Chapter 5
Repository Design and Site Selection Criteria

This chapter describes the establishment of the design criteria and the detailed process that has been undertaken to determine the preferred site and the two alternative sites. The design criteria set out the requirements and standards applicable to a near-surface repository for low level and short-lived intermediate level radioactive waste.

The site selection process began in 1992 and has involved the application of 13 site section criteria to identify a preferred site and alternatives for the national repository.

The repository site selection process and design criteria are described below.

5.1 Site Selection Criteria

The site selection criteria used to assess the preferred location for the national near-surface radioactive waste repository were drawn from the National Health and Medical Research Council (NHMRC) *1992 Code of practice for the near-surface disposal of radioactive waste in Australia* (NHMRC 1992 Code) and other siting requirements as indicated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) as part of any siting licence for the facility.

5.1.1 Siting Requirements

NHMRC Site Selection Criteria

In 1992 the NHMRC released a *Code of practice for the near-surface disposal of radioactive waste in Australia,* based on internationally accepted criteria adapted for Australia. The criteria were based on siting a near-surface disposal facility in an arid or semi-arid environment. The code includes 13 different criteria for the selection of sites for near-surface disposal facilities, to ensure that the selected site has characteristics that would facilitate the long-term stability of the repository, and appropriate isolation for waste. The criteria take into account a broad range of social, technical and environmental issues.

The criteria for site selection in the code were subdivided into two sections. The first subsection outlines important radiation health criteria and the second lists criteria about non-radiological factors that are also considered significant.

The criteria for the siting of a near-surface radioactive waste repository are:

(a) The facility site should be located in an area of low rainfall, be free from flooding and have good surface drainage features, and generally be stable geomorphologically.
(b) The watertable in the area should be at a sufficient depth below the planned disposal structures to ensure that groundwater is unlikely to rise to within 5 m of the waste, and the hydrogeological setting should be such that large fluctuations in watertable are unlikely.
(c) The geological structure and hydrogeological conditions should permit modelling of groundwater gradients and movement, and enable prediction of radionuclide migration times and patterns.
(d) The disposal site should be located away from any known or anticipated seismic, tectonic or volcanic activity that could compromise the stability of the disposal structures and the integrity of the waste.

(e) The site should be in an area of low population density and in which projected population growth or prospects for future development are also very low.
(f) The groundwater in the region of the site that may be affected by the presence of a facility ideally should not be suitable for human consumption, pastoral or agricultural use.
(g) The site should have suitable geochemical and geotechnical properties to inhibit migration of radionuclides and to facilitate repository operations.

Other factors which should be considered are:

(h) The site for the facility should be located in a region that has no known significant natural resources, including potentially valuable mineral deposits, and that has little or no potential for agriculture or outdoor recreational use.
(i) The site should have reasonable access for the transport of materials and equipment during construction and operation, and for the transport of waste to the site.
(j) The site should not be in an area that has special environmental attraction or appeal, that is of notable ecological significance, or that is the known habitat of rare fauna or flora.
(k) The site should not be located in an area of special cultural or historical significance.
(l) The site should not be located in reserves containing regional services such as electricity, gas, oil or water mains.
(m) The site should not be located in an area where land ownership rights or control could compromise retention of long-term control over the facility.

A potential site may not necessarily fully comply with all these criteria. However, there would be compensating factors in the design of the facility to overcome any deficiency in the physical characteristics of the site (NHMRC 1992).

5.1.2 ARPANSA, National and International Siting Requirements

Siting Requirements of ARPANSA

The code recommends that the natural characteristics of the site should provide an effective barrier to the release of radionuclides from the waste or to intrusion by humans.

The siting criteria and guidelines that would be used by ARPANSA as a basis for assessment of the siting of the repository (and consideration or issuing of a siting licence) would include:

- the International Atomic Energy Agency (IAEA) (1994) Safety Series document, *Siting of near-surface disposal facilities*
- the criteria given in the NHMRC 1992 Code (see Section 5.1.1)
- the criteria in the ARPANSA (1999) *Draft criteria for the siting of controlled facilities.*

The ARPANSA *Draft criteria for the siting of controlled facilities* applies to the siting of nuclear reactors and of plants for preparing or storing fuel used in a nuclear reactor, as well as nuclear waste storage or disposal facilities (which would include the national repository) and facilities for the production of radioisotopes with activities greater than the activity level prescribed by regulations.

Site characteristics must be outlined in an application to site a controlled facility. Relevant information includes:

- radiologic baseline
- geography
- demography
- meteorology
- hydrology
- geology and seismology

- services
- facilities and transportation routes.

The criteria are:

- The site characteristics that may affect the selection of the facility design bases and radiological consequences of normal operations and accidents at the controlled facility are identified. Where such characteristics are not identified, there should be a stated basis for their exclusion.
- Where relevant, the identified site characteristics are assigned a frequency and severity, including uncertainties, from historical records. Where site-specific frequency and severity data are unobtainable, data from other regions that are sufficiently relevant to the region are used. The degree of detail of identification of site characteristics is commensurate with the hazard categorisation of the controlled facility.
- An initial radiological survey of the site that includes the ambient radioactivity of the atmosphere, hydrosphere, lithosphere and biota is conducted prior to any site activities to establish baseline radiological levels for future assessments of the impact of the controlled facility.

Additional criteria relate to radiological assessment of sites, determination of design-basis external events, operational radiation doses and validation of the siting assessment.

Other Legislative Requirements Relevant to Siting

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act)

Siting of the repository is one of the matters relevant to the assessment of this draft environmental impact statement (EIS) under the EPBC Act. This is discussed in Sections 1.2.1 and 1.6.2.

International Siting Guidelines

International guidelines relating to the siting of the national near-surface radioactive waste repository, as highlighted above, come from *Siting of near surface disposal facilities* (International Atomic Energy Agency 1994).

The document states:

> The purpose of siting is to locate a site which along with a proper design, waste form, type and quantity of waste packages, other engineered barriers and institutional controls, will provide radiological protection in compliance with requirements established by the regulatory body.
>
> (International Atomic Energy Agency 1994, p. 3)

The document also identifies the relevant stages of the siting process. The guidelines used in choosing a suitable site should be developed in compliance with regulatory requirements and also reflect technical and institutional concerns.

The guidelines identify the factors which need to be taken into account in siting a near-surface disposal facility, including local geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, anthroprogenic events, transportation of waste, land use, population distribution and protection of the environment.

5.2 The Site Selection Process for the National Repository

In 1985 the Commonwealth/State Consultative Committee on Radioactive Waste Management recommended a national program to identify potentially suitable sites for a national near-surface radioactive waste repository. The committee reported that most of

Australia's radioactive waste was suitable for near-surface disposal at specially selected sites. Studies were undertaken by state and territory authorities to identify potentially suitable regions using international guidelines adapted for Australia (Bureau of Resource Sciences 1997).

These studies, presented in 1986, showed that in most States and the Northern Territory there were a number of regions that were likely to contain suitable repository sites. The committee recommended that prospective host governments advise the Commonwealth on what basis they would proceed to detailed investigation of possible locations, and that appropriate arrangements be made to enable at least one of those governments to proceed (Bureau of Resource Sciences 1997).

Although all governments initially supported the concept of a national repository, only the Northern Territory Government expressed interest in hosting one. In 1988 the Northern Territory Government agreed to a Commonwealth-funded feasibility study of a repository in the Northern Territory, which was completed in 1989. However, in May 1991 the Northern Territory Government advised the Commonwealth of its decision not to host the repository. (Bureau of Resource Sciences 1997).

Continuing concern expressed by some local communities regarding the storage of radioactive waste in their vicinity and the inadequate capacity of some existing storage facilities prompted the Commonwealth, in 1992, supported by the states and territories, to commence an Australia-wide search for a suitable site for the national repository (Bureau of Resource Sciences 1997). This section describes the process used to select the preferred site for the national near-surface radioactive waste repository.

5.2.1 Site Selection Study — Phase 1

Phase 1 of the site selection study involved a three-month preliminary study focused on developing the methodology for assessing the whole of Australia to find areas suitable for a national radioactive waste repository using a geographic information system (GIS) to apply the site selection criteria as set out in the NHMRC 1992 Code (see Section 5.1.1 for the criteria).

All regions of Australia were assessed against the selection criteria in order to identify potentially suitable sites for the repository. The methodology included the use of a computer-based system called ASSESS (**a** **s**ystem for **se**lecting **s**uitable **s**ites). The geographic information relevant to the radioactive waste disposal, such as groundwater quality, geology, cyclone risk and transport systems, together with other information was assembled for all regions of Australia. ASSESS was then used to compare this information to the site selection criteria set out in the NHMRC 1992 Code, in order to identify which regions were most suitable for a near-surface radioactive waste repository.

The following 18 themes were assembled for the Phase 1 assessment of the selection criteria (National Resource Information Centre 1992):

- locations — cities, towns, homesteads, water bores, tanks
- population density
- water balance — precipitation/evaporation
- bedrock geology
- earthquake risk
- lakes, rivers, streams, swamps
- vegetation
- hydrogeology — aquifer type
- groundwater — quality
- relief and landforms
- soils
- regolith — weathered surface materials
- Cainozoic geology (younger than 60 million years)
- faults

- cyclone risk
- thunderstorm frequency
- land ownership
- transport — roads, railways.

Specialists, including in geology, hydrogeology, seismology, ecology, meteorology and soils reviewed the information against the selection criteria and rated the suitability of different regions throughout Australia. The rating system classified regions to represent relative suitability (see Table 5.1) (Bureau of Resource Sciences 1997).

TABLE 5.1 The rating system used to represent suitability throughout different regions of Australia

Class	Suitability
Class 1	Suitable
Class 2	Mainly suitable
Class 3	Intermediate or indeterminate
Class 4	Mainly unsuitable
Class 5	Unsuitable

The system allowed for each of the themes listed above to be weighted so that those that directly impacted on radiological safety (the primary selection criteria from the NHMRC 1992 Code) were used. The results identified regions of Australia that were considered suitable, mainly suitable, intermediate or indeterminate, mainly unsuitable and unsuitable. Those regions deemed unsuitable or mainly unsuitable in any of the 18 themes listed above were excluded, leaving several regions identified as suitable, mainly suitable or intermediate/ indeterminate (see Figure 1.3).

The results of the Phase 1 study were made publicly available in the Phase 1 Discussion Paper *A radioactive waste repository for Australia: Methods for choosing the right site* by the National Resource Information Centre (NRIC), which was advertised nationally in October 1992 for public comment.

Comments on the Phase 1 Discussion Paper were received from Commonwealth and State agencies and local government; research, industry and environmental organisations; local community groups and individuals. Respondents included Greenpeace Australia Ltd, Environment Centre Northern Territory Inc, Mount Isa Development Strategy Group, the NHMRC, People for Nuclear Disarmament, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Nuclear Science and Technology Organisation (ANSTO).

The comments received fell under the general headings of support, objection and no position stated / more information requested, and are summarised below.

In response to comments received, the Commonwealth Government produced *A report on public comment* released in August 1993 (Department of Primary Industries and Energy 1993).

Support

The majority of supportive submissions noted the need for a national repository and supported the Commonwealth's action in developing such a facility. Of those submissions that commented on the methodology, most were supportive. A number of technical and general matters were raised for consideration by the project study group. Some submissions suggested possible suitable sites. Two submissions supported the concept but opposed establishment of the facility in their region. Particular aspects that attracted attention included:

- alternative repository concepts
- public consultation process
- monitoring and maintenance arrangements
- land use management options for the site
- repository design issues
- institutional control period
- nature of radioactive waste to be disposed of
- availability of the then draft NHMRC 1992 Code
- possible suitable sites
- importation of radioactive waste
- waste transport
- safety/risk aspects of a repository
- site selection methodology:
  - role of GIS
  - the relationship between the themes and the site selection criteria
  - site selection criteria.

Objection

Objection was based principally on the following propositions:

- Radioactive waste should be stored in above-ground dry stores at the site of origin.
- Highly radioactive waste would be disposed of at the facility.
- The waste would pose a radiological hazard for thousands of years.
- The public consultation process was insufficient.
- No consideration was given to alternatives to near-surface disposal.
- Site selection criteria were misapplied, resulting in the rating of regions that were unsuitable as suitable.
- Possible Commonwealth acquisition of a site is undemocratic.

Other comments raised matters concerning:

- risk to future generations
- risk associated with transport of radioactive waste
- costs of disposal
- nature of radioactive waste for disposal
- radiation dose limits
- possible importation of radioactive waste into Australia for disposal
- climate change and its implications for repository siting and design.

No Position Stated / More Information Requested

Authors of submissions that did not clearly state objection to, or support for, the project requested more information. Questions were asked and issues raised in relation to the following aspects:

- why near-surface disposal rather than above-ground storage
- the public consultation process
- alternatives to near-surface disposal
- importation of radioactive waste
- waste minimisation
- the design of the facility and proposed approach to containment of radionuclides
- monitoring arrangements
- funding arrangements
- transport issues (costs and risks)
- safety/risk associated with a repository
- disposal of radioactive waste at mine sites
- nature of radioactive waste for disposal
- climate change and its implications for repository siting and design.

One submission offered an alternative, unproven method of disposal and another suggested each State should make its own radioactive waste disposal arrangements.

The issues were responded to in the *Report on public comment* (Department of Primary Industries and Energy 1993), and are also addressed in this Draft EIS.

5.2.2 Site Selection Study — Phase 2

Public consultation on Phase 1 led to ASSESS being reorganised to include updated information and to test several different scenarios of the information (Bureau of Resource Sciences 1997).

The objective of Phase 2 was to reapply the site selection methodology outlined in Phase 1 (Section 5.2.1) to the continental-scale information, to identify regions in which large areas satisfy the selection criteria, and to assemble more detailed, regional-scale information to characterise the site suitability within each of these regions (National Resource Information Centre 1994).

In Phase 2 digital datasets were assembled in a GIS to describe all of Australia for several themes, for example geology or surface drainage features such as lakes and streams. The GIS was configured so that all the themes were used at the same notional scale. This was 1:5,000,000 for continental themes and 1:250,000 for regional themes. Each theme was sampled respectively into 5 km and 250 m grid squares (cells) to give an identical alignment of cells between themes (National Resource Information Centre 1994).

Each theme was reviewed against the NHMRC selection criteria (NHMRC 1992). Areas or features with similar suitability characteristics were assigned a numerical rating. Cells in which a characteristic was rated as ‘Suitable’ for a theme were assigned to Class 1. ‘Mainly suitable’ cells were assigned to Class 2, ‘Intermediate or indeterminate’, to Class 3, ‘Mainly unsuitable’ to Class 4 and ‘Unsuitable’ to Class 5 (National Resource Information Centre 1994).

As an example, the ‘water balance’ theme identified areas with climates ranging from very dry to relatively wet. Arid areas were deemed suitable and were given a rating of ‘1’, whereas wet areas were unsuitable and rated as ‘5’. With these initial (default) ratings, the values of many themes could be added to give a measure of overall suitability. In this approach, areas with lower summed values are relatively more suitable for a repository (National Resource Information Centre 1994).

The process used in the Phase 2 study proceeded through the following steps, each of which are reported in detail in Appendices to the report (National Resource Information Centre 1994):

1. Summarisation of the characteristics and the default for each theme. The GIS used to manage the themes allowed these default ratings to be varied so that other interpretations or scenarios could be assessed.
2. Selection of regions for more detailed assessment, after testing numerous combinations and weightings of the continental information themes. Descriptions of the themes, and the default suitability ratings, were provided.
3. Determination of issues important to the site selection criteria for radiation protection and criteria for non-radiological factors, as described in the NHMRC 1992 Code. The procedure was to identify issues for each criterion, select the themes relevant to each issue and interrogate each theme to determine and assign suitability ratings.

In this process it was found that some themes provided an excellent representation of suitability. Others appeared too simple when matched against complex systems or issues. Some themes substantially overlapped others, and some were only peripherally relevant, or were used as surrogates in the absence of directly relevant data.

The themes used for the regional assessments were sampled into cells at the scale of 1:250,000 (1 mm on the map = 250 m on the ground). All the information was assembled in ASSESS using the same method as in Phase 1. The ASSESS method was then re-applied to identify the regions most likely to contain suitable sites with areas of approximately 225 ha (a 6 x 6 mm square on a 1:250,000 map).

The results obtained from ASSESS by applying many different themes or scenarios indicated that several broad regions of Australia appeared consistently likely to contain highly suitable repository sites. Areas that remained suitable in many scenarios became the focus for selecting smaller regions for more detailed assessment.

In addition, public and broader scientific involvement suggested that other areas should also be considered, either because of their probable technical suitability or because of a perceived compatible land use such as existing contaminated areas. Five regions were chosen based on ASSESS and three were identified by consultation (Bureau of Resource Sciences 1997).

The five regions identified by ASSESS were:

- central–north SA (formally referred to as Billa Kalina)
- Bloods Range, NT
- Everard, SA
- Olary, SA and NSW
- Tanami, NT.

In addition, three regions were identified by consultation:

- Jackson, WA
- Maralinga, SA
- Mount Isa, Qld.

The themes used to identify these suitable regions on a national scale were applied at a regional scale to identify suitable, mainly suitable, intermediate/indeterminate, mainly unsuitable and unsuitable smaller regions within the eight regions identified above (see Figure 1.3).

The results of Phase 2 were released in a discussion paper *A radioactive waste repository for Australia: Site selection study — Phase 2* (Department of Primary Industries and Energy 1995). The release of this discussion paper was advertised in national and regional papers in the eight regions identified in the Phase 2 study. Comments were received on the Phase 2 discussion paper and in response to these comments a *Report on public comment* was released in November 1995.

As with Phase 1, public submissions were classified into three main response groups, being support, objection and no position stated / more information requested or constructive comment provided. The submissions received in each category are summarised below.

Support

Most submissions supported the repository concept and the site selection study approach. Seven submissions supported the process but suggested that certain areas within the regions identified were inappropriate for siting a national repository, either for social or technical reasons or because they did not support its establishment in their vicinity. Particular issues that attracted attention included (Department of Primary Industries and Energy 1995):

- the public consultation process
- repository design issues
- possible suitable sites
- management of the facility
- transport issues

- waste minimisation
- alternative repository concepts
- suitability/unsuitability of particular areas within identified regions
- site selection methodology.

Objection

Objection was based principally on the following (Department of Primary Industries and Energy 1995):

- transport risks
- disposal is not ‘environmental best practice’
- disposal does not encourage waste minimisation
- ‘not in my backyard’.

No Position Stated / More Information Requested or Constructive Comment Provided

Authors of submissions that stated neither clear objection to, nor support for, the project either requested more information or offered constructive comment on the process. Questions were raised and/or comments offered on the following aspects (Department of Primary Industries and Energy 1995):

- environmental and safety risks associated with disposal of radioactive wastes
- transport routes/risks
- future use of the repository
- radioactive waste storage
- Aboriginal interests
- mineral potential
- ecological significance
- access
- waste minimisation/prevention
- parties who should be consulted
- future technology for handling radioactive waste
- alternatives to near-surface disposal
- suitability/unsuitability of particular areas.

One submission indicated that a new technology could be used for radioactive waste disposal but did not provide any details.

The issues were responded to in the 1995 *Report on public comment* and are also addressed in this Draft EIS.

5.2.3 Site Selection Study — Phase 3

After the release of the Phase 2 paper more detailed regional datasets and two new datasets became available. The new datasets were:

- proximity to populated places
- location of mineral resources.

These datasets were incorporated into ASSESS, and the region assessments were re-evaluated (Bureau of Resource Sciences 1997).

All eight regions are likely to contain suitable repository sites; however, some have larger areas of potential suitability than others. Given the high cost of conducting field surveys in every region, it was necessary to select a single (preferred) region for more detailed field investigation. The aim was to select the region with the largest areas of high suitability (Bureau of Resource Sciences 1997).

In order to establish the region that best satisfied the requirements, two styles of assessment were used — one a descriptive comparison against the selection criteria, and the other based on ASSESS. The descriptive comparison provides an understanding of the suitability of features of each region against the NHMRC selection criteria (see Section 5.1.1), but it cannot provide a combined map showing the areas of high suitability for all the criteria. A summary of conformance with the criteria based on the descriptive comparison of the eight regions is shown in Table 5.2.

TABLE 5.2 Summary of conformance of the eight regions with the criteria

Criterion[1]	Central–north SA	Bloods Range (NT)	Everard (SA)	Jackson (WA)	Maralinga (SA)	Mount Isa (QLD)	Olary (SA/NSW)	Tanami (NT)
a	✓			✓			✓	
b	✓			✓			✓	
c	✓			✓			✓	
d	✓	✓	✓	✓	✓	✓	✓	✓
e	✓						✓	
f	✓						✓	
g	✓			✓			✓	
h	✓						✓	
I	✓						✓	
j	✓	✓	✓	✓	✓	✓	✓	✓
k	✓	✓	✓	✓	✓	✓	✓	✓
l	✓	✓	✓	✓	✓	✓	✓	✓
m	✓	✓	✓	✓	✓	✓	✓	✓

(1) Criteria are listed in Section 5.1.1

Following public comment on the Phase 2 discussion paper, new analyses of suitability were made for each of the eight regions using ASSESS. The ASSESS method provides an analytical synthesis of the suitability ratings and maps the distribution of combined suitability for all criteria (Bureau of Resource Sciences 1997).

In February 1998 the central–north region of South Australia (previously called Billa Kalina) was announced as the preferred region for investigation to identify a preferred site for the repository. It was the best of the eight regions identified in the Phase 2 report, as it contained the largest area of potential suitability based on review of the available data against the NHMRC selection criteria (Bureau of Resource Sciences 1997).

The results of the comparative regional study were released in February 1998 in the Phase 3 discussion paper, *A radioactive waste repository for Australia: Site selection study — Phase 3: Regional assessment* (Department of Primary Industries and Energy 1998). The release of this report was advertised nationally and within the central–north region of South Australia.

The responses to comments received on that report were published in the *Report on public comment*, which was released in June 1999 (Department of Industry, Science and Resources 1999). In addition, the Phase 3 discussion paper and information kit were sent to key groups representing a wide range of interests in the central–north region of South Australia, landholders, metropolitan and regional media, and individuals and groups who had expressed an interest in Phases 1 or 2 of the study.

As with Phases 1 and 2, public submissions were categorised under support, opposition and no position stated, and are summarised below.

Support

Submissions from people involved in health, research and other uses of radioactive materials generally stated their support for the project, the selection process and the identification of central–north region of South Australia as the most suitable region to site the national repository. There were some submissions from within the region that stated support for the project.

The need for a national purpose-built facility that provides for safe containment of radioactive material was widely supported by these submissions. A number of submissions commended the public consultation process and the site selection process, in particular the discussion paper and information kit. Questions were raised and/or comments made (Department of Industry, Science and Resources 1999) concerning:

- the site selection criteria — in particular it was suggested that some criteria are too stringent, which may suggest a greater risk than is actually the case
- the origin and type of wastes to be accepted
- packaging requirements
- transport arrangements of the waste to the site
- the total capacity of the facility and its operational period
- the effect on the local economy
- the need for continued consultation in the region
- the number of consultative committees — it was suggested that too many bodies had been formed, and that this would hinder the progress of the project
- the long-lived intermediate level radioactive waste store, in particular:
  - whether public consultation on the store would take place
  - whether the priority should be for the intermediate level waste store rather than the repository
- ownership of the facility
- the costs of using the facility.

Opposition

A number of submissions that stated opposition to the project were against the mining of uranium and viewed the facility as a means of encouraging the use of radioactive substances and hence uranium mining. Submissions that either opposed the project and/or its siting in the central–north region of South Australia raised issues relating to (Department of Industry, Science and Resources 1999):

- the region's proximity to the Great Artesian Basin
- possible effect of the repository on bore water used in the region
- possible impacts of siting the repository on Aboriginal land rights and heritage sites
- transport and facility safety requirements
- possible detrimental socio-economic impacts on the region, particularly for the tourism, agricultural and opal industries
- possible compounding effects on South Australia, due to the presence of other nuclear related activities
- the fact that a proportion of the waste had been generated outside South Australia, and should therefore be disposed of elsewhere
- the fact that the repository was not going to be sited at existing contaminated sites such as mines or Maralinga, and the suggestion that these locations would provide a more appropriate site
- the possibility that the repository site may be used for disposal of higher level wastes
- representation of views in the consultative committees.

No Position Stated

The majority of submissions that stated neither support nor opposition to the project were from South Australia. The points raised in these submissions reflected some of the issues raised by those that supported and opposed the project. Some of these submissions criticised what they perceived as inadequate public notification, because they were not aware of the proposal until too late to put in a more complete submission. They were concerned that their understanding of the project and its impact was incomplete and hence that their submission only reflected their initial reaction towards the project (Department of Industry, Science and Resources 1999).

The views outlined above were responded to in the 1999 response paper, and are also addressed in this Draft EIS.

5.2.4 Phase 3 Drilling Investigations — Assessment of Selected Sites

Stage 1 involved the drilling of 11 sites (one percussion drill hole on the corner of each site), and was undertaken in 1999. Stage 2 involved more extensive drilling of five sites (4 drill holes), and three sites were further investigated in Stage 3 (12 holes). Stages 2 and 3 were undertaken in 2000.

Stage 1 — Desktop geological and hydrogeological assessments were used to identify broad areas of suitability for siting the repository in the region, which were then inspected on the ground. The views of regional stakeholders, including pastoralists and Aboriginal groups, were taken into consideration when proposing and assessing sites.

As a result of these consultations, new sites were proposed for investigation, and the location of some of the sites was moved. Within the central–north South Australia area, over 40 potential sites for the national repository were identified and investigated between June 1998 and August 1999 (Bureau of Rural Sciences 2001a).

Twelve of these sites were cleared of heritage values by Aboriginal groups for the drilling of one hole per site in Stage 1 of the drilling investigations. Eleven sites were drilled in Stage 1, due to difficulties accessing one site at the time of drilling. Two nearby sites effectively tested the characteristics of the relevant area that was not drilled (Bureau of Rural Sciences 2001a).

The drilling and samples at these sites provided the information necessary to indicate the relative suitability of each site against several of the site selection criteria (NHMRC 1992). The main use of the drilling information was for the geological and physical criteria (criteria a, b, c, d, f and g). More specifically these criteria relate to the groundwater, geological, geochemical and geotechnical conditions, and to the potential for economic mineralisation (Bureau of Rural Sciences 2001b).

The performance of each site was reviewed according to the majority of the NHMRC (1992) site selection criteria. Many of the criteria refer to geotechnical considerations, and the field assessment program was designed to provide both the quantitative and qualitative data needed to assess site suitability. Two approaches were used to assess the comparative suitability of each site. The first was semi-quantitative, based on geotechnical conditions including the hardness and clay proportion of the ground in a potential trench zone, and the deeper conditions that could affect hydrogeological modelling and radionuclide adsorption. The second approach was a relative judgement of the site and whether it performed better, the same or worse than another site for each criterion (Bureau of Rural Sciences 2001b).

Stage 2 — Based on a drilling assessment of one corner of each site, all 11 sites were identified as potentially suitable but, based on assessment of the selection criteria, sites 14, 45, 12, 16, 33 and 40 were preferred for Stage 2 assessment (Bureau of Rural Sciences 2001a).

After consultation with stakeholders, Sites 16 and 33 were withdrawn from consideration for the national repository. Site 16 was withdrawn following concerns expressed by the Andamooka community and indigenous groups, and Site 33 was withdrawn based on concerns raised by indigenous groups and the Department of Defence.

After further consideration of the heritage significance of the sites by Aboriginal groups, some groups did not clear any sites for drilling on Stage 2 of the project (see Chapter 11).

(Bureau of Rural Sciences 2001b). Further site investigation and inspection identified five new sites, which were cleared for further work. These sites are identified as 10a, 14a, 40a, 45a and 52a (the 'a' suffix indicated that the site was close to a previously considered site but relocated nearby after consultation with Aboriginal groups on heritage issues).

Based on the data obtained from drilling and the assessment of the selection criteria, the Bureau of Rural Sciences concluded that all the sites performed well and were considered suitable for the repository. Sites 45a, 40a and 52a met the selection criteria better and were selected for Stage 3 assessment (Bureau of Rural Sciences 2001b).

Stage 3 — Stage 3 reviewed the geotechnically oriented criteria (NHMRC 1992); a, b, c, d, f and g for each of the three sites. These criteria relate to the groundwater, geological, geochemical and geotechnical conditions, and to the potential for valuable natural resources. Additional drilling and sampling was undertaken to provide the information necessary to indicate the relative suitability of each site against the geological and physical criteria (Bureau of Rural Sciences 2001c).

The Bureau of Rural Sciences Stage 3 assessment concluded that Site 52a performed the best against the selection criteria and was the preferred site over Sites 40a and 45a; however, the other two sites were also found to be highly suitable for the siting of the repository.

Site 52a was the preferred site because:

- The surrounding landforms indicate superior surface drainage with little or no run-on of water to the site from adjacent areas. This provides a highly favourable environment for the construction and maintenance of the disposal trenches.
- The rock type that would host the trenches, the Bulldog Formation (a shale), and the groundwater features mean that water drainage characteristics can be modelled more easily for this site than for the others.
- The host rock for the trenches is preferred as it consists of material which is resistant to groundwater flow, and which would therefore provide a highly effective natural barrier to the waste.
- There is no hard silcrete in the trench zone, and trenches could therefore be easily constructed.
- The site has superior transport access, with a well-formed road leading to the vicinity of the site.
- The site has superior prospects for long-term control, being located on the Woomera Prohibited Area, which has restricted public access (Bureau of Rural Sciences 2001c).

The drilling investigations also found that at Site 52a the watertable is 40 m below the surface, contains 16,000 ppm salt and has a very low replenishment rate. This high salt content — 60% above the upper limit for adult sheep on a diet of saltbush — makes the water unusable for pastoral purposes.

Site 40a did not perform as well against the selection criteria as Site 52a. Though highly suitable, it was considered less favourable mainly because it had more complicated surface features which could impound water on the site, less clay in the trench and sub-trench zones making trench construction less straightforward, and a greater distance for transport access. Site 45a ranked as intermediate, having good surface drainage qualities, but a greater prospect for run-on of rainfall to the site than for Site 52a (Bureau of Rural Sciences 2001c).

It was determined that all three sites have sufficient clay and other adsorbing materials in the profile to adequately retard radionuclides in the unlikely event of leakage from the repository trenches (Bureau of Rural Sciences 2001c).

Test bores showed the low volumes of underground water at the three sites were highly saline and unsustainable for human, agricultural or industrial use (Department of Industry, Science and Resources 2001). At all sites the watertable is at considerable depth (approximately 39, 51 and 65 m for Sites 52a, 45a and 40a, respectively, see Table 8.4), and surface water will take thousands of years to reach the watertable (14,000, 9,000 and 11,000 years for Sites 52a, 45a and 40a, respectively) and thousands of years for the water at the watertable to discharge onto the surface (16,000, 9,000 and 1,500 years for Sites 52a, 45a, and 40a, respectively). Further, extensive hydrological studies in the region have shown there is no connection between the Great Artesian Basin and underground water at any of the sites.

In addition, there is no known significant mineral potential at the three sites that would interfere with the proposal for the national repository (Section 1.5.2).

The process of selecting a suitable site for Australia's national repository has been comprehensive and has used an open and objective approach. The steps undertaken during the site selection process and application of the site selection criteria identified by the NHMRC (1992) have been rigorous and have involved extensive community consultation.

The siting of a national low level and short-lived intermediate level waste repository would also need to minimise potential impacts on the identified criteria of national environmental significance (Section 1.2.1), as well as meet the objects of the EPBC Act and the principles of ecologically sustainable development (ESD) (Section 1.6.2).

5.2.5 Siting in Context of Strategic Planning in South Australia

Once the final site has been chosen for the repository, and assuming the Draft EIS is approved, the land would be acquired by the Commonwealth Government and therefore would not require any state or local planning approvals. Commonwealth acquisition would proceed under the *Lands Acquisitions Act 1989*.

Further details of planning considerations can be found in Chapter 10.

5.3 Repository Design Criteria

In order to be considered acceptable, a near-surface repository must meet a number of criteria to ensure the waste is sufficiently isolated from the biosphere, and therefore human health and the environment is adequately protected over the period of the hazardous life of the waste. This section outlines the general criteria applicable to the national near-surface low level and short-lived intermediate level waste repository.

A number of general conditions need to be satisfied for the disposal of radioactive waste:

Independence from safety controls. The continued isolation of waste, after the withdrawal of controls, should not depend on actions by future generations to maintain the integrity of the disposal system.

Effects on the future. Predicted impacts on the health of future generations should not be greater than relevant levels of impact that are acceptable today.

Optimisation (as low as reasonably achievable). The radiological detriment to members of the public shall be **a**s **l**ow **a**s **r**easonably **a**chievable (ALARA), economic and social factors being taken into account (the ALARA principle).

Radiological protection standards. The assessed impact of the disposal facility must be consistent with dose and risk limits.

The IAEA also proposes that an evaluation of acceptable radionuclide inventories for disposal in a surface or near-surface facility should be based on an assessment of the risks posed to operators of the facility and to members of the public close to the facility (International Atomic Energy Agency 1995).

5.3.1 International Standards for Radioactive Waste Repositories

The IAEA has specified a set of fundamental principles to apply as the basis for the safe management of radioactive waste (International Atomic Energy Agency 1995). These principles are:

- protection of human health
- protection of humans and the environment
- protection beyond national borders
- protection of future generations
- reducing burdens on future generations
- establishing a national legal framework
- control of radioactive waste generation
- correlating radioactive waste generation and management
- safety of facilities.

These principles underpin the requirements and guidance for the regulatory, safety and technical requirements for radioactive waste repositories developed by the IAEA in their series of Safety Standards (International Atomic Energy Agency 1999).

The basic requirements that international experience has shown to be necessary for ensuring the safety of near-surface low level radioactive waste repositories are set out by the IAEA as a Safety Requirement document (International Atomic Energy Agency 1999). In this publication the IAEA emphasises that responsible radioactive waste management requires measures to be implemented that protect human health and the environment in accordance with the national system of radiation protection.

An essential aspect is the need to demonstrate compliance with safety criteria by performing a comprehensive and systematic assessment of the safety of the planned repository prior to construction. The IAEA provides a description of the technical requirements for each of the main activities related to the disposal of low and short-lived intermediate level radioactive waste — waste acceptance, siting characteristics, repository design, construction and operation, and the closure and post-closure phases (International Atomic Energy Agency 1999).

The required performance of a radioactive waste repository is that radioactive wastes should be disposed of in a manner that ensures that there are no unacceptable radiological consequences at present or in the future. Principles for radiological protection are prescribed by the International Commission on Radiological Protection (1996). The ICRP also provides more specific recommendations on the radiation protection policy for disposal of radioactive waste (International Commission on Radiological Protection 1997).

Addressing the above principles requires a comprehensive safety assessment, which is a procedure for evaluating the performance of a disposal system and, in particular, its potential radiological effects on human health and the environment (International Atomic Energy Agency 1999).

The safety assessment of a near-surface repository needs to take into account:

- interim storage for decay of radionuclides
- selection of techniques for conditioning of radioactive waste
- engineering for handling waste packages
- engineered barriers
- natural barriers
- institutional control period
- administrative methods.

The various pathways by which radionuclides might be released from the repository and reach the human environment must be assessed and the radiological consequences quantified (this analysis is provided in Chapter 12). The performance of the repository must then be evaluated by the regulatory authorities to determine whether it is acceptable, and to optimise performance if required.

Safety analyses must be performed to demonstrate that the potential risks do not exceed the limits prescribed by the regulations to protect the human environment during the lifetime of the repository, including the operational period, the institutional control period and the unrestricted site access period.

5.3.2 Stages of Repository Life

There are three main stages to the repository life, once construction is complete:

- disposal operations and closure
- post-operational phase with institutional controls in place when access is restricted — the institutional control period for the national repository is 200 years
- post-institutional control with unrestricted access or use.

The performance criteria may vary between the different phases. This is highlighted in the following sections, which discuss individual performance criteria for the radioactive waste repository.

5.3.3 Dose Limits

Worker Dose

The radiation protection standards for personnel who work at the disposal facility would follow the recommendations of the national standards described in Section 3.2.2. The applicable dose limit for people employed at the repository is an annual effective dose of 20 mSv averaged over five years, with no more than 50 mSv in any one year. Doses to workers should also be ALARA.

The potential for worker exposure would be greatest during the operational and closure phases of the repository life, but, given the nature of the waste being disposed of and its packaging, it is likely that any dose incurred by workers would be well below the occupational limit. During the operational phase, the site operator would ensure that appropriate work and radiation protection practices are in place to limit doses to site personnel.

Public Dose

The NHMRC 1992 Code states that the annual effective dose for exposure of members of the public shall not exceed the national standards. As noted in Section 3.2.2, the annual dose limit to the public applicable to the national repository is 1 mSv. This limit excludes the dose arising from natural background or the medical use of radiation, but includes any other potential exposure sources, which are unlikely given the siting of the repository. An additional requirement is that the dose rate to the critical group would need to be demonstrably ALARA.

During the period of institutional control, the critical group concept provides a well-established approach to assessing the dose to members of the public.

Beyond the period of institutional control, the exposure of any given group is not certain to occur, and would only result from the unlikely occurrence of specific events or actions. Therefore, each potential exposure is also associated with a probability, and risk targets are likely to be more useful criteria in this period than dose rates. A risk assessment of potential exposures in the post-institutional control period is described in Section 12.8 and detailed in Appendix E.8.

The regulatory authority may also deem it necessary that projections of doses or risks to members of the public should not exceed an appropriate fraction of the annual dose limit of 1 mSv, or the equivalent risk limit, to take into account the possibility of other sources of exposure, excluding natural radioactivity. This fraction is determined to be a dose or risk constraint. Other sources of exposure are considered very unlikely given the siting of the repository in a remote, arid region.

5.3.4 Risk Targets

The principal requirement for the performance of a radioactive waste disposal facility is generally set out in terms of risk to an individual from possible releases of residual radioactivity from the facility. Here the definition of individual risk encompasses the effective dose received, the associated probability of cancer or hereditary effects and the probability of the dose being received. The dose and risk to individuals is usually based on the potential exposure to a 'critical group' of individuals who, as a result of their particular habits and lifestyles, are likely to receive the highest doses resulting from releases from the facility.

The NHMRC 1992 Code suggests an effective dose limit for members of the critical group of 1 mSv/yr. This corresponds to a risk limit of approximately 5 $\times 10^{-5}$/yr for potential exposures which would be applicable for a site in an arid region for which no other potential artificial sources of exposure exist. No time cut-off is specified beyond which the radiological consequences of disposal do not need to be considered.

Recent advice from ARPANSA (pers. comm. to the Department of Education, Science and Training, January 2002) suggests that an effective dose constraint of 0.1 mSv/yr or a risk limit of 1 x 10^{-6}/yr would be desirable.

In addressing the calculation of risk, the risk of fatal cancer and serious hereditary effects in all subsequent generations is taken into account, using a factor of 0.06/Sv for converting dose to risk. If the risk is higher than the target of 1 $\times 10^{-5}$/yr, it should be shown that the design is optimised and that the increase in expenditure (in time, effort or money) of any further action is disproportionate to the risk reduction benefit gained.

The issue of radiation exposure risk is further dealt with in Chapter 12.

5.3.5 Multi-Barrier Approach

The repository design should demonstrate that adequate containment can be provided by a number of barriers to radionuclide release, for example:

- waste packaging and conditioning
- engineered safeguards
- natural barriers of geological host rocks, and groundwater characteristics.

Containment must be adequate to ensure that dose and risk constraints discussed earlier are met, and that doses to public and workers are ALARA. The multi-barrier approach concept ensures that even in the unlikely failure of one barrier, the repository performance targets would still be met.

The first barrier is usually the waste form and the conditioned waste package. The second form of barrier is engineered structures within the repository, for example the engineered cover which would assist runoff, minimise water infiltration and erosion, and limit the chance of intrusion by humans or animals (the buffer zone and security arrangements would also assist in this task). The third barrier is the geological barrier. The role of this barrier is to delay the radionuclide migration in case of failure of the first two barriers, in order to keep the releases within acceptable levels and in accordance with internationally accepted criteria and recommendations.

Conditioning of radioactive waste covers those actions that produce a waste package suitable for handling, transport and/or disposal. Category A waste (low concentrations, short half-lives) may not need to be conditioned, apart from minimal treatment such as compression to reduce voids, and may be placed directly into disposal trenches. Category B and C wastes comprise higher concentrations of radionuclides of short half-lives, and perhaps with low concentrations of longer-lived isotopes. These categories of waste must be conditioned or placed in suitable containers such that the waste would retain its physical dimensions and properties under the anticipated conditions of disposal.

The engineered barriers for the disposal facility need to be based on sound engineering principles and practice and good science. The proposed site and alternatives have been selected such that the natural environment provides a considerable degree of protection, including low watertable, saline groundwater and stable rock formation.

It should be shown that the safety of the facility is not based on any single component of the overall system. It is proposed therefore that the performance targets of the repository should be met through the presence of a number of barriers to radionuclide release.

5.3.6 All Reasonable and Practicable Measures

In its administration of the EPBC Act, undertaken by the Commonwealth uses the concept of ‘best practice environmental management’ in its environmental assessments. This means that ‘all reasonable and practicable measures’ would be applied to the design and operation of the facility. The concept of best practice environmental management is effectively a broader policy concept of best practice management (Environment Australia, pers. comm., 2002) used in South Australian environmental legislation. In summary, the application of this concept would ensure that the operation of the facility meets relevant engineering and environmental criteria, and that radiation protection is in accordance with the ALARA principle (see Section 5.3.3). Post-closure safety would be influenced by the choice of design features, and is discussed in detail in Section 12.8.

It is considered that for radiological assessments, demonstration of all reasonable and practicable measures should largely be undertaken on a barrier-by-barrier basis. Accordingly, the performance of each barrier with respect to retardation of movement of radionuclides would be calculated. A number of basic design criteria have been identified:

- The design would include a suitable engineered cover. The minimum cover depth outlined in the NHMRC 1992 Code is 2 m for Category A waste and 5 m for Category B and C waste. In practice, a cover of 5 m would be placed over the repository trenches/boreholes.
- Backfill material would be used to prevent subsidence within the disposal structure.
- A surface water management system would be provided to control water erosion of the cover.

The repository layout also includes a buffer zone, which would be maintained between the buried waste and the boundary of the site.

Safety Assessment

The safety of the radioactive waste facility should be ensured for its lifetime, including the operational period, the institutional control period and the unrestricted site access period. The performance of a disposal system, particularly its potential radiological impact on human health and the environment, is evaluated by conducting a comprehensive safety assessment. This assessment must be performed as part of the planning stage for the repository to demonstrate that the potential risks do not exceed the limits prescribed by the regulations to protect the human environment during the lifetime of the repository.

The safety assessment of a near-surface repository should consist of (International Atomic Energy Agency 1999):

- an estimate of system performance for all the situations selected
- an evaluation of the level of confidence in the estimated performance
- an overall assessment of compliance with safety requirements.

The assessment should take into account (Section 5.3.1):

- interim storage for decay of radionuclides
- selection of techniques for conditioning of radioactive waste
- engineering for handling waste packages
- engineered barriers
- natural barriers
- institutional control period
- administrative methods.

The outcome of the safety assessment can be used to assist in the optimisation of the disposal system and in the repository design. It is also useful to develop and/or confirm waste acceptance criteria. A principal function of the safety assessment is for regulatory purposes. The performance of the repository is evaluated by the regulatory authorities to determine whether it is acceptable, and to optimise performance if required.

5.3.7 Risk Assessment Methodology

In order to show that the criteria specified in preceding sections have been met, particularly those relating to safety, a detailed risk assessment, including modelling of biosphere effects, needs to be undertaken. This section describes the methodology that has been determined and is used internationally for risk assessment and modelling.

The safety of a disposal facility is assessed by addressing the possible migration pathways of radionuclides away from the facility. Various barriers limit radionuclide migration along these pathways and determine the performance of the facility. The engineered barriers are those of the disposal facility design and structure, including the waste forms and containers, known as the near-field of the disposal facility. The geology surrounding the near-field is known as the far-field or geosphere, and this can also act to retard and disperse radionuclides. A preliminary analysis is provided in Chapter 12 and is briefly reviewed here.

The international community has established the need to consider four pathways:

- groundwater transport
- gaseous transport
- human intrusion
- natural disruptive events.

The first phase of an assessment obtains relevant information on:

- waste streams
- repository design
- candidate site
- critical group behaviour.

The assessment methodology is then developed in terms of the following:

- overall approach
- assessment context
- scenario development
- formulation of conceptual and mathematical models.

Each pathway is usually considered separately, and these are discussed in the following sections.

Groundwater Transport

The repository would be sited in an area where the groundwater is unlikely to rise to within 5 m of the waste, and where large fluctuations in groundwater level are unlikely over the period of operation and institutional control of the national repository. (Note: the preferred site, and the two alternatives, all have groundwater levels in the range 38.8–68.7 m below the surface (Table 8.4).)

Modelling of the site should show that these criteria have been met. An assessment should also be undertaken of the probable effects if the groundwater were to rise significantly, for example as a result of climate change. The assessment should take account of a number of relevant exposure scenarios.

It is proposed that the radiological risk to a representative member potentially exposed due to migration of radionuclides in groundwater needs to be assessed for site specific conditions and should not exceed 1×10^{-5}/yr (Section 5.3.4).

Gaseous Transport

Gases can be generated in the waste due to the corrosion of metal compounds and wastes and the microbial degradation of organic wastes, and lead to the release of radionuclides by gaseous transport. In addition, radioactive gas may result from the decay of certain radionuclides, for example radon from radium decay, or if radionuclides such as tritium or carbon-14 are present in a volatile form. Any gases formed could migrate from the facility and may reach the biosphere, where exposure may occur via inhalation.

The radiological risk to a representative member potentially exposed via gas generation and transport needs to be assessed for site-specific conditions.

Human Intrusion

Institutional controls should be designed to prevent inadvertent human intrusion during the period for which they are active. An assessment of risk to members of the public after that time needs to be undertaken for a range of scenarios, which may include:

- construction of an unpaved road
- construction of a homestead
- residential use of a homestead
- use of disposal site for grazing
- archaeological investigations
- use of site for camping on an occasional basis, including by Aboriginal people leading a traditional hunter/gatherer lifestyle
- drilling investigations for mineral exploration.

A number of scenarios should be modelled to predict potential exposure to the affected groups.

In addition to potential future activities after institutional control has ceased, the potential impact from current activities would be assessed specifically, that is the potential for accidental intrusion with respect to Site 52a as a result of current Department of Defence and other activities on the Woomera Prohibited Area.

The radiological risk to a representative member of the potentially exposed group via relevant human intrusion scenarios, accidental and deliberate, would be assessed for site-specific conditions, and should not exceed an effective dose constraint of 0.1 mSv/yr or a risk limit of 1×10^{-6}/yr (Section 5.3.4).

Natural Disruptive Events

A preliminary analysis should be made of the probability that the facility might be disrupted by naturally occurring external events, for example erosion through weathering or flooding in future climate states.

The radiological risk to a representative member of the potentially exposed group via naturally disruptive events would be assessed for site-specific conditions and should not exceed an effective dose constraint of 0.1 mSv/yr or a risk limit of 1×10^{-6}/yr (Section 5.3.4).