scenario development process;

— use of the FEP list in the review and justification of scenarios, developed by using different approaches, such as expert judgment.

452. In both cases the FEP list can be a useful tool for gaining confidence in the scenario development process and in demonstrating that a comprehensive set of relevant FEPs has been considered.

453. Good scenario development procedures follow four steps: (1) identifying a comprehensive list of features, events, and processes, (2) screening the comprehensive list to a manageable number, (3) describing the relationships between the features, events, and processes, and (4) arranging them into useful sets, or scenarios, for the purposes of a quantitative safety assessment. These four steps are used both in developing and justifying scenarios. The key emphasis throughout is to ensure that the resulting scenarios are *defensible and traceable*.

Observations

454. In response to questions from the IRT about scenario development, the Applicant replied that the FEP screening procedure used for the earlier environmental restoration and waste disposal at Maralinga was considered to be appropriate for the NRWR and the process was, therefore, not repeated. Since that prior work is not part of the Licence Application, it could not be reviewed.

455. In the absence of this documentation, it is difficult to know whether all the scenarios that should have been included, actually have been included. This said, there are some surprising inclusions and possible omissions:

— some scenarios require excavation in excess of 5 meters deep, which seems very unlikely at this site;

— there is little consideration given to the potential effect of burrowing animals and insects, and deep-rooting plants on the safety of the facility.

Conclusions

456. Recommendation: the IRT recommends that scenarios should be developed based on a formal consideration of all site-specific features, events, and processes (FEPs) that could affect the disposal facility. Reasons should be given when FEPs are excluded from further consideration. The scenarios, which should be both traceable and justified, should consider all relevant exposure pathways and justify any exclusions. Appropriate attention should be given to both trenches and boreholes and their potential interactions.

MODEL DEVELOPMENT AND JUSTIFICATION

International best practice

457. The ISAM project [20] aimed to evaluate different approaches for formalising the process of conceptual model development and justification, and a number of approaches were identified that would provide (i) a suitably robust basis for the treatment of alternative conceptual models and (ii) an ability to produce a traceable safety assessment. These approaches are well developed in the radioactive waste management literature, and are considered to be international best practice.

458. The report of the ISAM project [20] notes that:

> *The development of models for safety assessment should be carried out in a formal and transparent way that facilitates independent review. It covers the following three main stages:*
>
> *1. The generation of conceptual models describing the disposal system behaviour using information from the system description and scenario generation steps of the safety assessment. A conceptual model should be made up of a description of: the basic FEPs; the relationship between these FEPs; and the scope of application in spatial and temporal terms. For the process of developing conceptual models it can be helpful to divide the system to be assessed into the near field, the geosphere, and the biosphere.*
>
> *2. The representation of conceptual models and their associated processes in mathematical models. This usually involves sets of coupled*

algebraic, differential and/or integral equations with appropriate initial and boundary conditions in a specified domain.

3. Application of mathematical models in computer tools to solve the mathematical models. Four main groups of codes can be identified, those for: the near field; geosphere; biosphere; and the total system.

459. The ISAM report also notes that:

....throughout this process, data are used to help develop the conceptual and mathematical models and provide input into the computer tools. The performance of safety assessment usually requires a significant amount of information and data related to the disposal system. The data are used throughout the safety assessment process, particularly in scenario development and justification, model formulation and implementation, and in the interpretation of the results.

460. Approaches are particularly crucial in the areas of:

— the sources of uncertainty in parameter values and methods for dealing with them in the safety assessment;

— the use of generic data in the absence of site specific data and the trade-off between the use of generic data and the requirement for the collection of further site data;

— the choice of methods used to select appropriate ranges for input parameters.

Observations

461. The models used in the post-closure safety assessment are very simple and, as explained in oral presentations to the IRT, are intended to bound the potential consequences. Radionuclide concentrations in media (e.g. soil) that lead to human radiation exposure are sometimes calculated using dilution factors that are intended to provide conservative approximations of the amount of dilution that would be produced through the use of a phenomenological model. However, some of the parameters used may not conservatively bound the possible range of values. For instance, the size of a

farm, used in calculating a number of dilution factors in many scenarios, is the mean area of "……most farms in the region....." (Section 8.4 of [10]) rather than a bounding value. Consequently, the selection of parameters has a mixed influence on the level of conservatism and, since numerous parameters are presented without substantiation, this leaves open the question of whether the models are conservative or not.

462. Exposure pathways included in the model for each scenario are listed, but there is no substantiation for the elimination of other pathways of potential importance.

463. Finally, there is no formal treatment of parameter uncertainty or sensitivity presented in the Licence Application. Uncertainties are argued to be bounded by the selection of parameters in a deterministic calculation but, as already noted, this may not be the case.

Conclusions

464. Recommendation: the IRT recommends that the Applicant should put greater emphasis on demonstrating that models and data used in safety assessment are both traceable and justified. All parameters need to be justified but special care is needed when simple but potentially non-conservative models (e.g. dilution factors) are used to approximate more complex behaviour.

465. Recommendation: the IRT recommends that a clear and consistent strategy should be applied to the selection of the level of conservatism used in the analysis. This strategy should be derived from the assessment philosophy established in the assessment context. The strategy may or may not include formal uncertainty and sensitivity analysis methods.

RESULTS AND CONFIDENCE BUILDING

International best practice

466. The ISAM report [20] describes a number of key points that represent international best practice with respect to evaluation and presentation of results, and on building confidence. The following are representative of these key points:

— Safety assessments should be structured in a way that provides maximum confidence in the decisions that are made relating to the radioactive waste disposal facility. Therefore confidence building is a process that needs to be followed through all steps of the safety assessment process.

— Formalized quality assurance (QA) procedures are essential for building confidence in safety assessments for near surface disposal facilities, particularly use of procedures based on international standards. Their use helps build confidence in the assessment and its associated results.

— A variety of communication methods are actively being used by various organizations involved in radioactive waste disposal. Development of a comprehensive safety case is an important mechanism for communicating the results of the safety assessment and the overall safety argument for the disposal facility to the regulatory authorities (often the audience of prime concern).

Observations

467. If, in developing the post-closure safety assessment, the Applicant and its contractors used formal approaches for:

— scenario development and justification;

— model formulation and justification;

— parameter selection and justification.

this was not evident in the Licence Application.

468. Details of the quality assurance programme used to manage the safety assessment were not evident to the IRT. The quality assurance programme described in [9] is focused mainly on operational aspects of the facility. In particular result, the extent to which the safety assessment was subjected to independent peer review prior to submission of the Licence Application is unclear.

Conclusions

469. The conclusions reached regarding scenario development (§456) and independent peer review (§346) also apply here. The IRT recommends that

scenarios should be developed based on a formal consideration of all site-specific features, events, and processes (FEPs) that could affect the disposal facility. Reasons should be given when FEPs are excluded from further consideration. The scenarios, which should be both traceable and justified, should consider all relevant exposure pathways and justify any exclusions. Appropriate attention should be given to both trenches and boreholes and their potential interactions. The IRT also recommend that independent peer review be undertaken on the safety assessment.

SURVEILLANCE AND MONITORING

International best practice

470. As defined by the IAEA [41]:

— Surveillance is periodic inspection and testing to verify that structures, systems and components continue to function or are in a state of readiness to perform their function.

— Monitoring is the measurement of dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive substances, and the interpretation of the results.

471. As expressed in Ref. [41], in relation to near surface disposal facilities, surveillance is taken to mean the periodic inspection and testing of disposal facility structures and of any systems and components on which the safety of the disposal facility depends. The design of the surveillance and monitoring programme should therefore be based on the assumptions, modelling and findings of the safety assessment. Such surveillance includes, by definition, monitoring of appropriate parameters both at and around the disposal facility. The results of both surveillance and monitoring can point to deficiencies in the disposal facility structures, systems and components that may need remedial action.

472. The general objectives of surveillance and monitoring programmes are to provide direct evidence of the measurable presence or non-detectability of radionuclides and radiation in the environment that could be attributable to the disposal facility [14]. The design of the programme will be closely linked to the findings of the safety assessment so that the results of the monitoring can be applied to confirming the assumptions made in the safety assessment. The

monitoring data obtained should form part of the information supporting demonstration of compliance with regulatory and legal requirements for the protection of human health and the environment. The monitoring data should also serve to indicate when investigation of an actual or potential inadequacy in the safety of the disposal facility is warranted during or after operations, and when remedial or protective actions may be needed [14].

473. There are three distinct phases associated with the lifetime of a near surface disposal facility: pre-operational, operational, and post-closure. There are different requirements on the surveillance and monitoring programme in each of the three phases. At each stage, the safety strategy is dependent on the proper functioning of the various safety features. The functions of these features therefore should form the basis for identifying which parameters to monitor, the frequency with which they should be monitored, and the required sensitivity of instrumentation.

474. Based on these comments, it is noted that international best practice should have three primary elements:

— The surveillance and monitoring plan should be linked to safety of the facility, so that plans to monitor specific parameters should be linked to the function of safety-related features of the repository;

— The surveillance and monitoring plan must have clear identification of detectability of radionuclides, and should have an action plan in case radionuclides are detected above a safety-related threshold;

— The surveillance and monitoring plan should allow for timely intervention if necessitated by failure of the safety functions of the facility.

Observations

475. An Environmental Monitoring and Management Manual is included in [9]. It contains a description of the management system for environmental monitoring and two plans: one for Environmental Management and Monitoring (EMMP), and another for Monitoring Implementation (MIP). Both plans contain elements of surveillance (as defined in §470) as well as monitoring. The EMMP contains a list of media to be monitored (including disposal structures, groundwater, soil, flora and fauna), but, for the most part, it does not explain why they need to be monitored. Meteorology is not included in the EMMP.

476. For each item to be monitored the EMMP provides a 'non-compliance and corrective action' section, which states, in general terms, how non-compliance is defined (e.g. "100% increase in radionuclides above the baseline" and "visual inspections¼will clearly identify signs of erosion") and what actions should be taken if non-compliance is discovered. Mostly, these actions focus on repeat measurements, further assessments and, if required, remedial works. The MIP describes the frequency of monitoring for baseline, construction-operation and surveillance (i.e. between disposal campaigns).

477. In both the EMMP and the MIP, decisions related to non-compliance and monitoring frequency appear to have been based largely on judgment, without direct consideration of the relationships between potential radionuclide transport behaviour, repository safety and the frequency of monitoring.

Conclusions

478. Recommendation: the IRT recommends that the Applicant should direct the monitoring plan towards supporting the safety of the facility by monitoring parameters relevant to the performance of all the repository barriers that are important to the safety of the repository. The dynamics of the repository system and the nature of the safety function should determine the frequency and the sensitivity of the monitoring measurements.

479. Recommendation: the IRT recommends that the Applicant should prepare a plan to identify the actions that would be taken if the monitoring programme were to produce an unexpected observation. This plan needs to be based on an understanding of the implications for safety if such observations occur.

480. Suggestion: the environmental monitoring plan deals with both the operational and post closure phases and proposes to monitor a wide range of environmental media, including fauna and flora. Because of the potential impact that infrequent but severe meteorological events could have on the site, which may be masked in the assessment by using average data, the IRT suggests that the plan should be extended to include site meteorological data.

5. OPERATIONAL SAFETY ASSESSMENT

INTERNATIONAL BEST PRACTICE

501. The operational phase of a near surface disposal facility is likely to include commissioning activities, waste reception, waste emplacement, backfilling, and site decommissioning and closure. In addition there may be a variety of engineering tasks including temporary storage or final conditioning of the waste. In some circumstances it may be appropriate to combine construction and operation as one activity. In any event construction cannot start until a licence has been granted, which according to the requirements for near surface disposal [14]

> *will usually mean after the detailed design has been approved, the necessary licensing procedures have been completed and an appropriate quality assurance programme has been established.*

502. Before granting a licence the Regulatory Body must review and assess all aspects of operational safety to satisfy itself (i) that the design and the management procedures will allow the facility to be operated safely with respect to both workers and the general public, and (ii) that the operations will deliver the post-closure safety functions on which the safety case depends (see Requirement 17 of [26]). The documents delivered to the Regulatory Body need to provide sufficient detail on the design, construction and operation of the facility to allow the Regulatory Body to carry out this review.

503. Construction and operation of the repository, as described by both the Reference and the Detailed Designs, must take into account subsequent steps in the development and operation of the repository including, for example:

— the characteristics of the available construction technologies;

— space needed for construction activities or for capping the repository structures;

— disturbance caused by additional construction-operation-closure activities (noting that filled disposal structures with a temporary or final cover are usually physically separated from ongoing operations);

— the need for regular and unscheduled maintenance;

— the arrangements for repository monitoring.

504. With respect to these activities, paras 7.2, 7.5 and 8.3 of Ref. [14] require inter alia:

> *The design of the repository shall minimize the need for active maintenance after site closure and complement the natural characteristics of the site to reduce any environmental impact. The design shall take into account operational requirements, the closure plan and other factors contributing to waste isolation and stability of the repository, such as protection of the waste from external events.*
>
> *The design of a near surface repository shall allow for implementation of a monitoring programme to verify the containment capability of the disposal system during operation and, as necessary, after closure of the repository. Arrangements for monitoring shall not compromise the long term performance of the disposal system.*
>
> *Part of the construction work is safety related. This shall be specified in the detailed design with all appropriate specifications for materials, technologies and control methods. If construction work extends into the operational phase, provision shall be made to preserve the integrity of the operational part of the repository.*

505. Exploration of the various combinations of engineered barriers and construction activities requires in most cases several iterations in the design - safety assessment loop, especially if additional site-specific data are obtained to suit the needs of the detailed design.

506. An important component of the operational safety case is the radiological protection plan (RPP), which describes how radiological hazards to workers and to members of the public are to be reduced under normal and abnormal (e.g. emergency) situations, para. 5.11 of Ref. [42]. This should document, amongst other things:

> *(a) The assignment of responsibilities for occupational radiation protection and safety to different management levels, including corresponding organizational arrangements and, if applicable (for example, in the case of itinerant workers), the allocation of the*

respective responsibilities between employers and the registrant or licensee;

(b) The designation of controlled or supervised areas;

(c) The local rules for workers to follow and the supervision of work;

(d) The arrangements for monitoring workers and the workplace, including the acquisition and maintenance of radiation protection instruments; etc.

A fully detailed RPP can only be assembled once the operational procedures are in place.

OBSERVATIONS

507. Construction and operation of the proposed facility are described in the Operations Manual (Section 5 of [10]) with additional information in the Appendices to [11]. Trench construction methods could include normal earthwork excavation techniques and ripping or blasting for cemented hard rock layers. The bottom of the trenches will be levelled with a compacted clay layer. On top of this a layer of gravel provides drainage to a sump where it would be possible to monitor for any water seepage through the waste layer. The detailed sampling arrangements have yet to be specified. Following emplacement of the waste packages, a free-flowing cement backfill will be used to fill the voids between the waste packages and between the waste packages and the trench walls. Finally the repository cap will be put in place.

508. In the case of waste receipt, Section 8 of the Operations Manual [9] simply says that:

Once the waste has reached the repository it will be unloaded from the transport container and the waste packages checked by the RSO for integrity and compliance with the Waste Acceptance Criteria is specified in the Waste Acceptance Plan. (Refer Appendix A). Conforming waste will be stockpiled awaiting burial.

The documentation does not address how the waste is to be unloaded, where and how many waste drums might be stockpiled, and how personnel are to be protected from any emitted radiation. Nor is there any detailed information on the arrangements for dealing with damaged drums.

509. Placement of waste packages within the trenches is described in similarly simple terms. Section 9.4 of the Operations Manual describes how the drums are to be stacked but does not detail how they are to be loaded into the trenches. Without this information it is not possible to assess operational doses to workers and the public and the IRT was informed that such calculations have not been carried out. Similar observations can be made in relation to trench capping, waste retrieval and emergency situations.

CONCLUSIONS

510. Recommendation: the IRT recommends that the Applicant should now develop a repository reference design that includes construction means and methods for both trenches and boreholes and submit these for licensing.

511. Recommendation: the IRT recommends that the Applicant should detail the safety relevant limits, controls, conditions and procedures to be used for the construction and operation of the repository (both boreholes and trenches), including the arrangements for dealing with emergencies. These will allow the assessment and the demonstration of radiological safety during repository operation. If the complete set of procedures, limits, controls and conditions is not reviewed and approved by the Regulatory Body, then the arrangements for their control (approval, modification etc.) should be agreed with the Regulatory Body, preferably in advance. In any event, sufficient information should be presented to the Regulatory Body to allow it to make an independent assessment of safety.

512. Recommendation: the IRT recommends that, once the reference design has been developed, the Applicant should consider the limits, controls and conditions that are necessary to ensure that the repository attributes that are necessary for post-closure safety are both delivered and preserved during the operational phase.

6. TRANSPORT SAFETY ASSESSMENT

INTERNATIONAL BEST PRACTICE

601. The IAEA Transport Regulations have been adopted into the Australian regulatory framework [24]. Compliance with the regulations constitutes international best practice.

OBSERVATIONS

602. Waste transport operations are described in Section 5 of the Operations Manual [9] and in Appendix F of [11]. The second document indicates that, if packages are to be transported without an overpack then restrictions would need to be placed on the numbers of certain waste types, particularly disused sealed sources (e.g. Co-60 sources, Am-241 smoke detectors) requiring Type B packages that could be placed in a single 200 litre drum. This restriction does not appear to have been incorporated into the Waste Acceptance Criteria. If it were exceeded, then the waste would need to be transported with an overpack but no overpack design is presented.

CONCLUSIONS

603. Good Practice: The IAEA Transport Regulations [16] have been adopted into the Australian regulatory framework and compliance with these regulations therefore constitutes international best practice.

604. Recommendation: The IRT recommends that, if waste is to be transported without an overpack, then the restrictions on waste loading should be incorporated into the Waste Acceptance Criteria. However, if the Applicant is to make other arrangements (e.g. an overpack), then the design should be specified and described to enable regulatory review.

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