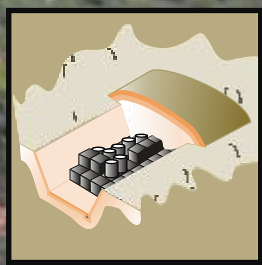
COMMONWEALTH DEPARTMENT OF EDUCATION SCIENCE & TRAINING

NATIONAL RADIOACTIVE WASTE REPOSITORY DRAFT EIS

MAIN REPORT







PPK
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Department of Education, Science and Training

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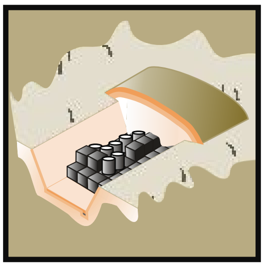

COMMONWEALTH DEPARTMENT OF EDUCATION SCIENCE & TRAINING

PPK
Environment&Infrastructure
A Parsons Brinckerhoff Company

VOLUME 1

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This environmental impact statement (EIS) has been prepared by PPK Environment & Infrastructure (PPK) on behalf of Department of Education, Science & Training (the Client). In preparing this EIS, PPK has relied upon and presumed accurate certain information provided by the Client, specialist subconsultants, certain State and Commonwealth government agencies and others identified herein. No warranty or guarantee, whether expressed or implied, is made with respect to the information reported or to the findings, observations or conclusions expressed in this EIS. Such information, findings, observations and conclusions are based solely on information in existence at the time of the investigation.

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How to Make a Submission

An important objective of the environmental impact statement (EIS) process is to ensure that all relevant information has been collected and assessed so that the Commonwealth Government can make an informed decision on the proposal. Making a submission is a way for the community to provide information to the proponent and the decision makers about the proposal. Interested persons, groups and authorities are encouraged to make a submission on this Draft EIS.

Viewing or Obtaining a Copy of the Repository EIS

The Draft EIS will be available for public review from the date published in press advertisements, which will also include the closing date for submissions and the locations of exhibition points.

The Draft EIS and Summary will also be available on the Department of Education, Science and Training's website: www.dest.gov.au/radwaste

What Can be Included in a Submission?

A submission can comment on any aspect of the proposal. It may provide information, options or suggestions on the material contained in the Draft EIS or may also identify errors or omissions. Comments may be made on general issues or specific items; they may cover related facts or topics that should be considered and may include suggestions on how to improve the proposal.

It is helpful if you can:
- provide your comments in point form so that the issues raised are clear to the reader
- refer each point to the appropriate sections of the Draft EIS
- include your name, address and date
- ensure that the submission is as clear as possible if hand written.

All submissions will be treated as public documents unless confidentiality is requested.

Contact Details

Submissions can be made by letter/fax/e-mail and should be sent to:
- Radioactive Waste Repository EIS
  Department of Education, Science and Training (Location 742)
  GPO Box 9880 CANBERRA CITY ACT 2601
- Facsimile: 02 6240 9184
- Email: repository@dest.gov.au

What Happens Next?

A supplement will be prepared taking into account and responding to the content of the public submissions received. It will be a public document. Together, the Draft EIS and Supplement will make up the Final EIS.

After receiving the Final EIS, Environment Australia will prepare its advice to the Minister for the Environment and Heritage taking into account the contents of the Final EIS and any additional documents relevant to the assessment. The Minister for the Environment and Heritage will then determine whether to give his approval for the proposal to proceed and, if so, set conditions under which it may do so.

Certificate of Compliance

	Submission of Environmental Impact Statement/Public Environment Report Prepared under the *Environment Protection and Biodiversity Conservation Act 1999*
EIS/PER prepared by	
Name	PPK Environment & Infrastructure
Qualifications	Consulting Engineers, Scientists and Planners
Address	101 Pirie Street Adelaide SA 5001
In respect of (general description of action)	Sections 21 and 22: Nuclear Action — establishing a facility for disposal of low level and short-lived intermediate level radioactive waste. Section 28: Commonwealth Action — requirement for approval of an action of significance by the Commonwealth.
Proposed action (short name)	Low level and short-lived intermediate level radioactive waste repository
Proponent name	Department of Education, Science and Training
Proponent address	16 Mort Street Canberra ACT 2601
Land to be developed (particulars of land to be developed. For example lot no., vol/fol, map reference, etc.)	Site 52a, near Koolymilka, Woomera Prohibited Area, South Australia, easting/northing coordinates at site centre 637,118.38E, 6,573,707.48N. Alternative sites: Site 40a, about 20 km east of Woomera, coordinates at site centre 695,222.13E, 6,545,570.63N; and Site 45a, about 50 northeast of Woomera, coordinates at site centre 705,973.61E, 6,586,975.27N
Certificate	I certify that I have prepared the contents of this statement/report and to the best of my knowledge ▪ it is in accordance with the guidelines prepared under Section 97/102 of the *Environment Protection and Biodiversity Conservation Act 1999*, and ▪ it is true in all material particulars and does not by its presentation or omission of information, materially mislead.
Signature	V. Farrington
Name	V. Farrington
Date	31 May 2002

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ABBREVIATIONS

Abbreviations

Abbreviations

The abbreviations for measurements and chemical formulae used in the document are listed below, followed by other abbreviations used in individual chapters and appendices.

Measurements

Technical units of measurement in this report are based on the International System of Units (SI) wherever possible. These technical units may be broadly grouped as prefixes and measurements. A prefix applies to the unit of measurement that immediately follows it, for example, milligram is abbreviated as mg.

Superscripts ^{2} and ^{3} following a linear unit indicate area and volume respectively, for example, m^2 (square metres) and m^3 (cubic metres). A solidus (/) is used to indicate ‘per’. For example, kilometres per hour is abbreviated as km/h, and megalitres per day per square kilometre is $ML/d/km^2$.

Prefixes

G	giga	1,000,000,000
M	mega	1,000,000
k	kilo	1,000
c	centi	0.01
m	milli	0.001
μ	micro	0.000001

Units of Measurement

a	year (annum)
Bq	becquerel (radioactivity)
C	degrees Celsius
d	day
eV	electronvolt (radiation energy)
g	gram
Gy	gray (absorbed radiation dose)
h	hour
ha	hectare
J	joule
K	kelvin
L	litre
m	metre
m^2	square metre(s)
m^3	cubic metre(s)
min	minute
N	newton
pH	degree of alkalinity/acidity
ppm	parts per million
s	second
Sv	sievert (radiation dose)
t	tonne
V	volt
W	watt
yr	year
$	dollar
%	per cent
Pa	pascal

Chemical Symbols and Formulae

^{228}Ac	actinium-228
^{241}Am	americium-241
^{7}Be	beryllium-7
^{14}C	carbon-14
^{36}Cl	chlorine-36
^{137}Cs	caesium-137
CO_2	carbon dioxide
^{60}Co	cobalt-60
^{2}H (or D)	hydrogen-2 (deuterium)
^{3}H (or T)	hydrogen-3 (tritium)
^{166}Ho	holmium-166
^{129}I	iodine-129
^{40}K	potassium-40
^{85}Kr	krypton-85
^{18}O	oxygen-18
^{210}Pb	lead-210
^{210}Po	polonium-210
^{222}Rn	radon-222
^{226}Ra	radium-226
^{228}Ra	radium-228
^{90}Sr	strontium-90
^{230}Th	thorium-230
^{232}Th	thorium-232
^{234}U	uranium-234
^{235}U	uranium-235
^{238}U	uranium-238

Other Abbreviations

δ	difference for isotope I (see permil in Glossary)
$^{0}/_{00}$	permil (see Glossary)
AADT	annual average annual daily traffic
ADF	Australian Defence Force
ADG Code	Australian dangerous goods code 1998
ALARA	as low as reasonably achievable
ANDRA	French National Agency for Radioactive Waste Management
ANSTO	Australian Nuclear Science and Technology Organisation
ANZECC	Australian and New Zealand Environment and Conservation Council
ARDU	Aircraft Research and Development Unit
ARPANS Act	*Australian Radiation Protection and Nuclear Safety Act 1998*
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ARPANSA 2001 Code	*Code of practice for the safe transport of radioactive material (2001)*
AS	Australian Standard
ASSESS	**A S**ystem for **SE**lecting **S**uitable **S**ites (computer-based system used to identify potentially suitable sites for the repository)
ASTEC	Australian Science and Technology Council
bgl	below ground level
BOM	Bureau of Meteorology
#a	geological symbol for Andamooka Limestone
CAMBA	China–Australia Migratory Birds Agreement
CBD	central business district
CPb	geological symbol for Boorthanna Formation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Defence	Department of Defence (Commonwealth)
SA DEH	South Australian Department for Environment and Heritage
DEST	Commonwealth Department of Education, Science and Training
DHS	Department of Human Services (SA)

DISR	(former) Commonwealth Department of Industry, Science and Resources
DPIE	Commonwealth Department of Primary Industries and Energy
DSIN	French Nuclear Safety Authority
DSTO	Defence Science and Technology Organisation
EIS	environmental impact statement
EMA	Emergency Management Australia
EMMP	environmental management and monitoring plan
EMP	environmental management plan
ENSF	engineered near-surface facility
Environment Australia	Commonwealth Department of the Environment and Heritage
EPA	Environment Protection Agency (South Australia)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESD	ecologically sustainable development
FSR	fundamental safety rules
GIS	geographic information system
GPS	global positioning system
GR	geological repository
HAZMAT	hazardous material(s)
HCA	Heritage Clearance Agreement
HDPE	high density polyethylene
HELP	Hydrological Evaluation of Landfill Performance (model)
HIFAR	High Flux Australian Reactor
HRGS	high resolution gamma spectrometry
I	hazard contained within the repository facilities or buildings
IAEA	International Atomic Energy Agency
ICP-MS	inductively coupled plasma mass spectrometry
ICRP	International Commission on Radiation Protection
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for the Conservation of Nature and Natural Resources
Ja	geological symbol for Algebuckina Limestone
JAMBA	Japan–Australia Migratory Birds Agreement
JNFL	Japan Nuclear Fuel Ltd
Kco	geological symbol for the Cadna-owie Formation
Kmb	geological symbol for the Bulldog Shale
MDA	minimal detectable activity
M_L	Richter Local Magnitude (measure of intensity of seismicity)
n.a.	not available
NH	national highway
NHMRC	National Health and Medical Research Council
NHMRC 1992 Code	*Code of practice for the near-surface disposal of radioactive waste in Australia (1992)*
NOHSC	National Occupational Health and Safety Commission
NP&W Act	*National Parks and Wildlife Act 1972* (SA)
NP&WMA Act	*National Parks and Wildlife (Miscellaneous) Amendment Act 2000* (SA)
NRC	Nuclear Regulatory Commission
NRIC	National Resource Information Centre
NRPB	National Radiological Protection Board (UK)

NTS	Nevada Test Site
O	hazard likely to affect the environment outside the repository facilities
OHS	occupational health and safety
PCB	polychlorinated biphenyl
pMC	per cent Modern Carbon
PPK	PPK Environment & Infrastructure
@wc	geological symbol for Corraberra Sandstone
@ws	geological symbol for Simmens Quartzite
QA	quality assurance
RAAF	Royal Australian Air Force
RCC	Regional Consultative Committee
RPO	radiation protection officer
SAHC	South Australian Housing Trust
SD	statistical division
SES	State Emergency Services
SH	state highway
SNSF	simple near surface facility
SSD	statistical subdivision
SST	sea surface temperature
SWIM	soil water infiltration and movement
TDS	total dissolved solids
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
USA	United States of America
WAC	waste acceptance criteria
WHI	Waterloo Hydrologic Ltd
WIR	Woomera Instrumented Range
WMC	WMC Limited (formerly Western Mining Corporation)
WPA	Woomera Prohibited Area

SUMMARY

Summary

Introduction

Most Australians benefit either directly or indirectly from the medical, industrial and scientific use of radioactive materials. This use produces a small amount of radioactive waste, including low level and short-lived intermediate level radioactive waste such as lightly contaminated soil, plastic, paper, laboratory equipment, smoke detectors, exit signs and gauges.

This waste is temporarily stored at more than 100 urban and rural locations around Australia, much of it in buildings that were neither designed nor located for the long-term storage of radioactive material and that are nearing or have reached capacity.

Storage locations include hospitals, research institutions, and industry and government stores. Storing such waste in many locations in non-purpose built facilities potentially poses greater risk to the environment and people than disposing of the material in a national, purpose-built repository where the material can be safely managed and monitored.

The objectives of the national repository are to:

- strengthen Australia's radioactive waste management arrangements by promoting the safe and environmentally sound management of low level and short-lived intermediate level radioactive waste
- provide safe containment of these wastes until the radioactivity has decayed to background levels.

To meet these objectives, it is proposed to construct a national near-surface repository at either the preferred site on the Woomera Prohibited Area (WPA) or either of the two nearby alternative sites.

The facility is not intended for the disposal of radioactive ores from mining. A national store for long-lived intermediate level waste will not be co-located with the national repository, and would be subject to a separate environmental assessment process.

The Proposed Site

One preferred and two alternative sites have been selected for the national repository, following an extensive site selection process. All three sites are located in northern South Australia in a region known as central–north South Australia, approximately 400 km north of Adelaide, between the townships of Woomera and Roxby Downs (Figure 1). The sites are located in stony desert country with sparse saltbush. The extensive site selection process described below identified the preferred and alternative sites.

Site 52a, within the WPA, remains the preferred site following the environmental assessment process. However the alternative Sites 40a and 45a are acceptable sites subject to the implementation of certain additional management procedures.

The Environment Protection and Biodiversity Act

A principal object of the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is to ensure that matters potentially significantly affecting the environment are fully examined and taken into account in decisions made by the Commonwealth Government. Under the Act, an action requires approval from the Minister of Environment and Heritage if it has, will have or is likely to have a significant impact on a matter of national environmental significance.

Matters of national environmental significance are defined under the Act as: World Heritage properties, Ramsar wetlands of international importance, listed threatened species or communities, migratory species protected under international agreements, nuclear actions, or the Commonwealth marine environment. In addition, the Act provides that certain actions taken by the Commonwealth and actions affecting Commonwealth land also require approval under the Act.

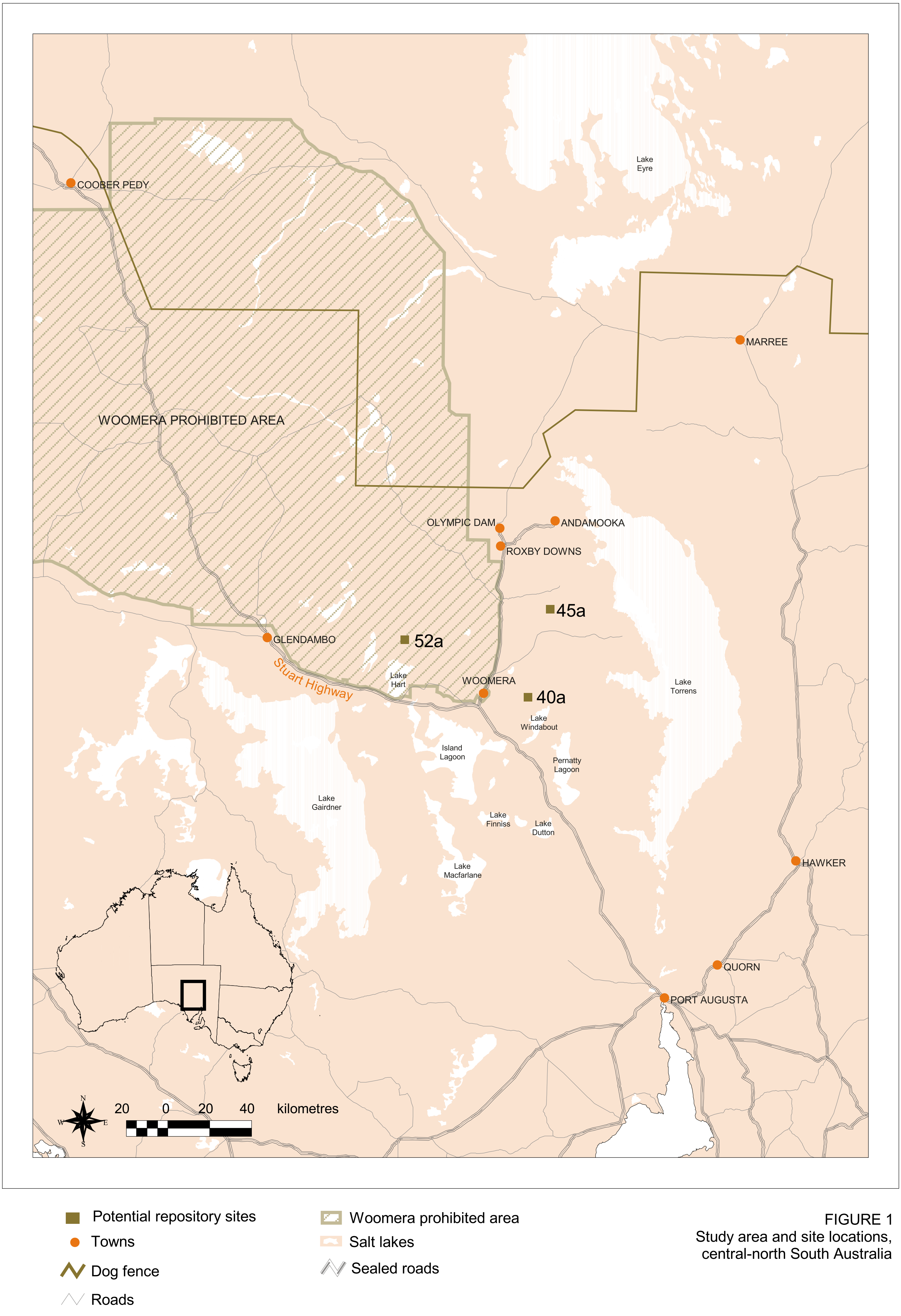


FIGURE 1
Study area and site locations, central-north South Australia

The national repository was determined to require the approval of the Minister for the Environment and Heritage under the EPBC Act, and the proponent (the Department of Education, Science and Training) was requested to prepare an environmental impact statement (EIS) to assist in the decision-making process. Guidelines were prepared by Environment Australia outlining the requirements for the EIS. Figure 2 shows the overall Commonwealth referral, assessment and approval process.

FIGURE 2
An overview of the referral, assessment and approval process

Project Need and Justification

Along with the benefits Australians receive from the medical, research and industrial uses of radioactivity, comes the responsibility for the safe management and disposal of radioactive waste.

Australia's low level and short-lived intermediate level radioactive waste is temporarily stored at more than 100 locations across urban and rural 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 of managing numerous waste storage areas, a national near-surface repository is proposed for the disposal of Australian low level and short-lived intermediate level waste. A national repository represents the safest and most effective option for Australia to manage this type of waste, particularly as the ongoing generation of waste is expected to be relatively small, and therefore technically and economically does not justify the establishment of separate facilities on a state-by-state basis.

Concerns about the possibility of acts of terrorism involving nuclear and radioactive materials have also assumed greater international prominence in the wake of the events of 11 September 2001 in New York City and Washington DC.

A purpose built facility would ensure that management and maintenance complies with Commonwealth government policy and legislation, and is in accordance with international practice and obligations.

Radiation, Radioactive Waste and Waste Management

Radiation

Radiation is the emission and propagation of waves or sub-atomic particles. There are two types of radiation: ionising radiation, so called because it has sufficient energy to 'ionise' matter that it hits, and non-ionising radiation. Ionising radiation includes X-rays and the radiation that comes from radioactive elements, and it has the ability to break the bonds that bind electrons to atoms, thus causing ionisation of the matter through which it passes and damage to living tissue. Non-ionising radiation includes light, heat and radar. The type of radiation associated with radioactive waste is ionising radiation.

Radioactivity

All matter is made up of atoms, some of which are unstable because they have excess energy. Radioactivity is the term used to describe the breakdown of unstable atoms and the associated release of energy, which is in the form of sub-atomic particles or electromagnetic waves. Over time, radioactive material is completely broken down, stable atoms are formed and there is no further release of energy or radiation. The time taken for this decay process is measured in terms of an atom's half-life. One half-life is the time for half of the radioactive atoms to decay to stable atoms. After two half-lives, one quarter of the original radioactive atoms remain. Some radioactive substances have half-lives of less than a second; others have half-lives of thousands and even billions of years.

Radioactivity is a natural part of our Earth and the universe. Naturally occurring radioactive materials are present in the soil and rocks; the floors and walls of our homes, schools and offices; and our food and drink. The radiation from these natural radioactive sources is called background radiation; the amount of background radiation we receive depends on where we live and the types of activities that we are involved in. The higher we are above sea level, the more we are exposed to radioactivity from cosmic radiation. Some soils and rocks, for example granites, are naturally more radioactive than others, and, if we live in areas where these occur, our exposure to background radiation is increased. Some activities, for example air travel and certain medical treatments, increase our exposure to radiation.

The energy emitted from unstable atoms can be released in four forms: alpha (α) particles, beta (β) particles, gamma (γ) radiation and neutrons. Alpha particles are atomic nuclei, and can only travel a few centimetres in air; a sheet of paper or a layer of skin can stop them. Beta particles, which are electrons or positrons, can travel metres in the air and several millimetres into the human body. They can be stopped by a small thickness of light material such as aluminium or plastic sheeting. Gamma rays are very energetic electromagnetic radiation and can pass through the human body. A thick barrier of lead, concrete or water will stop gamma rays. Neutrons are sub-atomic particles that have no electrical charge. On Earth, they are rarely encountered outside the core of a nuclear reactor. A thick barrier of lead, concrete or water can stop them. Figure 3 shows the penetrating power of the various forms of radiation.

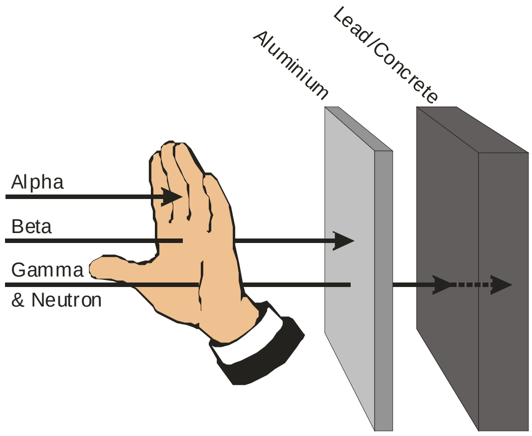


FIGURE 3
Penetrating power of radiation forms

Radiation Doses and Effects

A radiation dose is the measure of how much energy is absorbed when radiation hits body tissue. The different types of radiation (alpha, beta and gamma) have different penetrating power and carry different levels of energy, and therefore have different effects on humans.

Alpha radiation cannot penetrate skin; beta radiation will penetrate skin but will not penetrate far into human tissue (it is often referred to as a 'skin dose'). Thus the effects of alpha and beta radiation are of most significance if radioactive material is taken into the body by inhalation of contaminated dust, or by ingestion of contaminated food or drink. Gamma radiation penetrates most matter and so may be of health significance for both internal and external radiation sources.

The energy that radiation deposits in the body has the ability to break the bonds between atoms. In most cases, these bond breaks do not matter to the functioning of the body, and are either repaired or occur in places where they do no harm. If the break occurs in molecules that control the way a cell works, the cell can stop working, start working in a destructive way that can lead to cancer, or die.

Uses of Radioactivity in Australia

During the past 100 years, radioactive materials have come to be used in a wide range of beneficial medical, industrial, agricultural and environmental applications, including:

- diagnosis and treatment of diseases
- sterilisation of medical supplies and of personal care products
- tracking of pollution
- industrial process monitoring and control, and agricultural monitoring and pest control
- life-saving devices such as smoke detectors.

For most people one of the most important uses of radioactive material is for medical purposes. For example, in 1997–98 alone, some 347,000 patient doses of radiopharmaceuticals were produced by the Lucas Heights research reactor for medical procedures such as cancer diagnosis and treatment, and Australian Nuclear Science and Technology Organisation (ANSTO) estimates that in 2000–01 there were about 525,000 people in Australia who underwent a nuclear medicine procedure for the treatment of medical conditions such as cancer.

Radioactive Waste Classification

Radioactive waste is often broadly categorised as low, intermediate or high level waste. It can also be classified as short-lived or long-lived, depending on the concentration of radionuclides present and the type of radiation emitted.

Low Level Waste

Low level waste contains low levels of short-lived beta and gamma emitting radionuclides and normally very low levels of alpha emitters. Special shielding is not normally required for transport and handling of this material. It includes items such as wrapping materials and discarded protective clothing, and laboratory plant and equipment.

Intermediate Level Waste

Intermediate level waste contains significant levels of beta and gamma emitting radionuclides and could also contain significant levels of alpha emitters. This waste sometimes requires shielding during handling and transport.

Short-lived radioactive materials have a half-life of 30 years or less, and typically include gauges and sealed sources used in industry and medicine, and small items of contaminated equipment.

Long-lived intermediate level waste (often referred to as 'intermediate level waste') generally contains radionuclides that have a half-life of more than 30 years. In Australia, this waste consists of historical waste from mineral sand processing, disused sealed sources and industrial gauges, reactor components, irradiated fuel cladding and conditioned waste from the processing of spent fuel. Long-lived intermediate level waste would not be disposed of in the national repository.

High Level Waste

High level waste contains high levels of beta and gamma radiation emitters and significant levels of alpha emitters. It also generates a significant amount of heat (about the same as an electric kettle). Nuclear power reactors generate high level waste. No high level waste is generated in Australia.

Regulatory Framework

Australia's radioactive waste is managed in accordance with national regulatory requirements and, where applicable, internationally accepted procedures and practices.

International Organisations and Conventions

Australia is an active member of international organisations involved in encouraging the safe use and management of radioactive materials. The International Atomic Energy Agency, of which Australia is a member, has developed a series of Radiation and Waste Safety Standards that are followed by most countries including Australia. The standards identify the basic principles for the regulatory, safety and technical requirements for radioactive waste repositories.

Australia's Regulatory Framework

Each of the states and territories has its own legislation to regulate the use of radioactive materials. In the case of the Commonwealth, in 1999 the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) established the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which regulates the Commonwealth's use of radioactive materials and provides advice on the use and management of radioactive substances. Specifically, ARPANSA is responsible for:

- promoting uniformity of radiation protection and nuclear safety policy and practices across Australia
- providing advice to government and the community on radiation protection and nuclear safety
- undertaking research and providing services for radiation protection, nuclear safety and medical exposure to radiation
- regulating all Commonwealth entities (including departments, agencies and bodies corporate) involved in radiation or nuclear activities or dealings.

Approvals and Licences

Approval is required under the ARPANS Act for each stage of the repository project including siting, construction, operation and decommissioning. Assessment of the licence approval would be subject to the evaluation of detailed plans and arrangements for protection and safety, including the:

- safety management plan
- radiation protection plan
- radioactive waste management plan
- strategies for the decommissioning, disposal or abandoning of the facilities and/or the site
- security plan
- emergency plan for the controlled facility.

The regulatory branch of ARPANSA would review the monitoring results from the repository regularly to ensure its safety and compliance with licence conditions.

Radioactive Waste to be Held in the Repository

One of the key inputs to the design and management of the repository is to accurately define and quantify the types and volumes of low level and short-lived intermediate level radioactive waste to be disposed of at the facility.

Inventory of Existing Waste

Australia has accumulated about 3700 m^3 of radioactive waste from over 40 years of research, medical and industrial uses of radioactive material. Of this total 2010 m^3 is slightly contaminated soil stored near Woomera, which arose from Commonwealth Scientific and Industrial Research Organisation (CSIRO) research into the processing of radioactive ores during the 1950s and 1960s. Another major component is 1320 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. Figure 4 shows waste typical of this last category.

A summary of existing waste is provided in Table 1. Of the total inventory of 3700 m^3, 2228 m^3 (60%) is held in South Australia and, of that, 2010 m^3 is contaminated soil stored at Woomera.

TABLE 1 Summary of inventory of low level and short-lived intermediate level waste by state

State	Estimated volume
South Australia	2,228 $m^{3(1)}$
Victoria	33 m^3
New South Wales	1,335 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 2010 m^3 of contaminated soil stored near Woomera

FIGURE 4
Existing waste

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. Table 2 summarises estimated future low level and short-lived intermediate level waste arisings.

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).

TABLE 2 Summary of estimated future low level and short-lived intermediate level waste arisings

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

Waste Acceptance Criteria

Waste acceptance criteria (WAC) are the set of requirements that must be met before radioactive waste can be accepted for disposal at the repository. The criteria commonly include:

- general conditions for the acceptance of waste
- those materials excluded or treated prior to disposal
- conditions for the preparation of different types of waste
- acceptability of waste containers
- requirements for delivery of waste to the repository
- quality assurance requirements
- information required by the site operator from the consignor.

WAC would be developed for the facility before operations begin.

The Site Selection Process

Site Selection Criteria

In 1992 the National Health and Medical Research Council (NHMRC) released the *Code of practice for the near-surface disposal of radioactive waste in Australia (1992)* (NHMRC 1992 Code). The code includes 13 criteria designed to ensure that the selected site has characteristics that will facilitate appropriate isolation of waste and the long-term stability of the site. The criteria take into account a broad range of social, technical and environmental criteria, including:

- rainfall, potential for flooding and site drainage
- depth to the watertable, and fluctuations in the height of the watertable; suitability of groundwater for other purposes
- geology, geochemical and geotechnical factors
- seismic and volcanic activity
- population density and projected population growth
- potential of the land for other uses, or significant natural resources
- access for transport
- ecological, cultural or historical significance
- land tenure.

The Site Selection Process

The site selection process was undertaken in three phases. The first phase began in 1992 and involved the development of a methodology for site selection. The methodology used a geographic information system called ASSESS to compare a range of geographic factors with the 13 site selection criteria defined in the NHMRC 1992 Code.

The second phase of the process applied the site selection methodology to identify eight broad regions of Australia likely to contain suitable sites (Figure 5). The Great Artesian Basin and the Murray–Darling Basin, being major water resources, were excluded from the search. The central–north region of South Australia was selected as the preferred region. The third phase used the same selection criteria on a smaller scale to identify suitable sites within the central–north region, at which a more detailed drilling program was undertaken.

Description of Repository Facility

A preliminary design layout and an outline of operational concepts is presented below. The details of this concept plan will be further refined during the detail design phase of the project, which will be undertaken before the ARPANSA licensing process.

Design Basis

A multi-barrier approach would be used for the national repository, including physical containment provided by some, or all, of the following:

- the conditioned waste packages
- the waste form
- the trench/borehole design
- the host rocks, arid environment, and groundwater and surface water characteristics of the site.

Operational Usage and Institutional Control Periods

The operating life of the repository is expected to be approximately 50 years, after which there would be a review of operations. The low generation rate of radioactive waste in Australia means that once the existing waste has been disposed of, disposal campaigns would be separated by extended periods (2–5 years) of no disposal. At the end of each disposal campaign, the disposal structure (trench or borehole) would be closed and securely contained to prevent intrusion and minimise the ingress of rainwater.

The institutional control period (once the facility has ceased operations) would be 200 years. At the end of the institutional control period the radioactivity in the disposed waste would have decayed to low enough levels to allow unrestricted land uses.

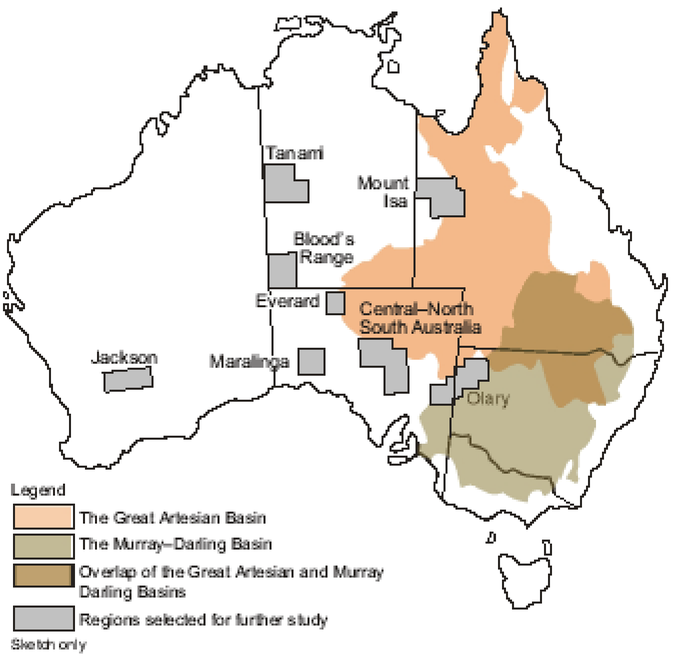


FIGURE 5
Eight regions selected for further study

Repository Layout

The repository would be on a site measuring 1.5 x 1.5 km, with the waste buried in the central 100 x 100 m part of the site in trenches or boreholes (Figure 6).

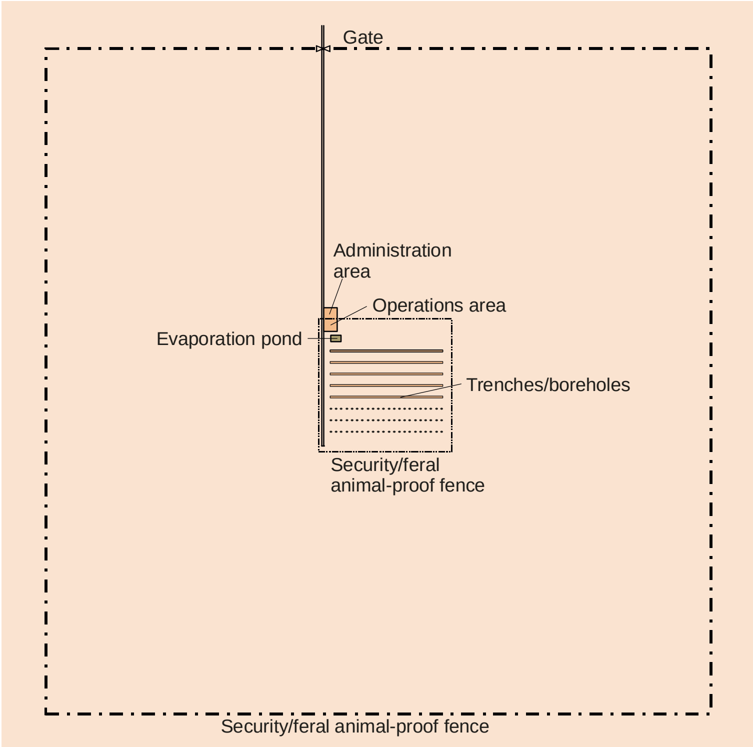


FIGURE 6
Indicative site plan

Trench and Borehole Design

The repository would be designed to meet the licence requirements of ARPANSA, and the performance criteria and safety requirements of the NHMRC 1992 Code. The facility would contain a number of disposal trenches and boreholes, designed and sized to account for the different waste types and the quantities received during operational campaigns.

The trenches are expected to be about 12 m wide at the base to enable adequate construction equipment access and crane reach during unloading operations. Figure 7 shows an indicative design of the trench disposal method. The depth to the base would vary depending upon which site is chosen but is expected to be about 15–20 m below ground level. The sides of the trench would be battered to prevent collapse. The trenches would be ramped at one end to allow access by heavy machinery.

Boreholes would be approximately 2 m in diameter and 15–20 m deep, depending upon the final site chosen. Figure 8 shows an indicative design based on that used for the Mount Walton East repository in Western Australia.

A suitable cover would be placed over the buried waste to limit infiltration of rainwater, discourage entry of animals, plant roots and humans, and inhibit erosion.

The NHMRC 1992 Code requires a 2 m depth of cover for Category A waste and a 5 m cover for Category B waste. For this repository a 5 m cover is proposed for all waste to limit the potential for escape of any radon generated by the waste.

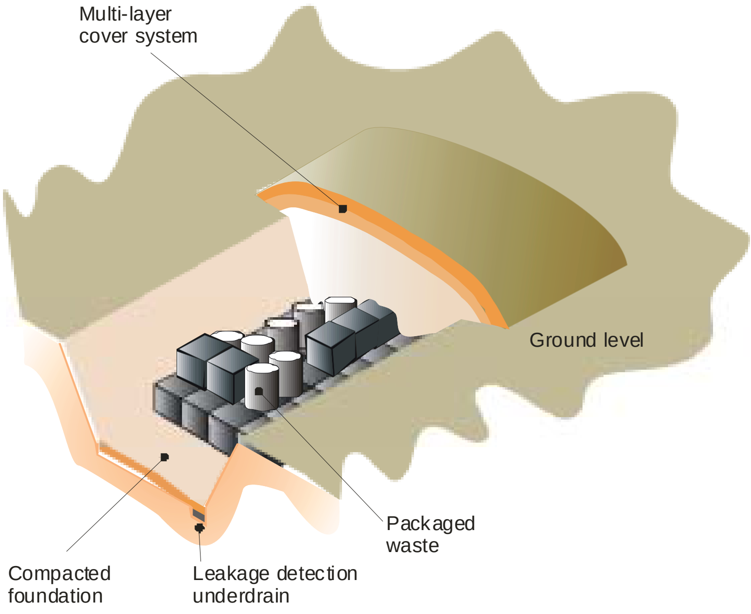


FIGURE 7
Indicative trench design

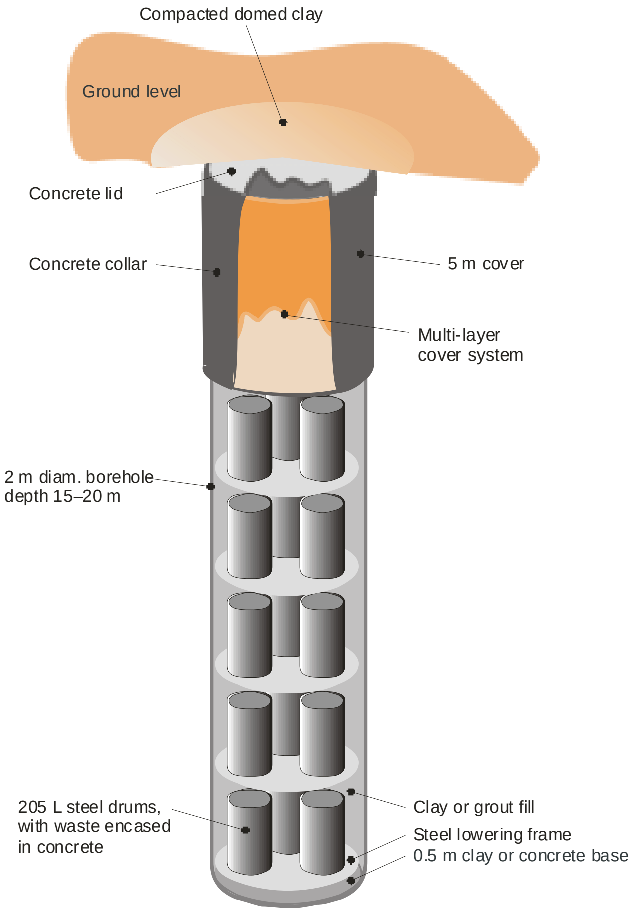


FIGURE 8
Indicative borehole design

Site Support Facilities

The extent of facilities at the site would largely be determined by the facility operator and would depend on a range of factors including the agreed nature of the packaging of arriving waste and the frequency of disposal operations.

The key features of the facilities (Figure 9) to be constructed are expected to include:

- **operations building** — containing facilities for waste receipt, holding, conditioning and retrieval, and a small laboratory for checking incoming waste
- **decontamination/washdown area** — for plant and equipment
- **office and associated facilities** — including administration, emergency services (first aid, health physics, fire), truck lay-by/check-in area, car park, change facilities (including showers)
- **health physics facility** — including clothing store, laundry, male/female showers, and equipment to monitor workers and for radiological surveillance of groundwater and other environmental monitoring
- **services compound** — including electricity, potable water and sanitation, and communication including portable power generators and a small workshop.

Description of Construction Works

The construction work program and first disposal campaign would begin after satisfactory completion of the EIS and ARPANSA licensing processes, including preparation of the detailed design and operating procedures and their approval by ARPANSA. A Commonwealth tender selection process would be used to let the construction works and the operation of the repository.

The initial construction would be expected to take two months, and would involve two main aspects:

- construction of buildings and infrastructure
- excavation of trenches and/or boreholes.

The specific design of the buildings, including preferred materials and colours, would form part of the detailed design process. It is expected that the office facilities would be portable buildings, and operational and storage sheds simple steel and corrugated iron buildings. All construction wastes other than spoil would be required by construction contracts to be removed from site. Spoil would be retained as backfill and for use in construction activities on site.

Description of Operations at the Repository

The main activities associated with operations at the repository would include:

- implementing criteria for acceptance of radioactive waste for disposal at the facility
- implementing a waste recording, documentation and quality assurance system
- planning and preparing waste for disposal
- designing and excavating trenches and boreholes
- transporting radioactive waste to disposal site
- receiving and checking consignment quantities on arrival
- accepting and checking radioactive waste for disposal
- providing short-term storage on site pending disposal
- responding to contamination or damaged packages
- implementing a site security system
- administering procedures for arrival of personnel and visitors on site, and for movement around the site and associated record keeping
- responding to incidents or accidents
- closing the facility between campaigns
- managing work methods for waste disposal operations, including safety procedures
- monitoring environmental radiation

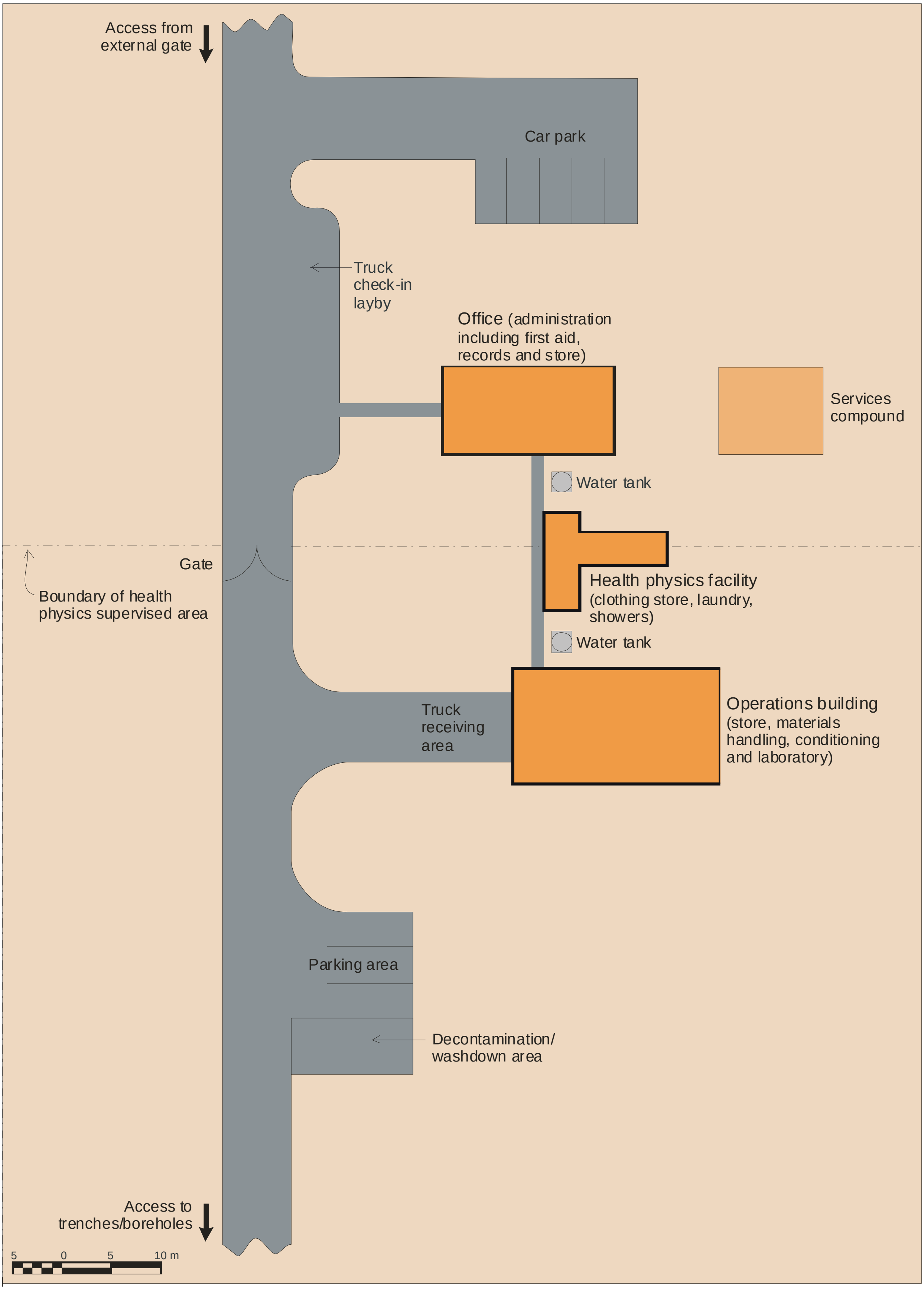


FIGURE 9
Indicative layout administrative and operations area

- capping trench and boreholes
- rehabilitating trench surrounds
- close-out reporting.

The workforce during campaigns would number up to 10 personnel, including an operations manager, health physicist, and operational and security personnel.

The timing of construction and disposal operations at Site 52a would be scheduled so as not to conflict with other uses of the WPA.

Waste holders would be required to arrange disposal of waste at the repository with the facility operator. Details of the waste would be provided to ensure that it is suitable for disposal at the repository and meets the WAC.

Waste packages made of concrete, steel or other suitable material would be placed in layers in the trench by either a crane or a forklift. For borehole disposal a light mobile crane would be used. The location of all packages would be recorded. The waste packages would be designed with adequate strength to enable stacking, and packages would be packed tightly to minimise voids.

Security and Health Safety

A security fence would be constructed around the 1.5 x 1.5 km buffer zone to prevent unauthorised human intrusion and to exclude grazing animals. A security presence would be in place during the initial and subsequent campaigns to ensure the safety of personnel. The site would be monitored for any potential breaches in security between campaigns.

The repository would have a health physics program that would govern all work at the site involving radioactive material. The procedures would cover the conditions for entry to areas where there are radioactive substances, precautions to be taken when working in those areas and the process for decontamination of personnel and equipment.

There would be a variety of general hazards potentially associated with operations at the facility: operational hazards such as excavation, heavy machinery, slip/trip/fall hazards and manual handling, and environmental factors such as lightning, bushfire, noise, heat stress, snakebites and remote locations (access and communication). Appropriate procedures would be developed to address these issues.

Receipt, Recording and Retrieval of Disposed Wastes

All waste packages for disposal would have a unique engraved or raised marking to indicate the batch of waste to which they belong. This would allow a detailed inventory to be kept of all the waste disposed of at the site. Any markings on the package would be designed for longevity and would provide sufficient information to allow identification of the complete contents of the package on reference to the inventory.

Surveillance Periods

During the surveillance periods between disposal campaigns, security would be maintained and environmental monitoring of the site undertaken.

Decommissioning/Closure Phase

The NHMRC 1992 Code contains detailed guidelines for the closure of the disposal facility. Disposal operations at the facility would cease when the authorised disposal space was filled or the authorised limit on total site radioactivity was reached. The estimated initial operational life of the national repository is 50 years, after which time there would be an operational review.

Ownership and Operation

The national repository would be owned by the Commonwealth and regulated by the Commonwealth's independent regulator, ARPANSA. Operations would be undertaken by private contractors, whose performance would be overseen by the responsible Commonwealth department.

Financial Arrangements

Commonwealth policy requires that there would be a charge for disposal of waste in the national repository. Charges would be set to encourage waste minimisation and disposal when no other option, such as recycling, exists. Disposal charges would also be set to encourage waste producers to use the facility, rather than continue to store waste in non-purpose built accommodation or dispose of waste in an inappropriate manner.

Transport of Waste to the Repository

The transport of radioactive substances within Australia routinely takes place for a variety of commercial and industrial applications. Over the past 40 years there have been no accidents in which there has been a significant radiological release harmful to the environment or public health. Shipments of such substances are strictly governed by relevant Australian and international regulations and codes that define how waste should be packaged, which warning signs must be placed on vehicles, and which instructions must be provided to carriers for safe operating procedures.

Transport Modes and Routes

It is expected that the waste material will be transported to the repository by road, as this provides a safe, flexible, secure and cost-effective mode of transport, considering:

- the location of waste at over 100 sites around Australia
- most sites have only small quantities of waste, thus requiring some load consolidation
- trucks have flexible load capacity to facilitate load consolidation at intermediate storage locations
- the need to maintain continuous chain of custody of material during transport.

Although rail offers an inherently lower risk of accidents en route, its main disadvantages relative to road transport include additional handling, more inefficient transport arrangements for the relatively small volumes of material and, in particular, the security of chain of custody when compared with road transport.

Water-borne transport is generally not relevant to the proposed national repository, apart from the specific case of Tasmania from where a small amount of waste would need to be shipped to the mainland. Airborne transport would only be considered where it is a practical alternative, for example possibly for the small quantities of waste from Tasmania.

Possible road routes to the national repository have been identified. Route alternatives were defined between each state and territory and the repository in a hierarchical approach, which sought to maximise the use of national highways, supplemented with state highways. Other secondary roads were only selected where a connection between highways was needed. This approach was designed to reduce the impacts of truck movements on communities along each route.

Figure 10 illustrates the proposed routes to the repository. Where feasible, at least two route alternatives have been defined for each state or territory.

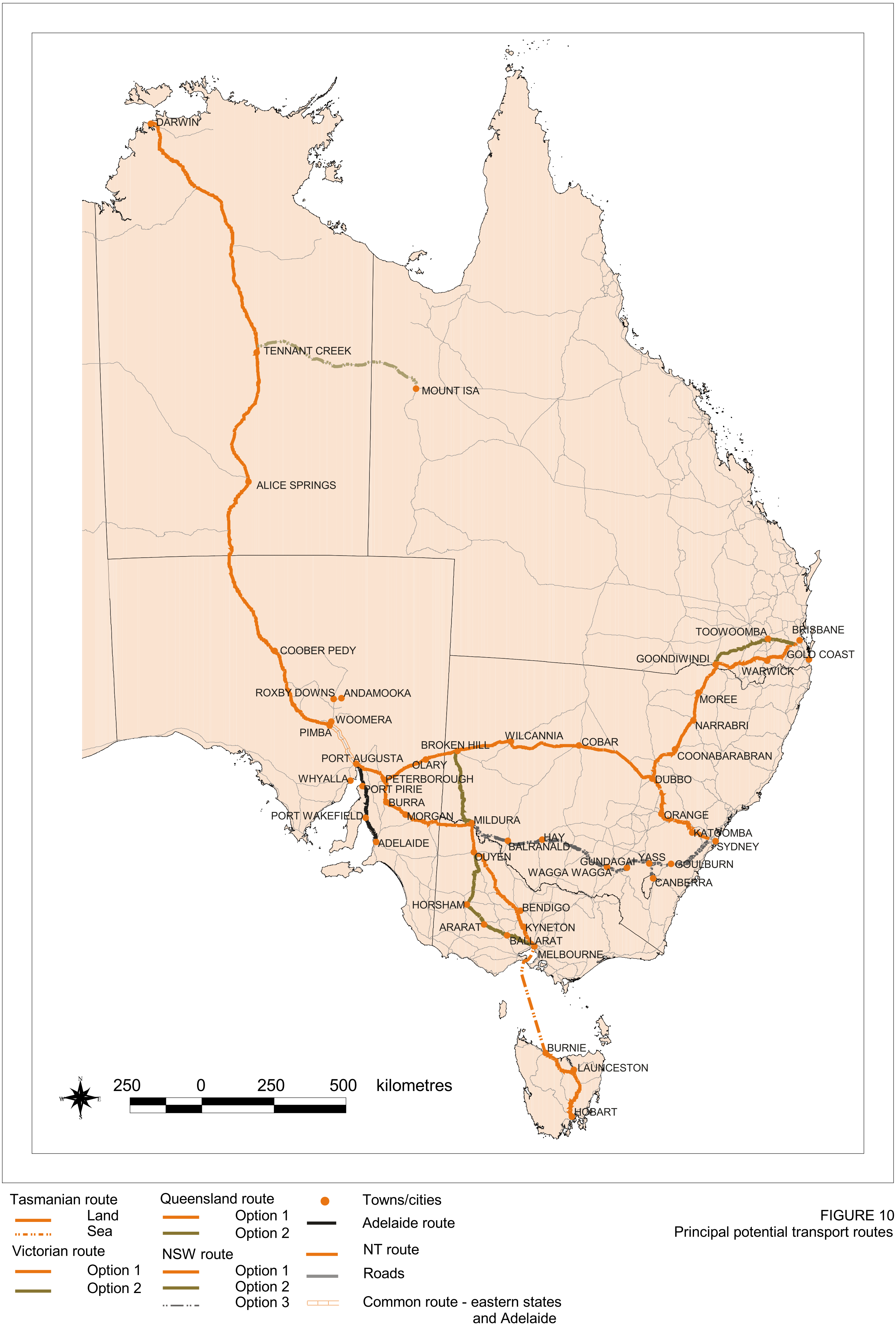


FIGURE 10
Principal potential transport routes

Frequency of Shipments

The total national volume of accumulated waste to be shipped to the repository is low, with conditioned waste estimated to be in the order of 1690 m^3, excluding that already at Woomera. Assuming that this material is packed in 205 L drums, with these drums then being double stacked into standard 6 m shipping containers for transport, the total number of shipments needed to clear the accumulated waste backlog is estimated to be 171 truckloads. This represents a very small number of truck movements over the road network.

Shipments of future waste are also expected to be very low, equivalent to about five 6 m shipping container loads per year nationally. More shipments would be needed to transport decommissioning wastes from ANSTO's research reactors. In practice, transport would be expected to be only for disposal campaigns, which are expected to be every 2–5 years after the initial campaign.

Community Consultation

Communities at selected locations along the proposed route network were consulted through a series of group discussions to seek their views on the transport issues. Representatives in Port Augusta (SA), Mildura (Vic), Broken Hill and Dubbo (NSW) were involved in the process.

The discussions revealed:

- a general low level of knowledge of the repository proposal and the shipments of waste
- concerns about the shipments, mostly over possible accidents and how such accidents might be treated, together with reservations about the potential frequency of shipments.

Generally, the community groups became less concerned about the proposal when key aspects of the transport proposals were outlined to them, in particular that:

- the low levels of accumulated waste nationally meant infrequent shipment
- radioactive materials are shipped daily and routinely in Australia, with an excellent safety record
- packaged waste must conform to codes, and would be designed to prevent dispersal or leakages of radioactive material during accidents
- the waste being transported would be solid and not able to spill in an accident.

Overall, the groups accepted the need for accumulated waste to be transported to a suitable location, and that the transport impacts and associated risks were low. There was a range of responses to the issue of transport of radioactive waste, from people being uninterested, through those who saw that the waste needed to be transported to a suitable location, to those who expressed reluctant acceptance as long as the material was transported safely. Others were more cautious in their response. The Port Augusta group accepted that the transport of radioactive materials, in the form of uranium oxide ore from Olympic Dam to Adelaide, already occurs through the city safely on a regular basis.

Transport Safety

A review of international transport experience confirmed a low likelihood of incidental exposure to radioactive materials as a result of shipments by road. The incidence of accidents has been historically low over a long period. Stringent controls and procedures placed on shipments internationally are largely responsible for this excellent safety record.

The potential for accidents involving trucks carrying waste to the repository was quantified, considering the individual transport routes, numbers of truck movements, historical accident rates and traffic conditions prevailing on the routes. Table 3 summarises the estimates of accidents involving trucks carrying waste. The rate of less than one expected accident when transporting the total accumulated waste inventory indicates a very low accident likelihood.

TABLE 3 Estimates of truck accidents involving trucks carrying waste

Source of waste	Volume of waste (m^3)	No. of waste shipments[1]	Total distance travelled (km)[2]	No. of accidents (in 1 year)[3]
SA/Adelaide [4]	218	22	490	0.004
NT/Darwin	16	2	2,600	0.002
Qld/Brisbane	45	5	2,100	0.011
NSW/Sydney[5]	1,355	136	1,580	0.208
Victoria/Melbourne	33	4	1,290	0.006
Tasmania/Hobart	15	2	1,610	0.003
Total	**1,682**	**171**		**0.234**

(1) Based on 10 m^3 per truck
(2) Rounded
(3) Calculated as a function of the number of truck movements, cumulative distance travelled on each route and the respective route accident rates
(4) Excludes waste material currently stored at Woomera
(5) Includes waste material from the ACT

In the unlikely event of an accident, the solid waste form and multiple packaging for sealed sources (an inner shielded container, the 205 L drum, and finally the 6 m ISO standard container) would help to ensure that radioactive material was not widely distributed around the accident site.

Additional analysis of truck accident potential on the national highway in Port Augusta, which forms a focus of all shipments to the repository except those from Darwin, demonstrated minimal risk.

Emergency Services

All states and territories have in place emergency response plans in case of accidents or incidents involving radioactive (or other hazardous) materials. In most emergency cases, the police, ambulance, fire services and state emergency services are the first responders. In addition, the Commonwealth can provide additional assistance if required.

The state and territory teams have the required level of training, and the protective clothing and equipment, needed to identify the nature of the hazard, and to retrieve material. Resources are located in various country centres around each state, enabling rapid responses to incidents at relatively short notice.

Physical Environment

The preferred and two alternative sites for the national radioactive waste repository are located in the Stuart Shelf geological province, to the west of Lake Torrens in South Australia. This province comprises incomplete sequences of flat-lying marine sediments of the Adelaide Geosyncline, overlying the northeastern part of the Archean Gawler Craton. The northern extension of the shelf is overlain by sediments of the Jurassic/Cretaceous Eromanga Basin, and a thin veneer of younger sediments or in situ deposits (e.g. silcrete or calcrete), which are commonly encountered at the landscape surface.

The Eromanga Basin is the largest and most central of the three depressions that together make up the Great Artesian Basin (the other two, the Carpentaria and Surat Basins, are in Queensland, and Queensland and New South Wales). Eromanga Basin sediments are absent from Sites 40a and 45a, and, where present at Site 52a, are interpreted to be an outlier of the Eromanga Basin. Hydrogeologically the Eromanga Basin sediments, where present in the study area, are part of the Stuart Shelf aquifer system, and there is no known or suspected hydraulic connection of this part of the Eromanga Basin with the Great Artesian Basin aquifers. Figure 11 shows the general geology and the hydrogeological relationships of the region in cross-section. The overall groundwater movement in the area is towards Lake Torrens.

The preferred and two alternative sites have undergone extensive study including drilling investigations in the previous phases of the repository site selection process (see above), as well as further investigation as part of the environmental assessment process. These investigations included a series of hydrological model simulations to assess the potential infiltration of rainwater through various capping and base lining systems, and also modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area.

The various capping and base lining systems included a low permeability clay barrier layer in the cap, low permeability liner at the base of the repository, a homogeneous earthfill cap and a composite barrier layer in the cap (incorporating a geomembrane and low permeability compacted clay).

The assessment indicated rainwater infiltration to be minimal for all cases examined, with the least infiltration through a composite lining system located at the base of the cover layer. The alternative design proposals would be investigated further in the design phase. The benefits or otherwise of installing a coarse cobble layer (rock material from the excavations) as an additional deterrent to burrowing animals would also be assessed.

It was found that the installation of a compacted clay liner at the base of the repository did not significantly alter the percolation rate through the repository. Nevertheless, it is proposed to compact the base of the repository and grade the finished surface to a sump to collect any free water and direct it to a sampling well.

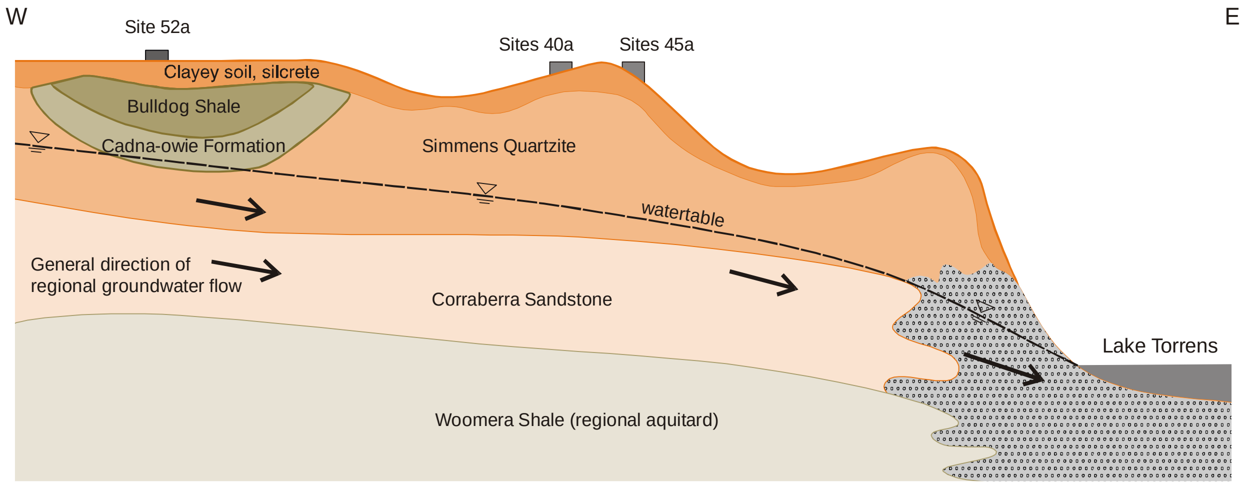


FIGURE 11
Schematic hydrogeological section

The modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area has suggested a transit time in the order of 60,000 years in the presence of vegetation and 6000 years in the absence of vegetation. These residence times are very long compared to the half-lives of typical radionuclides contained in wastes (maximum 30 years).

The adsorption and retardation characteristics of soil and rock samples were also investigated. The majority of radionuclides that would be present in buried waste adsorb to a greater or lesser degree on the surfaces of soil and rock particles, which further slows their movement relative to the already slow movement of water through the unsaturated zone towards the watertable.

The movement of three selected radionuclides through the unsaturated zone was further modelled for Site 52a. Simulations were completed for solute transport from the base of the waste repository during rain and storm periods for up to 100 years.

The modelling results indicate that the amount of solutes originating from the repository reaching the watertable under the conservative scenario of continual low-level seepage for 100 years would be so low as to be, to all practical extents, undetectable. Even if 100% of rainfall and stormwater were to penetrate the repository the amount of solutes reaching the watertable would not be detectable. The natural arid climatic regime of the study region, together with the design and construction of the repository, would provide considerable additional protection for the watertable.

Biological Environment

Flora

The Arcoona Tableland is primarily a treeless plain dominated by low chenopod shrubland. The region has had a long history of grazing by native, domestic and feral herbivores, as well as being subject to the operations and infrastructure of sheep and cattle stations, and the construction and operation of Woomera Rocket Range.

Following a detailed literature review, the field survey for this project was undertaken during August 2001 and coincided with above-average field conditions. Classification of the data collected showed that the vegetation communities of the three sites were relatively homogenous. At lower levels of dissimilarity, minor differences were present (based on slightly different floristic groups). All vegetation communities were in relatively good condition. Figure 12 is a photograph of typical flora at Site 52a.

FIGURE 12
Site 52a

There are no vegetation communities with recognised conservation status at any of the three sites or on the Arcoona Tableland generally. Seven plant species from the Arcoona Tableland have recognised State or national conservation status but none were recorded during the field survey. The two species with a national conservation status, Koch's saltbush (*Atriplex kochiana*) and Arcoona slipper-plant (*Embadium stagnense*) were not recorded during the field survey and are not expected to occur at any of the potential repository sites. *Brachycome eriogana* and *Sclerolaena holtiana* (Holt's bindyi) were not recorded during the August 2001 survey but could occur at any of the three potential repository sites.

Eight per cent of the species recorded during the field survey were identified as being introduced. This figure is slightly lower than the overall figure recorded on the Arcoona Tableland. The low incidence of introduced species is possibly a result of the relatively undisturbed condition of the study sites. Control of introduced species and prevention of the introduction of new species would be a key land management issue at the selected site.

Qualitative vegetation assessments were undertaken along access roads to all three potential sites. Access to Site 52a would cause the fewest environmental problems, while access to Sites 40a and 45a would cause the greatest problems. However, impacts to the biological environment of these latter sites would be minimal if access roads were upgraded within the existing disturbed corridor and using existing materials from this corridor.

Fauna

Results of the field surveys in August and October 2001 reflected exceptional seasonal conditions following well-above-average rainfall during late May and early June.

Canegrass swamp, gilgai and low open chenopod shrubland, the three major habitats that make up the Arcoona Tableland, were assessed. The results of the fauna survey indicated that a diversity of vertebrate and invertebrate species typical of the Arcoona Tableland are present at all three sites. All sites exhibited slight differences in species diversity and abundance.

Site 52a had the greatest faunal diversity (57 species of vertebrates, 8 genera of ants and 17 taxa of spiders), but the lowest mammal diversity, richness and abundance, with two species of small mammals compared to four at the other two sites. Site 45a contained the highest diversity of vertebrates. The assessment recorded 12 reptile species at Site 40a and 13 at each of Sites 45a and 52a. These totals probably underestimate the species diversity and abundance of reptiles in the project area. Figure 13 shows the central bearded dragon, which was found at all three sites.

FIGURE 13
Central bearded dragon

The most abundant mammal species captured for all sites was the striped-faced dunnart (Figure 14); this is consistent with other recent findings for the region. In comparison, the fat-tailed dunnart was the least trapped species; however, this species is widespread within the region. Low bat diversity and abundance (4 species) at each site is consistent with previous surveys in the area. Bird diversity was greatest at Sites 45a and 52a.

European settlement and the introduction of stock and pest species such as European rabbit, red fox and feral cat have changed the assemblage of native species in the Australian arid zone. There are eight introduced mammal species and three species of introduced birds recorded in the region. All contribute to the decline of native species. Providing that suitable management actions are undertaken, key threatening processes would not increase as a result of construction and operation of the waste repository.

Five threatened animal species were recorded within the project area. Of these, the most significant is the plains rat, which is listed as vulnerable under the EPBC Act. It is present at Sites 40a and 45a. The other four species are vagrant or nomadic bird species including Peregrine falcon and Australian bustard. A number of other bird and reptile species are of regional significance and may be of future taxonomic and conservation significance.

FIGURE 14
Striped-faced dunnart

The project's main impacts on the biological environment would be associated with construction. These potentially adverse environmental impacts can be managed or minimised through careful planning and monitoring. Impacts of vegetation clearance on the vegetation communities and habitats would be limited: the area to be cleared is very small in relation to the large distribution of the vegetation communities across the Arcoona Tableland. Development of stock, pest animal and kangaroo-proof fencing around the preferred site and elimination of pest species from within the fenced area would probably make a very useful ecological exclosure and reference area.

Land Use and Activity

The nature of human activity since European settlement at the three sites and in the region has been assessed, particularly for land use and activity, demographics and landscape character. Visual impact, site suitability and the potential for land use conflict now and in the future, have been assessed for the proposed facility.

The proposed facility is considered to be relatively minor in terms of its physical components and infrastructure (e.g. buildings, equipment, roads) particularly when compared to other land uses in the region (e.g. Olympic Dam). Similarly, over the life of the facility, the level of activity that it is likely to generate is considered to be relatively low.

The 100 x 100 m disposal area would be enclosed in a 1.5 x 1.5 km site, which would provide an extensive buffer and separate the operation from potentially incompatible land uses now and in the future. Security fencing would prevent unauthorised intrusion into the repository site.

The South Australian Government's Draft Planning Strategy for the region fundamentally acknowledges the existing land use activities but new land use activities are not specifically envisaged. Mining, defence and aerospace activities (including their support industries) are considered the key areas for potential economic growth and future development. Tourism (based on adventure, four-wheel drive, heritage and Aboriginal culture themes) is also considered a potential growth area. The strategic emphasis for rangeland grazing is one of adjusting practices to achieve a greater level of sustainability.

The location of the repository within the Woomera Instrumented Range (WIR) presents a small risk that a missile fired at a target within the WIR, most particularly at the Range E target, could strike the repository site. Smaller, low velocity projectiles can be expected to fragment on impact, with limited ground penetration, and damage only surface features or structures. However, larger or higher velocity weapons may strike with sufficient kinetic energy to penetrate the 5 m soil cover of the waste.

An assessment of the risk of such an occurrence — using US Department of Defense methodology, which considers 'the management of environmental, safety and health mishap risks encountered during the development, test, production, use and disposal of government systems, subsystems, equipment and facilities' — concluded that the mishap probability is Remote, the mishap severity is Marginal and the risk category is Medium, which is the second lowest risk category presented by the relevant standard. Risk mitigation measures would reduce the risk to a risk category of Low.

For land use and activity, Site 52a is considered to be the preferred site with respect to land use and activity for the following main reasons:

- Access to the WPA is already restricted, which would assist in addressing the potential for unauthorised intrusion.
- The visual impact of the proposed facility, its buildings and infrastructure, is considered to be minimal given that the landscape within the WPA is already characterised by a range of buildings, towers and other infrastructure.

Developing the facility at Site 40a or 45a would raise some concerns about the:

- need to upgrade road access, which may also improve public access to sensitive and fragile environments
- introduction of a new visual element and land use into predominantly pastoral areas.

The management of peak traffic generation during the construction stage would be important to avoid conflict with local peak traffic times. Sensitive design of permanent structures at the facility would minimise the visual impact and the proposed buffer is likely to minimise potential conflict with adjacent land uses. The timing of construction and disposal activities could be scheduled so as not to coincide with other uses of the WPA.

Cultural Heritage

Aboriginal

Results of the Work Area Clearance Surveys

The relevant Aboriginal groups have cleared the preferred site and two alternatives, and the access to them, for all works associated with the construction and operation of a waste repository. Certain conditions have been placed on these clearances. In undertaking their clearance work, all groups were concerned principally with ensuring that areas that were of cultural, social or spiritual significance to them were not adversely impacted to an unacceptable degree. Archaeological materials and sites were generally treated more peripherally.

No archaeological constraints to any of the three proposed repository areas were identified during the work area clearances. Part of the access track to Site 40a had extensive but sparse scatters of archaeological material and it was recommended that management strategies be formulated to minimise damage to and interference with this material.

Geomorphological Assessment

In order to provide more detailed information for planning and design purposes, a geomorphological assessment was made of the terrain of the three sites and their potential access routes. This assessment was undertaken to ensure that there are no landforms of high archaeological potential such as sand dunes, major water-holding claypans and canegrass swamps and creeks, or major rock outcrops that would be affected by the proposed development. It was confirmed that none of the three potential sites has archaeological constraints.

Sites 40a and 45a have extremely low background scatters of stone artefacts and their archaeological potential is low to negligible. Site 52a has a few quartzite flaking floors which can be avoided by the proposed activities of the repository, and a widespread background scatter of artefacts. Extensive but sparse scatters of stone artefacts associated with creeks were confirmed along parts of the access track to Site 40a. Sparse scatters of stone artefacts occur in the dunefield section of the access track to Site 45a.

Management Requirements

The Work Area Clearance Report prepared by the Antakirinja, Barngala and Kokotha claimant groups made specific recommendations on access to each of the three potential repository sites.

The proponent has noted these conditions and the proposals for accessing these three repository sites during the construction and operation phases incorporate commitments to use the existing access roads and tracks cleared by the various groups and, in the case of Site 40a, the potential new access track route defined by the Antakirinja, Barngala and Kokotha claimant groups.

Provided these conditions are adhered to, there should be no risks to cultural heritage sites and values of the land. The quartzite knapping floors at Site 52a are located away from proposed construction and operations areas and would be protected in accordance with management measures presented in the repository's environmental management and monitoring plan (EMMP). If the access road to Site 45a through the dunefield section requires road works with the potential to affect archaeological sites, then archaeological investigations and monitoring would be undertaken in accordance with the requirements of the EMMP.

European Heritage

Early Exploration

Edward John Eyre (1839) and John Horrocks (1846) reported that the region was desolate, which deterred initial development. Explorers in this area in the 1850s generally used a route immediately west of Lake Torrens. These explorers included BH Babbage (1853, 1858), Swinden (1857), Warburton (1858) and John McDouall Stuart (three major expeditions).

Pastoral Expansion and Historical Land Use

Pastoral activities began in South Australia in the 1830s, with licences issued to those wishing to use land for pastoralism. In 1851 the government introduced 14-year pastoral leases for Crown Land, which increased security for pastoralists. The definition and expansion of cropping and pastoral lands was considerably influenced by Goyder. By 1864 the northern edge of the pastoral expansion extended to the shores of Lake Eyre. Since the 1880s there have been many changes in the ownership and boundaries of pastoral leases in the area.

The development of the pastoral industry for sheep was aided by the construction of the dog fence (Figure 1) which extends from western Queensland to the Head of the Bight in South Australia. Pastoralism is the dominant land use in the region, with sheep grazing remaining the major pastoral activity on the Arcoona Tableland.

The first South Australian Pastoral Act was introduced in 1893. The *Pastoral Land Management and Conservation Act 1989* and the *Soil Conservation and Land Care Act 1989*, established a legislative framework to manage the pastoral lands. All of the project area is within the Kingoonya Soil Conservation District and is covered by the Soil Conservation Plan for the district.

Woomera Prohibited Area

Following World War II Great Britain sought to develop a facility for weapons research and testing. A 480,000 km^2 area north of Adelaide was chosen and the Long Range Weapons Organisation was established in 1947 as a joint venture between the British and Australian governments to undertake the firing, observation and recovery of long-range weapons.

Facilities developed for the rocket range included airfields, road and water reticulation networks, telecommunications, launch facilities, and a 132 kV transmission line and water supply pipeline. Personnel were accommodated in a purpose-built town, Woomera.

Eight of the nine independent and subsidiary live firing ranges initially established had closed by 1957. Resources were then concentrated on one main range, Range E, a world class facility for weapons testing.

Many short and long range weapons and research vehicles were completed and tested at the WPA, with the first missile launched almost two years after the establishment of the joint venture. During the 1960s, and subsequently, the functions of the WPA became less focused on weapons, and began to include research on a wide range of subjects, including satellite launches and deep space research.

The prohibited area now comprises a much smaller portion (127,800 km^2) of the original WPA.

Site 52a is located in WPA, approximately 10 km west-southwest of the Range E range head. Sites 40a and 45a are to the east of the eastern edge of the WPA.

Items of Heritage Value

No items of European heritage value for the project area are listed on the Australian Heritage Places Index. John Henry Davies' grave and the Philip Ponds Homestead are sign-posted as sites of local interest along the Woomera to Roxby Downs road.

Radiation

The existing background radiation at the sites has been evaluated from a series of measurements of radionuclide concentrations in the soil (both surface and underground), air, groundwater, plants and animals. All of these measurements indicate that the levels observed are typical of the region. There are no unusually high values of either naturally occurring radionuclides (e.g. uranium or thorium) or artificial radionuclides (e.g. caesium-137 from weapons testing). The natural background radiation would be the baseline against which the environmental monitoring program of the repository would be judged.

Initial construction of the repository trench would require that the excavation workers be exposed to the natural levels of radiation at the site. The radiological impact for this work has been assessed and found to be very low, at about 20 µSv, which is a very small addition to the average background radiation exposure in Australia of 2 mSv/yr. Should subsequent excavation be required at the site for future disposal campaigns in a trench adjacent to that where waste had previously been disposed, there would be an additional risk that construction workers might inadvertently expose the previously buried wastes. However, appropriate design and management controls would mitigate this risk. The construction of a borehole would result in lower levels of exposure to radiation than the construction of a trench.

During operation of the repository, radioactive waste would be brought to the site in an approved waste form and using approved waste packages. The packages would be assayed in accordance with a validation program to confirm compliance with the WAC. The waste would then be disposed of in the trench. There would be no operation at the site that involved the opening of these packages or the direct handling of radioactive materials. There would therefore be no routine radioactive discharges from the site.

All operations at the site would be conducted under a radiological protection regime consistent with the regulatory requirements and worker exposures would be as low as reasonably achievable (ALARA) and within the relevant dose constraints. There would be facilities at the site for the repackaging of waste, and some conditioning, if required.

Various potential accident scenarios in the operational/closure phase of the repository have been considered in some detail. One is the potential radiological impact resulting from a missile or aircraft crashing into the site from the nearby Woomera testing range. The assessment shows that the highest radiation exposures would be to a recovery team which, unaware of the fact that the repository had been hit, began their operations without taking any precautions and without any radiation protection supervision. The potential doses in such a case are of the order of a few mSv, which is well within the annual dose limit for a classified radiation worker (20 mSv per year averaged over 5 years).

After the wastes have been disposed of, and the trenches (or boreholes) capped, the repository area would be monitored and access controlled for a 200-year institutional period. During this period any release of radioactivity from the site would be detected and remediated if required.

In future years, when the repository site is no longer under institutional control and the waste form and waste packages have degraded, radioactivity could be released to the environment through a number of pathways. This aspect of the repository lifecycle has been considered in some detail. The potential pathways by which radionuclides may be released to the environment are discussed. The radiological impacts from such releases have been assessed. The scenarios and release pathways considered include:

- radioactive gaseous discharges and exposures to people living in dwellings over the repository site
- releases to groundwater through infiltration of rainwater and dissolution of the waste
- the effects of drilling and examination of borehole cores
- bulk excavation at the site
- the effects of building a road that runs across the repository
- the effects of archaeological digging at the site
- the longer term effects arising from exposure to excavated materials
- the effects of a rocket crash from the nearby Woomera test site
- the effects of an aircraft crash onto the repository site
- the effects of a transition to a wetter climate state
- the effects of a gross erosional event
- the effects of site flooding in the wetter climate state
- the effects of consuming contaminated waters obtained from a well drilled through the wastes
- the recovery of some of the more active sources or artefacts disposed of in the repository from the excavated materials.

The radionuclides that contribute most to radiation exposure in these scenarios are americium-241, caesium-137 (for source recovery only) and uranium-238 and its daughters, radium-226 and polonium-210. The inventory used for these assessments was based on the amount of radioactive waste identified as suitable for surface disposal using generic assumptions at the present time and assumptions about future arisings. The most significant postulated scenarios in terms of exposure are those of gas migration into a dwelling built on the repository site and recovery of the more active sources from the waste.

The conclusion from these assessments is that the risks are very low, and within the risk target value, for all of the scenarios other than major climate changes and gross erosional events. Where these major changes have been assumed to occur, the risks are only slightly higher than the risk target. However, computer modelling by CSIRO indicates that a transition to a wetter climate in the Woomera area is unlikely to occur in the next 10,000 years.

The total radionuclide inventory (both for bulk material and for individual sources), that would be acceptable for disposal at the repository would be determined by the Commonwealth's independent regulator, ARPANSA. ARPANSA would take into account the exact location of the site, the detailed repository design and the acceptance and verification of the scenarios and assumptions used in the risk assessments.

The radiation assessments are equally applicable to all three of the candidate sites. Overall it has been shown that the risks which might arise in future years, when the site is no longer under institutional control, are acceptably low and are in accordance with the NHMRC 1992 Code.

Environmental Management and Monitoring

An EMMP is required for operations at the national repository, covering both general environmental issues and the specific legislative requirements for radiation and near surface repositories. Development of the EMMP would take into account issues and responses raised in the EIS process, as well as formal regulatory requirements.

The general aims of the EMMP would be to establish:

- management processes and procedures that would ensure environmental impacts are minimised during construction, operation, surveillance and decommissioning
- ongoing monitoring (Figure 15) and reporting processes to evaluate any impacts of the operation on the surrounding environment
- audit processes for checking the implementation and effectiveness of management and monitoring systems.

FIGURE 15
Radiation monitoring

Proposed management and monitoring strategies broadly address the following areas:

- physical environment (Figure 16)
  - surface water runoff, soil erosion and siltation of watercourses
  - dust generation
  - noise
  - release of pollutants to soil, surface water or groundwater
- biological
  - potential for introduction of weeds
  - damage/removal of native vegetation
  - threatened species
  - off-road driving
  - loss of fauna
  - loss of habitat
  - increased competition for resources
  - pest species
- radiation
- land use planning conflicts
- consultation with Aboriginal groups.

FIGURE 16
Nevada test site repository, USA

Conclusions

Conclusions of the Assessment Process

1. A national repository is required to dispose of Australia's accumulated and expected future low level and short-lived intermediate level radioactive waste. Without a national repository, radioactive waste would continue to be stored in over 100 sites around Australia largely in facilities that were not purpose built. This poses potential public health and safety risks, including possible theft or misuse by terrorists. Alternatively, each state and territory would need to establish its own repository for a very small quantity of waste, which would be an inefficient and unnecessary use of resources.

2. The investigation process has been comprehensive and the consultation process extensive, extending over a total period of some 10 years.

3. The regulatory process in place is in accordance with accepted international practice, and the approval and licensing process is both comprehensive and rigorous.

4. The design of the proposed repository is in accordance with applicable national standards and codes of practice, as well as accepted international practice.

5. Transport of waste to the proposed repository would be in accordance with relevant Australian and international regulations and codes. The proposed mode of transport, principally by truck, is the preferred means of transport. The risk of an accident during transport is low. The solid waste would be packaged in accordance with the relevant codes and regulations. The waste would be confined by three levels of containment and, in the event of an accident, the package could simply be removed from the scene.

6. Hydrological model simulations indicated rainwater infiltration was minimal for all cases examined, with the least infiltration experienced using a composite lining system located at the base of the cover layer. The modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area has suggested a transit time in the order of 60,000 years in the presence of vegetation and 6000 years in the absence of vegetation. These residence times are very long compared to the half-lives of key radionuclides in typical wastes (e.g. caesium-137, 30 years).

7. Additional modelling of the movement of three selected radionuclides through the unsaturated zone undertaken for Site 52a has indicated that the amount of solutes originating from the repository reaching the watertable under the modelled, conservative scenario of continual low-level seepage for 100 years would be so low as to be, to all practical extent, undetectable at the watertable. The same conclusion is reached for Sites 40a and 45a, which have a deeper watertable, thus compensating for the absence of low-permeability shale. The natural arid climatic regime of the study region, together with the design and construction of the repository, would provide considerable additional protection for the watertable.

8. The preferred and two alternative potential repository sites lie within the Arcoona Tableland, which has been recognised as a distinct land system, the Arcoona land system. Site 52a would have the least potential biological impact; in particular as only minimal road construction works would be required. However Sites 40a and 45a are acceptable subject to implementation of suitable management procedures.

9. The proposed repository is consistent with the existing land use. The existing use includes the storage of radioactive waste, and presently over half the current inventory of waste (2010 m^3 of slightly contaminated soil compared with the total of 3700 m^3 requiring disposal) is stored within the WPA. A risk assessment using US Department of Defense methodology concluded that the risk associated with the use of the WIR was Medium, the second lowest category, and that risk mitigation measures could reduce the risk to a risk category of Low. The timing of construction and disposal activities could be scheduled so as not to coincide with other uses of the WPA.

10. No archaeological constraints with any of the three proposed repository areas were identified during the work area clearances. All sites had a low background scatter of stone artefacts. The quartzite flaking floors identified on Site 52a would be avoided. Part of the access tracks to Sites 40a and 45a have scatters of archaeological material and it was recommended that management strategies be formulated to minimise damage to and interference with this material.

11. No items of European heritage value for the project area are listed on the Australian Heritage Places Index. No impact on items of European heritage is predicted.

12. Overall, it has been shown that the radiation risks during construction and operation, and those that might arise in future years when the site is no longer under institutional control, are acceptably low and are in accordance with the NHMRC 1992 Code.

13. An EMMP would be prepared for both construction and operations at the repository, covering the general environmental issues and also the specific legislative requirements in relation to radiation and near surface repositories. Development of the EMMP would take into account issues and responses raised in the EIS process, as well as formal regulatory requirements.

Comparison of Sites

A comparison of the individual sites is also provided in order to determine if the preferred site as identified following the previous phases of the site selection process remains the preferred site after the environmental assessment process.

The key advantages and disadvantages of the preferred and two alternative sites are summarised in Table 4.

TABLE 4 Advantages and disadvantages of the preferred and two alternative sites

Potential issue	Site 52a (preferred)	Site 40a (alternative)	Site 45a (alternative)
Construction	Need to coordinate with Defence use of WPA	Access road upgrade required prior to works (see below)	Access road upgrade required prior to works (see below)
Operation	Need to coordinate with Defence use of WPA	No significant issue identified	No significant issue identified
Access roads from Woomera	Good access using existing roads; 1.5 km requires minor upgrade	Requires 35.5 km of road upgrade construction through sensitive environment	Requires 12.5 km of road upgrade construction
Transport of waste to site	No significant issue identified; approx half the waste is presently 10 km from Site 52a	No significant issue identified	No significant issue identified
Geology	No significant issue identified; mud and siltstones on site provide better fill and cover characteristics than Sites 40a and 45a	No significant issue identified; may require blasting during construction	No significant issue identified; may require blasting during construction
Hydrology and hydrogeology	Presence of shale provides lower permeability material for trench base; favourable surface drainage features	Greatest depth to groundwater; large canegrass swamp near the site	Depth to groundwater intermediate compared with other two sites; favourable surface drainage features
Biology	No significant issue identified; this site has least biological impact	No significant issue identified; 35.5 km of road upgrade construction required	Site has high biodiversity; 12.5 km of road upgrade construction required
Land use (including activities on WPA)	Limited impact on WPA activities and pastoral usage	Limited impact on pastoral usage	Limited impact on pastoral usage
Heritage	Two knapping floors to be avoided on the site	Potential archaeological sites to be avoided during access road upgrade	Potential archaeological sites to be avoided during access road upgrade
Radiation	No significant issue identified	No significant issue identified	No significant issue identified
Security	Good; in Commonwealth protected area (WPA)	Requires more security measures than 52a	Requires more security measures than with 52a

Site 52a, within the WPA, remains the preferred site following the environmental assessment process. It has good existing access and superior security compared with the two alternative sites. The presence of shale provides the availability of lower permeability material for the trench base, and it has favourable surface drainage features. Its main disadvantage compared with the two alternative sites is its potential impact on activities within the WPA. However, the assessment has indicated that any such impacts can be managed.

The alternative Sites 40a and 45a remain as acceptable sites subject to the implementation of certain additional management procedures. These procedures relate to site security, and to construction and operational management to protect possible archaeological sites along the access road to Site 40a, and to protect biodiversity at Site 45a.

Site 45a has a significantly shorter length of required road construction than Site 40a; also the required road construction for Site 40a passes through areas of greater environmental and heritage sensitivity than for 45a. Site 45a has a higher biodiversity than Site 40a in terms of vertebrates and birds, although the footprint of the repository is small. Overall, of the alternative sites, Site 45a would be preferred over 40a, but both remain acceptable alternatives.

PART A

Introduction & Background

Chapter 1
INTRODUCTION

Chapter 2
RADIOACTIVITY

Chapter 3
REGULATORY FRAMEWORK

Chapter 1
Introduction

Most Australians benefit either directly or indirectly from the medical, industrial and scientific use of radioactive materials. But this use generates a small amount of radioactive waste including lightly contaminated soil, plastic, paper, laboratory equipment, smoke detectors, exit signs and gauges.

Australia's radioactive waste is temporarily stored at more than 100 urban and rural locations around Australia, much of it in buildings that were not designed for the long-term storage of radioactive material and that are nearing or have reached capacity. Storage locations include hospitals, research institutions, industry and government stores. Storing waste in many locations in non-purpose built facilities potentially poses greater risk to the environment and people than disposing of the material in a national, purpose-built repository where the material can be safely managed and monitored.

It is internationally accepted practice that low level and short-lived intermediate level radioactive waste be disposed of in near-surface repositories, and more than 100 repositories for this type of waste are either operating or are in the process of being established in over 30 countries.

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 for Australia's low level and short-lived intermediate level radioactive waste. The committee's decision recognised that, for the small amount of radioactive waste that Australia has, it would be technically and economically inefficient for each jurisdiction to establish its own disposal facility.

The committee reported that most of Australia's radioactive waste is suitable for near-surface disposal at a specially selected site. In 1992, the Commonwealth Government, supported by the states and territories, began an Australia-wide search for a suitable site for the disposal of Australia's low level and short-lived intermediate level radioactive waste. In January 2001, following extensive scientific investigation and community consultation, the then Minister for Industry, Science and Resources, Senator Nick Minchin, announced a preferred site and two alternatives for the national repository in central–north South Australia.

The location of the preferred site, 52a, and the two alternative sites, 40a and 45a, is shown in Figure 1.1.

The proposal to establish the national repository was referred to the then Minister for the Environment and Heritage, Senator Robert Hill, under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), who stipulated that an environmental impact statement (EIS) should be prepared on the proposal for assessment under the EPBC Act.

The Department of the Environment and Heritage (Environment Australia) subsequently developed the guidelines (or terms of reference) for preparing the EIS, after taking public comment into consideration. The final guidelines were released on 26 June 2001.

The Commonwealth, through the Department of Education, Science and Training (DEST), is the proponent under the EPBC Act for the proposal to construct and operate a national repository for Australia's low level and short-lived intermediate level radioactive waste. The department is responsible for preparing the EIS in line with the guidelines, to provide the Minister for the Environment and Heritage with the basis for making a decision on the proposal. In July 2001 the Commonwealth, through the former Department of Industry, Science and Resources (DISR), appointed PPK Environment & Infrastructure (PPK) in association with Halliburton KBR to prepare the EIS. After the 2001 federal election, responsibility for the national repository project was transferred to DEST.

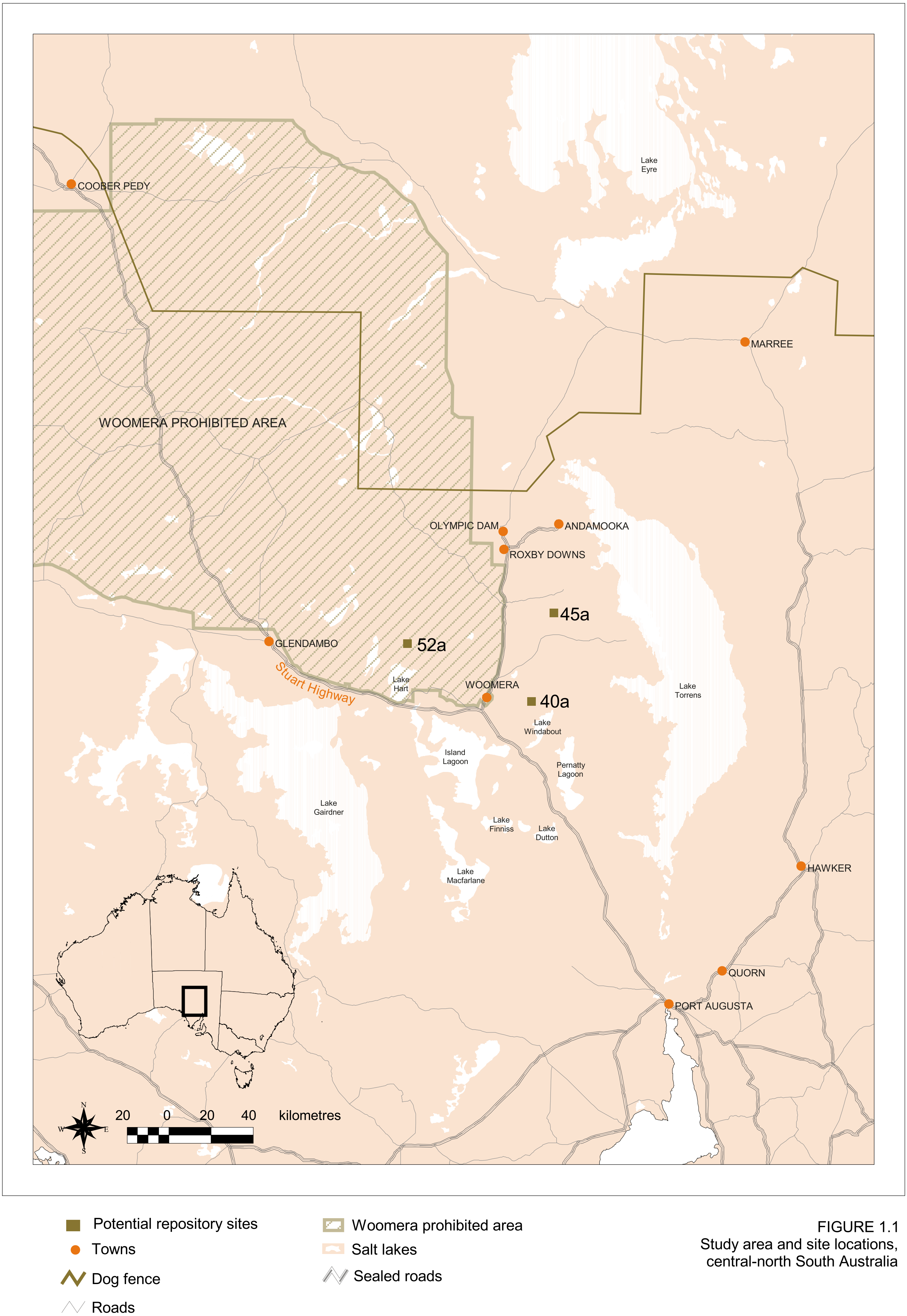


FIGURE 1.1
Study area and site locations, central-north South Australia

1.1 Objectives of the Proposal

The objectives of the national radioactive waste repository project are to:

- strengthen Australia's radioactive waste management arrangements by promoting the safe and environmentally sound management of Australian low level and short-lived intermediate level radioactive waste by establishing a purpose built, near-surface repository
- provide safe containment of radioactive wastes until the radioactivity has decayed to background levels.

To meet these objectives, it is proposed to construct a near-surface repository at the preferred site, or at one of the two alternatives, in central–north South Australia, for the disposal of Australian low level and short-lived intermediate level waste generated from the medical, research and industrial uses of radioactive materials.

The repository would be constructed and operated in accordance with Commonwealth regulations by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), and in a manner that meets all health, safety, environmental and quality standards. The construction and operation would also be consistent with 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), other relevant codes, legislation and guidelines, and accepted international practice (including International Atomic Energy Agency (IAEA) Safety Standards Series *Near surface disposal of radioactive waste*, WS-R-1 (1999) and *Safety assessment for near surface disposal of radioactive waste*, WS-G-1.1 (1998) and the IAEA Safety Series *Siting of near surface disposal facilities 111-G-3.1* (1994)).

The facility is not intended for the disposal of naturally occurring radioactive waste from mining or mineral processing. Radioactive waste from the mining and processing of uranium ores and heavy mineral sands is disposed of in accordance with the national *Code of practice on the management of radioactive wastes from the mining and milling of radioactive ores* (Department of the Arts, Sport, the Environment, Tourism and Territories 1982) or as is otherwise provided for in the legislation of individual jurisdictions. This type of waste is usually generated in bulk quantities and is disposed of at or near the relevant mine or processing site.

A national store for long-lived intermediate level waste will not be co-located with the national repository. A separate nationwide search, announced by the Minister for Industry, Science and Resources in August 2000 and February 2001, has begun to identify a site on Commonwealth land for a national store for long-lived intermediate level waste produced by Commonwealth agencies. The Minister ruled out co-location of the store for intermediate level waste on the same site as the repository for low level waste in South Australia, to avoid any suggestion that the two processes are not completely separate.

Australia does not produce high level radioactive waste and will not accept the nuclear wastes of other countries for storage or disposal in Australia. The Government's position is based on the principle that countries deriving benefits from nuclear applications should expect to make their own arrangements to safely dispose of their nuclear waste. This has been the policy of successive Australian governments.

1.2 Environmental Assessment under the EPBC Act

1.2.1 Application of the Act

The EPBC Act, which came into force on 16 July 2000, has the object to ensure that matters potentially significantly affecting the environment are fully examined and taken into account in decisions by the Commonwealth Government.

The term 'environment' refers to all aspects of the surroundings of human beings, whether they affect human beings as individuals or in social groupings. The term includes the natural environment, the built environment and social aspects of our surroundings. The definition covers such factors as air, water, soils, flora, fauna, buildings, roads, hazards and risks, and human safety.

Under the EPBC Act an action will require approval from the Minister for the Environment and Heritage if the action has, will have or is likely to have a significant impact on a matter of national environmental significance. Matters of national environmental significance are defined by the Act as:

- World Heritage properties
- Ramsar wetlands of international importance
- listed threatened species and communities
- migratory species protected under international agreements
- nuclear actions
- the Commonwealth marine environment.

The criteria for determining whether or not the proposed action is of national environmental significance are listed below.

Extinct in the Wild Species Criteria

An action has, will have or is likely to have a significant impact on extinct in the wild species if it does, will or is likely to:

- adversely affect a captive or propagated population or one recently introduced/ reintroduced to the wild, or
- interfere with the recovery of the species or its reintroduction to the wild.

Critically Endangered and Endangered Species Criteria

An action has, will have or is likely to have a significant impact on a critically endangered or endangered species if it does, will or is likely to:

- lead to a long-term decrease in the size of a population, or
- reduce the area of occupancy of the species, or
- fragment an existing population into two or more populations, or
- adversely affect habitat critical to the survival of the species, or
- disrupt the breeding cycle of a population, or
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline, or
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat, or
- interfere with the recovery of the species.

Vulnerable Species Criteria

An action has, will have or is likely to have a significant impact on a vulnerable species if it does, will or is likely to:

- lead to a long-term decrease in the size of an important population of a species, or
- reduce the area of occupancy of an important population, or
- fragment an existing important population into two or more populations, or
- adversely affect habitat critical to the survival of a species, or
- disrupt the breeding cycle of an important population, or
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline, or
- result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat, or
- interfere substantially with the recovery of the species.

An important population is one that is necessary for a species' long-term survival and recovery, and may include populations that are:

- key sources either for breeding or dispersal, and/or
- necessary for maintaining genetic diversity, and/or
- near the limit of the species range.

Critically Endangered and Endangered Ecological Communities Criteria

An action has, will have or is likely to have a significant impact on a critically endangered or endangered ecological community if it does, will or is likely to:

- lead to a long-term adverse affect on an ecological community, or
- reduce the extent of a community, or
- fragment an occurrence of the community, or
- adversely affect habitat critical to the survival of an ecological community, or
- modify or destroy abiotic (non-living) factors (such as water, nutrients or soil) necessary for the community's survival, or
- result in invasive species that are harmful to the critically endangered or endangered community becoming established in an occurrence of the community, or
- interfere with the recovery of an ecological community.

Nuclear Actions Criteria

All nuclear actions, as detailed in section 22 of the EPBC Act, should be referred to the Commonwealth Environment Minister for a decision on whether approval is required. These actions are:

- establishing or significantly modifying a nuclear installation or a facility for storing spent nuclear fuel, or
- transporting spent nuclear fuel or radioactive waste products arising from reprocessing, or
- mining or milling uranium ore, or
- establishing or significantly modifying a large-scale disposal facility for radioactive waste, or
- decommissioning or rehabilitating any facility or area in which an activity described above has been undertaken, or
- any other action prescribed by the regulations.

In addition to actions having a significant impact on a matter of national environmental significance, the EPBC Act provides that certain actions taken by the Commonwealth and actions affecting Commonwealth land also require approval under the Act. See Section 1.6.2 for further discussion on the objects of the EPBC Act, and the principles of ecologically sustainable development (ESD) as identified by the EPBC Act.

An overview of the EPBC Act referral, assessment and approval process is provided in Figure 1.2.

FIGURE 1.2
An overview of the referral, assessment and approval process

1.2.2 EIS Progress to Date

In January 2001, the selection of and proposed use of either the preferred site or one of the two alternatives for the national repository project was referred to the Minister for the Environment and Heritage under the EPBC Act because the action was being undertaken by the Commonwealth, and because the proposal was relevant to the matter of national environmental significance relating to nuclear actions.

The project was declared a controlled action, which is an action of national significance for which ministerial approval is required, under three provisions of the EPBC Act:

- listed threatened species and communities
- nuclear actions
- the Commonwealth is the proponent.

This Draft EIS is the means by which the Minister for the Environment and Heritage is informed of all aspects of the repository proposal. The requirements for the EIS are clearly defined in guidelines prepared by Environment Australia (see Appendix A).

1.2.3 Role and Purpose of the EIS

This environmental impact assessment is required to adequately define those elements of the environment that may be affected by a proposed development, and identify the significance, risks and consequences of the potential impacts of the proposal at a local, regional and national level.

As such the EIS will be the primary source of information upon which the environmental impacts of the proposal will be assessed, and will be the basis for an informed decision by the Minister for the Environment and Heritage. The EIS used as the basis for the decision by the Minister will comprise this Draft EIS, the Supplement and the Commonwealth's Assessment Report.

This Draft EIS describes the existing environment in the area and the proposed operations involved in the activity. It evaluates the environmental impacts and proposes measures to avoid or minimise the expected or likely impacts. The aims of the Draft EIS and the associated public review process are to provide:

- a source of information so that interested individuals and groups may gain an understanding of the proposal, the need for the proposal, the alternatives, the environment that it would affect, the impacts that may occur (including those on the community and its safety) and the measures to be taken to minimise these impacts
- a forum for public consultation and informed comment on the proposal
- a framework in which decision makers may consider the environmental aspects of the proposal in parallel with economic, technical and other factors.

The guidelines also state that the EIS will demonstrate compliance with the goals, objectives and guiding principles of ESD as set out in the *National strategy for ecologically sustainable development* (Environment Australia 1992) and the EPBC Act.

1.3 Structure of this Document

The Draft EIS is structured to provide a logical progression of the issues and to be consistent with the general content, form and style specified in the guidelines. The key considerations that have shaped the structure of this Draft EIS are the need to:

- present background information on the need for the proposal, work undertaken to date, definitions and information on types of radioactive waste, and the legislative framework for the management of waste in Australia (Part A)
- present information on the design and characteristics of the repository (Part B)
- undertake a detailed assessment of the potential effects of the proposal on the environment and identify strategies to mitigate potential effects (Part C)
- summarise the commitments on environmental management and monitoring (Part D)
- summarise the conclusions of the Draft EIS (Part E).

The Draft EIS has been printed as two volumes. Volume One provides the background information and the main results of the environmental assessment. Volume Two provides more detailed information in appendices as follows:

- Appendix A — EIS guidelines
- Appendix B — Radioactive waste inventory
- Appendix C — Physical environment
- Appendix D — Biological environment
- Appendix E — Radiation
- Appendix F — Assessment of climatic change at Woomera
- Appendix G — Organisations consulted
- Appendix H — Study team.

1.4 Study Area and Regional Setting

The study area is located in northern South Australia in a region known as central–north South Australia (formerly referred to as Billa Kalina) (Figure 1.3). The region is located approximately 400 km north of Adelaide, in stony desert country with sparse saltbush. A preferred site and two alternative sites have been selected, all of which are located in the area between the townships of Woomera and Roxby Downs.

The lack of obvious and easily accessible water sources, limited transport and urban infrastructure, and the open desert environment has significantly limited post-European human activity in the region. The activity since European settlement has generally been confined to:

- mining (Mount Gunson, Olympic Dam, and the Andamooka and Coober Pedy opal fields)
- pastoral activities (primarily sheep and cattle grazing south of the dog fence, and cattle grazing north of the dog fence; the dog fence, which is to the north of the preferred and two alternative sites, excludes dingoes and wild dogs from the southern pastoral areas)
- remote area tourism and research activity
- some high technology research and business activity (primarily weapons, communications and satellite industries).

The preferred site (Site 52a) is located on state pastoral lease within the Woomera Prohibited Area (WPA), an area of 127,800 km^2 on the western side of the Woomera–Roxby Downs Road. Two alternative sites, Sites 45a and 40a are located on state pastoral leases on the eastern side of the Woomera–Roxby Downs Road.

The sites are covered by three overlapping native title claims, Barngarla (SC 96/004), Kokatha (SC 99/002), and Kujani (SC00/003) (see Chapter 11).

It is intended that the Commonwealth would acquire the final site once the Minister for the Environment and Heritage makes a decision on the repository proposal. The acquisition would be undertaken under the *Lands Acquisition Act 1989* (Cwlth).

1.5 Previous Study Phases

1.5.1 Site Selection

The site selection process has been undertaken in three phases, each outlined below.

Phase 1 of the national radioactive waste repository project began in 1992 with the development of the methodology for siting a national repository. The method used a computer-based geographic information system, A System for Selecting Suitable Sites (ASSESS), to apply internationally accepted site selection criteria adapted for Australia on a nationwide basis.

Geographic information relevant to radioactive waste disposal, such as groundwater quality, earthquake risk and geology, was collated for all of Australia. ASSESS compared this information to the 13 site selection criteria set out in the NHMRC 1992 Code. These criteria included natural physical characteristics relating to geology, groundwater and surface water, and socio-economic, ecological and land use factors (see Section 5.1).

A public discussion paper, *A radioactive waste repository for Australia: Methods for choosing the right site* (National Resource Information Centre), was released for public comment in 1992. In response, 124 submissions about the repository concept, methodology, disposal and site selection processes were received from the public. In 1993, a response paper, *National radioactive waste repository: Site selection study — Phase 1: A report on public comment* (Department of Primary Industries and Energy), was released, which commented on the issues raised in public submissions.

In Phase 2 of the investigation, which began in 1994, the site selection methodology developed in Phase 1 was applied (after taking into consideration public comment) to identify eight broad regions of Australia likely to contain suitable sites (Figure 1.3): three in South Australia, one across the South Australia–New South Wales border, two in the Northern Territory, one in Western Australia and one in Queensland. The Great Artesian Basin and the Murray–Darling Basin, being major water resources, were excluded from the search areas.

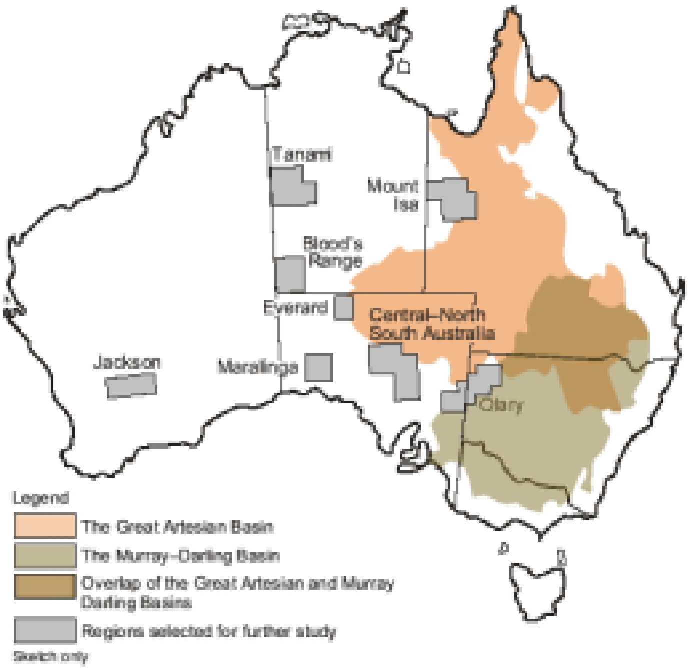


FIGURE 3.1
Regions of Australia likely to contain suitable sites

The results of the Phase 2 investigation were published in the 1994 public discussion paper, *A radioactive waste repository for Australia: Site selection study — Phase 2* (National Resource Information Centre 1994). In response to the paper, 45 submissions were received which raised issues such as the siting and consultation process, and safety issues. In 1995, a paper responding to the public comment, *National radioactive waste repository: Site selection study — Phase 2: A report on public comment*, was published (Department of Primary Industries and Energy 1995).

Phase 3 of the study began in 1998, with the selection of central–north South Australia, as the preferred area for more detailed investigation. The region, which covers approximately 67,000 km^2, contained the largest area potentially suitable for siting the repository, based on the available data. Following the release of the public discussion paper, *A radioactive waste repository for Australia: Site selection study — Phase 3: Regional assessment* (Bureau of Resource Sciences 1997), 69 submissions were received from 84 respondents. Issues raised included the siting process and particularly the selection of the region, and the possible impact on the region from the siting of the repository. These issues were responded to in the 1999 paper, *National radioactive waste repository: Site selection study — Phase 3: A report on public comment* (Department of Industry, Science and Resources).

1.5.2 Drilling Investigations — Selection of the Preferred Site

An expert advisory committee, the National Repository Advisory Committee, advised DISR on the siting process. The committee was chaired by the Bureau of Resource Sciences, and had members from ARPANSA, and the Australian Nuclear Science and Technology Organisation (ANSTO). Technical assessment was undertaken and coordinated by the Technical Assessment Group, with members from the Bureau of Resource Sciences, ANSTO, and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

After the selection of central–north South Australia, the selection criteria were applied on a local scale within the area. Desktop studies and community consultation identified 1.5 x 1.5 km sites within the region that would be suitable for further investigation. The sites were all located on raised, stony desert plateaux.

In Stage 1 of the drilling program, in 1999, 11 sites were drilled. In 2000, Stage 2 of the program involved more extensive drilling of five sites, and three sites were further investigated in Stage 3. The scientific investigations described and assessed the:

- rock types and their structures
- potential for mineral deposits
- the depth, quality, quantity, age and movement of groundwater
- surface drainage characteristics.

The local community and relevant interest groups were extensively consulted throughout the siting investigations and their input had an effect on the sites investigated.

In January 2001 the former Minister for Industry, Science and Resources announced the selection of the preferred site at Evetts Field West (Site 52a) and two alternative sites (Sites 45a and 40a) in the central–north region of SA (Figure 1.3), based on advice from technical experts in the Technical Assessment Group and the National Repository Advisory Committee, for further investigation in an environmental assessment process.

Site 52a at Evetts Field West was selected as the preferred site as it performed best against the selection criteria, particularly with respect to geology, groundwater, transport and security. Two alternative sites, Site 45a and Site 40a, were also found to be highly suitable for the siting of the national repository.

In particular, Site 52a was preferred because:

- the surrounding landforms near the site indicated that there was little run-on of water onto the site, providing a highly favourable environment for the construction and maintenance of the disposal trenches
- the rock formation that would host the disposal trenches and its groundwater features meant that the water drainage characteristics could be modelled more easily for this site than the others
- this rock formation consisted of materials resistant to groundwater flow, which would therefore provide a highly effective natural barrier for the waste
- the well-formed road to the site provided superior transport access
- the site's location in the WPA, which has restricted public access, gave excellent prospects for long-term control and security.

In addition, groundwater beneath Site 52a and the two alternatives was highly saline and therefore unsuitable for human, agricultural or industrial use, and water movement in the saturated zones and potential extraction rates was low.

Logging of samples from the drilling program at each of the three sites showed that there was no significant mineralisation down to depths of 100 m. Other available geological and geophysical information suggests that there is no significant mineral potential at greater depths below the three sites. Thus there appears to be no significant mineral potential at the three sites that would interfere with the proposal for a radioactive waste repository.

Isotopic studies of groundwater at the three sites indicated that it takes thousands of years for surface water to move downwards to the watertable or groundwater level, and then further thousands of years for the water at the watertable to move to an area of discharge, such as a salt lake.

There is no known hydrological link between groundwater at the three sites and the Great Artesian Basin (Bureau of Resource Sciences 1997). Hydrogeological information collected during the drilling program is summarised in Chapter 8 of this document.

Further details on the site selection studies are given in Section 5.2.

1.5.3 Consultation

The extensive public consultation throughout the site selection process included the national release of public discussion papers and the establishment of a toll-free information line and internet site to consult with regional stakeholders. Consultation activities in central–north South Australia included information days, the establishment of a regional information office, the distribution of a newsletter, and the formation of a Regional Consultative Committee (RCC), with members from soil conservation boards, Aboriginal groups, local industry, and local and State government.

Issues raised during consultations have been addressed in publications, letters and at meetings, are further addressed in this EIS, and have been taken into account during the siting process.

The key elements of the public consultation process undertaken so far are outlined below. Specific issues are addressed in the sections of the EIS indicated in brackets.

Public Discussion Papers

At the start of Phases 1, 2, and 3 of the project, in 1992, 1994 and 1998 respectively, public discussion papers were released and distributed throughout Australia to those who expressed an interest in the proposal. The availability of these documents for public comment was advertised in major national and regional papers.

More than 1300, 1850 and 2400 copies of the Phase 1, 2 and 3 discussion papers respectively, were distributed around the time of the releases. In addition, an information kit with 12 fact sheets detailing the siting process, the reason for the selection of the region, and information about radioactivity and radioactive waste, transport of radioactive waste and other relevant issues, was distributed with the Phase 3 discussion paper (Bureau of Resource Sciences 1997).

Broadly similar issues were raised in response to the Phase 1 and 2 discussion papers, including:

- the need for a national repository and alternatives to the proposal (Section 1.6)
- the siting process (Section 5.1)
- suggested regions or sites (Sections 5.1 and 5.2)
- the consultation process (Section 1.5.3)

- the type of waste to be disposed of in the facility (Section 4.1)
- transport of waste to the facility (Chapter 7)
- safety of the environment and people (Chapters 8–12)
- design of the facility (Chapter 6).

After the selection of the central–north region of South Australia for further siting studies, public comments became more focused on the specific region. Issues raised included:

- why the central–north region of South Australia had been chosen
- the environmental impact of siting the repository
- the socio-economic impact of siting the repository.

The issue of whether the store for long-lived intermediate level waste would be co-located with the repository was also raised (Section 1.1). Some submissions also raised the issue of whether the national repository would accept international nuclear waste (Section 1.1).

The issues were addressed in papers responding to public comment (Department of Primary Industries and Energy 1993, 1995; Department of Industry, Science and Resources 1999).

Regional Consultation, 1998

Once the central–north region of South Australia had been selected, significant effort was put into consulting with people in the region to inform them about the proposal and to listen to their views about the repository and possible siting options. The company Halliburton KBR (formerly Kinhill) was engaged by DISR to assist with the public consultation process until the preferred site for the national repository was identified.

Key elements of the community consultation process included the operation of a temporary regional information office, community information days, establishment of a toll-free information line, an internet website, meetings with community and stakeholder groups, briefing of regional media, and the establishment of the RCC.

The Phase 3 discussion paper (Bureau of Resources Sciences 1997) and a comprehensive information kit were distributed widely in the region to key stakeholders, and to council offices and libraries. Community-based meetings were held with the following groups in the week following their release:

- Andamooka Progress and Opal Miners Association
- District Council of Coober Pedy
- Northern Region Development Board
- Roxby Downs Administrator
- Corporation of the City of Port Augusta
- *Coober Pedy Times*
- WMC (Olympic Dam Corporation) Pty Ltd
- Woomera Administrator and Board.

These meetings provided an opportunity to identify other key groups in the community who should be consulted and to discuss the most appropriate mechanisms for promoting and conducting community information days. Interviews were held with the media to inform the public about the project, including the *Coober Pedy Times*, the *Port Augusta Transcontinental* newspapers, the regional ABC radio stations in Port Augusta and Port Pirie, and Channel 9 television in Adelaide. Pastoral lessees in the region were consulted on the proposal and the views of pastoralists were also sought on possible sites.

The regional information office was established in the main street of Port Augusta from 24 February until 17 March 1998. The office was equipped with visual display material, information brochures, the ASSESS system on laptop computer, and people from the project team were on hand to discuss the project and answer questions. Approximately 20 people visited the office.

Information Days

Community information days were widely advertised through letters sent to groups in the region, leaflets distributed to people living and working in the region, and advertisements in regional newspapers.

A total of 275 people attended the information days held at five locations in the region (Table 1.1).

TABLE 1.1 Information days and attendance, 1998

Date	Town	Number of attendees
18 March 1998	Roxby Downs	90, including school students
19 March 1998	Woomera	40
20 March 1998	Andamooka	13
24 March 1998	Coober Pedy	115
26 March 1998	Port Augusta	17

In conjunction with the information days, meetings were held with the following community groups in the region:

- Andamooka Land Council
- Andamooka Progress and Opal Miners Association
- Country Women's Association via School of the Air
- District Council of Coober Pedy
- Kupa Piti Kungka Tjuta Aboriginal Corporation
- Nullakarinku Wanga Association
- Port Augusta Native Title Working Group (the group no longer exists but comprised members from Barngarla, Kokotha and Kujani claimants)
- Regional Coober Pedy School.

The Spencer Gulf Alliance Group was also invited to meet with Commonwealth officers. The group declined the invitation but members did attend the community information day held at Port Augusta.

The consultation process was very effective in hearing the views of a wide cross-section of the population. The personalised, one-on-one nature of the process also provided the opportunity of explaining the proposal in more detail, answering specific questions and clarifying misunderstandings about the impact of the proposal. The success of this process led to additional direct consultation with stakeholder groups and information days as the project progressed.

The diverse opinions expressed at the information days ranged from those who felt quite comfortable with the repository being located in South Australia's central–north region through to those who strongly opposed the proposal. Those who were in agreement understood and accepted the need for improved, more responsible management of Australia's radioactive waste. They expressed confidence in the government's decision-making processes given the stringent criteria to be applied in selecting and managing the repository. A few people expressed an interest in opportunities for involvement in the construction or ongoing management of the repository.

Others accepted the need for one national radioactive waste repository and acknowledged that the proposed region met all the criteria, but still had concerns about the repository being located there. Some thought the central–north region already had its fair share of radioactive waste with the current activities at Olympic Dam and previous activities at nearby Maralinga. Others thought that the case for locating the repository in central–north South Australia had not been sufficiently proven.

Some considered that waste should be stored at the point where it is generated. Those most strongly opposed to the proposal also had broader concerns about mining uranium, the use of nuclear energy and contribution to nuclear waste internationally. The issues were responded to by the project officers at the information days and are addressed in this EIS.

Regional Consultative Committee

Shortly after the announcement of the selection of the central–north region for siting studies, the RCC was established by the Commonwealth to facilitate information exchange between the Commonwealth and stakeholders in the region. The RCC is not a decision-making body: it was established to ensure that stakeholder views are taken into account in decision making. The RCC currently includes representatives from:

- Andamooka Land Council Association
- Andamooka Progress and Opal Miners Association
- Andamooka Country Women's Association
- Antakirinja Land Management Aboriginal Corporation
- Arid Areas Catchment Water Management Board
- Barngarla Native Title Claimants
- Corporation of the City of Port Augusta
- Defence Estate Organisation
- Defence Support Centre (Woomera)
- District Council of Coober Pedy
- Northern Regional Development Board
- Flinders Ranges and Outback Tourism Board
- Kingoonya District Soil Board
- Kokatha Native Title Claimants
- Kujani Native Title Claimants
- Marree Soil Conservation Board
- Marla–Oodnadatta Soil Conservation Board
- Municipal Council of Roxby Downs
- Office of the SA Minister for Environment and Heritage
- Outback Areas Community Development Trust
- SA Department for Environment and Heritage
- SA Department of the Premier and Cabinet
- SA Health Commission
- SA Tourism Commission
- WMC (Olympic Dam Corporation) Pty Ltd
- Woomera Board.

Guests invited to meetings of the RCC are:

- the Member for Grey (Commonwealth Parliament)
- the Member for Giles (SA Parliament).

The RCC has met at both the beginning and end of each phase of the project. To the end of 2001, the committee had met on eight occasions, mostly at Roxby Downs or Woomera.

A range of issues has been discussed at the meetings, with a particular focus on the progress and results of the siting investigations. In addition, presentations have been given to the committee by representatives of ARPANSA and Environment Australia on various aspects of the review and approval processes, and by ARPANSA on the nature of radioactive materials and their safe management. At the July 2001 meeting in Roxby Downs, the consultants for this EIS, PPK and Halliburton KBR, described the EIS process and the scope and conduct of the study.

The views of regional stakeholders have been taken into consideration in selecting sites for investigation. Pastoralists, members of the RCC, and Aboriginal groups (further detail on the discussion with Aboriginal groups is given in Chapter 11) were extensively consulted on the heritage value of potential sites. As a result, new sites were selected for investigation and work did not proceed on others.

Consultation from 1999 Onwards

A newsletter, *The Monitor*, was distributed to all addresses in the region. To the end of 2001, five issues of the newsletter had been published and distributed. Articles in various issues described the status and next phases of the project, and provided information on various issues raised during public consultation such as the safety of the proposed facility, transport of waste, and the Government's refusal to accept radioactive waste from overseas. Community participation was encouraged throughout the project public consultation process.

In 2000, an informal consultative group was established with pastoralists in the region. Meetings with the group took place the day before the RCC, and provided a framework for discussion of the siting process with those who had potential sites located on their pastoral leases or on adjacent properties. The EIS consultants described the EIS process and scope and conduct of the study to a meeting of the group in Roxby Downs in July 2001.

In July 2000, a scientific liaison officer, Dr Keith Lokan, was appointed to talk to community groups and the media about the national repository proposal and, in particular, to respond to scientific and technical questions. Dr Lokan, the former head of the Australian Radiation Laboratory, is both nationally and internationally recognised as an expert in radiation-related matters, and currently serves on the SA Radiation Protection Committee, a statutory committee formed under the *Radiation Protection and Control Act 1982* (SA).

Dr Lokan has addressed the RCC and pastoralist group, and has accompanied media representatives on visits to the preferred sites and alternatives. He has addressed the South Australian Science Teachers Association and the Australian New Zealand Association for the Advancement of Science, and other meetings organised by local government in the region and by various political parties. He has also interacted with a number of environmental groups.

Information Days

With the start of the EIS process, information days were held in the region in July 2001, and an up-to-date information kit with 10 fact sheets was prepared for distribution. The aim was to provide the regional community in particular with further information on the project and the review and approval process, and to give the community an opportunity to ask questions about the proposal. Gutteridge, Haskins and Davey Pty Ltd, appointed as project manager for the Repository Project in April 2001, assisted with the information days.

The dates and venues for information days were advertised in *The Monitor* newsletter, with the exception of the Glendambo Field Day, which was a privately organised event. Fliers were sent to council offices and local libraries. Local papers, such as the *Woomera Gibber Gabber*, also advertised the relevant information.

A total of 247 people visited the five information sessions (Table 1.2).

TABLE 1.2 Information days and attendance, July 2001

Date	Town	Number of attendees
6 July	Woomera	21 (all visitors)
7 July	Andamooka	43 (41 locals)
8 July	Roxby Downs	24 (22 locals)
17 July	Port Augusta	104 (about 97 locals)
18 July	Glendambo	55 (all visitors)

Both locals and visitors to the district attended the information days. Project officers and representatives from ARPANSA answered questions about the project, and provided information about the proposal and radioactive materials.

Issues raised and views expressed were similar to those expressed during the 1998 information days.

Some supported the national repository project, saying that the waste had to go somewhere and that it made sense to get it out of universities, hospitals and industry stores and put it in a purpose-built facility.

Some raised questions about the design of the repository, and the safety of the environment near the facility (Chapters 8 and 9). Others asked whether the national store for intermediate level waste would be co-located with the repository, and others were concerned that the repository might take international nuclear waste (Section 1.1). Some asked questions about the transport of waste to the facility (Chapter 7) and the regulation of the facility (Chapter 3).

Some raised the issue of why alternative sites had not been selected: in particular, Maralinga, Radium Hill and Olympic Dam Mine (see Section 1.7.2). Others opposed the concept of radioactive waste disposal as part of a general opposition to the nuclear fuel cycle.

Consultation with the SA Government

There has been extensive consultation with the South Australian Government both before and after the central–north region was selected for siting studies. To facilitate consultation between the SA Government and the Commonwealth, a South Australian/Commonwealth Government Consultative Committee was established. This committee meets directly before the RCC meetings and includes officials from the following SA Government agencies:

- Department of the Premier and Cabinet
- Department for Environment and Heritage
- Department of State Aboriginal Affairs
- Department of Human Services
- Department of Primary Industries and Resources
- Department for Transport, Urban Planning and the Arts
- Department of Industry and Trade.

Some of the SA Government officials that attend the SA/Commonwealth Consultative Committee also attend RCC meetings.

The EIS consultants made a presentation to the SA/Commonwealth Consultative Committee on the timetable, scope and conduct of the EIS at a meeting in Adelaide in July 2001.

Other Consultative Committees

Consultation with other Commonwealth Government agencies has been provided through an interdepartmental consultative committee, which generally meets about the same time as the RCC and the SA/Commonwealth Consultative Committee, at the start or conclusion of each phase of the project. The EIS consultants met with the interdepartmental committee in Canberra in August 2001, and described the timetable, scope and conduct of the EIS.

In addition, the Commonwealth/State Consultative Committee on Radioactive Waste Management, with members from departments and agencies with the responsibility for managing radioactive waste in the various jurisdictions, is regularly briefed on progress of the project.

After the conclusion of the environmental assessment process, when a final site is decided, a local consultative committee of stakeholders with a direct interest in the site will be established.

1.6 Project Need and Justification

At present, low level and short-lived intermediate level waste is stored at over 100 locations around Australia, in rural locations and highly populated urban centres. Generally speaking, waste producers have the responsibility of looking after the radioactive waste in circumstances that, although safe, are not ideal and cannot be guaranteed continuity of arrangements.

In many cases storage space is limited, and the storage is in facilities that were not purpose-built. Where radioactive waste is stored by waste producers the potential exists for incidents in which employees or even members of the general public are needlessly exposed to radiation, through lack of security or lack of willingness on the part of waste producers to take responsibility for the waste.

The establishment of a national repository for Australian low level and short-lived intermediate level radioactive waste will ensure that the waste is disposed of in a purpose-built facility where it can be managed in a safe and responsible manner. The community and environment would benefit from the establishment of such a facility by ensuring that the waste is isolated, as much as possible, from the environment and people, and responsibly monitored and managed until its radioactivity decays to background levels.

In developing the project a range of alternatives has been considered, including the ‘no project’ alternative, alternative locations, alternative disposal methods and alternative technologies. The advantages and disadvantages of these options are further discussed in the following sections, particularly as they relate to the identified national environmental significance criteria and the EPBC Act (Section 1.2.1), ESD principles (1.6.2), local and international strategies and accepted international practice.

1.6.1 The Need for a National Near-Surface Radioactive Waste Repository

Why a Repository?

Australia has generated a relatively small amount of low level and short-lived intermediate level waste. Recent estimates indicate that about 3700 m^3 (about the volume of eight average houses) has been generated from medical, industrial and research use of radioisotopes over the last century. Over half of this waste consists of 2010 m^3 of lightly contaminated soil, a result of experimentation into radioactive ores by CSIRO in the 1950s and 1960s, which has been stored in the WPA since 1994–95.

The balance of the existing waste consists of materials such as paper, plastics, glassware and protective clothing, luminous watches, compasses, gauges and exit signs, and radioactive materials used in a variety of medical and industrial equipment. Much of the waste is a legacy of the past use of radioactive materials in medicine, industry and research.

Most Australians benefit from the medical, research and industrial uses of radioactivity. For instance, in 1997–98 alone, some 347,000 patient doses of radiopharmaceuticals were produced by the Lucas Heights research reactor for medical procedures such as cancer diagnosis and treatment (PPK Environment & Infrastructure 1998). Also, ANSTO estimates (pers. comm. to DEST 2002) that in 2000–2001 about 525,000 people in Australia underwent a nuclear medicine procedure for the treatment or diagnosis of medical conditions such as cancer.

With the benefits of the medical, industrial and research use of radioactivity comes the responsibility for the safe management and disposal of radioactive waste. Radioactive wastes will continue to be produced and will therefore need to be disposed of in a manner that reduces potential risks to the environment, society and the economy. Disposal of radioactive waste is the end point in the responsible cycle of use and management of radioactive material.

The more than 100 locations around Australia that currently store low level and short-lived radioactive waste include hospitals, research institutions, and industry and government stores. The waste is largely stored in buildings that were not designed for the long-term storage of radioactive material. Space at many of these storage sites is nearing or has reached capacity. The risk to the environment and people is greater when material is stored in many locations in non-purpose built facilities, than when it is disposed of in a national, purpose-built repository.

The following two examples illustrate the potential for accidental exposure. A few years ago, when an Australian hospital was being demolished, two demolition contractors took a safe from a basement, unaware that it contained radioactive sources that had not been used for years. They used a blowtorch to cut the safe open in a domestic back yard but, luckily, no one was exposed to radiation in the incident. In the other example, a basement used to store radioactive material in an Australian university was flooded. Although there was no leakage of radioactive material, the incident demonstrates the difficulties of storing radioactive waste in facilities that are not purpose built.

Concerns about the possibility of acts of terrorism involving nuclear and radioactive materials have assumed greater international prominence in the wake of the events of 11 September 2001 in New York City and Washington DC.

While it would be very difficult for terrorists to develop effective nuclear weapons, a radiological weapon could be within their capabilities. This could involve, for example, the use of explosives with radioactive materials to spread radioactive contamination (what some term a ‘dirty bomb’). It is unlikely that the low level radioactive materials might be sought for such purposes. However, there is a possibility, and thus an even stronger reason than before to establish a national process for the orderly collection and safekeeping of these types of materials.

To minimise the risk of radioactive materials falling into the wrong hands, the IAEA — of which Australia is a prominent and respected member — has placed a high priority on strengthening security arrangements for radioactive materials. Under its nuclear safeguards agreement with the IAEA, and as a signatory to several IAEA conventions governing the safety and security of radioactive materials and nuclear facilities, the Australian Government is obliged to use its best efforts to ensure that such materials are used, stored and transported in accordance with the highest international standards.

Without a national repository for low level and short-lived intermediate level radioactive wastes, disposal of radioactive sources used in medical, industrial and scientific fields is not an option for most Australian users when the sources reach the end of their life. Sources that cannot be recycled must be stored.

This current practice of having hazardous radioactive materials stored in many locations nationwide is clearly unsatisfactory in the long-term from the perspective of public health and safety. It is also strongly in the interests of public security both in Australia and internationally to secure radioactive materials from possible theft or misuse by terrorists, through collecting and disposing of them at a facility specifically designed for this purpose.

The objects of the EPBC Act, and the principles of ESD as identified by the Act, are highlighted in Section 1.6.2, and the application of the EPBC Act is described in Section 1.2.1. The current storage situation can be considered unsustainable and not consistent with the objectives of the EPBC Act or the principles of ESD, because of the risks associated with multiple-storage locations, in non-purpose designed facilities.

In particular, the present ad hoc approach is not considered to be in compliance with several objectives of the EPBC Act, including providing protection for the environment (object (a) of the Act), providing a cooperative approach to protection and management of the environment (object (d)) and not conforming with international safety and guidelines for the disposal of the wastes (object (e)).

The present arrangements do not fully address the following principles of ESD as described in Section 1.6.2, including that of inter-generational equity as the current arrangements place the burden of disposal of waste on future generations.

Why a 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. This decision recognised that, for the small amount of radioactive waste that Australia has, it would be technically and economically inefficient for all jurisdictions to establish their own disposal facilities.

A national repository for low level and short-lived intermediate level waste will ensure that waste currently largely stored in facilities which are not purpose built is disposed of in a purpose-built repository where it can be safely monitored and isolated, as much as possible, from the environment and people.

The committee reported that most of Australia’s radioactive waste is 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.

Although all governments supported the concept of a national repository, states and territories were reluctant to volunteer to host the facility. This resulted in the siting study by the Commonwealth, begun in 1992, with the support of state and territory governments. The previous study phases are described in detail in Section 1.5.

Why a Near-Surface Repository?

It is internationally accepted practice that low level and short-lived intermediate level radioactive waste is disposed of in near-surface repositories. There are more than 100 repositories for low level and short-lived intermediate level waste either operating, or in the process of being established, in over 30 countries including the United States of America (USA), England, France, South Africa and Spain (Section 2.5.2).

Shallow near-surface disposal has been practised successfully in other countries for decades. The environment in the central–north region of South Australia is broadly similar to the arid environments in the USA and South Africa where near-surface disposal of low level and short-lived intermediate level waste has been successfully practised in trenches with very little engineering. In Australia, near-surface disposal of hazardous and radioactive wastes has been successfully undertaken at Mount Walton East in Western Australia. There is also a purpose-built storage facility at Esk, Queensland. Further information on near-surface repositories operating in Australia and overseas can be found in Sections 2.4 and 2.5 of this document.

A national near-surface repository for the disposal of Australian low level and short-lived intermediate level waste would reduce the cumulative risks of managing numerous waste storage areas. It represents the safest and most effective option for Australia to manage our low level and short-lived intermediate radioactive waste.

The Commonwealth government considers that the establishment of a national repository represents the safest and most effective option for Australia to manage this type of waste, particularly as the ongoing generation of waste is expected to be relatively small, and therefore technically and economically does not justify the establishment of separate facilities on a state-by-state basis.

As noted previously, the exercise for determining a location for a national store for long-lived intermediate waste produced by Commonwealth agencies is being undertaken separately from the process to site a national repository for low level and short-lived intermediate level waste. It is not proposed that the store would be co-located with the repository on the same site in SA.

1.6.2 The Benefits of a National Near-Surface Radioactive Waste Repository

The continued production of radioactive wastes in Australia through the medical, industrial and research use of radioactivity, will exacerbate the pressure on the current storage arrangements. Disposal of this waste in a national repository would allow many of the existing temporary storage facilities to be closed. The community expects that the Government will act responsibly to ensure minimal risks to the environment and society. A national near-surface repository will ensure that any potential risks are properly managed in accordance with the NHMRC 1992 Code. In addition to this code, the IAEA guidelines — Safety Standards Series (*Near surface disposal of radioactive waste*, WS-R-1 (1999) and *Safety assessment for near surface disposal*, WS-G-1.1(1998)) and Safety Series *Siting of near surface disposal facilities 111-G-3.1* (1994) — will be referred to.

There will be an overall benefit to the Australian community by disposing of national low level and short-lived intermediate level radioactive waste in the optimal region for hosting the repository.

Disposal of waste in a suitable, purpose-built repository is in keeping with the guiding principles outlined for the management of radioactive waste (International Atomic Energy Agency 1995), detailed in Section 3.1. Waste classifications and international practice are discussed in Sections 2.3 and 2.5.

The expected community, regional, state or national benefits can be considered in terms of:

- facility management benefits
- socio-economic benefits
- regulatory benefits.

Facility Management Benefits

Much of the existing radioactive waste is stored in highly populated urban environments largely in buildings that were neither designed nor located for the long-term storage of radioactive material. Waste producers have the burden of managing this material under circumstances that were not designed for its long-term management.

A purpose built national near-surface repository, which is managed and maintained in compliance with government legislation and regulations, and which is in accordance with the NHMRC 1992 Code, would ensure that Australian low level and short-lived intermediate level radioactive waste is managed safely until it decays to background levels and no longer poses a potential danger to people or the environment. It would also, indirectly (through the removal of potential hazards), provide benefits to the environment and also to the population in the vicinity of many current storage locations.

Socio-Economic Benefits

Some employment and economic benefits have been generated by the national repository project. The siting phase has employed contractors for drilling, scientific analysis of data, and environmental assessment. Aboriginal groups have been remunerated for undertaking heritage clearances of sites.

As Australia only holds and generates a small amount of radioactive waste, the national repository will be a small operation, with infrequent disposal activities. There will be some opportunities for contractors to become involved in the operation and construction of the facility. Some upgrading of existing infrastructure may be required depending on the location of the final repository site.

Regulatory Benefits

The regulatory benefits of the proposal are evident by considering the objects and principles of the EPBC Act and ESD. The objects of the EPBC Act are to:

(a) provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance
(b) promote ESD through the conservation and ecologically sustainable use of natural resources
(c) promote the conservation of biodiversity
(d) promote a cooperative approach to the protection and management of the environment involving governments, the community, landholders and indigenous peoples
(e) assist in the cooperative implementation of Australia's international environmental responsibilities
(f) recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity
(g) promote the use of indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge.

The EPBC Act identifies the following principles of ESD:

1. Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.

2. If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

3. The principle of inter-generational equity — the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

4. The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision making.

5. Improved valuation, pricing and incentive mechanisms should be promoted.

The purpose of this EIS is to enable formal assessment of whether the proposed national repository addresses the objects of the EPBC Act. It aims to show that the disposal of radioactive waste in a purpose-built facility addresses the objects of the EPBC Act better than the current ad hoc arrangements. It also aims to show that disposal of radioactive waste in a safely monitored and managed facility would provide better protection for the environment (object (a)), and the establishment of a national facility would provide a cooperative approach (object (d)) to radioactive waste management, and assist in the cooperative implementation of Australia's international environmental responsibilities.

The establishment of a purpose-built facility for the safe disposal of low level and short-lived radioactive waste will address protection of the environment in a manner consistent with the objects of the EPBC Act and the principles of ESD. Managing waste by disposal in a purpose-built facility will better address these objects and principles of protection of the environment and people, than the current ad hoc arrangements.

Issues relating to biodiversity, the protection and management of the repository site, the consideration of long-term and short-term economic, social and equitable considerations are addressed in this EIS.

Under current arrangements various state, territory and Commonwealth Acts and Regulations govern the management of radioactive waste. The states and territories are responsible for monitoring the use, transport and disposal of radioactive materials in their jurisdictions, and the Commonwealth Government is responsible for managing radioactive materials in organisations under its control, including government departments and agencies.

The recently created ARPANSA, which reports to the Minister for Health and Ageing, is responsible for regulating all Commonwealth departments, agencies and bodies corporate (including contractors to these organisations) involved in radiation or nuclear activities or dealings (through the ARPANSA regulatory branch). Other branches of ARPANSA are responsible for:

- promoting uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the states and territories
- providing advice to government and the community on radiation protection and nuclear safety
- undertaking research and providing services on radiation protection, nuclear safety and medical exposures to radiation.

As a Commonwealth facility, the national radioactive waste repository would be regulated by ARPANSA, which would assist in facilitating a more coordinated approach to radioactive waste management in Australia.

1.6.3 Implications of Not Establishing a National Near-Surface Radioactive Waste Repository

The implications of not establishing a national near-surface radioactive waste repository are summarised as follows:

- Australia has about 3700 m^3 of low level and short-lived intermediate level waste currently being stored in over 100 locations around the country. Many of these temporary stores are nearing capacity. Australia currently produces about 40 m^3 of this type of waste annually. Without a national repository, each state and territory may have to site, design and operate its own near-surface radioactive waste repository in the future, which would be an inefficient and unnecessary use of resources.
- Of the over 100 locations around Australia used for the storage of radioactive waste, many are in urban environments in buildings that were neither designed nor located for the long-term storage of radioactive material. Some of the packaging and containment of these wastes is deteriorating, and security cannot be guaranteed. Not proceeding with the national repository would mean that waste would continue to be stored largely in non-ideal circumstances, with the potential for future loss of control or accidental exposure of people or the environment to radiation.
- If the proposal for a national repository did not go ahead, the storage of radioactive waste in non-ideal arrangements will continue to be an issue. Community concern may focus on these numerous storage locations and their perceived risk of accidental exposure and possible terrorism activity.

1.7 Alternatives to the Proposal

An extensive process of scientific assessment and community consultation has selected the preferred site and the preferred method of disposal. This section briefly discusses alternatives to the proposal presented in this EIS.

There are no feasible alternatives to the storage and disposal of low level and short-lived intermediate level radioactive waste.

1.7.1 The No Repository Option (Maintaining the Status Quo)

Previous sections have discussed the overall need for a national near-surface repository for low level and short-lived intermediate level waste and described a number of the benefits of such a facility. This section outlines some of the advantages and disadvantages of maintaining the current waste management practice of indefinite storage of radioactive waste.

Maintaining the status quo does not provide best long-term protection to the environment. It also does not address the objects of the EPBC Act nor ESD principles (Section 1.6.2). Indefinite storage in non-purpose-built facilities poses a potential threat to both present and future generations, thereby contradicting the principle of inter-generational equity.

In addition, storage represents an interim stage in the management of waste, and disposal is the final step. Disposal of low level and short-lived intermediate level radioactive waste as proposed by the Commonwealth is an internationally accepted method for the management of this type of waste.

The advantages and disadvantages of maintaining current storage arrangements can be considered in terms of:

- impacts on the environment and society
- continuity of arrangements
- potential contamination risks.

Impacts on the Environment and Society

If the proposed national repository were not constructed, there would be no disruption or alteration to the local physical and biological environments at the preferred site, or potentially one of the two alternatives, in the central–north region of South Australia during construction, operation and decommissioning. Nor would there be any impacts on proposed transport routes. There would be no disruption to the communities living in the vicinity of the proposed development sites. There would also be no visual impact of development or operation. Therefore there are benefits to the local environment at the proposed site in maintaining the status quo.

However, low level and short-lived intermediate level radioactive waste would continue to be stored on the WPA near Woomera as well as at over 100 other locations around Australia, in non-purpose-built accommodation, which poses the ongoing risk of radiation environmental impact and, in any event, given the ongoing accumulation of waste material, is not a sustainable arrangement.

Continuity of Arrangements

Under the present arrangements medical, industrial and research organisations (public and private) producing radioactive waste are responsible for managing it. Although strict Commonwealth, state and territory legislation governs the storage of radioactive wastes, current arrangements are not ideal, generally, because they cannot be guaranteed in the long term.

Maintaining the status quo may result in Australia not meeting its long-term responsibilities in terms of managing and disposing of radioactive waste.

Potential Contamination Risks

Without a national repository, low level and short-lived intermediate level radioactive wastes would continue to be stored in over 100 locations around Australia, largely in facilities which were neither designed nor located for the long-term storage of radioactive material, and which are reaching, or have already reached, their storage capacity. In the medium to long term there is potential for future loss of control or accidental exposure of people or the environment to radiation. In addition, there are considerations of excessive cost in maintaining an adequate level of safety and security of the numerous storage facilities over the long term.

Disposal in Facilities of Different Designs to the Proposed National Repository

Accepted international practice (International Atomic Energy Agency 1995) is that low level and short-lived intermediate level radioactive waste is suitable for disposal in near-surface repositories. The disposal structures may either be below-ground trenches or disposal units above the ground surface. Facilities built above the ground surface are intended to be mounded-over during closure to create an artificial hill. Some nations also dispose of low level and short-lived intermediate level waste in rock caverns.

The choice of repository design takes into account the groundwater, climatic conditions and rock type as well as the type and volume of waste to be disposed of. What is a suitable design for one environment or situation is not necessarily suitable for another.

The proposed design for Australia’s national repository takes into account the arid environment, and the type and volume of radioactive waste that Australia currently has, along with that which will be generated in the foreseeable future.

Some countries dispose of low level and short-lived intermediate level radioactive waste in bedrock of up to approximately 100 m below the ground surface, but these facilities are not the usual method of disposal of this type of waste. They are used in some countries that have large quantities of short-lived intermediate level waste, or where climatic conditions are extreme, or in countries that are actively advancing the consideration of models for geologic disposal facilities (e.g. Sweden) because of the large quantities of high level and long-lived intermediate level waste they produce from nuclear power programs.

Alternative Locations

An extensive site selection process has been undertaken and is described in more detail in Sections 1.5 and 5.2 of this document. The site selection process considered a number of locations, both across the country and within central–north South Australia. The preferred site and two proposed alternatives have been selected on the basis that they best met the internationally accepted selection criteria adapted for Australia on a nationwide basis.

Potential Longer-Term Use of the Proposed National Repository

Presently, it is suggested that the disposal operations would continue for 50 years with a period of review after this to consider the possibility of continued disposal. An option to continue the life of the national repository would provide the following benefits:

- It would avoid potentially returning to the current ad hoc storage arrangements with the potential for loss of control of radioactive waste, and accidental exposure of people and the environment to radiation.
- The need to find a new site for a disposal facility would be postponed.

1.7.2 Alternative Disposal Methods

There are a number of alternative disposal options for low level and short-lived intermediate level radioactive waste. These include:

- disposal in disused or used mine sites
- geological disposal
- ocean disposal.

Disused or Operating Mine Sites

The Commonwealth Government has considered the option of siting a national radioactive waste repository in a disused or operating mine. The use of a disused or operating mine site would need to be assessed against the technical selection criteria, and the proposed method of disposal, regulation and monitoring would need to meet the regulator's requirements. In addition, ore deposits may occur in areas of fractured rock, and the behaviour of radioactive substances in such an environment is hard to predict.

During public consultation, disposal of waste in either the operating Olympic Dam Mine or at the disused Radium Hill mine was suggested.

Disposal of radioactive waste in an operating mine such as Olympic Dam would pose operational difficulties in several respects. These include the inclusion of a Commonwealth facility within a privately run mine, security issues, interference with the separate logistics for the operations, the potential interference of regulatory monitoring requirements for the two operations, and the potential compromising of future mining operations.

At Radium Hill, there are high levels of radon gas in the mine and reopening it for the disposal of radioactive waste would be difficult and potentially hazardous. An above-ground area within a stockpile of sand at Radium Hill has been used by the SA Government for the disposal of small quantities of mining ore samples. This arrangement has the potential for destabilisation by erosion and is at potential risk of intrusion by people and animals. This option is not suitable for many of the wastes destined for the national repository.

Geological Disposal

Geological disposal involves disposing of radioactive waste packages in a stable geological formation at, typically, several hundred metres below the surface. Engineered barriers are constructed around and/or between the waste packages and the surrounding rock.

Geological disposal is considered to be a technically excessive and unnecessarily expensive approach for disposal of the type of waste to be disposed of in the national repository. Internationally accepted practice is that geological disposal is only required for long-lived intermediate level radioactive waste or high level waste.

Ocean Disposal

Australia is party to both the *United Nations Convention on the Law of the Sea 1994* (UNCLOS), which it ratified in 1994, and the *United Nations Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972* (London Convention), to which it acceded in 1984. The Commonwealth regulates the dumping of wastes into the sea, and fulfils Australia's obligations under these international conventions (Australian and New Zealand Environment and Conservation Council 1998). The dumping of radioactive wastes at sea is prohibited under these conventions and regulations.

Therefore, to adopt this option for the disposal of low level and short-lived intermediate level radioactive waste would contravene both international conventions on protection of the marine environment and Australian legislation.

1.7.3 Alternative Technologies

Alternative technologies have been suggested for disposal of long-lived intermediate level and high level waste rather than for radioactive waste that is suitable for near-surface disposal. The suggested alternative technologies include:

- transmutation
- space disposal
- Synroc.

Transmutation involves the conversion of long-lived radionuclides into shorter-lived or even stable nuclides by bombardment either with neutrons in a nuclear reactor or with protons in high-powered linear accelerators. This technique is not considered feasible or commercially viable in the near future (Miller et al.1994) for low level radioactive waste.

Disposal in space has been considered as, if successfully achieved, it provides the greatest degree of isolation from man's environment (Rice and Priest 1981; Coopersmith 1999), but its practicality, cost, technological complexity and potential risks all argue against it.

The use of a material such as Synroc to encapsulate radioactive waste does not provide an alternative to storage and disposal. Synroc can be used, instead of cement or glass, to act as binding material to encapsulate long-lived (or high level) radioactive waste. The resulting material still needs to be disposed of in a repository appropriate to this class of waste. It is not cost effective to use a material such as Synroc for the encapsulation of low level or short-lived intermediate level radioactive waste.

Chapter 2
Radiation, Radioactive Waste and Waste Management

This chapter provides background to radiation and types of radioactive waste, and presents a summary of waste management practices from around the world.

2.1 Radiation and Radioactivity

2.1.1 Radiation

Radiation is the emission and propagation of waves or sub-atomic particles. There are two types of radiation — ionising radiation, so called because it has sufficient energy to 'ionise' matter that it hits, and non-ionising radiation. Ionising radiation includes X-rays and the radiation that comes from radioactive elements, and it has the ability to break the bonds that bind electrons to atoms, thus causing ionisation of the matter through which it passes and damage to living tissue. Non-ionising radiation includes light, heat and radar. The type of radiation associated with radioactive waste is ionising radiation.

2.1.2 Radioactivity

All matter is made up of atoms, some of which are unstable because they have excess energy. Unstable atoms break down spontaneously and release their excess energy, thus forming stable atoms. Radioactivity is the term used to describe the breakdown of unstable atoms and the associated release of energy, which is in the form of sub-atomic particles or electromagnetic waves.

Over time, radioactive material is completely broken down, stable atoms are formed and therefore there is no further release of energy or radiation. The time taken for this decay process is measured in terms of an atom's half-life. One half-life is the time for half of the radioactive atoms to decay to stable atoms. After two half-lives, one quarter of the original radioactive atoms will remain. Some radioactive substances have half-lives of less than a second; others have half-lives of thousands and even billions of years.

Radioactivity is a natural part of our Earth and the universe. Naturally occurring radioactive materials are present in:

- soil and rocks
- floors and walls of our homes, schools and offices
- our food and drink.

There are also radioactive gases in the air we breathe and naturally occurring radioactive elements in our muscles, bones and tissues.

The radiation from these natural radioactive sources is called background radiation and it varies from place to place. The amount of background radiation we receive depends on where we live and the types of activities in which we are involved. The higher we are above sea level, the more we are exposed to radioactivity by way of cosmic radiation. Some soils and rocks, for example, granites, are naturally more radioactive than others, and if we live in areas where these occur, our exposure to background radiation is increased. Some activities, for example air travel and certain medical treatments, increase our exposure to radiation.

During the past 100 years, radioactive materials have come to be used in a wide range of beneficial medical, industrial and environmental applications, including:

- diagnosis and treatment of diseases
- sterilisation of medical supplies and of personal care products
- tracking pollution
- industrial process monitoring and control, and agricultural monitoring and pest control
- in life-saving devices such as smoke detectors.

Further information on the beneficial uses of radiation in Australia is provided in Section 2.2.

The energy emitted from unstable atoms can be released in four forms: alpha (α) particles, beta (β) particles, gamma (γ) radiation and neutrons.

Alpha particles are atomic nuclei. They can travel only a few centimetres in air. A sheet of paper or a layer of skin can stop them. They are intensely ionising, but are only dangerous if they are released inside our bodies. Substances that emit alpha particles are safe if kept in containers sealed to air.

Beta particles, which are electrons or positrons, can travel metres in the air and several millimetres into the human body. They can be stopped by a small thickness of light material such as aluminium or plastic sheeting. Exposure produces an effect like sunburn, but which is slower to heal. Substances that emit beta particles are safe if kept in appropriate sealed containers.

Gamma rays are very energetic electromagnetic radiation, and are the main hazard to people in dealing with sealed radioactive materials. They are much more penetrating than alpha particles or beta particles, and are much more energetic than such non-ionising electromagnetic radiation as ultraviolet, visible and infrared radiation, radar and radio waves. A thick barrier of lead, concrete or water will stop gamma rays.

Neutrons are sub-atomic particles that have no electrical charge. They are released by nuclear fission and are also a very small component of cosmic radiation. On Earth, they are rarely encountered outside the core of a nuclear reactor. Neutrons can be very penetrating as well as being (indirectly) strongly ionising and hence very destructive to human tissue. A thick barrier of lead, concrete or water can stop them.

Figure 2.1 indicates the relative penetration of each type of radioactivity.

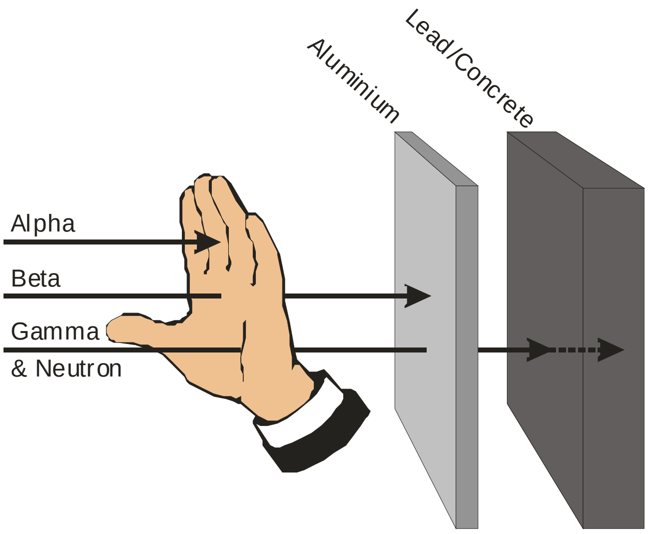


FIGURE 2.1
Penetrating powers of forms of radioactivity

2.1.3 Radioactivity and Radiation Protection

A radiation dose is the measure of how much energy is absorbed when radiation hits body tissue. The different types of radiation (alpha, beta and gamma) have different penetrating power and carry different levels of energy, resulting in different effects on humans. Alpha radiation cannot penetrate skin; beta radiation will penetrate skin but will not penetrate far into human tissue, and therefore is often referred to as a 'skin dose'.

Thus the effects of alpha and beta radiation are of most significance if radioactive material is taken into the body by inhalation of contaminated dust, or by ingestion of contaminated food or drink. Gamma radiation penetrates most matter and so may be of health significance for both internal and external radiation sources.

In biological tissues, the process of changing atoms through ionisation also changes the molecules containing those atoms and it may thus cause damage to the cells containing those molecules. If cellular damage does occur and it is not adequately repaired, it may either prevent the cell from surviving and reproducing, or it may result in a viable or modified cell.

Most organs and tissues of the body are unaffected by the loss of even substantial numbers of cells, but if the number lost is large enough, there will be observable harm reflecting a loss of tissue function. The probability of causing such harm will be zero at small doses but, above some level of dose (the threshold), it will increase steeply to unity (100%). Above the threshold, the severity of the harm will also increase with the dose. This type of effect is called 'deterministic', meaning 'results from prior conditions'.

The outcome is very different if the irradiated cell is modified rather than killed. Despite the existence of highly effective defence mechanisms, the clone of cells resulting from the reproduction of a modified but viable cell may result, after a prolonged and variable delay called the latency period, in the development of a cancer.

The probability of a cancer resulting from radiation usually increases with increments of dose, probably with no threshold, in a way that is roughly proportional to dose, at least for doses well below the thresholds for deterministic effects. The severity of the cancer is not affected by the dose. This kind of effect is called 'stochastic', meaning it is of a random or statistical nature. If the damage occurs in a cell whose function is to transmit genetic information to later generations, any resulting effects are expressed in the progeny of the exposed person. This type of stochastic effect is called 'hereditary'.

These considerations are taken into account in international recommendations and national standards for radiation protection, and are discussed further in Sections 3.1 and 3.2 respectively.

2.2 Uses of Radioactivity in Australia

Radioactive materials play a number of important roles in our everyday lives, being used in medicine, industry and even in our homes. Both naturally occurring and artificial radioactive materials can be used.

2.2.1 Medical Uses

For most people, perhaps the most important use of radioactive materials is by medical practitioners and hospitals. Radiation from these materials is important in the treatment of a number of diseases, particularly cancers such as thyroid cancer. Radiopharmaceuticals (drugs that contain a radioactive material) are also important in diagnoses of many diseases or conditions, in therapeutic uses, and for the palliation of pain. They can be injected into the body, inhaled or taken orally to enable imaging (or picturing) of body organs such as the heart, kidneys, liver and lungs.

Millions of hospital patients have benefited from the therapeutic and diagnostic uses of radioactive materials. As noted in Section 1.6.1, the Australian Nuclear Science and Technology Organisation (ANSTO) estimates that in 2000–2001 about 525,000 people in Australia underwent a nuclear medicine procedure for the treatment or diagnosis of medical conditions such as cancer (pers. comm. to DEST 2002).

2.2.2 Industry

Australian industry uses radioactive materials in a variety of ways to improve productivity and safety, and to obtain information that could not be obtained in other ways.

Radioactive materials are used in industrial radiography, measuring devices, process control in factories, civil engineering, checking gas and oil pipelines for leaks and weaknesses, material analysis, and in oil and mineral exploration. These uses directly and indirectly influence our everyday lives. For example, nuclear measuring devices are used in tasks ranging from testing the moisture content of soils, to measuring the thickness of paper and plastics during manufacturing, to checking the fluid height in bottles. Radioactive materials are even used in devices designed to detect explosives.

2.2.3 Agriculture

In agriculture, radiation and radioisotopes are used to improve food crops, preserve food, and control insect pests (by sterilising pupae). They are also used to measure soil moisture content in vineyards, erosion rates, salinity and the efficiency of fertiliser uptake in the soil and to quantify the sustainable yield of aquifers.

2.2.4 Sterilisation

One of the most beneficial uses of radiation is for sterilisation. Syringes, dressings, surgical gloves, heart valves and surgical instruments can be sterilised after packaging by using radiation. This type of sterilisation can be used where more traditional methods such as heat treatments or toxic chemicals cannot be used, such as in the sterilisation of powders and ointments, as well as in biological preparations like tissue grafts. Like other applications of radioactive materials, the radiation sources used to sterilise these materials must then be disposed of at the end of their useful lives.

2.2.5 Environment

Radioactive materials are used as tracers to measure environmental processes, including the monitoring of silt, water and pollutants. They are also used to measure and map effluent and pollution discharges from factories and sewerage plants, and sand movement around harbours, rivers and bays. As well, they are used to measure and monitor physiological processes to assist conservation of fauna. Radioactive materials of this nature have short half-lives and quickly decay to background levels (in several days).

2.2.6 In Our Homes

One of the most common uses of radioactive isotopes in the home is in smoke detectors. These life saving devices contain tiny amounts of radioactive material that make the detector sensitive to smoke. The radiation dose to the occupants of the house is very much less than that from natural background radiation. Nevertheless, it is important that this material is disposed of in a responsible way.

2.3 Radioactive Waste Classification

According to the International Atomic Energy Agency (IAEA) ‘radioactive waste may be defined as material that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body, and for which no use is foreseen’ (International Atomic Energy Agency 1994a). This is essentially a legal or regulatory definition in that material with radionuclide concentrations or activities below the established exempt levels (i.e. below levels of radionuclide activity that would warrant safety concerns) is still radioactive from a physical point of view but represents a negligible radiological hazard, and so would not need to be subject to regulatory controls.

Radioactive waste is often broadly categorised as low, intermediate or high level (International Atomic Energy Agency 1994a), depending upon the specific activities of radionuclides present, the type of radiation emitted, the level of shielding required and the amount of heat, if any, generated during the radioactive decay process. It can also be classified as short-lived or long-lived, depending on the half-lives of the radionuclides present.

The IAEA has proposed various classifications for radioactive waste, notably in 1981 and 1994. The latter document recommends that classification distinction between intermediate and low level wastes should be based on criteria including site/disposal specific criteria. ‘Activity limitations for a given disposal facility will in particular depend on the radiological, chemical, physical and biological properties of individual radionuclides ... Classification should be related in individual radionuclides, taking the various exposures and exposure pathways into account’ (International Atomic Energy Agency 1994a). In practice, most nations use their own classification schemes, particularly for low level and intermediate level waste, based on the clearance levels for radioactive materials in their particular jurisdiction, on the types of waste that they produce and broadly on international classification schemes.

The disposal method adopted for any particular category of radioactive waste must ensure that the environment is adequately protected and that present and future members of the general public, and disposal site personnel, are not subjected to an unacceptable radiological dose or risk.

The 1992 National Health and Medical Research Council (NHMRC) 1992 *Code of practice for near-surface disposal of radioactive waste in Australia* (NHMRC 1992 Code) proposed four categories for Australian radioactive waste, in which the activity concentrations of radionuclides exceed the limits permitted under the 1985 *Code of practice for disposal of radioactive waste by the user* (NHMRC 1985). The classifications were based on international recommendations for radioactive waste management adapted for the types of radioactive waste generated in Australia. Those categories of waste suitable for near-surface disposal are:

- Category A
- Category B
- Category C.

Radioactive waste that does not meet quantitative and qualitative criteria for near-surface disposal is designated as Category S in the NHMRC 1992 Code. The waste categories are described in Table 2.1.

The classifications in Table 2.1 are only used by Australian regulatory authorities for classifying waste destined for disposal, not as a general classification system.

Category A, B and C waste has been referred to collectively as 'low level and short-lived intermediate level waste' (e.g. Department of Industry, Science and Resources 1999), or 'low level waste' (e.g. Department of Industry Science and Resources 2001) in publications relating to the national radioactive waste repository or national store. In this environmental impact statement (EIS), we refer to Category A, B and C waste as low level and short-lived intermediate level waste.

TABLE 2.1 Categories of radioactive waste from the NHMRC 1992 Code

Category	Definition
Category A	Solid waste with radioactive constituents, mainly beta or gamma emitting radionuclides, whose half-lives are considerably shorter than the institutional control period. The radioactivity will decay substantially during this period. Long-lived alpha-emitting radionuclides should only be present at very low concentrations. This category of waste comprises, predominantly, lightly contaminated or activated items such as paper, cardboard, plastics, rags, protective clothing, glassware, laboratory trash or equipment, certain consumer products and industrial tools or equipment. It may also include lightly contaminated bulk waste from mineral processing or lightly contaminated soils.
Category B	Solid waste and shielded sources with considerably higher levels of beta or gamma radiation than Category A wastes. Long-lived alpha-emitting radionuclides should be at relatively low levels. This category typically includes gauges and sealed sources used in industry and medical diagnosis and therapy, and small items of contaminated equipment.
Category C	Solid waste containing alpha-, beta- or gamma-emitting radionuclides with activity concentrations similar to those for Category B. However, this waste comprises bulk materials, such as those arising from the processing of radioactive minerals, significantly contaminated soils, or large items of contaminated equipment.
Category S	Waste that does not meet the specifications of Categories A, B, C. Typically, this category comprises sealed sources, gauges or bulk waste which contain radionuclides at higher concentrations than are allowable under Categories A, B, or C.

2.3.1 Low Level Waste

Low level waste contains low levels of short-lived beta and gamma emitting radionuclides and normally very low levels of alpha emitting radionuclides. Special shielding is normally not required for transport and handling of this material. It includes items such as wrapping materials and discarded protective clothing, and laboratory plant and equipment.

Low level waste corresponds to Category A, B or C waste under the NHMRC 1992 Code, and broadly corresponds to short-lived low and intermediate level waste as defined in the IAEA Safety Guide, number 111-G-1.1 (International Atomic Energy Agency 1994a).

Disposal in near-surface structures is commonly practised for this category of waste as it does not need to be isolated from the human environment for periods of longer than a few centuries. It is considered that institutional control of disposal sites can be maintained for such periods of time and should not be an unacceptable burden on future generations.

2.3.2 Intermediate Level Waste

Intermediate level waste contains significant levels of beta and gamma emitting radionuclides and could also contain significant levels of alpha emitters. The waste sometimes requires shielding during handling and transport. According to IAEA classification, short-lived radioactive materials have a half-life of about 30 years or less, and typically include gauges and sealed sources used in industry and medical diagnosis and therapy, and small items of contaminated equipment.

Short-lived intermediate level waste corresponds to Category A, B, and C waste in the NHMRC 1992 Code, and broadly corresponds to short-lived low and intermediate level waste as defined in the IAEA Safety Guide (International Atomic Energy Agency 1994a). Disposal options for short-lived intermediate level waste are similar to those for low level waste as the waste decays to very low levels within the institutional control period.

'Long-lived intermediate level waste', or 'intermediate level waste' (e.g. Department of Industry, Science and Resources, 2001), is not suitable for near-surface disposal. It is classified as Category S waste in the NHMRC 1992 Code, and broadly corresponds to the long-lived low and intermediate level waste as defined in the IAEA Safety Guide (International Atomic Energy Agency 1994a). The levels of radionuclides in long-lived intermediate level waste exceed the amounts allowed in Category B and C waste.

Australian long-lived intermediate level waste consists of historical waste concentrates from mineral sands processing, some types of disused sealed sources and industrial gauges, reactor components, irradiated fuel components, and ion-exchange resins and filters (e.g. as a result of reactor operation). In the future it will also include waste arising from the processing of research reactor fuel, which will be returned to Australia in glass or cement in around 2015.

2.3.3 High Level Waste

High level waste contains high levels of beta and gamma radiation emitters and significant levels of alpha emitters, and generates significant amounts of heat (greater than 2 kW/m^3, or about the same as an electric kettle). This category of waste corresponds to the high level waste as defined in the IAEA Safety Guide (International Atomic Energy Agency 1994a).

Such waste requires careful handling, substantial shielding, provision for dissipation of heat and long-term immobilisation and isolation from the biosphere. Outside of Australia, nuclear power reactors and some military activity generate high level waste. Australia does not generate high level radioactive waste and thus has no need or responsibility to store or dispose of any such material.

2.4 Waste Management in Australia

Two states have purpose-built facilities for the management of radioactive waste: Western Australia and Queensland.

2.4.1 Mount Walton East, Western Australia

Western Australia has an intractable waste disposal facility, operated in the form of a near-surface repository, which accepts low level and short-lived intermediate level radioactive waste, as well as toxic and chemical wastes. The facility is located at Mount Walton East, 100 km northwest of Kalgoorlie, and about 480 km northeast of Perth. It is owned by the WA Government and was established in 1992.

The Radiation Health Section of the Health Department of WA, located at the Queen Elizabeth Medical Centre in Perth, had been a collection point and store for unwanted radioactive sources for over 20 years. The store was nearing capacity and the WA Government decided that it needed to establish a disposal facility to accommodate this waste, as well as chemical wastes for which WA was responsible.

The site was chosen after extensive site investigations and community consultation. The repository site occupies 25 km^2 and at present less than 2% of the site has been used for waste disposal.

All of the low level radioactive waste disposed of at the site has been buried as Category B waste, which requires a minimum of 5 m backfill/overburden. Chemical wastes disposed at the site include hydrocarbons, pesticides, herbicides, fungicides, arsenic wastes and heavy metal wastes.

The radioactive waste accumulated at the Queen Elizabeth II Medical Centre store originated from hospitals, various government departments, private companies and members of the public. Waste types disposed of at the facility include:

- used radiation gauges
- wastes from medical use of radioisotopes
- disused exit signs containing tritium
- process equipment from the mineral sands industry containing radium-contaminated scale or build-up on the interior surfaces of production pipes.

Up to 1996, 125 m^3 of low level and short-lived intermediate level waste had been conditioned and disposed of at the site. It is projected that by 2014 a further 40 m^3 of conditioned waste will be disposed at Mount Walton (International Atomic Energy Agency 2000).

All of the waste disposed of at the facility is the responsibility of the state of Western Australia. The corporate entity that operates the site is Waste Management (WA), which was required to obtain the approval of the responsible authorities, the Western Australian Environmental Protection Authority and the Radiological Council of Western Australia, to build and operate the facility.

The disposal of radioactive waste is controlled by the *Radiation Safety Act 1975* of Western Australia, and *Radiation Safety (General) Regulations 1983*. As part of its approval, the disposal operation is required to comply with the requirements of various management plans associated with the site and with the NHMRC 1992 Code. The facility has been operated under the Western Australian *Environmental Protection Act 1986* since 1992.

All low level radioactive wastes received at the Mount Walton East facility must be packaged in compliance with the *Code of practice for the safe transport of radioactive substances 1990*. Generally, the low level radioactive waste is conditioned by placing it into a 60 L steel drum, which is then filled with a fluid cement mixture and returned to the Radiation Health Section store in Perth. Once the waste has set within the drums, the 60 L drums are placed into the centre of a 205 L steel drum. A specific and dense concrete mix is then poured into each 205 L drum to encase the waste, after which the lids of the drums are fitted.

The contents of each drum are recorded and a number for identification purposes is painted on its surface. Each drum is inspected after concreting and radiation levels at a distance of 1 m from the drum are measured and recorded and the correct signage is then applied for transport. The conditioning process provides both a primary and secondary level of protection against spillage of the waste in the event that primary containers are breached, and keeps the risk of emission to the environment of waste spilt or emitted from the primary package, in the event of a traffic accident, as low as reasonably achievable.

The transport of all radioactive wastes to the facility is undertaken by Waste Management (WA) and transport operations such as methodology, controls, routes, emergency response and timing are described in specific transport procedure documents. Transport to the facility is by trucks, usually in convoys of two or more vehicles (at least one of which is fitted with a satellite telephone for an emergency) during daylight hours. Emergency response teams are on-call during loading, transport and the unloading operations.

Performance and Safety

Before the initial disposal of radioactive waste at the facility, a comprehensive pre-disposal radiation monitoring program was initiated. In November 1992, baseline measurements of gamma radiation levels, radionuclides in air and radionuclides in soil were taken. Radon concentrations in air were also measured before any radon generating waste was disposed of at the site.

Since 1992 a continual environmental radiation monitoring program has investigated the gamma radiation levels over the disposal structures and perimeters of the security compounds and the radon concentrations in the air, both in the vicinity of the disposal sites and at a remote site.

The environmental impacts of the operations are restricted to the site and include:

- the clearing of vegetation
- dust generation
- use of septic tanks/leach drains.

An independent compliance audit of the management of the facility, commissioned by the Waste Management Division of the Western Australian Department of Environmental Protection, commented that the encapsulation of the waste in concrete and the waste disposal techniques used at the facility exceeded the requirements of a good radioactive waste management practice (Radiation Dosimetry Systems 1996).

The report recommended that all sampling and monitoring techniques should be detailed and properly documented, a detailed facility closure plan be developed, and post-rehabilitation monitoring and surveillance programs be outlined.

The general conclusions drawn were that the facility and the waste management program met the crucial requirements set out in the NHMRC 1992 Code, and that the program and facility were in general compliance with the IAEA’s recommendations for a good low level radioactive waste disposal facility.

2.4.2 Esk, Queensland

The Queensland Government has a purpose-built store at Esk, which holds much of that State’s low level and short and long-lived intermediate level radioactive waste. The facility is not a repository in that it is not a disposal structure. The waste held in the store, which is suitable for near-surface disposal, will be disposed of in the national repository.

The Esk storage facility is located in an elevated flood free area of state-owned pine forest, approximately 10 km west of Esk in southeast Queensland. The process of site selection involved extensive public consultation and a detailed environmental impact assessment.

The Esk facility began operation in December 1994 and consists of three storage areas, two general storage areas and a special radium storage area, providing approximately 120 m^2 of floor space. There is also an external preparation area that is to be used for conditioning of waste, when the material is prepared for final relocation to the national repository.

The storage facility is designed and constructed to withstand an earthquake one point higher on the Richter scale than the maximum recorded for the area. The outer walls of the three key storage areas are constructed of 400 mm thick reinforced concrete. All other walls and ceilings are 200 mm concrete (Wallace et al. 1995).

The comprehensive security and environmental monitoring system developed and implemented on site ensures the safety of both the public and the environment. The system includes a 30 m buffer zone surrounded by a 3 m barbed wire topped fence; soil, groundwater and air monitoring stations, external and internal sensors that activate a remote alarm and cameras to monitor and record intrusion; and daily site inspections by a local security firm (Wallace et al. 1995).

The Esk store only accepts radioactive materials produced from industrial, medical and research activities that are appropriately conditioned and packaged. The facility does not accept unsealed liquid radioactive material, radioactive material from other states, or medical wastes that may be contaminated with pathogens.

All aspects of the store and its operations are well regulated and subject to the requirements of Queensland radiation safety and control legislation, and the Esk Operation Management Plan. Under the facility management plan monthly, quarterly and six monthly internal audits have been undertaken (Wallace et al. 1995).

2.5 Accepted International Practice

In developing the proposal for a near-surface repository in Australia, a range of waste management practices from around the world has been considered. The term ‘accepted practice’ is considered less subjective than the term ‘best practice’ and is therefore used in this report. What is ‘best’ for one environment and set of circumstances is not necessarily ‘best’ in another example.

This section highlights what is required for the national near-surface radioactive waste repository to achieve internationally accepted practice and describes in general terms the different types of waste repositories.

This section also provides examples of existing international repositories elsewhere. Included are examples of repositories located in parts of countries where population densities and climatic conditions are similar to those of central–north South Australia such as the USA, China and South Africa. Also described are some examples of repositories designed for wet and densely populated environments.

Most facilities overseas are designed to take large volumes of radioactive waste generated by the nuclear power industry or by military use of radioactive materials.

2.5.1 Overseas Strategies and Accepted Practice

A near-surface repository should fulfil two important and related functions: one is to limit dispersion of the radionuclides contained in the waste so that acceptable levels in the human environment are not exceeded; the other is to protect the waste from surface and near-surface deteriorating processes such as erosion, encroachment by deep-rooted vegetation, burrowing by animals and intrusion by humans.

International experience shows that near-surface disposal can be safely applied when sites are carefully selected and repositories are designed and operated to take into account the characteristics of the site and the waste (International Atomic Energy Agency 1985).

Accepted international practice, as outlined in IAEA Guidelines (e.g. International Atomic Energy Agency 1981, 1984) is that solid low level and short-lived intermediate level radioactive waste is suitable for disposal in near-surface repositories. This type of facility provides the required isolation for this type of waste to decay to acceptable levels within a period of time for which institutional control of the repository can reasonably be expected to continue (International Atomic Energy Agency 1981, 1984). The content of long-lived radionuclides in near-surface disposal facilities should be less than the limits established by the relevant regulatory authority.

The IAEA Radioactive Waste Safety Standards are aimed at establishing a comprehensive and coherent set of principles, requirements and recommendations for the safe management of radioactive waste and formulating the guidelines necessary for their application (International Atomic Energy Agency 1999a). The operation of near-surface disposal facilities should be consistent with the following IAEA Safety Standards:

- The principles of radioactive waste management (1995)

- Siting of near-surface disposal facilities (1994b)
- Safety assessment for near-surface disposal of radioactive waste (1999b)
- Near-surface disposal of radioactive waste: safety requirements (1999a).

IAEA's Safety Standard Series *Near surface disposal of radioactive waste: Safety requirements* (1999a), sets out the basic requirements that international experience has shown to be necessary for ensuring the safety of near-surface radioactive waste repositories. It covers the requirements relating to protection of human health, the assessment procedures needed to ensure that safety is achieved, and the technical requirements for waste acceptance and for siting, design, construction, operation and closure of the repository, and the post closure phase.

This IAEA standard also provides guidelines for establishing a comprehensive quality assurance program which should be applied to all safety related activities, structures, systems and components of the disposal system, including all related activities from planning through to siting, design, construction, operation, the various steps in the safety assessment process, closure, long-term record keeping and institutional control activities associated with the repository. The quality assurance program ensures that the relevant safety requirements and criteria are met.

In relation to national legislation and regulations, acceptable practice for the national radioactive waste repository would be achieved by complying with the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act), and the relevant licence conditions once licences to site, construct and operate the facility had been issued. The ARPANS Act makes reference to the NHMRC 1992 Code, which is intended to encourage uniform practice in Australia for the near-surface disposal of radioactive waste. It also requires compliance with internationally accepted practice, including relevant IAEA safety series and other international documents.

The following system of radiation protection is recommended by the International Commission on Radiological Protection (1991, 1997) and has been adopted by NHMRC. The NHMRC 1992 Code recommends that the characteristics of the site chosen for the disposal facility and the design of facilities for waste treatment, packaging or conditioning for disposal shall ensure that the following system of radiation protection is adhered to:

- No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiological detriment it causes (justification).
- The magnitude of individual radiation exposures, the number of people exposed and the likelihood of incurring the exposures where these are not certain to be received shall be kept as low as reasonably achievable, economic and social factors being taken into account (optimisation).
- The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits or to some control of risk in the case of potential exposures (individual dose and risk limits).

Accepted practice could be interpreted as meaning 'a facility designed in such a way that there is no unacceptable risk or detriment to humans, other biota or the environment, at present, and that future risks or detriment will not exceed those currently accepted' (NHMRC 1992).

Siting the repository in accordance with the selection criteria discussed in Sections 1.5 and 5.2 of this report and taking the characteristics of the selected site into account would address accepted practice for siting the facility.

The hydrogeological characteristics of a site are usually the main factors controlling radionuclide migration, as water is the most likely medium for off-site transport of radioactive materials. If the site with its hydrogeological characteristics does not provide adequate confinement, various artificial barriers are commonly used to improve site performance. This may be by the conditioning of waste (e.g. with concrete) or special engineering of the repository (International Atomic Energy Agency 1985).

2.5.2 Type and Number of Repositories

Near-surface disposal structures may be:

- below ground trenches or pits (e.g. repositories in the western USA; Mt Walton East, Western Australia; Rokkasho-Mura, Japan)
- disposal structures above the ground's surface (e.g. Centre d'Aube, France; El Cabril, Spain); facilities built above ground are intended to be mounded-over during closure, to create an artificial hill (International Atomic Energy Agency 1999a).

Some nations also dispose of low level and short-lived intermediate level waste in subsurface facilities located in rock caverns tens of metres or more below the ground's surface (International Atomic Energy Agency 1999), for example, Sweden, Finland and Germany.

Near-surface disposal has been practiced since the 1940s and there are more than 100 near-surface repositories for low level and short-lived intermediate level radioactive waste either operating or being established in over 30 countries around the world (Table 2.2; International Atomic Energy Agency 1999b).

TABLE 2.2 Near-surface repositories around the world

Country	Repository (date opened/closed)	Repository concept
In the process of site selection		
Australia		ENSF
Belgium		ENSF
Brazil		ENSF
Bulgaria		ENSF
Canada (historic low level waste)		–
China (East)		–
(Southwest)		–
Croatia		–
Cuba		MC
Ecuador		ENSF
Hungary		–
Indonesia		ENSF
Korea, Republic of		
Pakistan		
Slovenia		
Turkey		ENSF
United Kingdom		GR
United States (Connecticut)		–
(Illinois)		ENSF
(Massachusetts)		–
(Ohio)		ENSF
(Michigan)		ENSF
(New Jersey)		–
(New York State)		ENSF
(Pennsylvania)		ENSF

Country	Repository (date opened/closed)	Repository concept
Site selected		
China	Guangdong Daya Bay	ENSF
Cyprus	Ari Farm	SNSF
Egypt	Inshas	ENSF
Mexico	Laguna Verde	ENSF
Peru	RASCO	ENSF
Romania	Cernavoda	ENSF
Switzerland	Wellenberg	MC
Under licensing		
Canada	Chalk River	ENSF
Germany	Konrad	GR
Norway	Himdalen	MC
Slovak Republic	Mohovce	ENSF
United States	Ward Valley, California	ENSF
	Boyd County, Nebraska	ENSF
	Wake County, North Carolina	ENSF
	Fackin Ranch, Texas	ENSF
Under construction		
China	Gobi, Gansa	ENSF
Finland	Loviisa	MC
In operation		
Argentina	Ezeiza (1970–)	ENSF
Azerbaijan	Baku (1960s–)	ENSF
Australia	Mt. Walton East (1992–)	ENSF
Belarus[(1)]	Ekores, Minsk reg. (1964–)	ENSF
Brazil	Abadia de Goias (1996–)	ENSF
Czech Republic	Richard II (1964–)	MC
	Bratrstvi (1974–)	MC
	Dukovany(I994–)	ENSF
Finland	Olkiluoto (1992–)	MC
France	Centre de I'Aube (1992–)	ENSF
Germany	Morsleben (1981–)	GR
Georgia	Tabilisi (1960s–)	ENSF
Hungary	RHFT Puspokszilagy (1976)	ENSF
	Solymar (1960–1976)[3]	ENSF
India	Trombay (1954–)	S/ENSF
	Tarapur (1968–)	ENSF
	Rajasthan (1972–)	ENSF
	Kalpakkam (1974–)	ENSF
	Narora (1991–)	ENSF
	Kakrapar (1993–)	ENSF
Iran	Kavir Ghom–desert (1984–)	SNSF
Israel	Negev Desert	SNSF
Japan	Rokkasho (1992–)	ENSF
	JAERI, Tokai (1995–1996)	SNSF
Kazakhstan	Almaty	ENSF
	Kurchatov (1996–)	ENSF
	Ulba (1996–)	ENSF
Kyrgyzstan	Tschuj (1965–)	ENSF
Latvia	Baldone (1961–)	ENSF

Country	Repository (date opened/closed)	Repository concept
Lithuania	Maishiogala (1970s–1989)	ENSF
Mexico	Maquixco (1972–)	SNSF
	La Piedrera (1983–1984)	ENSF
Moldova	Kishinev (1960–)	ENSF
Norway	Kjeller (1970–1970)(4)	ENSF
Pakistan	Kanupp (1971–)	SNSF
	PINSTECH (1969–)	SNSF
Poland	Rozan (1961–)	ENSF
Romania	Baita–Bihor (1985–)	GR
Russia(2)	Sergiev Posad, Moscow reg. (1961–)	ENSF
	Sosnovyi Bor, Leningrad reg.	ENSF
	Kazan, Tatarstan	ENSF
	Volgograd	ENSF
	Nijnyi Novgorod	ENSF
	Irkutsk	ENSF
	Samara	ENSF
	Novosibirsk	ENSF
	Rostov	ENSF
	Saratov	ENSF
	Ekaterinburg	ENS
	Ufa, Bashkortostan	ENSF
	Cheliabinsk	ENSF
	Habarovsk	ENSF
South Africa	Pelindaba (1969–)	SNSF
	Vaalputs (1986–)	SNSF
Spain	El Cabril (1992–)	ENSF
Sweden	SFR (1988–)	MC
	Oskarshamn NPP (1986–)	SNSF
	Studsvik (1988–)	SNSF
	Forsmark NPP(1988–)	SNSF
	Ringhals NPP (1993–)	SNSF
United Kingdom	Dounreay (1957–)	SNSF
	Drigg (1959–)	S/ENSF
Ukraine	Dnepropetrovsk center	ENSF
	L'vov center	ENSF
	Odessa center	ENSF
	Kharkov center	ENSF
	Donetsk center	ENSF
United States	RWMC, INEEL (1952–)	S/ENSF
	SWSA 6, ORNL (1973–)	S/ENSF
	Disposal Area G,LANL (1957–)	SNSF
	Barnwell, South Carolina (1971–)	SNSF
	200 East Area Burial Ground, Hanford (I940s–)	SNSF
	200 West Area Burial Ground, Hanford (1996–)	SNSF
	Richland. Washington (1965–)	SNSF
	Savannah River Plant site (1953–)	SNSF
	Beatty, Nevada (1962–1992)	ENSF
	Maxey flats. Kentucky (1963–1978)	SNSF
	ORNL SWSA I (1944–1944)(3)	SNSF

Country	Repository (date opened/closed)	Repository concept
	ORNL SWSA 2 (1944– 1946)	SNSF
	Shefield, Illinois (1967–1978)	SNSF
	West Valley New York (1963–1975)	SNSF
Uzbekistan	Tashkent (1960s–)	ENSF
Viet Nam	Dalat (1986–)	ENSF
Operation stopped or under closure		
Armenia	Ereven	ENSF
Bulgaria	Novi Han (1964–1994)	ENSF
Estonia	Tammiku (f. Saku) (1964–1996)	ENSF
France	Centre de la Manche (1969–1994)	ENSF
Germany	Asse (1967–1978)	GR
Russian Federation(2)	Mormansk	ENSF
	Groznyi Chechnya	ENSF
Tajikistan	Beshkek	ENSF
Ukraine	Kiev center (–1992)	ENSF
Closed		
Czech Republic	Hostim (1953–1965)	MC
Hungary	Solymar (1960–1976)(3)	ENSF
Japan	JAERI, Tokai (1995–1996)	SNSF
Mexico	La Piedrera (1983–1984)	ENSF
Norway	Kjeller (1970–1970)(4)	ENSF
Lithuania	Maishiogala (1970s–1989)	ENSF
United States	Beatty, Nevada (1962–1992)	ENSF
	Maxey Falts, Kentucky (1963–1978)	SNSF
	ORNL SWSA 1 (1944–1944)(3)	SNSF
	ORNL SWSA 2 (1944–1946)	SNSF
	Shefield, Illinois (1967–1978)	SNSF
	West Valley, New York (1963–1975)	SNSF

(1) There are 77 repositories built to accommodate waste from Chernobyl accident.
(2) Repositories in Russian Federation started operation from 1961 to 1967
(3) Waste was moved to another repository (from Solymar to RHFT Puspokszilagy; from ORNL SWSA-1 to ORNL SWSA-2).
(4) Waste will be moved to a new repository (Himdalen) when constructed.

SNSF = simple near-surface facility
MC = mined cavity
ENSF = engineered near-surface facility
GR = geological repository
S/ENSF = SNSF and ENSF

Generally, near-surface repositories established in wet environments have greater levels of engineering than those established in arid environments, as commonly the watertable in wet environments is close to the ground surface and local groundwater is of good quality and in use as a resource.

Summaries of near-surface/subsurface disposal facilities are provided in: International Atomic Energy Agency 1995; Nuclear Energy Agency Nuclear Waste Bulletins (e.g. 1998); and Nuclear Energy Agency 1999.

The following section provides a brief outline of some representative examples of various types of operating facilities from around the world. Near-surface facilities are divided into those that operate in arid environments (e.g. Areas 5 and 3, Nevada Test Site (NTS), USA; Envirocare, Utah, USA; US Ecology, Richland, Washington, USA; Vaalputs, South Africa; Northwest Repository, China; Mount Walton East, WA, Australia); and those which are sited in wet environments (e.g. Centre de la Manche and Centre de l'Aube, France; Drigg, UK;

Rokkasho-Mura, Japan), as there are design differences between facilities sited in the arid and wet situations. An example of a subsurface facility (in Sweden) is also given.

Issues discussed include the size, age, characteristics, performance, safety and regulatory arrangements of these examples.

2.5.3 Near-Surface Repositories in Arid Environments

Area 5 and Area 3, Nevada Test Site, USA

Two disposal sites for US Department of Energy (US DOE) low level and short-lived intermediate level waste are located on the NTS in the USA.

The NTS is used by the USA to test military devices and, similarly to the Woomera Prohibited Area, is now being considered for additional uses such as launching of commercial satellites and various industrial uses. The NTS occupies an area of over 3500 km^2 of federally owned land with controlled access. The closest populated area is about 40 km to the southeast and the major population centre of Las Vegas is about 105 km southeast. The NTS is now the main disposal site for US DOE low level and short-lived intermediate level waste. Figure 2.2 shows the NTS repository.

FIGURE 2.2
Nevada Test Site repository

Once accepted for disposal at the NTS, low level waste is disposed either in the engineered pits and trenches at the Area 5 Radioactive Waste Management Site, at Area 3, or in subsidence craters created by the underground testing of nuclear devices. The environment is arid with an annual rainfall of 150 mm. Evaporation rates are high, surface water flows only rarely and the top of the watertable is deep (235 m below Area 5 and 488 m below Area 3) (US Department of Energy 2000).

From 1961, Area 5 was used to dispose of low level waste generated by NTS operations. In 1978, NTS began accepting low level waste generated by offsite US DOE facilities. The total site area at Area 5 is 37 ha, and it contains 17 landfill cells (pits and trenches). Four pits are currently in operation; one for mixed radioactive and toxic waste, two for disposal of low level waste, and one for disposal of low level waste containing asbestos.

Trenches are 25.3–345 m long, 9–102 m wide, and 3.7–14.6 m deep. Low level waste is disposed of in wooden or metal boxes (1.2 m or 60 cm high), which are placed in a specially arranged grid system in shallow excavated trenches without lining. Small gaps are left between boxes to allow soil backfill to infill voids. Steel drums (200 L) are placed on their sides in spaces between rectangular boxes.

The top of the emplaced wastes is 1.2 m below ground surface. A 2.4 m temporary cover of alluvium is placed on the wastes bringing the top to 1.2 m above the surrounding land. Any subsidence is filled to maintain a sloping top surface that will shed water. Work is underway on the final cover design, and the preliminary view is that a thicker alluvium cover might be all that is required. The total disposed volume is more than 254,880 m^3 and available capacity would allow for disposal of a further 141,600 m^3.

The disposal trenches are fitted with open-ended pipes that will allow the soil beneath the waste to be sampled. The mixed waste cells are fitted with vadose zone monitoring stations, consisting of pipes that extend 1.5 m below the bottom of the trench. The pipes are used for moisture meter monitoring and gas sampling.

Area 3 occupies 20 ha of the NTS, and uses the subsidence craters for the disposal of bulk low level and short-lived intermediate level debris, including soils, from US DOE and US DOE-approved on- and off-site generators.

The craters are 13.7–27.4 m deep. Packages for disposal include cargo containers, supersacks, burrito wraps (made of plastic) and uncontainerised waste such as large equipment. The container is the only barrier between the radioactive waste and the host rock. Each waste layer is covered by compacted soil of 30–90 cm in depth.

At the time of formation, the seven craters within Area 3 were 122–178 m in diameter and 14–32 m in depth. Five craters have been filled with more than 283,200 m^3 of disposed waste and the available capacity in two remaining craters is 226,560 m^3 (US Department of Energy 2001; US DOE pers. Comm. 2000).

The general policy for management of US DOE wastes is established in the *Atomic Energy Act 1954*, as amended. The US DOE is generally responsible for regulating its own waste, and regulates the low level waste facilities on the NTS. The US Environmental Protection Agency (US EPA), has responsibility for setting national environmental protection standards that serve as a basis for the regulations promulgated by US DOE (International Atomic Energy Agency 2000).

US DOE has the regulatory authority to implement its own regulations and to issue orders that implement health, safety and environmental protection policies on the radioactive waste generated at departmental facilities. The department is subject to regulatory oversight by the US EPA for the management of the non-radioactive hazardous constituents of radioactive wastes that are generated at US DOE facilities (International Atomic Energy Agency 2000).

The US DOE performance requirements for its facilities are comparable to requirements established by the Nuclear Regulatory Commission (NRC) (US Regulatory Commission 1990), which is responsible for regulating commercial facilities. The performance requirements include the following:

- Protection of the general population from releases of radioactivity — Concentrations of radioactive material that may be released to the general environment in groundwater, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable efforts should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.
- Protection of individuals from inadvertent intrusion — The design, operation and closure of the land facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.
- Protection of individuals during operations — Operations at the land disposal facility must be conducted in compliance with relevant standards for radiation protection.

Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

- Stability of the disposal site after closure — The facility must be sited, designed, used, operated and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site to that only surveillance, monitoring or minor custodial care are required.

Performance of Area 5, NTS

US DOE undertakes regular environmental monitoring around the NTS. Air monitoring and ecosystem monitoring have been undertaken at and around the NTS for about 20 years. Groundwater has been monitored for about eight years and the unsaturated zone has been monitored for contaminants for about 12 years. As of 2000 the monitoring results have shown no detection of contaminant transport exceeding health, safety and environmental standards (US Department of Energy 2000).

Owing to the comparable design and location of Area 5 with the repository proposed for central–north South Australia, only the performance of Area 5 is covered in this report. Details of the 2000 monitoring program for Area 3 can be found in Bechtel Nevada (2001a). The 2000 environmental monitoring results taken at and around Area 5 of the NTS are given below (Bechtel Nevada 2001a,b):

- Direct radiation was not above background levels.
- Air tritium concentrations were slightly above background levels but still well below any concentration of concern.
- Gross alpha radiation, gross beta radiation, gamma radiation, americium concentrations, and plutonium concentrations in air particulate monitoring data indicate that radionuclide concentrations in the air at Area 5 were not above surrounding background levels.
- Groundwater monitoring data indicate that the groundwater in the uppermost aquifer below Area 5 has not been contaminated by the facility (tritium groundwater concentrations from February 1993 to December 2000 were all below the investigation level, the minimum detection level and the drinking water standard).
- Vadose zone monitoring data indicate that in 2000 rainfall infiltrated less than one metre before being evaporated.
- Tritium concentrations in the surrounding area’s biota were reduced as compared to previous years.

Envirocare, Utah, USA

In the mid-1970s the US DOE and the State of Utah investigated 29 sites with potential to permanently receive uranium mill tailings from an abandoned uranium mill site. After an eight year siting process to determine the best location, a location in Utah’s West Desert was chosen in an area approximately 128 km west of Salt Lake City. The site, called Clive, was preferred because of its remote location (64 km from the nearest community), low annual rainfall (approximately 200 mm), annual evaporation rate of more than 1500 mm and poor quality groundwater (about twice the salinity of seawater) at 12 m below the surface. Non-saline water exists at depths of 400 m.

The facility is a commercial operation that began operating in 1984 when mill tailings were received. These tailings will be contained for 1000 years. The wastes disposed of at this site are naturally occurring radioactive materials including uranium mill tailings, and mixed low level and short-lived intermediate level waste (Envirocare of Utah 2001).

Separate trenches are used for different types of waste. The mixed wastes are placed on cell liners which comprise part of the cover. Drummed wastes are emptied, with the drums being crushed and buried with the waste. The cell embankment top slopes are covered with a compacted 2.1 m thick clay cover, a rock filter layer, and a 60 cm thick rock erosion barrier to ensure long-term protection of the environment (Envirocare of Utah 2001). Over 12 million m^3 of waste have been disposed of at the site.

The NRC is responsible for regulating and licensing commercial waste management facilities. The US EPA is responsible for setting national environmental protection standards that serve as a basis for the regulations promulgated by NRC.

Performance and Safety

The Envirocare facility is inspected on a quarterly basis and examined for overall site radiation safety, environmental monitoring procedures, quality assurance and the construction and integrity of the waste disposal cells (Envirocare of Utah 2000). The NRC reported that it found, during an audit in September 2000, that the facility was in compliance with all licence requirements, and was meeting or exceeding the reviewed regulations.

US Ecology, Richland, Washington, USA

The Richland Low Level Radioactive Waste Disposal Facility is a commercial operation that began in 1965 and is operated by US Ecology. The facility is located approximately 32 km northwest of the city of Richland, Washington and occupies approximately 40 ha of the 1450 km^2 US DOE Hanford Site, which leases the land to the State of Washington (Washington State Department of Health and Washington State Department of Ecology 2000).

Like the national near-surface radioactive waste repository proposed for central–north of South Australia, the Richland facility is located in a dry arid climate. The average annual rainfall at the site is approximately 159 mm, mostly falling during the months of November to February. The depth to groundwater under the facility is approximately 91 m. The geology of the site is characterised by thick basaltic lava flows, which are overlain by unconsolidated sediments. The two main formations under the site are the Hanford Formation to a depth of approximately 76 m consisting of alternating layers of silt, fine sand and medium to coarse sand over poorly sorted sands, silts and gravels; and the middle member of the Ringold Formation, consisting of silty, sandy gravel with well-rounded pebbles and small amounts of cementation (Washington State Department of Health and Washington State Department of Ecology 2000).

From 1965 to December 2000 more than 393,000 m^3 of low level waste had been received at the site. The waste consisted of solid or solidified materials, contaminated materials, cleaning wastes, protective clothing, gloves, laboratory wastes and naturally occurring or accelerator produced radioactive material (US Ecology 2001a).

Presently wastes are contained in 20 separate trenches that are excavated into the surficial sediments. Standard disposal trenches are up to 46 m wide, 396 m long and 14 m deep. Waste is contained in rectangular metal boxes, which are disposed of in the trenches within 2.4 m of the ground surface, and then backfilled with site soil. Drums (200 L) are randomly disposed of in the trenches. When the capacity of each trench is reached, it is covered with at least 2.4 m of soil and capped with a layer of gravel (US Ecology 2001a). The facility has about 1.27 million m^3 of unused capacity (US Ecology 2001b).

Performance and Safety

Operations and closure of the commercial facility are regulated by the Washington Department of Health under the authority of the *Washington Nuclear Energy and Radiation Control Act* (Chapter 70.98 RCW) and through agreement with the US NRC. The primary instrument for regulating the commercial low level radioactive waste disposal site is the Washington State Radioactive Materials License (WN-I019-2), issued by the Washington Department of Health NRC, to US Ecology (Washington State Department of Health and Washington State Department of Ecology 2000). The performance requirements established by the NRC, which is responsible for regulating commercial facilities, are similar to the DOE performance requirements for the NTS above.

Environmental monitoring is undertaken to ensure compliance with appropriate regulations and the facility standards manual. The environmental monitoring program at the site includes air, soil, vegetation and groundwater. Vadose zone monitoring for tritium and radon is an experimental program also currently operating at the site. The environmental monitoring assessment process is complicated by the facility's proximity to the Hanford 200 Areas, which contain irradiated uranium fuel processing facilities, plutonium separation facilities and major radioactive waste storage and disposal facilities (US Ecology 2001a).

The environmental monitoring program for 2000 did not detect any increase in environmental radioactivity. Results are summarised below (US Ecology 2001a):

- All site airborne emissions including gross alpha, gross beta, airborne iodine-125, gamma emitters, tritium and radon were below levels that would be detectable at offsite locations, and offsite doses from site operations were indistinguishable from background. Air monitoring results for 2000 either fell below the investigation level and the site reporting level, or were not significantly different to background levels or trend comparisons with historical data.
- Soil monitoring consists of gross beta, isotopic uranium and plutonium, and gamma emitters. The 2000 soil monitoring report indicated that all monitoring results were below their required investigation level, consistent with results from previous years and within normal background levels. Plutonium was not detected in the site soil samples.
- Vegetation samples in 2000 were analysed for gross beta, total uranium, isotopic plutonium, gamma emitters and tritium. The 2000 monitoring results indicated that analysed vegetation samples either fell below the investigation and the site reporting level or were not significantly different to background levels or trend comparisons to historical data.
- Groundwater samples were analysed for gross alpha, gross beta, tritium, ^{14}C, ^{99}Tc, gamma emitters, isotopic plutonium, isotopic uranium and other non-radiological parameters. The results indicated that there was no facility impact on groundwater in 2000.

Vaalputs, South Africa

The Vaalputs repository in South Africa takes low level waste from the Koeberg nuclear power reactors, and the South African Nuclear Energy Corporation Ltd, a public company owned by the state, previously called the Atomic Energy Corporation of South Africa, operates the facility. The facility has been operational since 1986, following a siting process that began in 1979.

The facility is situated on the Bushmanland Plateau, in an arid area of northwestern Cape Province, about 600 km north of Cape Town. The site covers an area of 10,000 ha, with the disposal area of some 35 ha, of dimensions 700 x 500 m. Rainfall is bimodal, with an annual average of about 74 mm and usually comes in the form of heavy storms. Groundwater at the site is generally about 50 m below the surface, and has an age of 6000–10,000 years (US Department of Energy 1998).

Operational wastes from the Koeberg nuclear power reactors, comprising clothing and other laboratory equipment, are compacted in steel drums; filter resins and short-lived intermediate level wastes are cemented into 5 tonne concrete canisters. Approximately 1500 drums and 500 concrete containers are produced per annum at Koeberg.

The wastes are transported by road from the Koeberg to the Vaalputs repository where they are disposed of in two pre-constructed trenches, 100 m long x 20 m wide x 7.5 m deep, one for concrete containers with intermediate level waste, and one for drummed low level waste. The trenches are excavated in a weathered residual clay formed above granite and metamorphic rocks. The clay is up to 30 m thick at the site, and is overlain by wind-blown sand and calcrete. As of December 1995, some 2345 concrete containers and 4609 other packages, mainly steel drums, had been disposed of. Up to this time material was placed in the repository and left uncovered until that section of the repository was full.

Deliveries of waste from Koeberg were halted in September 1996, when some of the concrete canisters and steel drums were observed to be cracked, thought by the Atomic Energy Corporation to be due to prolonged exposure to frost and rain. Sampling around the site did not find evidence of any contamination and the Council for Nuclear Safety lifted the delivery ban after an inspection in September 1997. The Atomic Energy Corporation invited an inspection by an IAEA review group, which confirmed the integrity and radiological safety of the site (Atomic Energy Corporation 1999). Waste shipments to the site recommenced in 1999.

Waste is now transported to the site once per year, and trenches are now compartmentalised to allow for more rapid filling and capping with 1.5–2 m of clay. A series of cut-off walls are constructed after emplacement of each shipment, so that they can be covered immediately and protected from the elements.

The Council for Nuclear Safety is the South African regulatory authority. It is the licensing agency for the construction and operation of nuclear installations, and was established in *Nuclear Energy Amendment Act 1988*.

Performance and Safety

Routine environmental monitoring on and around the Vaalputs repository site has been undertaken since 1984. Owing to the arid climate of the region environmental monitoring is limited to borehole water, soil and vegetation monitoring.

The 2000 environmental monitoring report (South African Nuclear Energy Corporation Ltd 2001) reached the following conclusion for the results on and around the Vaalputs site:

- The results for beta activity in water and soil indicated that the results were lower than 1999, while the alpha activities results showed a slight increase, which may be due to analytical or natural fluctuations.
- A single quarterly borehole result showed a caesium-137 (^{137}Cs) concentration higher than the analytical detection limit. Other boreholes closer to the trenches did not show any ^{137}Cs activity higher than the analytical detection limit. Four extra samples of that borehole were taken returning results that were below the detection limit for ^{137}Cs activity.
- The activities measured by the 2000 environmental monitoring program were well below the National Nuclear Regulator reporting levels.
- The monitoring results indicate that no measurable radiological impact could be detected from the activities at Vaalputs.

The Northwest Repository, China

China began operating a low level and short-lived intermediate level waste repository, known as the Northwest Repository, in the Gobi desert at the Lanzhou Nuclear Fuel Complex in 1998. The area is arid, with an average annual precipitation of 61.5 mm and a watertable at 30–35 m below the surface. A thick clay layer, which has good sorption properties for ^{137}Cs, exists at the site. The distance between the nearest river and site is over 2.5 km (De 1997; US Department of Energy 1998).

The total capacity of Northwest Repository is 200,000 m^3 of waste, with the initial phase having a capacity of 20,000 m^3. The waste is disposed of in underground vaults without a concrete base. The repository is divided into controlled and non-controlled areas. The controlled area includes disposing, buffer and operating zones, and the non-controlled area consists of administrative, auxiliary and utility buildings (De 1997; US Department of Energy 1998).

Several safety measures were adopted in designing the repository to protect the environment and the public from the potential contamination of radionuclides. This includes a multi-barrier approach for disposal units to isolate waste effectively, and to prevent human, animals or plants from inadvertent access to the waste. The monitoring of radiation dose, and sampling of air, water, soil, animals and plants are stipulated for the activities of waste disposal and the area adjacent to the repository (De 1997).

The China National Nuclear Corporation is responsible for the siting, construction and operation of repositories, but the approval of environmental impact assessment, issue of standards and inspection of disposal activities are undertaken by the National Environmental Protection Agency and its local administration.

In China the National Nuclear Safety Administration is responsible for standards and regulations, construction permits and operating licences, and the monitoring of plant operations.

2.5.4 Near-surface Repositories in Wet Environments

Centre de la Manche, France

Low level and short-lived intermediate level wastes in France are disposed of in engineered repositories. Nuclear power plants generate more than 70% of the waste and the remainder comes from medicine, industry and research.

The Centre de la Manche facility, located in Brittany about 400 km west of Paris, began operations in 1969 and closed in 1994. Average annual rainfall is 500–1000 mm. Initially, waste was buried in two shallow soil trenches with gravel bases. After 1978, the waste materials were placed in rectangular concrete trenches with drainage channels built at the trench bases. The waste is completely encapsulated by backfilling with concrete to form a monolith. A rainwater catchment system was also incorporated into the trench bottom structure. The whole monolith is capped with reinforced concrete.

In addition tumuli were built on top of the burial monolith consisting of stacked concrete containers of lower activity wastes, which were backfilled with gravel and stones, covered with compacted soil and clay, and topped with topsoil. The operational phase was completed in 1994, with 525,000 m^3 of waste successfully disposed of.

During 1991–97, the 15 ha repository site was capped with a multi-layered engineered cover, comprising layers of compacted coarse grained materials and a drainage layer of fine-grained sand on both sides of a bituminous geomembrane. The repository has now entered a 300-year institutional control period.

A complex water collection system was built into the facility to collect runoff water, water from the cover drainage, and water from drains along the base and walls of the facility.

A new environmental monitoring program was initiated in 1998 to monitor the integrity of the cover as well as potential releases from the waste into the water collection systems or into the general environment through surface water and groundwater. Supplementary monitoring of air, radon levels, and the ambient radiation dose rate and cover vegetation also takes place as part of the program.

Performance and Safety

A report to Greenpeace France in 1993 stated that there had been off-site contamination due to leachate migration away from the stored wastes. It was reported that activity levels of up to 500 times the natural background had been recorded in the general area of the site, and evidence of accumulation of long-lived alpha-emitting radionuclides had been found in the local St Helene stream. These claims have not been substantiated by the monitoring program (US Department of Energy 1998).

For the first 10 years of the 300-year institutional control period, a high level of surveillance is maintained. Surveillance of the centre involves monitoring of gamma radiation around the centre, grass, rainwater, subterranean water, air and surface water (ANDRA 2001a).

The maximum limit for gamma radiation around the centre is 570 nGy/h. Monitoring in 2000 and 2001 has recorded average values of 80–87 nGy/h of gamma radiation around the centre (ANDRA 2001b). Air monitoring around the centre also involves the measurement of alpha activity, beta activity and tritium levels.

Alpha activity has also remained well below the limit of 8 mBq/m^3, with all average quarterly values being too low to be detected by the measurement device. A similar situation occurred for beta activity and tritium levels during the same monitoring period with all average quarterly values being below the detection threshold of the measuring device as well as being below the limit of 6000 mBq/m^3 for beta activity and 80,000 mBq/m^3 for tritium (ANDRA 2001a).

Groundwater monitoring around the site consists of measuring alpha activity, beta activity and potassium-40 (^{40}K). The limit of alpha activity in groundwater is 18 Bq/L and the limit of beta activity is 91 Bq/L. As with the air monitoring results, all average quarterly values during the period from the second quarter 2000 up to and including the second quarter 2001 for both alpha and beta activity were too low to be detected by the measurement device. ^{40}K is a naturally occurring radioactive element and the average quarterly value during the measurement period was 0.06 Bq/L (ANDRA 2001a).

Centre de L'Aube, France

The Centre de L'Aube site, about 200 km east of Paris and about 60 km from Rheims in the Champagne district, was selected through a siting process that began in June 1984. Average annual rainfall is 500–1000 mm. The 95 ha site was selected based on its geology, which consists of an unsaturated layer of sand covering a thick layer of clay. Work on the site began in 1988 and the disposal facility started operations in 1992.

Waste sent to Centre de L'Aube is placed in 200 L and 400 L drums, metallic containers and reinforced concrete boxes. All waste packages are well characterised in terms of their radionuclide content, concentration and form. The wastes are solid. The centre is designed to accept 1,000,000 m^3 of waste over a 40-year period, and will be Europe's largest repository of this type. The disposal technology has evolved from the technology used at the Centre de la Manche.

The site uses near-surface concrete vaults and not the tumulus design used at the Centre de la Manche. All waste packages are placed in above-grade concrete vaults that are 24 x 21 x 8.5 m high. The vaults have 30 cm thick walls and each vault can accept 2500-3500 m^3 of waste depending on the waste package type. Waste emplacement takes place under a movable shelter equipped with an overhead crane and other waste handling equipment. The shelter prevents rainwater from contacting the waste, and eliminates the need for elaborate systems to collect and monitor surface runoff. Depending on waste type, the vaults are back-filled with either gravel or concrete, and are then topped with a concrete slab. All vaults are equipped with a system of drainage galleries to collect and monitor water.

As disposal vaults are completed, the spaces between the vaults will be filled with soil, which is mounded and graded to a smooth surface. Swales and surface drainage will be constructed to facilitate the rapid runoff of rainwater to minimise infiltration. Finally, a multi-layered engineered cover will be constructed over the entire repository. Once vegetated, the mound will look like a hill.

Performance and Safety

More than 1500 measurements have been taken at the Centre de L'Aube since it began receiving radioactive waste. Measurements are taken regularly and are compared with the baseline measurements at facility start-up. Monitoring for radiation sources at the centre involves measuring the air, plants, milk, surface water and groundwater (ANDRA 2001b). The monitoring program is similar to that described for Centre de la Manche, discussed above, and the limits are the same.

The following monitoring results are from the period from the second quarter 2000 up to and including the first quarter 2001. The average quarterly value for gamma radiation ranged from 92 to 98 mBq/m^3 (compared with the baseline level of 60–130 mBq/m^3). For alpha activity the results were too low to be detected, with all results for the period being less than the detection threshold of the measuring device (less than 0.04 mBq/m^3) and the baseline level was 0.15 mBq/m^3. Beta activity during the measuring period has ranged from an average quarterly value of 0.29 to 0.45 mBq/m^3 (compared with the baseline level of 0.02 mBq/m^3). Tritium monitoring results were also below the detection threshold of the measuring device (<0.7 Bq/m^3), compared with the baseline level of 2.2 Bq/m^3 (ANDRA 2001b).

Statutory limits for groundwater are 18 Bq/L for alpha activity, 91 Bq/L for beta activity and 270,000 Bq/L for tritium. The results at the Centre de L'Aube during the same monitoring period indicated above, showed that the average quarterly value for tritium and alpha and beta activity were below the detection threshold, while the average quarterly value for ^{40}K was 0.1 Bq/L (compared to the baseline level of 0.3 Bq/L (ANDRA 2001b).

Regulation

The Division for the Safety of Nuclear Installations shares overall nuclear regulations with the Radiation Protection Agency. The French National Agency for Radioactive Waste Management (ANDRA) is responsible for long-term radioactive waste management in France. The regulatory body for licensing nuclear facilities in France is the French Nuclear Safety Authority (DSIN). Repositories are required to comply with general rules for 'Nuclear Basic Facilities'. Fundamental Safety Rules (FSR) were also issued by DSIN and must be complied with (International Atomic Energy Agency 2000):

- FSR 1.2: Safety objectives and principles for design of surface long term disposal facilities for L/ILW-SL solid radioactive waste (19 June 1984)
- FSR 3.2e: Conditions for radioactive waste packages acceptance to be disposed in surface facilities (29 May 1995).

FSR 1.2 defines safety objectives and design bases for near-surface facilities in terms of:

- the short and long-term performance objectives for the facility in terms of dose limits for workers and members of the public
- safety-related design basis which provides for three distinct containment systems — the form and packaging of the waste, the engineering of the facility (including cover) and the natural materials of the site (soil or rock)
- site selection criteria
- limits on long-lived radionuclides in the waste
- an appropriate quality assurance program for the design construction and operation of the facility.

FSR 3.2e specifies acceptance criteria for solid radioactive waste packages that place conditions on the type of waste, conditioning requirements, characteristics of waste packages, the absence of non-radioactive hazardous materials, and quality control measures to confirm compliance of waste packages with specifications.

Drigg, Cumbria, United Kingdom

British Nuclear Fuels Ltd owns and operates the principal solid low level waste disposal site in the UK at Drigg, in West Cumbria. The annual average rainfall is about 1016 mm and the watertable is a few metres below the ground surface.

The 110 ha site has been operational since 1959 and has accepted more than 900,000 m^3 of waste. It is approximately 6 km south of the Sellafield nuclear fuel reprocessing site and waste comes from Sellafield and other British Nuclear Fuels Ltd sites, nuclear power plants, hospitals, research establishments and other industries. The waste typically consists of paper, packaging materials, plastic sheeting, protective clothing and scrap metal. All waste, including drums, is highly compacted before disposal.

In the past, disposal procedures at Drigg involved cutting a trench into the glacial clay deposit, and then tipping the waste into the trench. There are seven waste-filled trenches that occupy 17 ha of the Drigg site. Each trench is covered with an interim cap, which incorporates an impermeable membrane.

Since 1988 the waste has been containerised and stacked in a concrete engineered vault. The reason for changing the design was that past trenches had earthen bases and these were less effective in collecting rainwater for drainage and monitoring. The rain also softened the base and made it unstable under heavy loads (AEA Technology pers. comm. 2001). A concrete base also provides an adequate foundation for containers and forklifts. There is an underlying drainage system.

The current disposal trench is sited in an area of soft clay soil and high watertable. As the trench is some 5 m deep, lateral inflow of water is high and the trench sides are unstable. Consequently, concrete retaining walls have been constructed around the trench perimeter.

The concrete vault occupies 4 ha, and has the capacity to accept 180,000 m^3 of waste. The vault has three bays each about 60 m wide, 200 m long and 5 m deep. Waste is disposed of in solidified cubes in which the entire contents have been consolidated by grouting.

Before final closure of the site the seven waste filled trenches and concrete vaults will be capped with a thick, durable and low permeability engineered cover system, which will ensure that the waste is isolated from the local environment for the institutional control period.

Within the UK, the producers and owners of radioactive waste are responsible for managing wastes according to Government policy and the regulatory framework. Disposal of radioactive wastes is regulated by the Environment Agency (in England and in Wales), the Scottish Environment Protection Agency (in Scotland) and the Environment and Heritage Service (in Northern Ireland). The relevant information for radioactive substances and waste are:

- *Radioactive Substances Act 1993* (RSA93)
- *Health & Safety at Work Act 1974*
- *Nuclear Installations Act 1965*
- Disposal Facilities on Land for Low and Intermediate Level Radioactive Wastes: Guidance on Requirements for Authorisation 1997.

Performance and Safety

The British Nuclear Fuels Ltd *Discharge and monitoring of the environment in the United Kingdom: Annual Report 2000*, indicates that at no time during 2000 did the disposal of radioactive wastes at Drigg or discharges of radioactivity from the facility exceed the quantitative limits required by the Certificates of Authorisation. Furthermore, monitoring of the principal pathways that may affect members of the public due to the disposal at Drigg during 2000, confirmed that their impact was minimal.

The environmental monitoring program at and around the Drigg facility as required by the Radioactive Substances Act included monitoring of the marine pathway (as the facility is located on the coast, unlike that proposed for central–north South Australia), airborne and terrestrial pathways (including air, foodstuffs, surface water and sediments, boreholes and groundwater).

In 2000 the radioactivity in the air at Drigg indicated that the mean radioactivity concentrations of strontium-90 (0.0009 mBq/m^3), ruthenium-106 (<0.04 mBq/m^3), caesium-134 (<0.005 mBq/m^3), caesium-137 (<0.004 mBq/m^3) and plutonic alpha (<0.0001 mBq/m^3) were all below the detection limits. Detectable mean radioactivity concentrations were measured for the radionuclides americuim-241 (0.0003 mBq/m^3) and uranium alpha (0.0001 mBq/m^3).

The estimated maximum doses to members of the public from inhalation of airborne radioactive particulate material in the vicinity of the site, determined by combining the above results with the assumption of continuous occupancy, was 0.03 μSv, which may be due to aerial discharges from the nearby Sellafield facility (undertaking the reprocessing of fuel, waste management and decommissioning and other processes), with only a negligible contribution from Drigg.

The borehole and groundwater monitoring results for 2000 measured the mean radioactivity concentration for total alpha, total beta and tritium. With the exception of tritium they were generally below the limits of detection for the eight monitoring locations across site.

Rokkasho-Mura, Japan

The Rokkasho-Mura repository, operated by Japan Nuclear Fuel Limited (JNFL) is an engineered repository designed for the disposal of large volumes (up to 600,000 m^3) of low level and short-lived intermediate level waste produced by the Japanese nuclear power industry (Japan Nuclear Fuel Ltd website; Nuclear Engineering International 1999).

The facility is located in Aomori Prefecture, in northeast Honshu, about 60 km east of Aomori city, and is located adjacent to a saltwater marsh. The watertable is 1 m from the ground surface. The annual average rainfall is 500–1000 mm.

The facility began operation in 1992, and a second disposal facility on the same site began operations in 2000. The waste disposal centre occupies a 360 ha site. The low level waste produced by power stations is compressed or burned, mixed with concrete or cement, and placed in 200 L drums.

Waste is transported to Rokkasho-Mura by sea. Drums are inspected for physical integrity and radioactivity at the repository after arrival and repackaged if necessary. The drums are then placed in large concrete vaults in concrete containers. The vaults are 14–19 m below ground surface, in low permeability host rocks. The drums are placed in concrete disposal units below the watertable, and bentonite clay is placed around the concrete to act as a barrier to water flow.

The first disposal facility was designed to accept solidified waste (wastewater, filters and ion exchange resins) mixed with cement, bitumen or plastic. The disposal facility consists of 40 vaults and each vault can accept approximately 5000 waste drums. The reinforced concrete vaults have external dimensions of 24 x 24 m and are 6 m high. The walls and bottom slabs are 500 mm and 600 mm thick, respectively.

A cement grout backfill is placed between the drums after emplacement and the vaults are capped with a 500 mm thick reinforced concrete slab. The vault structures will eventually be covered by a low permeability sand–bentonite mixture at least 2 m thick. The entire repository site will be covered by 4 m of soil and then vegetated.

A 100 mm layer of porous concrete surrounds each compartment so that if any moisture leaks into the vault, it will flow through the porous layer and be taken by a drainage system to an inspection tunnel, instead of penetrating the drum disposal area (Nuclear Engineering International 1999).

The second disposal facility is designed to take dry, active waste. The facility was commissioned in 2000 and has received 1440 drums.

Performance and Safety

The performance of the repository (stage 1 and 2) is ensured by a multi-barrier approach:

- In the first stage, 30 years from waste disposal, the engineered barriers will remain intact and will contain radionuclides.
- In the second stage, 60 years from disposal, there is reliance on artificial and natural barriers for control of radioactive materials (as concrete starts to break down).
- In the third stage, reliance is on natural barriers for containment.

Soil and water near the repository is routinely monitored. In addition, sediment in the marsh, marsh and river water, and agricultural products such as crops, milk and fish are monitored.

The dose equivalent that the public could receive from radioactive materials in Disposal Facility 1 or 2 is well below the dose limit of I mSv per year specified by law (Japan Nuclear Fuel Ltd 1999).

For all scenarios investigated for the institutional control period, a maximum uptake of 0.029 mSv per year is calculated. After the institutional control period, a maximum value of 0.014 mSv per year is calculated.

There will be a 300-year institutional control period following closure of the repository.

The Nuclear Safety Commission is the regulatory authority in Japan.

2.5.5 Subsurface Engineered Facilities

Some countries (e.g. Sweden, Finland and Germany) dispose of low level and short-lived intermediate level waste in rock caverns commonly about 50–100 m below the ground’s surface. This type of facility is used in countries with large quantities of short-lived intermediate level waste, and/or where possible sites for near-surface disposal are limited. In Sweden, the Swedish Final Repository is a sort of prototype for a geological disposal facility (SKB, pers. comm. 2001).

Swedish Final Repository, Sweden

The Swedish Final Repository is an example of a repository located in a mined cavity. It is used for operational waste from nuclear power plants (low level and short-lived intermediate level) as well as waste from other sources. The facility is located in eastern Sweden near the Forsmark nuclear power plant, and is situated 1 km offshore and 60 m below the bottom of the Baltic Sea. It is connected to the surface by two 1 km long tunnels.

The main features of the site that make it highly suitable for a radioactive waste repository are the nature of the bedrock, the depth below the water surface, and the very low groundwater flux. The bedrock in which the repository is built provides a good barrier to human intrusion and is very effective in retarding any movement in radionuclides. The water depth at the site is so great that exposure of the seabed is not expected to occur for more than a thousand years. In addition, there is effectively no flow in groundwater, and the natural environment therefore provides an effective barrier to the movement of radioactive materials, in a similar way to a sub-aerial environment with a deep watertable.

The repository has been in operation since 1988.

Its four rock caverns have a length of 160 m and a width of 14–18 m. The design of the cavern varies depending on the type of waste to be disposed — some are for low level waste, and some are for intermediate level waste. Further vaults are planned to accept decommissioning waste when it arises.

More active intermediate level waste is buried in a concrete silo, packaged in steel or concrete. The silo is 50 m high and has concrete walls approximately 1 m thick. Between the silo wall and the host rock is a thick layer of bentonite clay, which acts as a seal and prevents groundwater from flowing through the silo. The repository has a current capacity of 60,000 m^3 with a planned storage capacity of 90,000 m^3 and when it is full the entrance tunnels will be plugged and sealed with concrete to isolate and prevent further access. After sealing, no further monitoring of the repository is considered to be necessary, given its location.

2.5.6 Implications of International Disposal Practice for Australia

Near-surface repository designs vary depending on the environment, particularly with respect to rainfall and groundwater level, and the type and volume of waste. A repository design that is appropriate for a wet environment where there is a large amount of waste from the nuclear power industry would not be appropriate for Australia's needs or environment. Similarly, a rock cavern is not required for disposal of Australia's small quantity of low level and short-lived intermediate level waste when suitable sites are available for a near-surface facility.

Countries that have arid environments, for example USA, South Africa, China and Australia, tend to site near-surface disposal facilities in these areas. Facility designs are chosen to suit an environment with a deep watertable, where there is low average annual rainfall. There tends to be less engineering in these repositories compared to those sited in wet environments, as the natural environment provides a more effective barrier to the waste.

Given that about 70% of Australia is arid or semi-arid, and the successful operation of near-surface repositories in desert environments overseas, the design chosen for Australia's national repository is one of near-surface disposal in subsurface trenches or boreholes.

Apart from any other consideration, concrete structures above ground for the disposal of waste to be eventually covered by an artificial hill (similar to the design of Centre de l'Aube) would not be suitable for the landscape in central–north South Australia — the desert environment is flat, and in this setting such a structure would attract attention, and, potentially, human intrusion, and may be prone to accelerated erosion. The extra height is not required as the groundwater is between 38.8–68.7 m below surface at the three potential sites for the national repository (Table 8.4), whereas the base of the trenches will be only about 15–20 m below ground surface, well above the watertable.

Some engineering adopted in recent trenches designed for the Drigg facility aimed to keep rain out of trenches left open for successive disposal operations. In Vaalputs, leaving drums exposed in open trenches led to some failure of the containers and this practice is no longer used. Waste is now transported to the site once per year and the trenches are compartmentalised for rapid filling and capping.

The proposed Australian national repository would have trenches or boreholes (see Section 6.2.1) that are open only during short disposal campaigns and the structures will be covered between campaigns. Concrete disposal containers will be used for short-lived intermediate level waste.

The Mount Walton repository for toxic and radioactive waste, of broadly similar design to that proposed for the national repository, has operated safely in Western Australia since 1992.

2.6 Reviews Relevant to the Proposal

Over the last 20 years, a number of reviews in Australia by various bodies, including Parliamentary and expert committees, have examined matters relating to Australia's use of radioactive materials. Issues considered have ranged from the mining of uranium, to the need for a replacement research reactor and the management of radioactive waste.

Some recommendations and conclusions arising from the reviews, and the Government responses, are relevant to this proposal, and have been taken into consideration in progressing the national radioactive waste repository project.

Of particular relevance are the 1984 Australian Science and Technology Council (ASTEC) Report to the Prime Minister on Australia's role in the Nuclear Fuel Cycle, the 1996 Senate Select Committee on the Dangers of Radioactive Waste report, *No time to waste*, and the Government's response report (Commonwealth Government of Australia 1996).

Since 1999, issues associated with radioactive waste management arising from inquiries into the replacement research reactor have particularly focused on the management of long-lived intermediate level waste, rather than on the management of low level or short-lived intermediate level waste, the type of waste of interest in this EIS.

Relevant reviews and recommendations on radioactive waste management are summarised below.

Australia's Role in the Nuclear Fuel Cycle, ASTEC 1984

In 1983, in response to a request from the Prime Minister, ASTEC undertook an inquiry into Australia's role in the nuclear fuel cycle (Australian Science and Technology Council 1984). One of the aspects examined included 'the adequacy of existing technology for the handling and disposal of waste products by consuming countries and the ways in which Australia could further contribute to the development of safe disposal methods'.

ASTEC supported containing and isolating radioactive waste as far as practicable. The committee agreed on the placement of stable packaged waste in a multiple barrier repository (surface soils or in deeper rocks) as the most effective way of containment and isolation of radioactive waste. The committee indicated that, once the waste is isolated and contained, the main purpose of barriers should be to avoid or control water reaching the waste, as this would be the main mechanism for radionuclides to escape to the environment. It stated that, once such a disposal repository has been filled and closed, the waste and surrounding barriers should be passive and require minimal management.

ASTEC recommended that Australia should act as quickly as possible to complete a code of practice for the disposal of radioactive waste, to identify suitable sites for disposal of low level radioactive waste and to develop facilities for interim storage and disposal of low and intermediate level radioactive waste.

In response, 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 repository.

In 1986, the NHMRC requested that its Radiation Health Standing Committee prepare a code of practice and guidelines on radioactive waste management to develop criteria for classifying radioactive waste for disposal and to provide guidance on the selection of sites for near-surface disposal of waste. The *Code of practice for the near-surface disposal of radioactive waste in Australia* was published in 1992.

Senate Select Committee, Research Reactor Review report: Future Reaction, August 1993 (McKinnon Report)

In 1992, the High Flux Australian Reactor (HIFAR) was identified by ASTEC as a facility likely to be in need of replacement.

In 1993, a review evaluated the costs and benefits of a new research reactor. The review stated that a 'crucial issue is final disposal of high-level wastes, which depends upon identification of a site and investigation of its characteristics. A solution to this problem is essential and necessary well prior to any future decision about a new reactor' (McKinnon 1993).

The review also recommended that HIFAR should be kept operational; that a probabilistic risk assessment be commissioned to ascertain HIFAR's remaining life and refurbishment possibilities; and that work should be started immediately to identify and establish a high level waste repository.

The former (Keating) Government broadly accepted the findings of the report.

It should be noted that Australia does not produce, and will not need to manage high level waste (see Section 2.3.3.)

Senate Select Committee Inquiry on the Dangers of Radioactive Waste Report: No Time to Waste, April 1996, and Government Response paper, November 1996

The Government's response to the Senate Select Committee's recommendations provided the framework for current radioactive waste management policy, with the establishment of a body to regulate the Commonwealth's use of radioactive materials, and projects to establish a national repository for low level and short-lived intermediate level waste, and a national store for long-lived intermediate level waste.

The Senate Select Committee recommendations and Government responses are summarised as follows:

- The Committee recommended that a regulatory body should be established to regulate the Commonwealth's use of radioactive materials. The Government responded that it was currently considering proposals for an independent body to regulate and licence radiation related activities of Commonwealth agencies. This resulted in the establishment of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).
- The Committee recommended that an up-to-date inventory be prepared of all existing and potential radioactive waste and that any changes to current accumulation rates be detected. The Government responded that it was in the process of compiling such an inventory.
- The Committee recommended that transport of radioactive materials should require assessment of the most appropriate transport mode, and the Government responded that the transport of all radioactive materials within Australia was controlled by the *Code of practice for the safe transport of radioactive substances 1990* (Department of the Arts, Sport, the Environment, Tourism and Territories 1990). This code was updated in 2001 by ARPANSA, as the *Code of practice for the safe transport of radioactive material (2001)* (Australian Radiation Protection and Nuclear Safety Authority 2001).
- The Committee recommended that feasibility studies be conducted into the suitability of disposing of low level contaminated soil from Fisherman's Bend in an active uranium mine, and the suitable portion of ANSTO's waste at a municipal tip. The Government accepted these recommendations. Disposal of low level waste in an operating uranium mine was subject to confirmation of cost, operational feasibility and safety.
- The Committee recommended the establishment of an above ground storage facility with the capacity to take low, intermediate and high level radioactive waste. The Government response stated that near-surface disposal, rather than storage, is more appropriate for low level and short-lived intermediate level radioactive waste and that the Government would proceed with a study to identify a suitable location for siting such a disposal facility. The study would also address the possibility of co-locating an above ground storage facility for long-lived intermediate level waste, at the same site (co-location of the two facilities has subsequently been ruled out).
- The Committee recommended that the national repository and store be adequately engineered to withstand all possible climatic conditions. The Government responded that a thorough safety assessment would be conducted of any radioactive waste management facility.
- The Committee recommended that the public should be consulted on the construction of a national storage facility and the transport arrangements. The Government responded that public participation had formed an important part of the site selection phases to date, and would be an integral part of further phases of the study.

Senate Select Committee on Uranium Mining and Milling, May 1998

This inquiry reported on issues associated with uranium mining and milling (Senate Select Committee on Uranium Mining and Milling in Australia, 1998). Wastes derived from these activities are disposed of at the relevant mine site, under a proposed new *Code of practice and safety guide radiation protection and radioactive waste management in mining and mineral processing* (to be released in 2002), which replaces the *Code of practice on radiation protection in the mining and milling of radioactive ores (1987)* (Department of the Arts, Sport, the Environment, Tourism and Territories, 1987) and the *Code of practice on the management of radioactive wastes from the mining and milling of radioactive ores (1982)* (Department of Home Affairs and Environment 1982).

The conclusions of the inquiry are not directly relevant to this proposal. However, the inquiry did note that a major issue was the disposal of radioactive waste, whether from the mining of uranium ore or at later stages of the ‘nuclear fuel cycle’.

Senate Economics References Committee: A New Reactor at Lucas Heights, September 1999

In 1997, the Government announced its intention to build a new research reactor at Lucas Heights and to make available the funds to remove spent nuclear fuel for offshore reprocessing.

The Senate tasked the Senate Economics References Committee to review whether or not a new reactor should be built to replace the HIFAR reactor at Lucas Heights on the same site or at another site in Australia. In particular, the committee was to evaluate whether the issues raised by the 1993 Research Reactor Review (McKinnon 1993) had been satisfactorily addressed in the decision to proceed with a new reactor at Lucas Heights. The committee subsequently found, in September 1999, that the issues had not been satisfactorily addressed (Senate Economics References Committee 1999).

The committee noted that, while the government had nominated a site (region) for the location of a low level above-ground radioactive waste repository, the issue of where the Lucas Heights reactor waste would be stored had not been addressed. The spent fuel rods from the reactor at Lucas Heights cannot be stored at a low level repository, even if reprocessed overseas and returned as intermediate level waste.

The Government broadly accepted the findings of the report, and is progressing the establishment of a national store for the long-term storage of intermediate level radioactive waste.

Recommendations arising from the EIS into the Replacement Research Reactor, March 1999

In 1998 an EIS was prepared for the replacement research reactor. In March 1999 the Minister for the Environment and Heritage issued a number of recommendations, which subsequently became conditions when accepted by the former Minister for Industry, Science and Resources, in response to the EIS into the replacement research reactor.

The management of low level and short-lived intermediate level radioactive waste was not mentioned. However, the management of longer-lived intermediate level radioactive waste was referred to in the Environment Minister’s Recommendation 27, which said:

> The Minister for Industry, Science and Resources, and the Minister for Health should give timely consideration to strategies for the long-term management and eventual permanent disposal of Australia’s long-term intermediate level nuclear wastes, and associated issues.

Also, the Chief Executive Officer of ARPANSA (Dr John Loy) has recently stated that progress on the establishment of the national store will be a consideration in his assessment of the licence applications from ANSTO for the replacement research reactor. Dr Loy stated on 5 April 2002 in his decision on the construction licence for the replacement research reactor that he was expecting ‘there will be significant progress by the time any licence to operate the replacement research reactor is sought’.

Parliamentary Standing Committee on Public Works: Replacement Nuclear Research Reactor, Lucas Heights, NSW, August 1999

In August 1999, the Parliamentary Standing Committee on Public Works gave approval for the replacement Research Reactor at Lucas Heights, following an inquiry which concluded that ‘HIFAR is obsolete and will need to be permanently decommissioned in 2005’ and that a need exists to replace HIFAR with a modern research reactor. The new reactor must be operational before 2005 (Parliamentary Standing Committee on Public Works 1999).

The committee concluded that the storage of radioactive waste at Lucas Heights is of major concern to the local community. It recommended that the removal of radioactive waste for disposal or storage at a national repository must be of high priority and is dependent on the timely provision of the repository and store.

The Government responded that it was progressing with the establishment of the national repository for low level and short-lived intermediate level waste, and the national store for long-lived intermediate level waste.

Senate Select Committee for an Inquiry into the Contract for the New Reactor: A New Research Reactor, May 2001

The majority of the *Report of the Senate Select Committee for an inquiry into the contract for a new reactor* (Senate Select Committee for an Inquiry into the Contract for a New Reactor 2001) dealt with issues directly relating to the need for a replacement research reactor and relevant contractual matters. The committee addressed the management of spent fuel and long-lived intermediate level radioactive waste in its recommendation that the Government should satisfactorily resolve the question of the safe disposal of new reactor spent fuel before approval to construct a new reactor is given.

The committee did not make any recommendations concerning the management of low level or short-lived intermediate level radioactive waste.

The Government responded to the committee’s recommendations on radioactive waste management by noting the establishment of a process, separate from the project to establish a national radioactive waste repository, to site a store for long-lived intermediate level radioactive waste produced by Commonwealth agencies.

Chapter 3
Regulatory Framework

Australia's radioactive waste is managed in accordance with national regulatory requirements and, where applicable, internationally accepted procedures and practices. A broad description of the legislative regime and approvals requirements relevant to the repository, and codes of practice, relevant to the repository is provided in this chapter.

3.1 International Organisations and Conventions

Australia is an active member of the following international organisations, which encourage the safe use and management of radioactive materials:

- The International Atomic Energy Agency (IAEA) is an autonomous intergovernmental organisation founded in 1957 in accordance with the General Assembly of the United Nations. It is the world's central intergovernmental forum for scientific and technical cooperation in nuclear matters, including the management of radioactive waste.

- The Nuclear Energy Agency is a specialised agency of the Organisation for Economic Co-operation and Development, an intergovernmental organisation of industrialised countries.

- The International Commission on Radiological Protection (ICRP) is an independent advisory body, founded in 1928 that provides recommendations that form the basis of the international system of radiological protection. Australian scientists have served and continue to serve on ICRP committees and Australia follows ICRP standards.

The IAEA has developed a series of Radiation and Waste Safety Standards based on recommendations made by a number of international bodies, principally the ICRP, and estimates of radiation risk made by the United Nations Scientific Committee on the Effects of Atomic Radiation. These standards, which are followed by most countries including Australia, identify the basic principles for the regulatory, safety and technical requirements for radioactive waste repositories, in:

- protecting human health
- protecting the environment
- protecting beyond national borders
- protecting future generations
- reducing burdens on future generations
- establishing a national legal framework
- controlling radioactive waste generation
- correlating radioactive waste generation and management
- ensuring facilities are safe.

In 1996, the IAEA Secretariat introduced a hierarchical structure for IAEA Safety Standards Series publications: Safety Fundamentals, Safety Requirements and Safety Guides are supplemented by Safety Reports.

The key ICRP radiation protection recommendations are provided in ICRP Publication 60 (International Commission on Radiological Protection 1991) and also in a number of subsequent publications (e.g. International Commission on Radiological Protection 1997), which give guidance on the application of the recommendations. These recommendations have been formally adopted in Australia as the *National standard for limiting occupational exposure to ionizing radiation* which is accompanied by recommendations (NHMRC 1995a).

The ICRP framework of radiation protection contains three basic principles (International Commission on Radiological Protection 1991):

(a) No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (This is called the justification of a practice.)

(b) In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received, should all be kept as low as is reasonably achievable, with economic and social factors being taken into account (the ALARA principle). This procedure should be constrained by restrictions on the doses to individuals (dose constraints) or the risks to individuals in the case of potential exposures (risk constraints), so as to limit the inequity likely to result from the inherent economic and social judgments. (This is called the optimisation of protection.)

(c) The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible to control by action at the source and it is necessary to specify the sources to be included before selecting a dose limit. (This is called individual dose and risk limitation.)

There are various international conventions that deal with the management of radioactive waste. Australia is either a signatory to, or has ratified the following:

- *Joint convention on the safety of spent fuel management and on the safety of radioactive waste management*
- *Convention on the prevention of marine pollution by dumping of wastes and other matter* (London dumping convention)
- *Convention for the protection of natural resources and environment of the South Pacific Region* (SPREP Convention)
- *Convention to ban the importation into Forum Island countries of hazardous and radioactive waste and to control the transboundary movement and management of hazardous waste within the South Pacific Region* (Waigani convention)
- *Code of conduct on the safety and security of radioactive sources.*

Australia signed the *Joint convention on the safety of spent fuel management and safety of radioactive waste management* on 13 November 1998, having actively participated in developing the text. The aims of the joint convention are to:

- promote a high level of safety in spent fuel management and safety in radioactive waste management, through enhancement of national measures and international cooperation
- ensure effective defences against potential hazards so that individuals, society and the environment are protected from the harmful effects of radiation
- prevent accidents with radiological consequences and mitigate their consequences should they occur.

The treatment, transboundary movement, storage and disposal of spent fuel and radioactive waste were also covered. The joint convention states that each contracting party should:

- take the appropriate steps to ensure that at all stages of radioactive waste management, individuals, society and the environment are adequately protected against radiological and other hazards in so doing, each contracting party should take appropriate steps to aim to avoid imposing undue burdens on future generations
- in the framework of its national law, take the appropriate steps to ensure that the possession, re-manufacturing or disposal of disused sealed sources takes place in a safe manner

- ensure that all reasonably practicable improvements are made to upgrade the safety of radioactive waste management facilities.

The establishment of a national, radioactive waste repository would ensure that radioactive waste, including sources, is managed in the safest, most appropriate manner possible.

Contracting parties to the joint convention must report on radioactive waste management facilities and the inventory of radioactive waste. Australia is working towards ratification of the joint convention. When Australia becomes a contracting party, the national radioactive waste repository, as well as other waste management facilities, must be reported on under guidelines set out by the contracting parties to the convention.

The London Dumping and SPREP Conventions prohibit the dumping of radioactive waste at sea. The Waigani Convention, which Australia has ratified but which has not yet entered into force, seeks to ban the export of radioactive waste to all Pacific Island developing countries that are members of the South Pacific Forum.

The IAEA *Code of conduct on the safety and security of radioactive sources* was finalised in 2000. It states that to protect human health and the environment, every jurisdiction should take the appropriate steps necessary to ensure that the radioactive sources within its territory, or under its jurisdictional control, are safely managed during their useful lives and at the end of their useful lives; and are not stored for extended periods of time in facilities not designed for the purpose of such storage. The General Conference of the IAEA has called on member states to implement the code. Australia's policy of establishing a purpose-built facility for the disposal of disused sources is in keeping with the code.

3.2 Australia's Regulatory Framework

Each of the states and territories has its own legislation to regulate the use of radioactive materials.

In the case of the Commonwealth in 1999, the *Australian Radiation Protection and Nuclear Safety Act 1999* (Cwlth) established the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which regulates the Commonwealth's use of radioactive materials and provides advice on the use and management of radioactive substances. Before ARPANSA was established, the following organisations undertook this role:

- The Australian Radiation Laboratory provided advice to Government and the community on the health effects of radiation, and undertook research and provided services in this area.
- The Nuclear Safety Bureau regulated the High Flux Australian and Moata research reactors at Lucas Heights in Sydney.

The organisations were combined to form ARPANSA, which is specifically responsible for:

- promoting uniformity of radiation protection and nuclear safety policy and practices across jurisdictions of the Commonwealth, the states and the territories
- providing advice to government and the community on radiation protection and nuclear safety
- undertaking research and providing services on radiation protection, nuclear safety and medical exposures to radiation
- regulating all Commonwealth entities (including departments, agencies and bodies corporate, and contractors to these organisations) involved in radiation or nuclear activities or dealings.

Before ARPANSA was formed, the Commonwealth provided national advice and recommendations on radiation protection, through the Australian Radiation Laboratory, and through the Radiation Health Committee of the National Health and Medical Research

Council (NHMRC) which has published several codes of practice on radioactive waste management in Australia, covering user disposal, uranium mining and milling, and near-surface disposal.

The national repository would be owned by the Commonwealth and regulated by ARPANSA. States and territories would be involved as suppliers of waste to the facility and have the responsibility for waste management until the Commonwealth accepts control of the waste.

An ARPANSA licence would control how the repository was operated.

3.2.1 Relevant Acts and Regulations

The importation of radioactive waste into Australia is prohibited under Regulation 4R of the *Customs (Prohibited Imports) Regulations*.

The use, transport and disposal of radioactive material and waste in Australia is bound by Commonwealth and State legislation, through licensing requirements, and by codes of practice and standards. The following key Commonwealth elements are most relevant:

By specific exclusion in Commonwealth legislation:

- *Nuclear Non-Proliferation (Safeguards) Act 1987*

By Commonwealth legislation:

- *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act)
- *Australian Radiation Protection and Nuclear Safety (Consequential Amendments) Act 1998*
- *Australian Radiation Protection and Nuclear Safety (Licence Charges) Act 1998*
- *Australian Radiation Protection and Nuclear Safety Amendment Regulations 1999*
- *Australian Radiation Protection and Nuclear Safety Amendment Regulations 2000*
- *Australian Radiation Protection and Nuclear Safety (Licence Charges) Regulations 2000*

By reference in commonwealth codes and standards:

- *Recommendations for limiting exposure to ionizing radiation 1995* (National Health and Medical Research Council and National Occupational Health and Safety Commission 1995a)
- *National standard for limiting occupational exposure to ionizing radiation 1995*
- *Code of practice for the disposal of radioactive waste by the user 1985* (NHMRC 1985)
- *Code of practice for the near-surface disposal of radioactive waste in Australia 1992* (NHRMC 1992 Code)
- *Code of practice for the safe transport of radioactive material 2001* (Australian Radiation Protection and Nuclear Safety Agency 2001)
- *Code of practice on the management of radioactive wastes from the mining and milling of radioactive ores 1982* (Department of Home Affairs and Environment 1982)
- *Code of practice on radiation protection in the mining and milling of radioactive ores 1987* (Department of the Arts, Sport, the Environment, Tourism and Territories 1987)

The ARPANS Act applies within and outside Australia and prohibits certain nuclear activities. The ARPANS *(Consequential Amendments) Act* amended and revoked parts of the *Australian Nuclear Science and Technology Organisation Act 1987*, and revoked the whole *Environment Protection (Nuclear Codes) Act 1978* with transfers of assets and transitional arrangements. The ARPANS (Licence Charges) Act sets the framework for imposing license fees and, as such, will be directly relevant to the repository proposal.

The NHMRC 1992 Code is the guide for the management of radioactive waste in Australia. Although pre-dating the more recent IAEA Waste Safety publications (e.g. *Near surface disposal of radioactive waste*, WS-R-1 (1999), *Siting of near surface disposal facilities* 111-G-3.1 (1994), and *Safety assessment for near surface disposal*, WS-G-1.1 (1998)), the 1992 Code is entirely consistent with current IAEA philosophy and recommendations on the safety requirements for radioactive waste management. It focuses on the importance of natural site characteristics in providing a barrier to the dispersal of any radioactivity from the waste. The code is of primary importance to the repository proposal. Reference to subsequent IAEA codes will also be observed in the construction and operation of the repository.

The Nuclear Non-Proliferation (Safeguards) Act incorporates the treaty on the Non-Proliferation of Nuclear Weapons and covers licensing, control, monitoring and auditing of materials and equipment of strategic importance in the development of nuclear reactors, nuclear fuel processing and nuclear weapons. Non-proliferation of nuclear weapons has been an objective of the highest priority. Most states have joined the treaty as non-nuclear-weapon states and have accepted comprehensive IAEA safeguards. As the national repository will solely be for the storage of low level and short-lived intermediate level radioactive waste, the Nuclear Non-Proliferation (Safeguards) Act is not of direct relevance.

As a Commonwealth facility, the national radioactive waste repository will also be subject to the *Occupational Health and Safety (Commonwealth Employment) Act 1991*. The Act prescribes the use, management and storage of hazardous material at the workplace. The preferred and two alternative sites for the national radioactive waste repository are located in central–north South Australia between Woomera and Roxby Downs (see Figure 1.1). The preferred site, Evetts Field West (52a), is located inside the Woomera Prohibited Area (WPA). Commonwealth legislation, under part VII of the *Defence Force Regulations (No. 35) 1952*, has declared the WPA as a prohibited area for the purposes of ‘the testing of war material’.

The regulations of the *Defence Act 1903* (part XI) prohibit entering into and the use of a prohibited area without permission. The Defence Force Regulations confer on the Minister for Defence the right to control all access and activities within the WPA. The regulations also stipulate that standards on issues such as range safety, hazardous materials handling and environmental management are established and must be met by users of the WPA. The Department of Defence is committed to managing the WPA in an exemplary manner. The WPA and its activities are described in detail in Chapter 10.

3.2.2 Radiation Protection Limits

On the basis of recommendations from the International Commission for Radiation Protection, the NHMRC, in conjunction with the National Occupational Health and Safety Commission (NOHSC) has published Radiation Health Series No. 39 comprising *Recommendations for limiting exposure to ionizing radiation (1995b)* and *National standard for limiting occupational exposure to ionizing radiation (1995a)*.

This document sets limits on dose which, if not exceeded, will prevent deterministic effects from occurring. The system of radiation protection described is designed to keep the probability that stochastic effects will occur from exceeding a level that is regarded as unacceptable. The document notes that while the system of radiation protection described does not specifically refer to other species or the environment, it is generally believed that the standard of environmental control required for protection of people will ensure that other species are not put at risk.

The recommendations provide for a radiation dose limit, for people employed in occupations involving exposure to radiation, of 100 mSv in any five-year period with no more than 50 mSv in any one year. This corresponds to an annual effective dose of 20 mSv, averaged over five years. Doses to workers must be as low as reasonably achievable.

For members of the public, the recommendations provide for an annual radiation dose limit of 1 mSv and apply to exposure from all sources excluding those arising from natural background and the medical use of radiation. In certain circumstances a higher value of effective dose could be allowed in a single year, provided that the average over five years remains at 1 mSv per year.

3.2.3 Transport Regulations

Regulatory authorities in the Commonwealth, states and territories are responsible for the regulation of the transport of radioactive materials by road, rail or waterways within their respective jurisdictions. Regulation in states and territories is provided by the department responsible for either health or the environment. ARPANSA is the Commonwealth regulator.

Radioactive materials in Australia must be transported in accordance with the relevant code of practice, and state and territory regulations, to protect persons, property and the environment from the effects of radiation during transport.

The Code of practice for the safe transport of radioactive substances (1990) published by the former Department of the Arts, Sport, the Environment, Tourism and Territories under the *Environment Protection (Nuclear Codes) Act 1978*, was based on 1985 IAEA regulations adapted for Australia. The Commonwealth followed this code of practice until its revision in 2001. It also formed the basis of relevant state and territory legislation and regulations.

While the *Code of practice for the safe transport of radioactive substances (1990)* provides a high degree of safety, some of its aspects became dated with the publication in 1996 of new IAEA regulations. These regulations were in turn revised by the agency in 2001. In the light of the current knowledge of the risk of exposure to radiation some packaging controls needed to be tightened and others relaxed (Australian Radiation Protection and Nuclear Safety Agency 2001).

A working group of the Radiation Health Committee of ARPANSA has revised the 1990 code of practice. The new code, the *Code of practice for the safe transport of radioactive material (2001)* (ARPANSA 2001 Code) has now been adopted by the Commonwealth, and is referred to in the relevant parts of the ARPANS Act. Adoption of the new code by jurisdictions will ensure that the requirements for transport of radioactive materials in Australia are in keeping with current international practice.

The new code is in the process of being adopted by states and territories and, until it is, the 1990 Code of Practice and relevant existing state and territory regulations continue to apply. Persons are free to transport radioactive materials by road, provided that:

- they have obtained any necessary approval under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (the EPBC Act)
- they have obtained any necessary source (or other) licence under the ARPANS Act or, if that Act is not applicable, the relevant state or territory radiation protection laws
- they comply with the ARPANSA 2001 Code or, in some cases where the ARPANS Act is not applicable, the *Code of practice for the safe transport of radioactive substances 1990* (the previous code)
- they comply with the other requirements of any applicable radiation protection legislation and the conditions of any relevant licence
- they comply with generally applicable road transport laws.

The 1985 and 1996 IAEA regulations (International Atomic Energy Agency 1985, 1996), on which the 1990 and 2001 codes of practice are based respectively, establish standards of safety with the purpose of providing an acceptable level of control of the radiation, criticality and thermal hazards to persons, property and the environment associated with the transport of radioactive material. This is achieved by requiring:

- containment of the radioactive materials

- control of external radiation levels
- prevention of criticality
- prevention of damage caused by heat and impact.

In the 2001 code as in the 1990 code, packaging, labelling and licensing requirements are structured around a series of packaging levels, which are defined by the radionuclides present and their level of activity.

Differences between the two codes include changes to some packaging types, exemption levels and radiation protection program requirements. The essence of the codes is that the package design is commensurate with the potential hazard of the contents being transported.

Packaging

Packaging is defined as the assembly of components necessary to enclose the radioactive contents completely. It may consist of one or more receptacles, absorbent materials, spacing structures, radiation shielding and service equipment for filling, emptying, venting and pressure relief; devices for cooling absorbing mechanical shocks handling and tie-down and thermal insulation; and service devices integral to the package. The packaging may be a box, drum or similar receptacle, or a freight container tank or intermediate bulk container.

The following broad categories are defined in the 2001 Code of Practice:

- Excepted package
- Industrial package Type 1 (TypeIP-1)
- Industrial package Type 2 (TypeIP-2)
- Industrial package Type 3 (TypeIP-3)
- Type A package
- Type B(U) package
- Type B(M) package
- Type C package.

Type C is the most stringent of the packaging types. Freight containers can be used for industrial package classes. The code defines, for each packaging type where appropriate:

- requirements before first shipment
- requirements before each shipment
- appropriate transport documentation for each shipment
- segregation from other goods
- requirements for packaging materials and packages (including geometry and temperature requirements)
- requirements and controls for contamination and leaking packages
- specific additional requirements for each packaging type
- labelling requirements
- responsibilities of the consigner
- requirements for transport documentation to be provided by the consigner, including relevant actions to be taken by the carrier (instructions for loading, stowage, carriage, handling and unloading, and emergency arrangements appropriate to the consignment)
- general provisions regarding considerations for emergency response
- additional specific requirements for different transport methods (e.g. road, rail, air, ship)
- procedures for testing and sampling contents of packages and potential for leaching/leaking
- approval and administrative requirements (e.g. notification to the competent/regulatory authority on shipment information, including date of shipment and arrival and proposed route, required for Type B and C packages).

Radiation Dose Limits

Radiation dose limits are specified for transport containment. The dose limits apply at the surface and at a defined distance from the transport package. The dose limits for occupational and public exposure are defined in the *national standard for limiting occupational exposure to ionizing radiation* [NOHSC: 3022] and *Recommendations for limiting exposure to ionizing radiation* (Guidance note [NOHSC: 1013 (1995)]), together known as Radiation Health Series No. 39 (National Health and Medical Research Council and National Occupational health and Safety Commission 1995a,b).

Prior Notification

If the radioactive material (waste or other) is packaged in accordance with the relevant code of practice, there is no requirement that any authority be notified about the shipment, including the 'competent government authority' (regulator). Given that radioactive material is transported throughout Australia on a routine basis it would not be practicable to notify the competent government authority of every occurrence of transport of these substances.

Emergency Response

In the unlikely event of a radiation-related accident or incident, emergency response is a matter for the relevant state or territory emergency services and is covered by existing emergency planning arrangements in accordance with the transport code. In most emergency situations, the police, ambulance, fire services and state emergency services are the first responders. The fire services maintain specialised Hazmet teams trained to deal with chemical, biological and radiological incidents.

In addition the Commonwealth can provide assistance on request from the states. This assistance is provided through requests from the state emergency services to Emergency Management Australia. ARPANSA and the Australian Nuclear Science and Technology Organisation also maintain trained radiation emergency response teams that can provide assistance on requests from the state authorities. Further details on emergency response can be found in Section 7.6.4.

Regulatory Regime and the National Repository

Waste being transported by the Commonwealth would be regulated by ARPANSA, and would need to comply with the ARPANSA 2001 Code. The type of containment required for transport of waste to the repository would depend on the form and level of activity of the waste to be transported. In addition, conditioning requirements for acceptance of the waste at the repository will also be relevant to the packaging for transport. It is expected that a variety of packaging types will be required, as various types of low level and short-lived intermediate level waste will be transported for disposal in the facility.

Smoke detectors, for example, only require clear identification of the package contents. Depending on the activity, low level waste will generally require industrial packaging, which meets specified temperature and pressure specifications, drop tests, and water spray and penetration requirements. Type B packages may be used for some disused sources. These packages must withstand the effects of severe accidents and are tested for resistance to impact, penetration, and fire and water immersion.

Environmental impact or damage is very unlikely during the transportation of radioactive waste, given the solid and treated form of the wastes and the appropriate packaging requirements.

Transport of waste to the repository would also be considered in the context of the licensing of the facility by ARPANSA.

3.3 Approvals and Licences

The entire disposal process would be subject to regulatory requirements, including the characterisation and conditioning of waste to an acceptable form, transport of waste to the repository and the disposal operations. ARPANSA is the relevant regulatory authority and the regulatory framework would conform to the IAEA and ICRP standards and guidelines, together with Australian guidelines and legislation.

The environmental approval for the repository, including siting, design, construction, and operational and post-closure management is subject to the requirements of the EPBC Act, which is discussed separately in Section 1.2.

3.3.1 Approvals

The Commonwealth would own the low level and short-lived intermediate level radioactive waste repository, with regulatory oversight by ARPANSA, as the Commonwealth's independent regulator.

The repository site would be acquired by the Commonwealth and therefore would not require any state planning approvals. The Commonwealth acquisition would be undertaken under the *Lands Acquisition Act 1989*, and would formally commence once the Minister for the Environment and Heritage has reached a decision on the repository proposal. The Lands Acquisition Act allows land acquisition by agreement, or by compulsory process, following a well-defined series of steps.

3.3.2 Relevant Licences

Approval is required under the ARPANSA licence for each stage of the repository process including siting, construction, operation and decommissioning. The assessment of the licence approval would be subject to the evaluation of detailed plans and arrangements for protection and safety, including:

- the safety management plan
- the radiation protection plan
- the radioactive waste management plan
- strategies for the decommissioning, disposal or abandoning of the facility and/or the site
- the security plan
- the emergency plan for the controlled facility.

The regulatory branch of ARPANSA would review the monitoring results from the repository regularly to ensure its safety and compliance with licence conditions.

Public consultation is an important part of the licensing process. Public comment is invited on licence applications. The actual licence application fees are prescribed in the ARPANS Amendment Regulations 2000 and ARPANS (Licence Charges) Regulations 2000.

PART B

The Repository

Chapter 4
RADIOACTIVE WASTE IN THE REPOSITORY

Chapter 5
DESIGN AND SITE SELECTION BACKGROUND

Chapter 6
DESCRIPTION OF THE REPOSITORY FACILITY

Chapter 7
TRANSPORT OF WASTE TO THE REPOSITORY

Chapter 4
Radioactive Waste to be Held in the Repository

One of the key inputs to the design and management of the repository is to accurately define and quantify the types and volumes of low level and short-lived intermediate level radioactive waste to be disposed of at the facility.

This chapter provides:

- an overview of the existing inventory of low level and short-lived intermediate level waste
- estimates of potential future low level and short-lived intermediate level waste generation
- an outline of proposed waste acceptance criteria for waste to be disposed of at the repository.

4.1 Inventory of Existing Waste

Australia has accumulated about 3700 m^3 of low level and short-lived intermediate level radioactive waste from over 100 years of research, medical and industrial use of radioactive material. This is the conditioned volume requiring disposal. The approximate volumes are given below:

- 2010 m^3 of slightly contaminated soil from research by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) into ore processing, which is currently stored in drums near Woomera
- 1320 m^3 of operational waste from Australian Nuclear Science and Technology Organisation (ANSTO) operations at Lucas Heights near Sydney
- 210 m^3 of contaminated soil, sealed radioactive sources and other equipment held by the Department of Defence
- 160 m^3 (allowing for conditioning) of sealed radioactive sources used in gauges, smoke detectors, medical equipment and luminous signs stored at numerous locations around Australia, including in government stores, research institutions and industry stores.

The 2010 m^3 of slightly contaminated soil stored near Woomera arose from CSIRO research into the processing of radioactive ores during the 1950s and 1960s. This material is located at Woomera close to Site 52a, and is contained in some 9726 drums of 207 L capacity. It is low level waste ready for transport and disposal without further conditioning.

The 1320 m^3 of ANSTO operational waste, including clothing, paper and glassware, is stored at Lucas Heights near Sydney, and is in a conditioned form ready for disposal. It comprises packed waste of about 5000 drums of 205 L capacity and 400 drums of 300 L capacity, and unpacked waste of approximately 250 further drums of 205 L capacity.

The 210 m^3 of Department of Defence waste, which consists of contaminated soils from land remediation, sealed sources, gauges, electron tubes, equipment (watches and compass parts) and some aircraft ballast, is 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, industry (including factories) and other 'small' waste producers and holders, and is distributed throughout the country. Figure 4.1 illustrates an example of such waste.

FIGURE 4.1
Existing waste

A summary of existing waste by state is provided in Table 4.1. The total inventory is 3700 m^3 (60%) is held in South Australia. Of the 2228 m^3, 2010 m^3 is contaminated soil stored at Woomera. See Appendix B for more detailed inventory of key radionuclides.

4.2 Future Waste Generation

Recycling of disused sources or radioactive materials used in medicine, industry or research is now extensively practised, and estimated future waste arisings are therefore relatively small.

It is expected that about 40 m^3 of low level and short-lived intermediate level waste will be generated in the future in Australia on an annual basis. Of this, about 30 m^3 (conditioned) is expected to be generated each year by ANSTO through routine operational activities. Other waste producers are expected to generate up to approximately 10 m^3/yr in conditioned form ready for disposal.

Table 4.2 summarises estimated routine future arisings of low level and short-lived intermediate level radioactive waste, and also notes the waste volume which would be generated from the decommissioning of the High Flux Australian Reactor (HIFAR), and from the replacement research reactor. There are various decommissioning options possible for HIFAR, and the amount of low level and short-lived intermediate level waste generated would vary from 500 to 2500 m^3 depending on the option chosen.

Option 1 involves immediate dismantling of HIFAR to a new site after its decommissioning, which would generate about 2500 m^3 of low level and short-lived intermediate waste. Option 2 involves the removal of fuel and heavy water, followed by care and maintenance for approximately 30 years, then entombment of the remaining structure in concrete. This option would involve the generation of 500 m^3 of low level waste. Option 3 would involve the removal of fuel and heavy water, followed by care and maintenance for up to 120 years, then dismantling to a new site, and would generate 2000 m^3 of low level and short-lived intermediate waste (PPK Environment & Infrastructure 1998).

ANSTO's preferred HIFAR decommissioning strategy is either Option 2 or 3 (PPK Environment & Infrastructure 1998). The amount of low level and short-lived intermediate level radioactive waste generated from the decommissioning of the replacement research reactor is likely to be within the range of volumes for the decommissioning of HIFAR.

TABLE 4.1 Summary of inventory of low level and short-lived intermediate level waste by state (approximate conditioned volumes for disposal)

State	Locations	Estimated volume[(1)]
South Australia	Adelaide and regional hospitals, universities and other research organisations, private companies and some government departments Locations include: Adelaide CBD and surrounding suburbs, including Salisbury; Mt Gambier, Woomera, Olympic Dam, Port Pirie, Whyalla and Loxton Includes 2010 m^3 of slightly contaminated soil stored near Woomera from CSIRO research into the processing of radioactive ores during the 1950s and 1960s	2228 m^3
Victoria	Melbourne and regional hospitals, universities and other research organisations, private companies and some government departments Locations include: Melbourne CBD and surrounding suburbs, including Clayton; Geelong, Sale and Wodonga	33 m^3
New South Wales	Sydney and regional hospitals, universities and other research organisations, private companies and some government departments Locations include: Sydney CBD and surrounding suburbs including Lidcombe, Liverpool, Menai (Lucas Heights), North Ryde; Griffith, Wollongong and Armidale Includes 1320 m^3 of ANSTO material stored at Lucas Heights near Sydney	1355 m^3
Queensland	Brisbane and regional hospitals, universities and other research organisations, private companies and some government departments Locations include: Brisbane CBD and surrounds, Esk, Mt Isa, Rockhampton and Townsville	45 m^3
Tasmania	Hobart, Launceston and regional hospitals, universities and other research organisations, private companies and some government departments Locations include: Hobart CBD, surrounding suburbs and regional areas	15 m^3
Australian Capital Territory	Hospitals, universities and other research organisations, private companies and some government departments Locations include: Canberra CBD, surrounding suburbs and regional areas	8 m^3
Northern Territory	Hospitals, universities and other research organisations, private companies and some government departments Locations include: Darwin CBD, surrounding suburbs and regional areas	16 m^3
Western Australia	Low level and short-lived intermediate level waste in WA is disposed at the intractable waste disposal facility (IWDF), Mount Walton East	
TOTAL		3700 m^3

(1) Further information on the waste inventory is provided in Appendix B. This information includes estimates of the total concentrations of key radionuclides that are expected to be disposed of in the repository.

TABLE 4.2 Summary of future low level and short-lived intermediate level waste arisings

Locations 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	500–2500 m^3
Lucas Heights replacement research reactor decommissioning	Amount expected similar to HIFAR

About 55 m^3 (100 tonnes) of low-level radioactive waste will also be generated from ANSTO's 100 kW Moata research reactor, which was shut down in May 1995, and the fuel, cooling system and electric systems were removed. A decommissioning plan has been prepared and agreed to by the regulator (ARPANSA). The timing of dismantling the reactor has not yet been decided.

The repository would be designed to take about 10,000 m^3 of low level and short-lived intermediate level radioactive waste (although the limit would be set for total activity for various radionuclide groups). The estimated initial operational life of the repository is 50 years, after which time there would be an operational review. The finalised volume and total activity would be in accordance with ARPANSA approvals (Section 3.3).

4.3 Waste Acceptance Criteria

4.3.1 Waste Acceptance Criteria General Factors

A key feature influencing the performance and safety of the repository would be the nature of the wastes that are accepted for disposal at the site. Waste acceptance criteria (WAC) are the set of requirements that must be met before radioactive waste can be accepted for disposal at a repository. It is accepted international practice to establish such criteria for the acceptable of waste at disposal facilities. Factors that influence WAC can be associated with a number of areas of waste management, in particular:

- transport
- operations and handling at the disposal facility
- post-closure safety assessment.

WAC Scope

WAC commonly include:

- general conditions for the acceptance of waste
- those materials excluded or treated prior to disposal
- conditions for the preparation of different types of waste
- acceptability of waste containers
- requirements for delivery of waste to the repository
- quality assurance requirements
- information required by the site operator from the consignor.

The WAC define the specific requirements to be met by a consignor for a radioactive waste package to be accepted for transport and disposal at the repository. The WAC address the characteristics of both the package and the waste, and other key issues such as documentation, procedures to be used by the consignor, authorisations and demonstrations of conformity.

The WAC also incorporate the requirements for packaging, labelling and transport of the waste following accepted international practice (as described in International Atomic Energy Agency (IAEA) Waste Safety Standards Committee documents and others, such as IAEA-TECDOC-1097 (International Atomic Energy Agency 1999), and are covered by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) 2001 *Code of practice for the safe transport of radioactive material* (ARPANSA 2001 Code), described in Section 3.2. Therefore, the WAC establish the acceptable standards for radioactive waste packaging through processing, transport, storage and disposal.

The WAC are developed from applicable national and international regulations and guidelines, which cover the safe management of radioactive waste at all stages. A safety assessment of the complete waste management system, from production to final disposal and post-closure, is also used in determining the criteria, especially those quantitative aspects.

To meet regulatory and safety requirements, constraints are imposed on both the waste packages and the components of the waste packages, taking account of implications on the waste inventory and the ultimate wasteform for disposal at the repository. Within these constraints it is then possible to define specifications for acceptable waste and waste packages and hence the WAC.

Although safety considerations are of primary importance in establishing WAC, non-safety-related elements that may affect the acceptability of a waste package at a disposal facility also need to be taken into account. Considerations may include, for example, compatibility with package handling equipment at the site and the need to provide a disposal record.

The detailed WAC for any consignment may be derived from a combination of factors, including transport package restrictions and/or limitations imposed by handling equipment at the disposal site. Compliance of the waste package with the WAC would be determined by a range of methods, including records of the waste characteristics and information obtained during the design and production of the waste package. The generation and management of these records of waste characteristics is covered by quality assurance and quality control arrangements, which may include waste records, waste assays, the recording of key plant and process information, and post-production testing.

Radionuclide Activity Factors

WAC would be applicable to each individual waste package. Restrictions may also be placed on individual radionuclides within a particular package (or group of packages from a waste supplier, constituting a consignment) in order to determine the appropriate disposal strategy for the package within the repository.

Activity concentration limits for each type of radionuclide accepted into the facility would be derived from a full assessment of the risks posed by radioactivity reaching the biosphere. For example, exposure scenarios due to inadvertent intrusion after the period of institutional control would be used as an input into determining the maximum acceptable total concentration of longer-lived isotopes. The risk from possible groundwater leaching would be considered throughout the lifetime of the facility.

Activity limits would be derived from a detailed pathway analysis, looking at normal operational and accident conditions.

4.3.2 Proposed Waste Acceptance Criteria

Proposed WAC are being developed for the national repository. Aspects of the proposed criteria (which will be further refined) are summarised below.

Conditions of Acceptance

A number of general conditions of acceptance of waste have been developed, including:

- Only low level and short-lived intermediate level waste (see Sections 2.3.1 and 2.3.2) will be accepted.
- Waste will require a current certificate or letter of authorisation issued by the appropriate government department (State/Territory/Commonwealth radiation safety regulator) before it will be accepted for disposal.
- Waste generated outside of Australia will not be accepted.
- Category S (long-lived intermediate level waste) material will not be accepted.

Materials to be Excluded or Treated Prior to Disposal

In addition, a number of criteria have been developed that relate to materials that need to be excluded or treated prior to disposal. Key factors include:

- Liquid waste would not be accepted. There would be a limit on the moisture content of solids.
- Wastes that may enhance the migration of particular radionuclides or heavy metals should be treated to reduce the possible long-term effects of leaching by water.
- No PCBs or PCB-contaminated items would be accepted.
- Oils and corrosive materials would not be accepted.
- Waste should not contain or be capable of generating gaseous materials in quantities that may result in the release of harmful vapours or fumes, or build-up of pressure.
- If compressed gases are present in the material, they must be appropriately treated so that they do not release fumes or build up pressure. The would only be disposed of if appropriately treated.
- Highly flammable materials, as defined in the *Australian code for the transport of dangerous goods by road and rail* (ADG Code; Advisory Committee on the Transport of Dangerous Goods 1998) would not be accepted, and flammable and non-flammable material would be separated and packed accordingly.
- Waste containing pyrophoric material would be processed to render it inert and approval of such processing confirmed by site operator prior to dispatching.
- Waste should not contain any explosive materials as defined in the ADG 1998 Code.
- Waste should be free of biological material or treated to destroy any relevant micro-organisms.
- No radioactive waste containing toxic, pathogenic or infectious material would be accepted unless appropriately treated or conditioned in accordance with relevant guidelines.
- Putrescible materials in waste should be excluded as far as practicable and should not exceed 1% of the primary containment weight.
- Radioactive waste material containing hazardous chemicals/agents would only be accepted if the radiological hazard clearly exceeds the toxic chemical/agent hazards, (other than covered by previous points).

Radioactivity Limits

Limits on radionuclide content would apply for the acceptance of waste for disposal, in accordance with criteria specified in the National Health and Medical Research Council (NHMRC) 1992 *Code of practice for near-surface disposal of radioactive waste in Australia* (NHMRC 1992 Code), or as subsequently modified by ARPANSA under any facility licence.

- Radioactivity concentrations for Category A, B and C (see Section 2.3) waste packages shall not exceed the predetermined values for each radionuclide group, as authorised by ARPANSA, based on site-specific risk scenarios of an annual effective dose of 1 mSv being received by a member of the public from the presence of the waste (NHMRC 1992 Code).
- The activity concentration for Category A and B wastes shall be calculated by averaging the activity over the whole conditioned package or container, while Category C bulk waste activity may be averaged over the volume of the disposal structure.
- The activity concentration of radionuclides in waste packages containing a mixture of radionuclides shall not exceed the maximum value as calculated using the summation rule.
- Waste packages containing radionuclides within two or more inner packages shall be classified and labelled according to the most restrictive classification.

Waste Packaging

The proposed waste package for general application is a standard industrial 205 L drum made of mild steel with a lid held on by a band secured with a bolt. These drums are not hermetically sealed, and have limited shielding properties, but are suitable for most low level and short-lived intermediate level radioactive waste. Packages other than the standard 205 L industrial drum may also be used, with the approval of ARPANSA and the facility operator (see Section 3.3).

Where contents are of higher total activity, and thus require more radiation shielding they would be placed inside 205 L steel drums together with a cementitious grout mixture. Where contents are of higher specific activity, for example sealed sources, they would be placed inside 205 L drums that have concrete shielding and separate inner containers.

The principal transport method is proposed to be by trucks. Standard 6 m International Organization for Standardization (ISO) containers, with the 205 L drums stacked inside using appropriate packing for stability, may be used. Transport methods would be in compliance with the requirements of the ARPANSA 2001 Code and any other conditions imposed by ARPANSA licensing.

Preparation of Category A, B and C Waste for Disposal

Category A, B and C wastes shall be conditioned so as to comply with packaging and container conditions (as set out in the ARPANSA 2001 Code and any ARPANSA licensing requirements). Category A wastes (low concentrations, short half lives) may need minimal treatment and may be placed directly into disposal trenches. Waste containing radium (Category B) would not be accepted unless it complied with established activity concentration limits.

Transport Packages

The following waste acceptance criteria would relate to transport packages:

- Waste would only be accepted inside transport packages approved by the site operator and properly labelled in accordance with applicable transport regulations.
- The external non-fixed contamination levels on transport packages arriving at the repository must not exceed 4 Bq/cm^2 beta/gamma and 0.4 Bq/cm^2 alpha averaged over 300 cm^2.
- External dose rates must comply with applicable transport regulations, and packages not be left un-vented for more than 30 days prior to delivery to site.

Waste Containers

The following limitations would be applicable to acceptance of waste containers within transport packages:

- A maximum dimension of any waste container would be imposed and the containers and metal drums should not weigh more than limits set by the site operator.
- All individual containers within a transport package must be appropriately and clearly labelled to enable traceability to point of origin.
- The site operator must be satisfied with the qualification of all waste container design, manufacture, filling and handling to meet all specifications for waste acceptance and disposal.
- The external non-fixed contamination levels on waste containers arriving at the repository must not exceed 4 Bq/cm^2 beta/gamma and 0.4 Bq/cm^2 alpha averaged over 300 cm^2.
- External dose rates must comply with applicable health physics regulations for the safe handling of the containers.
- The placement of all waste containers inside transport packages must be such as to allow easy retrieval.

Delivery of Waste to the Repository

The repository would only be open for receipt of waste at a certain specified interval for the initial campaign, and subsequent campaigns (every 2–5 years). The following criteria have been set for the delivery of waste to the repository:

- A minimum notice period will be applicable for any potential waste delivery to the site and no waste will be accepted without prior consent from the site operator.
- Waste will only be accepted during normal operating hours, unless specific arrangements have been made with the site operator.

- Delivery personnel will at all times abide by the site rules when on site.
- Empty containers will be returned to customers within a set time from delivery.

Quality Assurance

A quality assurance (QA) system for acceptance of waste would be put in place and strong adherence to the following aspects of this system would be enforced:

- Customers would implement a suitable quality assurance system for effective management of low level and short-lived intermediate level waste up to the time of acceptance at the repository, including arrangements for periodic review. This customer QA plan would require the site operator's approval prior to delivery.
- All waste shall be accompanied by a valid waste description document as approved by the site operator. The following information would be provided by waste producers:
  - the waste identifier (number and name) and consignor code
  - a description of the process generating the waste
  - estimated arisings from the waste producer in terms of activity, volume, mass and timescale
  - whether the waste is a new arising or has been identified in previous Australian radioactive waste inventory estimates
  - physical and chemical composition
  - the non-radiological hazardous waste components
  - type of conditioning and stabilisation undertaken
  - consolidation undertaken
  - method of assessment of radioactivity content
  - radionuclide composition
  - waste category.
- Acceptance of waste would be subject to waste receipt monitoring, which may include testing and inspection of each consignment or samples of consignments before conditioning and transport and after delivery. Non-conforming waste would be appropriately managed at the repository site, and the customer charged a cost penalty, and could be subject to an investigation with potential restrictions on further deliveries.

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 $x10^{-5}$/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 $x10^{-5}$/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).

Chapter 6
Description of Repository Facility

This chapter describes the preliminary design layout and aspects of the facility, and presents an outline of operating concepts. The detail of these aspects would be determined during the detail design stage, which would form the next stage of the project.

6.1 Facility Objectives and Design Basis

6.1.1 Objectives

The purpose of the facility is to:

- strengthen Australia's radioactive waste management arrangements by promoting the safe and environmentally sound management of its radioactive waste through the establishment of a purpose-built, near-surface repository
- provide safe containment of radioactive waste until the radioactivity has decayed to background levels.

In achieving these objectives, the facility shall comply with Australian radiation dose limits for workers and the public under normal operation, including during any foreseeable events, after closure and during and after the institutional control period.

6.1.2 Performance Specifications for the Repository

The operational requirements for the design of the repository are to:

- be suitable for the disposal of low level and short-lived intermediate level radioactive waste generated within Australia
- be a near-surface engineered facility that ensures the waste is isolated from the biosphere for a period long enough for the radioactivity to decay to acceptably low levels
- accommodate all existing waste and future arisings over a period of at least 50 years
- comply with international guidelines and accepted international practice
- comply with the following Australian regulatory requirements:
  - 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), the regulatory requirements of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and the environmental conditions imposed by the Commonwealth Department of the Environment and Heritage (Environment Australia) (see Section 3.3)
  - the national radiation protection dose limits for workers and members of the public, for both the operational and post-closure periods (see Section 3.2.2).

The basic design requirements of the facility would be to:

- minimise water ingress
- minimise intrusion by flora and fauna
- prevent unauthorised or inadvertent human intrusion during both the operational and post-closure periods
- minimise effects of weathering/erosion
- provide sufficient structural stability to accommodate waste packages
- provide a level of monitoring sufficient to detect inadequate performance.

The facility operator would put in place a management structure and monitoring program for the facility that clearly define:

- responsibility and procedures for the operation of the facility
- compliance with contractual, statutory and licensing obligations.

6.1.3 Design Basis

A multi-barrier approach would be used including physical containment provided by some, or all, of the following:

- the trench/borehole design
- the waste form
- the conditioned waste packages
- the host rocks, arid environment, and groundwater and surface water characteristics of the site.

The disposal trenches (capped with an engineered system to minimise the potential for water infiltration) and boreholes (lined with clay or cement grout) would provide an engineered barrier for waste containment, in addition to containment provided by packaging. In some instances, for example short-lived intermediate level waste, cement overpacks would provide a containment barrier for the solid waste. The characteristics of the surrounding and underlying rock strata would provide additional containment for the waste.

The environment provides a natural barrier to isolate the waste through the rock type, the low rainfall and high evaporation rate, the deep and saline watertable, the time needed for the small amount of surface water that does not evaporate to travel to the watertable, and the time needed for the groundwater to then move to a point of discharge.

Waste would arrive at the repository in a conditioned form suitable for disposal (waste acceptance criteria (WAC) are described in Section 4.3). There would be some provision at site for concreting or emergency minor repackaging of waste, should this be required. More active sources may be placed in concrete overpacks at the site for disposal.

The design would be assessed in terms of its:

- operational safety
- environmental compliance
- post-closure performance
- cost.

The assessment would indicate the key performance and safety parameters and the design would be reviewed and revised to optimise these parameters. Figure 6.1 shows the preliminary design concept for the national repository; the groundwater depth and movement shown in the figure are based on the local conditions at Site 52a.

6.1.4 Operational Usage and Institutional Control Periods

The repository would receive the current inventory of low level and short-lived intermediate radioactive waste held at various facilities around Australia in an initial disposal campaign. Disposal campaigns would then be conducted every few years for a period of approximately 50 years, at which time a major review would be undertaken to determine the ongoing requirements for disposal space, and the ability of the facility to meet the ongoing requirements.

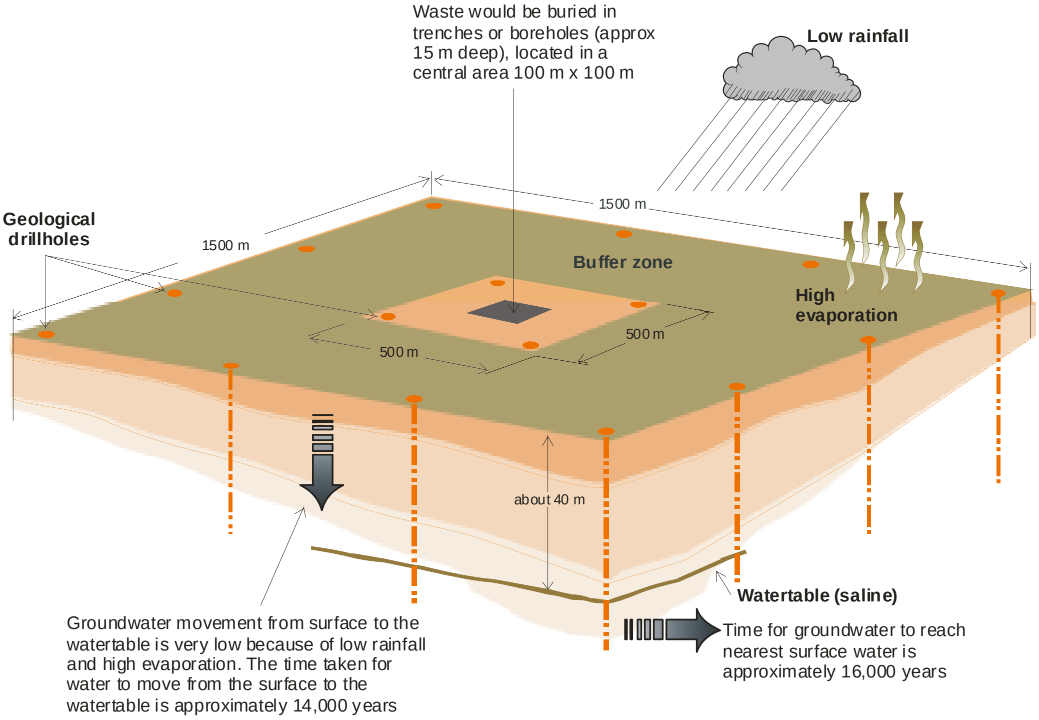


FIGURE 6.1
Graphic representation of repository site (Site 52a)

To clarify the terminology on the phases of the project in Sections 8.3 and 8.4 of the EIS Guidelines (Appendix A): surveillance would be undertaken in the periods between operational campaigns (expected to be every 2–5 years); decommissioning would take place at the end of the operational phase (nominally 50 years); and the institutional period of 200 years would follow the decommissioning and closure of the repository.

The low generation rate of low level and short-lived intermediate level radioactive waste in Australia means that once the current inventory has been disposed of, disposal campaigns at the repository may be separated by extended periods of two to five years where no disposal may occur. The quantities to be disposed of in the existing inventory, and expected future arisings, are discussed in Sections 4.1 and 4.2.

At the end of each campaign the disposal structure (trench or borehole) would be closed and securely contained to prevent intrusion by people or animals, and to minimise the ingress of rainwater. Most or all buildings would be removed from the site between campaigns.

Periodic monitoring and surveillance would be undertaken in the periods between campaigns to ensure the facility remains secure, and the waste contained. At the end of the operational period, the facility would enter the institutional control period. This is the length of time following closure for which land use restrictions are applied. Over this time, the facility would be monitored and access restricted.

The institutional control period for the facility would be 200 years. At the end of this period the radioactivity in the disposed waste would have decayed to low enough levels to allow unrestricted land use. Long-lived radionuclides would be buried at an acceptably low level of activity concentration to ensure this requirement.

Arrangements for the timing of campaigns would be determined in consultation with waste producers, and would take into consideration the amount of waste requiring disposal.

6.1.5 Repository Layout

The repository would be located on a site measuring 1.5 x 1.5 km, with the waste buried in the central part of the site in a series of trenches about 15–20 m deep (depending on the final site) and also in boreholes. These would be placed within an area of approximately 100 x 100 m, about the size of a soccer or rugby field. Support buildings and other infrastructure would be located on the site adjacent to the trenches. An indicative site plan is provided in Figure 6.2.

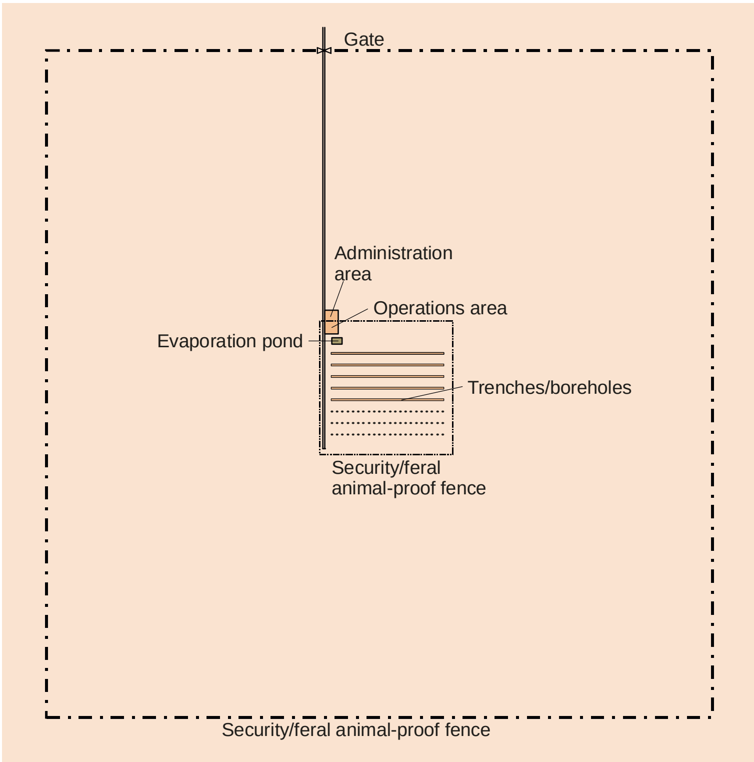


FIGURE 6.2
Indicative site plan

A security fence would be constructed around the 1.5 x 1.5 km margin of the buffer zone to prevent human intrusion and exclude grazing animals. It would also be designed to exclude key feral animal species (rabbits, cats and foxes, which would be eradicated from the site) and allow the regeneration of native species within the buffer zone. Similarly, a fence would be provided around the 100 x 100 m disposal area, to exclude animals.

6.2 Disposal Facility Design

A preliminary design concept has been prepared, which would be further defined during the detailed design phase of this project. A summary of the preliminary design is presented in the following section.

The regulator would provide formal assessment of the performance and safety of the facility during the licensing process.

6.2.1 Key Features

The repository would be designed to meet the overall performance criteria and safety requirements of the NHMRC 1992 Code. The facility would contain a number of disposal trenches and boreholes to best meet operational requirements, and would be designed and sized to account for the different waste types and quantities. The trenches and boreholes would be constructed, and disposal operations conducted, in such a manner as to minimise the time the structures were open.

As noted in Section 6.1.3, the trenches would be capped with an engineered system to minimise the potential for water infiltration, and the boreholes would be backfilled with clay or cement grout. In some instances, based on safety assessment, concrete overpacks or modular canisters would provide the containment barrier, rather than engineered barriers in the disposal structure (see Section 6.5.5).

The characteristics of the surrounding and underlying rock strata would provide further containment to prevent contaminants leaching into the environment.

To allow waste to be securely contained between campaigns, new excavation(s) would be prepared for each campaign.

Figure 6.3 provides an indicative trench design, and Figure 6.4 provides an indicative borehole design based on the methodology previously used at the Mount Walton East facility in Western Australia. The trench and borehole designs would be finalised during the detail design phase as part of the ARPANSA regulatory approval process (see Section 3.3).

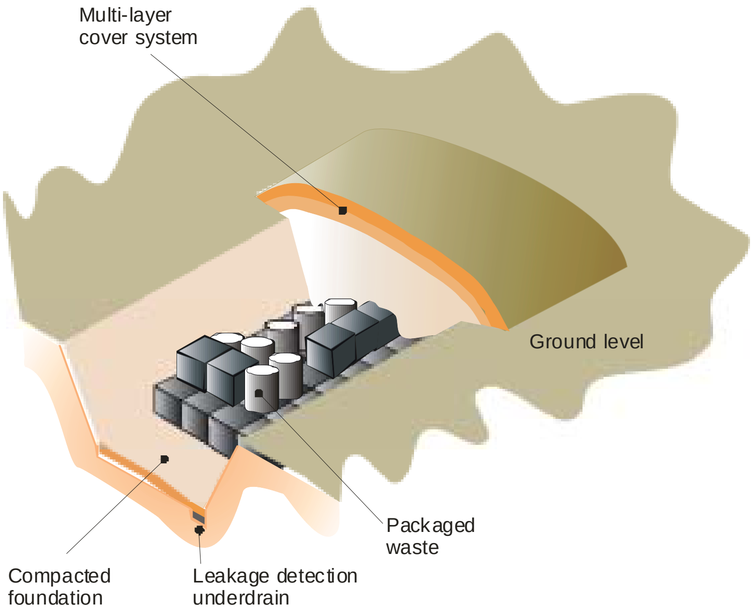


FIGURE 6.3
Indicative trench design

6.2.2 Surface Drainage

The trench sites would have low, natural vertical relief. Existing surface water flow paths or engineered drainage systems would ensure that there is no likelihood of flooding or surface flow to the trench (or boreholes), even in the event of a 1-in-100-year storm event. The completed slope of the repository would be designed to minimise the potential for ponding and ensure erosion is not significant over the life of the repository (including the institutional period).

Predicted rainfall intensities for a 1-in-100-year storm in the region are 59.6 mm/hr for a 1-hour duration storm, 9.7 mm/hr for a 12-hour duration storm, 5.5 mm/hr for a 24-hour duration storm and 2.1 mm/hr for a 72-hour duration storm (see Table 8.12).

The design would ensure that surface water from rainfall events does not accumulate in the vicinity of the buried wastes, or enter trenches or boreholes, both during operations and after closure. Surface drains from operational areas where radioactivity is handled would be led to an evaporation pond within the repository compound to collect runoff and contain potentially contaminated surface water on site.

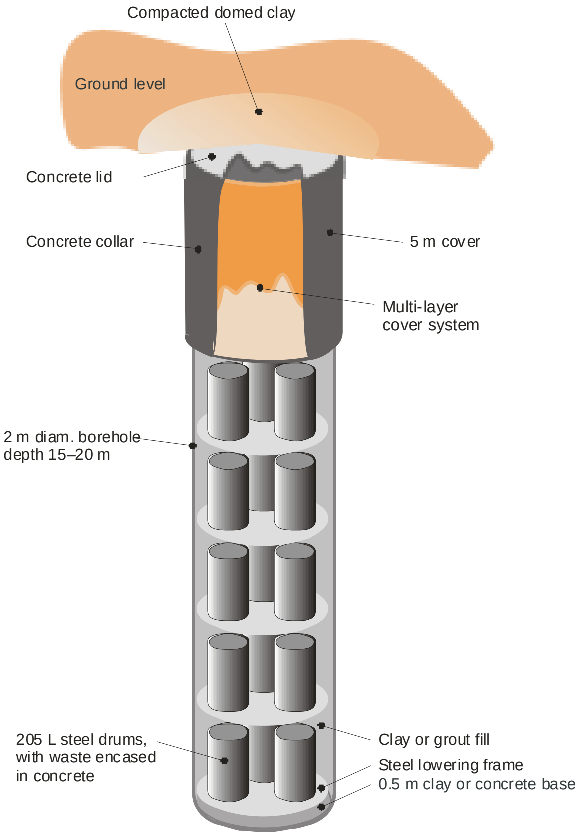


FIGURE 6.4
Indicative borehole design

During operations, while trenches or boreholes were open, facilities would be available to collect any rainwater that accumulates in the bottom of a trench. Modelling undertaken as part of the project assessment indicates that rainwater infiltration would be insignificant with an engineered cover. This is discussed further in Section 8.10.3. It is also proposed to compact the base of the repository and grade the finished surface to a sump to collect any free water and direct it to a sampling well.

6.2.3 Trench and Borehole Design

The disposal facility (trench and/or borehole) would be designed to hold the total volume of waste proposed for each disposal campaign. The trenches and boreholes would be designed to ensure adequate containment of the emplaced waste such that the safety criteria are met.

Trench Design

The trenches are expected to be about 12 m wide at the base to enable adequate construction equipment access, and crane reach during unloading operations. The base would vary depending on the final site, but would be expected to be about 15–20 m below ground level. The sides of the trench would be battered to prevent collapse (Figure 6.3). The trenches would be ramped at one end to allow access by heavy machinery.

Excavated topsoil would be separately stored for use in the final cover. The zone adjacent to the top of the trench would have an earth berm to exclude rainfall runoff and to keep heavy trucks or other vehicles away from the edge of the trench to lessen the risk of the batters collapsing.

Borehole Design

Boreholes would comprise holes approximately 2 m in diameter and of similar depth (15–20 m) to the trench design described above. The indicative design shown in Figure 6.4, which is based on the methodology used at the Mount Walton East facility in Western Australia, would be finalised during the design stage.

Construction at the Mount Walton East facility (see Section 2.4.1) used a manual method of pneumatic jackhammers with spade bit drills and a vacuum ore-lifter to raise the spoil to the surface (provided the ground was not too hard). A concrete collar was poured at the top of the shaft to ensure stability of the shaft at the surface.

An alternative method would be to use large diameter augers for borehole drilling. The actual method to be used would be determined during the design phase.

At Mount Walton East waste was prepared for disposal in 205 L drums, using steel frames lowered into the borehole, with three 205 L drums placed on each frame. Waste was placed on a concrete block inside the 205 L drums, and the drums filled with concrete. After being lowered into the borehole, the drums and complete frame were covered with cement grout, and the next frame was lowered into place before the grout had set. The actual method to be used for the national repository would be determined during the design phase.

Upon completion of the placement of waste packages into the borehole, the top 5 m would be backfilled with a compacted multi-layer system similar to that used for trench backfill, to minimise water ingress into the borehole. Depending on the depth of the borehole (15–20 m), it is expected that 15–27 drums would be disposed of in each borehole.

6.2.4 Backfill

In view of the long institutional control period of the repository and the requirement of structural stability for the stored wastes, it would be important to minimise settlement arising from consolidation over time of the backfill material used to cover the waste. This would involve voids being filled, and adequate compaction of backfill and cover materials.

Criteria for the backfill material, its placement and compaction and testing requirements would be determined in the detail design phase for the facility. Materials recovered during excavation would be investigated for suitability as a backfill material. There may be a need to process the material excavated from the lower portion of the repository to produce a well-graded backfill.

6.2.5 Cover

A suitable cover would be placed over the buried waste to limit infiltration of rainwater; discourage entry of animals, plant roots and humans; and inhibit erosion. The cover would be designed to ensure that the layer properties and thicknesses were adequate to comply with requirements on water ingress and intrusion over the long term. Likely settlement or adjustment would be assessed to ensure that the cover would maintain its integrity during any consolidation.

The NHMRC 1992 Code requires a 2 m cover for Category A waste and a 5 m cover for Category B and C waste. For this repository it is proposed to use a 5 m cover for all waste to limit the potential of radon release from the waste.

A possible cover design may consist of the following layers (from the top):

- **The surface profile**, which would direct any rain or storm surface water away from the burial trenches and be constructed of material with low susceptibility to erosion (such as gibbers, cobbles or rock). Plant growth on the cover would increase evapotranspiration and decrease erosion. The final cover would be of sufficient height above ground level

to shed surface water and allow for possible consolidation. All slopes would be shallow enough and covered with material to prevent sheet erosion
- **A soil layer** that supports vegetation similar to that in the surrounding landscape
- **A cobble layer** to discourage digging animals
- **An impermeable layer,** possibly an impermeable geomembrane
- Possibly **a clay layer** at sufficient depth to maintain adequate water content extending from one side of the trench to the other
- Possibly **a layer of site spoil** (or other material), an extension of the material used to backfill the spaces between placed wastes.

There would be an access road to transport waste materials to the site and the trenches. The transport routes are described in detail in Chapter 7.

6.3 Site Support Facilities

The extent of facilities at the site would largely be determined by the facility operator and would depend on such issues as the agreed nature of the packaging of arriving waste and the frequency of disposal operations.

6.3.1 Key Facilities

The key features of the facilities to be constructed are expected to include (Figure 6.5):

- an operations building
- a decontamination/washdown area
- office and ancillary facilities
- a health physics facility
- services Infrastructure.

These facilities are described below. As noted in Figure 6.5, the operations building and associated facilities would be located within the health physics supervised area, with personnel access through the health physics facility. The office and associated facilities would be outside of this area.

6.3.2 Operations Building

The operations building would include facilities for waste receipt, holding, conditioning and packaging and a small laboratory for monitoring waste. It would be about 20 x 12 m in size.

Waste Receipt and Holding

After the waste packages have been received at the repository, and are confirmed as acceptable for disposal, they may require a short period of storage, probably a period of days or a few weeks at most, prior to disposal while quality assurance and assay activities are undertaken. Depending on the type of package design required, additional stillages (support structures) might be provided in the waste store to add structural stability to the stacked packages.

Prior to disposal at the repository, the radionuclide inventory of a waste package would be recorded. This would enable safety assessments to be carried out during handling operations and post-closure repository conditions.

The recording system would also identify what packages have been accepted and where they are located. A document quality assurance trail would be used to establish the contents of any package, using records from the origin of the package, the conditioning undertaken before transport to the repository, any additional conditioning undertaken on site and storage prior to disposal.

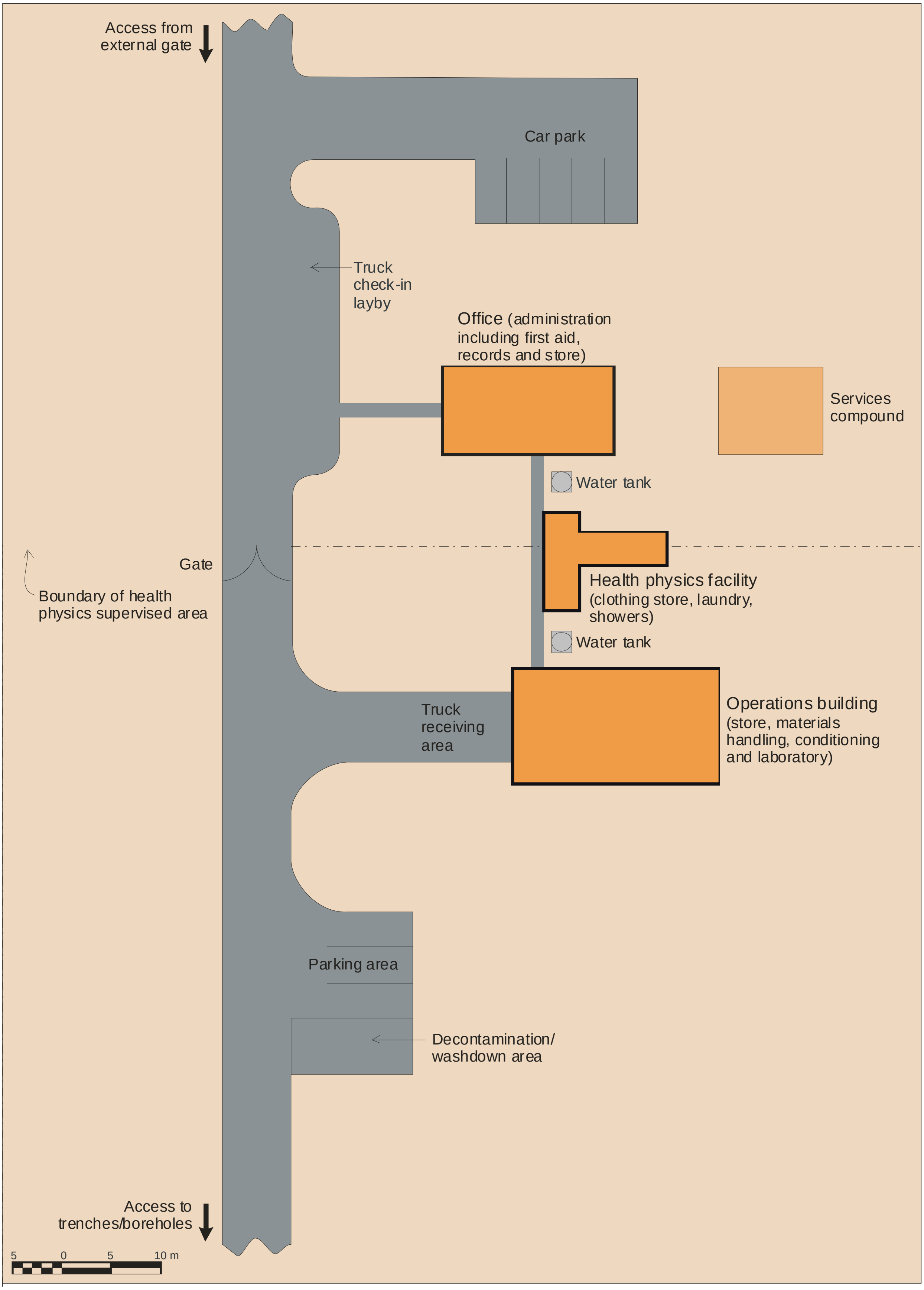


FIGURE 6.5
Indicative plan layout — administrative and operations area

Packaging/Waste Conditioning

Waste would only be accepted for disposal if all relevant WAC had been met. However, in the unlikely situation of in-transit damage, it is possible that some waste packages arriving at the repository may need repackaging prior to disposal. Provision would be made for some simple repackaging of waste as required. Facilities would be provided for the handling of such materials, with appropriate radiation protection and waste management handling facilities for the resulting waste. Some additional packaging of waste could occur at the repository, that is placing of waste in concrete overpacks.

It is intended that waste would arrive at the site in a conditioned form ready for disposal. In-drum compaction facilities and mobile concrete mixing equipment would be available at site if required.

Waste Retrieval

It is possible that waste may require retrieval after disposal. Key features to be provided to retrieve a waste package include:

- use of package identification markings and records of location to identify an individual waste package in the repository
- excavation equipment and a mobile crane to recover the identified package
- a container in which to place the subject package, to provide containment and shielding
- radiation protection and decontamination facilities for the lifting gear and personnel, and for the potential contaminated part of the repository and its surroundings
- a transport and storage facility with appropriate containment, radiation protection and security.

Waste retrieval is described in greater detail in Section 6.7.2.

Laboratory

The laboratory would house monitoring equipment used for checking radiation levels of incoming waste and of equipment during operations.

6.3.3 Decontamination/Washdown Area

The decontamination and washdown area would be designed to decontaminate plant and equipment after use. All waste handling areas and the decontamination facility would be bunded, and washwater from these areas would be passed to an evaporation pond. The pond would be monitored periodically and, if necessary, material from the pond would be disposed of in the repository. Provision would be made for the washing of vehicles or personnel as required.

6.3.4 Office and Ancillary Facilities

The office and ancillary facilities would include:

- administration
- emergency services (first aid, health physics, fire)
- truck lay-by / check-in area
- car park
- change facilities (including showers)
- a separate services compound including portable power generators and a small workshop.

6.3.5 Health Physics Facility

The health physics facility would be located at the boundary of the health physics supervised area, which would include the repository itself, the operations building and the decontamination/washdown area. The facility would include:

- radiation monitoring equipment used to monitor workers, and for radiological surveillance of groundwater and other environmental monitoring
- used protective clothing store and laundry
- male and female change rooms and showers
- clean protective clothing store.

6.3.6 Services Infrastructure

The main infrastructure items to be provided comprise access roads, water supply, electricity supply, telecommunications and sewage disposal.

The requirements for construction of access roads to the preferred and alternative sites are discussed in Section 7.4. In summary, the preferred (Site 52a), which is 55.5 km by road northwest of Woomera township, has good existing access and would require no significant construction works. Site 40a, which is approximately 42 km by road east of Woomera, would require about 35.5 km of significant road upgrading, including 13 km of reconstruction along the old Woomera–Port Augusta road route. Site 45a, which is 91 km northeast of Woomera via the current access route, would require 12.5 km of road upgrading in gibber terrain along the old Woomera–Andamooka Road.

Water would be transported into the site by truck, and pumped to tanks located near the office facilities and in the health physics supervised area, from where it would be reticulated.

Temporary generators would be provided for site power generation, and would be located within the services compound. Fuel would be stored in drums or above-ground tanks in a bunded area within the services compound. Telecommunications would be by satellite phone or UHF radio.

Sewage would be disposed of in septic tanks and associated soakage trenches. The design would conform to South Australian Department of Human Services design guidelines.

Any other wastes arising during operational periods would be appropriately conditioned, packaged and disposed of on site in a small landfill in the trench area. The landfill design and operation would conform to South Australian Environmental Protection Agency guidelines.

6.4 Description of Construction Works

6.4.1 Construction Program

The construction works program and first disposal campaign would commence after satisfactory completion of the environmental assessment and ARPANSA licensing processes as described in Section 3.3 and land acquisition by the Commonwealth, Section 3.3.1. If the Minister for Environment and Heritage made a positive assessment of the proposal in the second half of 2002 or early in 2003, application to ARPANSA for the relevant licences would follow shortly afterwards. A Commonwealth tender selection process would be used to let the construction works and the operation of the repository.

The ARPANSA licensing process also requires an assessment of risk to the environment or at least referral to the assessment of the environment undertaken by Environment Australia, which must be satisfied that no risk is posed to ‘people or the environment from a radiological safety perspective’.

Land acquisition would commence after a decision is made on a final site by the Minister for the Environment and Heritage.

The initial construction would be expected to take a period of two months, not including any access road construction (discussed in Section 6.4.3).

6.4.2 Construction Works

Construction work for the repository would involve two main aspects:

- construction of buildings and infrastructure
- excavation of the trench and boreholes.

The first disposal campaign would occur directly after the construction of the disposal structure to ensure that the trenches and/or boreholes are open for a minimum amount of time. This would minimise the chance of rain water collecting in the structures.

The specific design of the buildings including preferred materials and colours, would be undertaken during the detailed design phase. However, it is expected that they may be portable buildings for the office and similar facilities, and simple steel and corrugated iron buildings for operational purposes. It is intended that most of the buildings and other on-site infrastructure, apart from the security fencing, concrete slabs or roads, would be removed from the site between disposal operations.

A portable site office would be established during the construction phase and removed following completion of construction works. The bunded fuel storage area would be built during the initial construction works.

The excavation of the trench or trenches would involve earthmoving equipment including bulldozers, excavators and trucks. The sides of the trenches would be battered to prevent collapse. The boreholes would be dug using either augers or pneumatic jackhammers with spade bits, and a vacuum ore-lifter designed to suck the spoil to the surface (see Section 6.2.3).

The site preparation works would involve clearance of the central 100 x 100 m area, as well as the access road and any area required for other infrastructure. Only the minimum area necessary for the construction of the repository and ancillary activities would be disturbed.

All buildings, structures and infrastructure would be designed in accordance with Australian Standards, including provisions for stability under seismic conditions.

6.4.3 Construction Access

The requirements for construction of access roads to the preferred and alternative sites are discussed briefly in Section 6.3.6, and in more detail in Section 7.4. For Sites 40a and 45a, road construction work would need to precede any site works, and would add approximately one to two months to the overall construction time. Site 52a would not need any immediate roadworks, although 1.5 km of the mainly unsealed road has a narrow seal (4 m wide) that is in poor condition and could be removed.

Any road construction works for Sites 40a and 45a would comprise upgrading of the existing roads and tracks, and would involve minimal disturbance to the existing road verges. Any previously identified sensitive environmental or heritage area would be identified using bunting, with appropriate signage advising people to keep clear of the area.

6.4.4 Construction Workforce

Owing to the relatively modest extent of the construction work required for the repository, the construction workforce would also be modest in size, numbering up to about 15 persons at any one time. The actual numbers would vary during the construction phase, and would be determined more precisely during the design and project planning phase.

The initial works would involve construction and fitout of buildings and provision of infrastructure. The later works would involve construction of the trenches and boreholes ready for waste disposal.

6.4.5 Accommodation

Adequate motel and caravan park accommodation for the projected workforce for Sites 40a and 52a is available at Woomera. For Site 45a, alternative motel and caravan park accommodation is available at Roxby Downs, which is a similar distance from the site as Woomera.

6.4.6 Construction Waste Disposal

All construction wastes other than spoil would be required by construction contracts to be removed from the site. Spoil would be retained as backfill and for use in construction activities on site.

6.5 Description of Operations at the Repository

6.5.1 Main Activities

The main activities associated with operations at the repository would include:

- implementing criteria for acceptance of radioactive waste for disposal at the facility
- implementing a waste recording, documentation and quality assurance system
- planning and preparation of waste for disposal
- trench and borehole design and excavation
- transport of radioactive waste to disposal site
- receipt and checking of consignment quantities on arrival
- acceptance of radioactive waste for disposal
- short-term storage on site pending disposal
- response to contamination or damaged packages
- implementing a site security system
- administering procedures for arrival of personnel and visitors on site and for movement around the site, and associated record-keeping
- response to incidents or accidents
- closure of facility between campaigns
- managing work methods for waste disposal operations, including safety procedures
- monitoring of environmental radiation
- capping trenches and boreholes
- rehabilitation of trench surrounds
- close-out reporting.

6.5.2 Workforce and Accommodation

During the initial and subsequent disposal campaigns a small workforce would carry out the activities at the repository. In between campaigns the repository would have no permanent staff; however, a security presence (visits to the site on a regular basis by security personnel) would be maintained.

The workforce during campaigns would number up to 10 personnel, including an operations manager, radiation protection officer and operational and security personnel, depending on the volume of waste to be disposed of during the campaign. The actual numbers would be determined in greater detail during the design and project planning phase.

Adequate temporary accommodation for the projected workforce for Sites 40a and 52a is available at Woomera. For Site 45a, alternative accommodation is available at Roxby Downs, which is similar distance from the site as Woomera.

6.5.3 Interface with Department of Defence Activities (Site 52a)

The timing of construction and disposal operations at Site 52a would be scheduled so as not to conflict with other uses of the Woomera Prohibited Area (WPA). It would be possible, during construction and operations, to suspend activities to allow for other uses on the WPA and within the Woomera Instrumented Range (WIR), as described in greater detail in Section 10.4.4.

6.5.4 Planning and Preparation of Waste for Disposal

Waste holders would be required to arrange disposal of waste at the repository with the facility operator, and to provide details of the waste to be disposed of to ensure it is suitable for disposal at the repository and that the WAC are met (see Section 4.3).

All aspects of health and safety requirements would be examined and documented and approved before waste is dispatched to the repository. In addition, the operator would ensure that the correct equipment and facilities are ready before approval is given to transport the waste.

Where practicable, packages would be used that are suitable for direct disposal. Quality checks would be undertaken to ensure compliance with packaging requirements and the WAC.

All waste would comply with the packaging requirement of the ARPANSA 2001 (ARPANSA 2001 Code) *Code of practice for the safe transport of radioactive material* (ARPANSA 2001 Code) (see Section 3.2.3). In addition, any waste classified as dangerous goods would comply with the requirements of the National Road Transport Commission and Federal office of Road Safety *Australian dangerous goods code 1998* (ADG Code).

6.5.5 Packaging and Placement in the Repository

The packaging, placement and disposal methodology would conform to the NHMRC 1992 Code. The repository would accept Category A, B and C wastes as defined by the code.

Packaging and placement would also comply with other documents reflecting accepted international practice, such as relevant International Atomic Energy Agency documents.

Packaging

The types of packaging able to be used for the waste are described in the various codes by parameters covering strength and durability. Packaging could be constructed out of different materials to meet these parameters, and the final choice of packaging used would be determined by reference to the requirements of the various applicable codes and regulations, and also practicality and availability. Acceptable types of packaging include polyethylene high integrity containers, steel or concrete-lined steel drums, large steel boxes or prefabricated concrete containers.

Waste packages made of concrete, steel or other suitable material would be placed in layers in the trench by either a crane or a forklift. For borehole disposal a light mobile crane would be used. The location of all packages would be recorded. The waste packages would be designed with adequate strength to enable stacking.

The packages would be packed tightly to minimise voids. For trench disposal the voids between the packages would be filled with spoil material from the excavation of the trench, or other suitable and approved material, once each layer is in position. Boreholes would be backfilled with clay or cement grout.

The common types of packages that are likely to be used include:

Steel Drums

Direct disposal in 205 L steel drums would be appropriate for very low level (Category A) waste. Where the container is being used to provide structural stability, steel drums may be suitable as containers for transport and short-term storage only, not for long-term containment after disposal.

Modular Canisters

Modular canisters or overpacks would be appropriate for some waste. The canisters would be required to comply with structural and containment criteria, could be designed to meet long-term containment criteria, where the degree of containment required would depend on the radiotoxicity of the waste.

Canisters can be constructed of a variety of materials including concrete special, high-strength concrete, fibre reinforced concrete, polyethylene or steel, but concrete is the most probable material for storage canisters.

Canisters can be constructed of a variety of materials including concrete, special high-strength concrete, fibre reinforced concrete, polyethylene or steel, but concrete is the most probable material for storage canisters.

6.5.6 Transport of Radioactive Waste to Site

Transport of the waste would conform to the ADG Code, Australian Dangerous Goods Regulations (as applicable), the ARPANSA 2001 Code and any conditions required under ARPANSA licensing.

Waste would only be accepted at the repository within limited time frames during disposal campaigns.

Transport operations, including methodology, controls, routes, emergency response, communication arrangements and timing would be described in specific transport procedure documents to be produced by the facility operator. These would cover provisions for emergency response during loading and transportation of the waste, as well as health and safety issues relating to the loading and transport of the waste to the repository, and any conditions required under ARPANSA licensing.

All personnel involved in transport and loading operations would undergo formal training, including as appropriate:

- health and safety issues related to the waste
- relevant provisions of the transport documentation including emergency response procedures

- communication arrangements
- general environmental awareness training in relation to the waste
- the use and significance of 'chain of custody' documentation.

The facility operator would prepare and put in place operating procedures addressing:

- assessment of the radiation dose to workers and to the public during the transport of radioactive material
- emergency provisions in the case of accidents during transport
- assessment of waste being transported to the repository, to determine:
  - its labelling category
  - the class of packaging required
- packaging and conditioning requirements for transport.

Further detail on the transport of waste to the repository is provided in Chapter 7.

6.6 Security, Health, Safety and Environment

6.6.1 Security and Surveillance

A security fence would be constructed around the 1.5 x 1.5 km buffer zone to prevent unauthorised human intrusion and to exclude grazing animals. The fence would be designed to exclude key feral animal species (rabbits, cats and foxes) and would allow the regeneration of native species within the buffer zone once feral species had been eradicated from the site.

A fence would be constructed around the central 100 x 100 m area, to exclude native animals within the buffer zone from the repository itself.

Appropriate security monitoring measures would be adopted to ensure the safety of the site. A security presence would be in place during the initial and subsequent campaigns to ensure the safety of personnel. The site would be monitored for any potential breaches in security between campaigns.

In addition, the waste would be protected by burial at depth and would be covered between disposal campaigns.

6.6.2 Health Physics Requirements

The repository would have a health physics framework that reflects the facility's radioactivity parameters and the nature of work undertaken. This framework would include procedures governing all work at the site that involves radioactive materials, as well as such matters as conditions for entry to areas where there are radioactive substances, precautions to be taken when working in those areas, and procedures for decontamination of personnel and equipment.

The facility operator would be responsible for implementing procedures complying with the health physics framework and occupational health and safety requirements as approved by the regulator (ARPANSA) including:

- statutory record keeping and maintenance of health physics documentation
- the system for keeping records of health and safety issues
- precautions for personal protection to be taken by personnel working with contaminated materials
- procedures for monitoring and recording the health and especially the exposure of site personnel

- procedures for leaving the contaminated areas, including procedures for the decontamination of personnel
- procedures for monitoring dose uptake by workers, including as appropriate:
  - whole body monitoring for each campaign
  - personal and fixed air sampling
  - urine analysis
- training for workers on the hazards involved with ionising radiation, and on appropriate precautionary measures for personal protection
- any modifications to plant and machinery for use with contaminated materials, to give radiological protection to the plant operators
- procedures for the decontamination of plant and equipment, including monitoring.

6.6.3 General Health and Safety Requirements

There would be a variety of general hazards potentially associated with operations at the facility. These can be divided into operational hazards and environmental hazards.

Operational Hazards

- excavation activities and working in and around an excavation
- heavy machinery and heavy vehicle movement:
  - general activities and traffic control
  - overhead activities
  - vibrations
- slip/trip/fall hazards
- manual handling
- electrical hazards
- waste unloading and placement operations and exposure to radionuclides.

General/Environmental Hazards

- lightning
- bushfire
- environmental hazards:
  - heat stress
  - noise
  - snake bites
  - allergies such as bee stings
  - dust
- remote location — access and communications
- domestic hazards.

Procedures would be developed to address the occupational health and safety management required for general site operations such as excavation, traffic movements, waste conditioning and burial. These procedures would include the identification of potential hazards and their management, as well as emergency response procedures and incident management planning.

The facility operator would be responsible for implementing procedures and complying with occupational health and safety requirements including:

- providing correct personal protective equipment
- providing washdown facilities for general hygiene and decontamination purposes
- maintaining safety records
- undertaking health surveillance and maintaining associated records
- providing communications and managing traffic
- providing first aid facilities (including personnel)
- monitoring personnel for heat stress
- developing protocols for safe disposal operations when using heavy machinery and cranes, including creating exclusion zones

- conducting appropriate training, inspections and safety audits
- making provision for dust suppression if necessary
- providing appropriate firefighting equipment.

Other requirements would be identified and described during the development of site-specific health and safety and emergency response plans.

6.6.4 Environmental Monitoring

A comprehensive monitoring program would be undertaken to ensure that the repository is performing as designed and that any radioactivity is effectively contained.

Data baseline surveys have been undertaken as part of the previous study phases (see Section 1.5) and as part of this environmental impact study process. The need for any additional baseline surveys would be determined during the design and licensing processes (see Section 3.3). These surveys, together with previous data, would provide a basis for assessing the results of subsequent monitoring surveys conducted through the operational and the institutional control periods.

The operational and institutional monitoring program would also be developed during the design and licensing process. The following may be monitored in the program:

- vegetation samples from the site, buffer zone and restricted occupancy zone, for gross alpha, gross beta and gamma emitters
- fauna on the site, buffer zone and restricted occupancy zone, for uptake of radioactivity
- soil, for gross alpha, gross beta and gamma emitters
- air (upwind and downwind), for gross alpha, gross beta and gamma emitters
- surface gamma radiation
- groundwater from bores on the site and in the buffer zone
- surface water, for radionuclides after major rains
- trench cover material, using neutron moisture meters and gamma probes installed in boreholes
- gas samples collected from within and beneath the cover material, for tritium, carbon-14 and radon
- the Vadose zone (the zone below the surface and above the watertable) around and below the disposal zones, using neutron moisture meter and gamma spectra probes. These would be installed in vertical and/or slant sampling boreholes alongside the trenches, with casing fitted with gas sampling ports; soil sampling holes may also be installed
- presence of water in floor drains beneath the waste, for gross alpha, gross beta and gamma emitters.

Water from operational areas of the site would be collected and monitored to check for contamination. An evaporation pond would be constructed to collect runoff from operational areas, thereby avoiding any off-site release of surface water.

Additional information on monitoring is provided in Chapter 13.

6.7 Receipt, Recording and Retrieval of Disposed Wastes

6.7.1 Receipt and Documentation

Arrangements would be made for the appropriate receipt and documentation of waste when it arrives at site, and for its safe storage prior to disposal. As disposal campaigns (including the receipt of waste at the repository) would be conducted during a limited time frame, storage would only be required for a short period.

A quality assurance system would be established to ensure that waste has been appropriately conditioned for final disposal either prior to transport to site or at the repository.

All waste requiring acceptance for transport to the repository would first be checked against the WAC. Non-conforming waste would not be accepted for transport. On arrival at the facility, waste would be stored for an interim period of a few days to weeks. This storage period would be kept as short as possible.

6.7.2 Recording and Retrieval

As noted in Section 4.3.2, all waste packages prepared for disposal would have a unique engraved or raised marking to indicate the batch of waste to which they belong and to allow a detailed inventory to be kept of all waste disposed of at the site. Any markings on the package would be designed for longevity and would provide sufficient information to allow identification of the complete contents of the package, on reference to the inventory. This would be important for transport and disposal, and also for the potential retrieval of any package.

During burial operations, a record would be kept of the location of each package in the excavation. This information would be incorporated into the permanent inventory of waste disposed of at the site. The boundaries of the operational area and locations of boreholes would be accurately surveyed, and a grid system and level designation used for recording the location of a particular package.

Once a package had been accurately inventoried and its location in the excavation recorded, the process of retrieval would be a matter of assembling the required equipment and exhuming the waste package. Since any requirement to retrieve the package would not arise for many years, if at all, the methodology used to retrieve the package would be more fully developed at that time. A specific retrieval plan would be developed that described the requirements of excavation retrieval and reinstatement of the capping structure.

It is possible, however, that boring techniques such as those used to sink the boreholes (see Section 6.2.3) would be used to access the appropriate area in the excavation (whether a trench or shaft), as this would cause the least disruption to the remainder of the backfill and capping structure. Where necessary, hand-held or machine directed pneumatic hammers, spades or cutting techniques would be used to retrieve a particular package.

The final phase of the retrieval process, once the required package had been accessed and removed, would be the reinstatement of the capping and backfill structure. This would only happen after the void generated by removal of the package had been satisfactorily filled.

6.8 Description of Surveillance Period

Arrangements would be put into place for periodic monitoring and surveillance during the closed periods between campaigns to ensure protection of people and the environment. Further details on surveillance and monitoring are given in Chapter 13.

In the periods between disposal campaigns, the facility would be closed and no personnel would remain on site. As noted in Section 6.4.2, it is intended that most of the buildings and other on-site infrastructure, apart from the security fencing, concrete slabs and roads, would be removed from the site between disposal operations. The period between campaigns would possibly be about two to five years. The site would be routinely inspected and monitored between campaigns, and a security presence maintained.

6.9 Description of Institutional Control, Decommissioning and Closure

At the end of the operational period the facility would enter the institutional control period, which is the length of time, following closure, for which land use restrictions apply. Over this time the facility would be monitored and access restricted. An institutional control period of 200 years has been adopted for the repository.

The NHMRC 1992 Code contains detailed guidelines for the closure of the disposal facility. Disposal operations at the facility would cease when the authorised disposal space had been filled or the limit on total site radioactivity reached. The estimated initial operational life of the national repository is 50 years, following which a review would be conducted.

In accordance with the NHMRC 1992 Code, conceptual or draft plans for decommissioning the facility and rehabilitating the site would be prepared and submitted to ARPANSA for approval before operations began. These plans would be reviewed every five years and resubmitted for approval. Detailed decommissioning plans would be submitted at least three years prior to closure.

Upon closure of the site, all visible structures would be removed (apart from fences, signs and drains around the disposal structures).

The decommissioning plans would also address aspects of any remaining revegetation requirements. This would only be required for areas where infrastructure had been finally removed, since revegetation activities would have been undertaken where necessary during the operational life of the site.

At the end of the institutional control period, no further control of the repository site would be necessary as the radioactive materials would have decayed to levels safe enough to enable unrestricted access. Further details on radiation doses and risks for a number of potential exposure scenarios are provided in Chapter 12.

6.10 Ownership and Operation

The national repository would be owned by the Commonwealth and regulated by the Commonwealth's independent regulator, ARPANSA. Operations at the national repository would be undertaken by private contractors, whose performance would be overseen by the Commonwealth department responsible for radioactive waste management policy (currently the Department of Education, Science and Training) and by ARPANSA.

In its oversight of the facility, the Commonwealth would ensure that the repository:

- satisfies all licence requirements
- maintains appropriate safety
- maintains appropriate security
- maintains appropriate records
- satisfies the needs of waste producers, and encourages waste minimisation.

The Commonwealth would ensure that disposal campaigns are effectively conducted, and that the facility is efficiently monitored and the waste secured between campaigns.

Details of arrangements for the operation of the facility would be fully outlined when application is made to ARPANSA for an operating licence for the facility (see Section 3.3).

6.11 Financial Arrangements

Commonwealth policy requires that there would be a charge for disposal of waste in the national repository.

Charges would be set in such a way that waste minimisation is encouraged, and that disposal is chosen when no other option, for example recycling, exists. Disposal charges would also be set in such a manner as to encourage use of the facility, rather than have waste producers continuing to store waste in non-purpose-built accommodation, or disposing of waste in an inappropriate manner.

The Mount Walton East repository in Western Australia (see Section 2.4.1) sets charges to cover the cost of disposal operations. This model may provide a practical basis for the Commonwealth to determine disposal costs for waste in the national repository.

Factors that could be considered in setting charging rates for disposal of waste in the national repository may include:

- the physical size and volume of the waste (i.e. a per cubic metre charge)
- the activity of the waste and amount of various radionuclides (i.e. whether the waste is Category A, B or C according to the NHMRC 1992 Code)
- transport costs associated with delivering waste to the repository
- costs associated with packaging the waste for disposal, if additional packaging is required at the repository (e.g. placing short-lived intermediate level waste into concrete overpacks).

The cost of each disposal campaign would depend on the volume of waste to be disposed of and the type of disposal structure (trench or borehole). Waste disposal is likely to be most cost-effective during the first disposal campaign, which would dispose of the largest volume of waste.

Various strategies could be used in subsequent campaigns to improve cost-effectiveness (while not compromising safe disposal):

- An extended period of time could be allowed between campaigns.
- The design of the disposal structures could be varied to suit the amount and type of waste; for example, a borehole may be more appropriate for a small volume of waste than a disposal trench.

Chapter 7
Transport of Waste to the Repository

7.1 Introduction

Internationally and in Australia, there has been a long record of safe transport of radioactive substances. More than 20 million packages containing such material are safely transported throughout the world each year. Over the past 40 years there have been no accidents where there has been any significant radiological release harmful to the environment or public health.

In Australia over 30,000 packages of radioactive material are routinely and safely transported each year by road, rail and air. Radioactive substances for a wide range of commercial and industrial applications are routinely transported for use. For example, radioactive materials used in medicine (radiopharmaceuticals) are transported to hospitals and clinics for use, and equipment such as moisture meters used in agriculture and road construction, and gauges for use in minerals exploration and the petroleum industry, are routinely transported.

Internationally accepted regulations govern the transport of radioactive materials in Australia. The regulations are designed to protect people, property and the environment from the effects of radiation during the transport of radioactive material.

The result of the application of these regulations is that transport of radioactive materials is considerably less hazardous than the transport of flammable and corrosive materials.

Radioactive waste would be transported to the national repository in accordance with the relevant regulations and codes (including any requirements under Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) licensing), to ensure the safety of people and the environment.

7.2 Proposed Transport Routes

7.2.1 Introduction

The transport of low level and short-lived intermediate level radioactive waste to the proposed repository would be undertaken in compliance with the requirements of the ARPANSA 2001 *Code of practice for the safe transport of radioactive material* (ARPANSA 2001 Code), ARPANSA licensing, and relevant state and territory regulations as described in Chapter 3. These requirements relate to the movement of each discrete consignment of radioactive waste, and define, *inter alia*:

- how differing types of waste materials should be packaged and labelled, and the maximum volumes that could be incorporated into a single load
- the specification of hazard warning signs to be displayed on vehicles transporting waste
- instructions for the carriers contracted to ship the waste, including proposed routes.

The transport of solid radioactive waste in accordance with packaging requirements and standards as outlined in the code does not provide a hazard to people or the environment.

Factors relevant to the type of transport chosen, and arrangements for shipments include the:

- present location of radioactive waste at over 100 sites around Australia
- fact that most sites have only small quantities of waste

- need or requirement for conditioning of waste prior to transport
- location of sites which would generate radioactive waste in the future, after the current inventory of waste had been removed to the repository
- need to ensure secure management of material during transport.

The scale of the transport task, and the logistical factors affecting shipments from each individual storage site, would influence the choice of transport mode (although most waste would be transported by road) and transport route. The following sections describe the main factors likely to drive these processes, and how they are likely to impact upon transport arrangements.

7.2.2 Transport Task

Existing Waste

As described in Section 4.1, Australia has accumulated about 3700 m^3 of low level and short-lived intermediate level radioactive waste from medical and industrial use of radioactive material during the last 100 years. This waste, which would be disposed of in the repository, is currently stored at over 100 sites around Australia. The main sources of this waste are described in more detail in Appendix B. The approximate volumes requiring disposal are restated below:

- 2010 m^3 of slightly contaminated soil, from research by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) into ore processing, which is currently stored in drums near Woomera
- 1320 m^3 of waste from Australian Nuclear Science and Technology Organisation (ANSTO) operations at Lucas Heights near Sydney
- 210 m^3 of waste held by the Department of Defence (Defence) at various locations around Australia
- 160 m^3 of waste, which includes sealed radioactive sources used in gauges, smoke detectors, medical equipment and luminous signs, held by governments, industry, hospitals and research institutions and stored at numerous locations around Australia.

Over half, by volume, of the existing waste (i.e. that stored near Woomera) would need to be transported only a small distance to the repository.

Efforts would be made to consolidate shipments of waste from those organisations holding small amounts of waste, to minimise the number of trucks going to the repository. The waste would be conditioned before transport to be ready for disposal upon arrival at the repository (waste would be conditioned at the repository only in circumstances where a package had been damaged during transport etc).

Future Waste

As described in Section 4.2, future quantities of waste suitable for disposal in the repository are estimated to be less than about 40 m^3 per year. About 30 m^3 is expected to be generated at the ANSTO site, while other waste producers are expected to generate about 10 m^3/yr in conditioned form ready for disposal.

Some consolidation of waste from organisations producing smaller amounts of waste would be sensible in future campaigns in order to minimise shipments.

In addition to that indicated above, waste would arise from the decommissioning of the Moata Research Reactor in 1995 (about 55 m^3), the High Flux Australian Reactor (HIFAR), and from the replacement research reactor. There are various decommissioning options possible for HIFAR and the amount of low level and short-lived intermediate level waste generated would vary from 500 to 2500 m^3, depending on the option chosen. Table 4.2

summarises the estimated routine future arisings of low level and short-lived intermediate level radioactive waste.

7.2.3 Transport Mode

The selection of a preferred mode for transporting the waste is influenced by the following:

- a large number of storage sites nationally, largely holding/generating small volumes of waste to be transported, with some sites located in regional areas
- a potential need to consolidate partial loads for conditioning and packaging
- the need to ensure secure management of material during transport.

Transporting the material to the repository by truck/road provides the most flexible transport option. Trucks have flexible load capacity to facilitate load consolidation at intermediate storage locations. In addition, the use of larger vehicles for longer distance haulage, with continuous chain of custody, provides secure environments for transport. Consideration of possible transport routes and safety issues therefore focuses on the use of the road mode for waste transport. The adoption of other modes is considered further as an option, and is described in Section 7.3.

7.2.4 Logistical Arrangements

The transport logistical arrangements and impact upon truck routing options are considered separately for the major sources of waste material as described in Section 7.2.2. The transport logistics issues associated with each of these sources are briefly described in the following paragraphs.

CSIRO Contaminated Soils

The 2010 m^3 of slightly contaminated soil is currently stored in 9726 drums of 207 L capacity near Woomera within the Woomera Prohibited Area (WPA). The condition of the drums is suitable for transport to the repository with no further containment or conditioning. Access to each of the preferred and alternative sites, including any necessary road works, is described in Section 7.4. In the case of Site 52a, transport would be from Evetts Field, where the waste is currently housed, to the preferred repository site 10 km to the west. In the case of the two alternative sites, waste would be transported approximately 85 km east to Site 40a or 135 km east to Site 45a, using the current proposed routes.

ANSTO Wastes

ANSTO currently holds 1320 m^3 of low level and short-lived intermediate level radioactive waste (conditioned volume) at a single site at Lucas Heights. It comprises packed waste of about 5000 drums of 205 L capacity and 400 drums of 300 L capacity, and unpacked waste of approximately 250 further drums of 205 L capacity.

All waste would be conditioned prior to being transported by licensed contractor to the repository.

Defence Wastes

Defence has about 210 m^3 of waste (conditioned volume), which consists of contaminated soils from land remediation, sealed sources, gauges, electron tubes, equipment (watches and compass parts) and some aircraft ballast and is held at a number of locations around the country. Conditioned waste would be transported by a Commonwealth-licensed contractor to the repository.

Miscellaneous Material Including Disused Sealed Radioactive Sources

The 160 m^3 of miscellaneous material including sealed radioactive sources used in gauges, smoke detectors, medical equipment and luminous signs is located throughout the country. Some is located at state and territory stores and others in hospitals, research institutions and industry stores. In some cases this waste has been conditioned to some degree, although it is likely that further conditioning for disposal would be required. In other cases, no conditioning of the sources has occurred.

All this miscellaneous material would be conditioned prior to transport to the repository site. The material would be consolidated as much as practicable to enable cost-effective transport services to be provided to the repository. The transport of the waste would be undertaken by Commonwealth-licensed contractors.

7.2.5 Proposed Truck Routes

National highway routes would be used for the transport of radioactive waste from capital cities to the national repository in central–north South Australia. Various options are available for alternative routes along state highways and regional connecting roads.

Selection of routes would depend on:

- logistical and operator considerations for the most efficient route to collect waste from a number of sites
- distances involved in various routes
- conditions of the transport route, including the quality of road surface
- weather conditions in various areas at the time of transport.

While the most likely transport routes are suggested below, a flexible approach would be adopted in terms of roads used for transport of waste to the repository, in accordance with the relevant regulations and requirements.

The discussion below excludes consideration of waste shipments from Western Australia to the national repository, as low level and short-lived intermediate level radioactive waste generated within Western Australia is disposed of in the Mount Walton East intractable waste disposal facility.

Route Selection Principles

The route alternatives for each state and territory have been selected with reference to the following road hierarchy:

- national highways
- state highways
- other connecting roads.

The rationale for this hierarchical approach is that national highways have the highest design standards, and provide the fastest most direct route between centres, with many towns and regional centres being bypassed. State highways, whilst also constructed to high standards, do not typically bypass towns, as they are designed to provide access to those towns. Other connecting roads may be used where needed to link between national and state highways, and between current waste storage locations and the national/state road network.

Adelaide to Repository

The most direct feasible route linking Adelaide to the repository is via the Princes Highway (NH1). The Princes Highway route bypasses all towns other than Port Wakefield and Port Augusta. The route comprises two sections:

- Adelaide to Port Augusta via Port Wakefield: on Princes Highway (NH1)
- Port Augusta to Woomera: on Stuart Highway (NH87).

Darwin to Repository

The Stuart Highway (NH87) provides the only feasible road link through the Northern Territory between Darwin and the repository. It comprises four main sections:

- Darwin to Katherine
- Katherine to Tennant Creek
- Tennant Creek to Alice Springs
- Alice Springs to Woomera.

The Stuart Highway is a designated national highway over its full length from Darwin to Port Augusta. Between Darwin and Woomera the route passes through the main centres of Katherine, Tennant Creek and Alice Springs, plus other minor towns and settlements.

Brisbane to Repository

Two separate route options have been defined linking Brisbane with the New South Wales border (near Goondiwindi), with a single preferred national/state highway route from there to the repository through New South Wales and South Australia. The inland routes to Goondiwindi avoid roads closer to the coast, which pass through more heavily populated areas. The route option segments within Queensland are:

Option 1: Brisbane to Goondiwindi via Warwick: on Cunningham Highway (SH15)
Option 2: Brisbane to Goondiwindi via Toowoomba and Millmerran on Gore Highway (SH54/85).

The inland route through New South Wales and South Australia between Goondiwindi and the repository comprises the following six national and state highway segments:

- Goondiwindi to Dubbo via Moree, Narrabri, Coonabarabran and Gilgandra: on Newell Highway (NH39)
- Dubbo to Nyngan: on Mitchell Highway (SH32)
- Nyngan to Broken Hill via Cobar and Wilcannia: on Barrier Highway (SH32)
- Broken Hill to Peterborough turnoff, via Olary and Yunta: on Barrier Highway (SH32)
- Peterborough turnoff to Port Augusta, via Peterborough, Orroroo, Wilmington and Stirling North: on SA state highway to Stirling North, then Princes Highway (NH1) to Port Augusta
- Port Augusta to Woomera: on Stuart Highway (NH87).

Sydney to Repository

Two main route options have been defined between Sydney and the repository. These comprise:

Option 1: via Broken Hill:

- Sydney to Molong via Katoomba, Bathurst and Orange: on Great Western Highway (SH32)
- Molong to Nyngan via Wellington and Dubbo: on Mitchell Highway (SH32)
- Nyngan to repository as per Brisbane to repository route (as described above).

Option 2: via Wagga Wagga:

This option seeks to use the Hume and Sturt national highways, and then state highways to Port Augusta. The Hume Highway is high standard, bypassing towns en route to Wagga. Sections along this option are:

- Sydney to Wagga turnoff via Goulburn, Yass and Gundagai: on Hume Highway (NH31)
- Wagga turnoff to Renmark via Narrandera, Hay, Balranald and Mildura: on Sturt Highway (NH20)
- Renmark to Burra via Morgan. This route bypasses all main Riverland towns, and utilises the recently reconstructed Morgan to Burra sealed road.
- Burra to Peterborough turnoff via Whyte-Yarcowie: on Barrier Highway (SH32)
- Peterborough turnoff to repository as per the route from Brisbane as described above.

A potential sub-option (Option 3) of this route comprises the route Sydney to Buronga in New South Wales (across the River Murray from Mildura as above), then:

- Buronga to Broken Hill via Wentworth: on Silver City Highway (SH79)
- Broken Hill to repository as per the route from Brisbane as described above.

It is expected that shipments to the repository from the ACT would take place via the Option 2 route from Sydney, with trucks travelling from Canberra to Yass on the Barton Highway.

Melbourne to Repository

In defining route alternatives between Melbourne and the repository, a key objective was to avoid trucks passing through metropolitan Adelaide. In meeting this objective, two main options have been defined. These are:

Option 1: via Bendigo:

This option uses the high standard Calder Highway, via the following route:

- Melbourne to Mildura via Woodend, Bendigo, Charlton and Ouyen: on Calder Highway (SH79)
- Mildura to Renmark: on Sturt Highway (NH20)
- Then Renmark to repository as per the Option 2 route from Sydney to the repository.

A sub-option of this route from Mildura to the repository would comprise:

- Mildura to Wentworth via Buronga, then via Broken Hill to the repository as per Option 3 from Sydney as described above.

Option 2: via Horsham:

This route option would use the following links:

- Melbourne to Horsham via Ballarat and Ararat: on Great Western Highway (NH8)
- Horsham to Ouyen via Warracknabeal: on Henty and Sunraysia highways (SH107/121)
- Ouyen to Mildura: on Calder Highway (SH79).

Then Mildura to the repository as per Melbourne Option 1 as described above.

Hobart to Repository

Three issues have been considered in defining routes for waste shipments to the repository. These comprise the use of the national highway network in Tasmania, the route for shipping the material to the mainland, and the overland route on mainland Australia to the repository.

Of these three issues, the one that most strongly influences the overall route choices is how waste should be shipped from Tasmania. Two main options are available:

Option 1: ship from Launceston to Melbourne on the Princess of Tasmania. This is a roll-on/roll-off passenger service

Option 2: ship from Burnie to Melbourne via a freight shipping service that operates daily between these ports

The latter option is preferred, as it offers a high service frequency. Ship movements from Tasmania to other Australian ports are much less frequent.

Having defined the trans Bass Strait shipping movement, route options between Hobart and the repository effectively reduce to the following components:

- Hobart to Burnie via Launceston: on Midlands and Bass Highways (national highways)
- Burnie to Melbourne: by sea
- Melbourne to repository via either of the two options described above for waste shipments from Melbourne.

In addition to the shipping option, depending on conditioning requirements, air transport of some waste from Tasmania to the mainland is potentially feasible.

7.2.6 Route Summary

Figure 7.1 illustrates the principal routes that may be used in the transport of radioactive waste from main centres to the national repository.

7.2.7 Method and Frequency of Waste Shipments

Estimates of the numbers of truck movements required to carry the accumulated waste from each respective state and territory to the repository have been prepared, based on the waste inventory as summarised in Section 4.1 and detailed in Appendix B. As the detailed arrangements for transport of waste to the repository have not yet been finalised, assumptions have been made as to how the waste would be packaged, the type of trucks to be used and how, in general, the waste would be loaded onto the trucks.

These assumptions are as follows:

- Most waste would be transported in standard 205 L industrial steel drums (Section 4.3.2).
- Packed 205 L drums may be carried in standard 6 m shipping containers for transport to the repository. Up to 72 drums could be double stacked into a standard 6 m shipping container.
- The shipping containers could be conveniently carried on standard container-carrying trucks designed for this purpose, and would provide additional protection for the solid waste in the unlikely event of an accident.
- The 205 L drums would have a maximum weight limit of 300 kg, and the maximum gross weight of a loaded container is proposed to be 20 t.

It is assumed that an average of 10 m^3 of waste is transported in each container. This corresponds to an average consignment of about 50 full drums per container. This is less than the maximum capacity of 72 drums per container; however, some drums may not be full and some containers may have part loads, and the drums would be subject to an upper weight limit of approximately 300 kg. Thus, the assumption is considered to be reasonably conservative.

Tasmanian route
Land
Sea

Victorian route
Option 1
Option 2

Queensland route
Option 1
Option 2

NSW route
Option 1
Option 2
Option 3

Towns/cities
Adelaide route
NT route
Roads
Common route - eastern states and Adelaide

FIGURE 7.1
Principal potential transport routes

Table 7.1 summarises the estimated number of truck movements to ship existing waste based on these assumptions. These estimates exclude truck movements to transport the 2010 m^3 of CSIRO material already being stored at Woomera.

TABLE 7.1 Estimated number of truck movements to the repository

State/Territory of origin	Volume of conditioned and packaged waste to be transported (m^3)	Number of truck movements(1)
South Australia(2)	218	22
Northern Territory	16	2
Queensland	45	5
New South Wales/ACT(3)	1,355	136
Victoria	33	4
Tasmania	15	2
Total	**1,682**(2)	**171**

(1) Rounded
(2) Excludes 2010 m^3 of CSIRO material stored at Woomera
(3) Includes 1320 m^3 of ANSTO material stored at Lucas Heights
Source: Department of Education, Science and Training/Consultant analysis

The estimated numbers of truck movements are very low. They could increase under alternative logistical arrangements, but in any event would remain low in comparison with other traffic on the route network.

The estimated volume of future waste of up to about 40 m^3 per year is equivalent to four 6 m containers per year nationally. Given the low volumes of waste involved, it is likely that disposal campaigns would occur at intervals of between two and five years. Allowing for accumulation of waste over several years, only a few trucks would be required for transport of the waste to the repository. Small trucks would be suitable as transport vehicles from some states/territories.

7.3 Transport Options

Road Versus Other Options

Table 7.2 compares the practicality and risk of using different modes of transport. The most practical is road transport, using normal or articulated trucks. Rail transport, where it is an option, is safer than road for accident rates; however, rail transport has distinct disadvantages compared with road transport. All transport operations would be managed in accordance with the ARPANSA 2001 Code (see Section 3.2.3).

Waterborne transport is generally not relevant to the proposed national repository, apart from the specific case of Tasmania where there is a requirement for shipment of a small amount of material to the mainland. Airborne transport would only be considered where it is a practical alternative, for example the small quantities of waste from Tasmania.

As described in Section 7.2.3, the preferred mode for transporting waste material to the repository is by truck. The main reasons for this are:

- the transport of low level and short-lived intermediate level radioactive waste would involve relatively small loads from numerous storage sites, with many of these located in regional areas
- a potential need to consolidate partial loads at a limited number of centralised locations
- a high degree of flexibility in the pick up, consolidation and transport of waste

- the need to maintain a continuous chain of custody of the movement of each load or partial load.

TABLE 7.2 Comparison of risks of different modes of transport

Mode of transport	Comparison of practicality	Comparison of risks
Road	This is the most practical option. Road transport has the most secure chain of custody, as drivers accompany each consignment.	The probability of accidents reduces on major interstate roads, and is higher on minor single-lane roads. The probability of accidents increases with speed. The risks are lower on rural roads and higher as the vehicle drives through urban areas. Overall, the environmental pollution (non-radiation) risks of road transport are higher than for rail transport.
Rail	Road transport to the nearest railway station with freight loading facilities is required, meaning additional handling. Also, additional handling would be required with the unloading of the waste for transfer to a truck for shipment to the repository. Chain of custody is poor compared with road transport.	The risks of rail transport are less than road transport because the probability of a crash is lower, and access to the rail reserve is better controlled. However, although accident rates are lower, in the event of a rail accident, the potential for damage to the waste containment is higher owing to the larger momentum forces. The security of chain of custody is poor compared with road transport.
Air	This is generally likely to be impractical for the large volumes of waste to be transported, and is considered feasible only for remote locations a long way from the repository, e.g. Tasmania.	Type C containers have been specially designed for air transport of higher activity sources. Air transport is suitable provided the special restrictions in the International Atomic Energy Agency (IAEA) Regulations (International Atomic Energy Agency 2000) are followed.
Inland waterways vessel	No inland waterway vessels would be utilised in the transport of material to the repository.	
Ocean-going ship	This is only relevant to the small amount of waste from Tasmania, which could be transported in two trucks on either a commercial freight ship or car ferry.	The recovery of materials in event of an accident is more problematical, but consignments would be conditioned and of comparatively low activity. However, because the distance from Tasmania to the mainland is short, the number of journeys few and the contents small, the transport risks are insignificant.

Notwithstanding the road transport advantages, consideration has also been given to the potential use of alternative modes, how these would fit into the logistics chain, and how they would meet the requirements for transport to the repository. This is described in the following subsection. Again, this consideration excludes reference to waste generated in Western Australia, for reasons outlined in Section 7.2.5.

Rail

The national standard gauge mainline rail network links Brisbane, Sydney, Melbourne and Adelaide to a siding on the Port Augusta to Alice Springs line at Pimba. Canberra is linked into the network, with Darwin to be connected following completion of the Alice Springs to Darwin rail line. Tasmania is effectively linked via the shipping service across Bass Strait from Burnie to Melbourne.

An overview of potential logistical arrangements for packaging, conditioning and (possibly) consolidating waste was described in Section 7.2.4. Most of those (intra-state) arrangements could similarly apply if rail was used for transporting waste. Additional steps in the logistics process would require, however, the following activities:

- movement of ISO standard containers onto a railway wagon (an additional transfer step)
- transhipment of the wagon/container between trains at marshalling yards in the various capital cities, and potentially at Port Augusta
- transhipment of containers from the railway wagons at Pimba by truck (a further additional transfer step) and then to the repository.

Waste from Darwin would, in the short term prior to the completion of the railway line, be shipped by road down the Stuart Highway to the repository.

Although rail offers an inherently lower risk of accidents en route, its main disadvantages relative to road transport include:

- additional handling of containers, thereby increasing the potential for accidents and increasing the overall costs of transport
- more inefficient transport arrangements, given the relatively small volumes of material to ship from most locations, both now and in the future
- potential delays in transport of waste; wagons containing the waste could be shunted onto sidings for several days at intermediate locations before being attached to an onwards train
- difficulty in adding further material to a train en route between capital cities; this transfer could be undertaken relatively easily by trucks at nominated intermediate staging points
- longer door-to-door transit times
- poorer security of chain of custody.

In the unlikely event of a rail accident occurring, it could be more severe than a road accident.

Air

Transport of waste material by air offers a secure transport option. However, it is not a practical/cost-effective alternative for moving relatively large volumes of material. Issues relevant to the transport of waste by air include:

- the need for additional handling of material between consolidation points and airports, and between the Woomera airport and the repository
- the likelihood of conditioned waste being heavy, leading to high air transport costs.

Transport by air is not considered further as an option for mainland sources of waste. It remains, nevertheless, an option for transport of small volumes of waste between Tasmania and the mainland.

7.4 Site Access Routes from Woomera

The access routes from Woomera to the preferred and two alternative sites are shown in Figure 7.2. Site 52a is near Evetts Field West, west of the Woomera–Roxby Downs Road and within the WPA. The two alternative sites (Sites 45a and 40a) are about 20 km east of the Woomera–Roxby Downs Road.

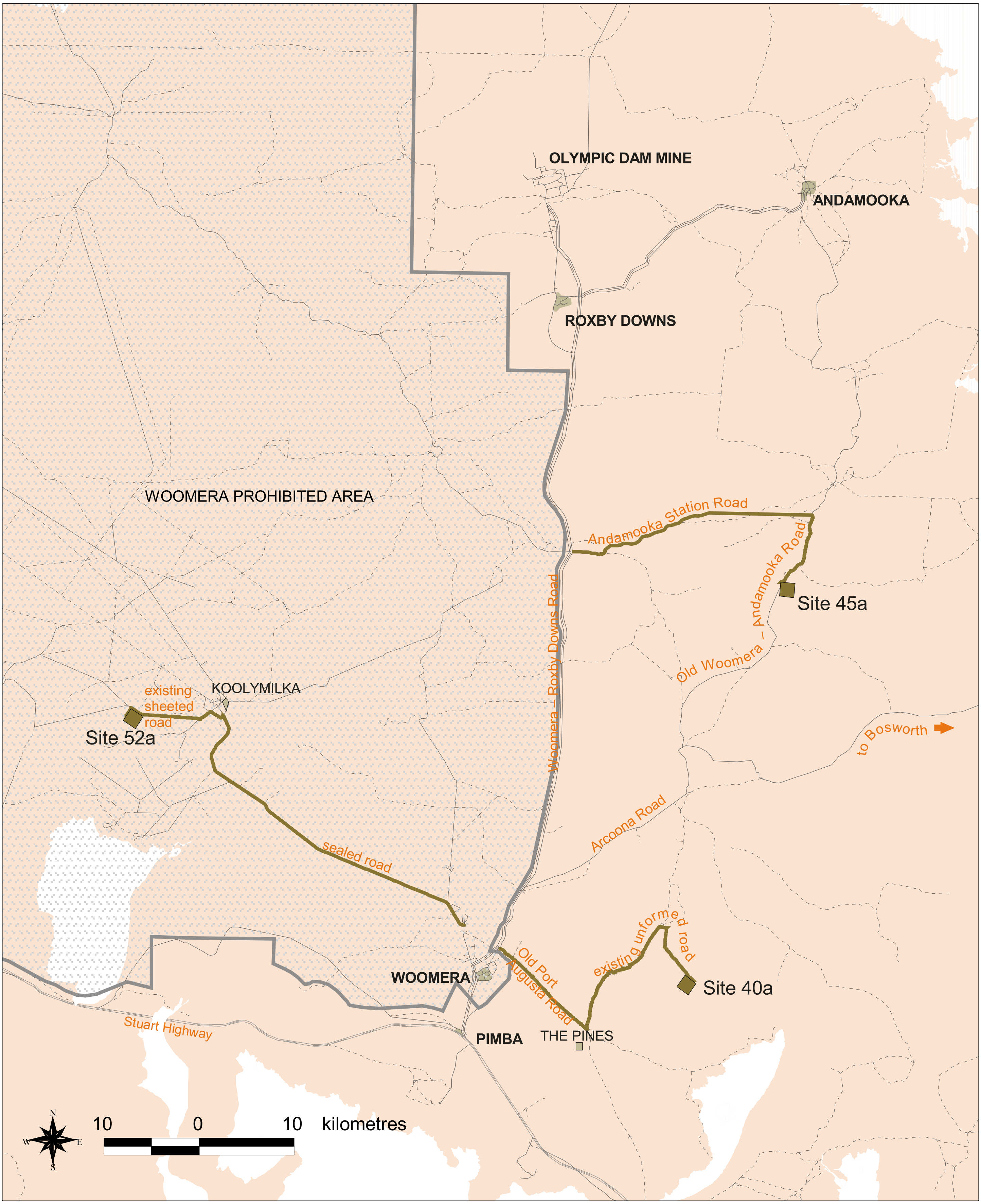


FIGURE 7.2

Access roads

Repository waste sites
Access roads
Woomera prohibited area
Salt lakes
Towns/settlements
Major road
Sealed seconday road
Minor road
Track

Access to each of the preferred and alternative sites, including any necessary road works, is described below.

7.4.1 Access to Site 52a

Site 52a lies at approximately 158 m above sea-level and just north of Wild Dog Creek (which flows east into Koolymilka Lake). The site is 55.5 km by road northwest of Woomera township. The current access comprises 45 km of two-lane sealed road (approx 6 m wide) in flat to undulating terrain to Koolymilka (old town); and then a further mainly unsealed 10.5 km of road to the west, which is sheeted 6–7 m wide with Bulldog Shale.

This mainly unsealed road includes an initial 1.5 km of narrow seal (4 m wide), which is in very poor condition (this sealed surface could be removed and the road returned to an unsealed state). The existing unsealed surfacing is weak and becomes sandy under traffic, and slippery when wet. The road is currently suitable for dry weather travel; however, use by heavy vehicles in wet weather would lead to accelerated deterioration. Options covered include upgrading the road to be useable in all weather or non-use of the road in wet weather.

The road in the WPA has several sharp angle bends, which would not prevent the passage of large vehicles, but minor sheeting works could be carried out to accommodate large vehicles.

7.4.2 Access to Site 40a

Site 40a lies approximately 189 m above sea-level. The site is approximately 42 km by road from Woomera. This route includes 6.2 km of sealed road (Roxby Downs Road) to the junction with the now unused Woomera–Port Augusta Road. The access route then follows the old Woomera–Port Augusta Road southeast for about 13 km through undulating gibber terrain to The Pines.

This old road is not maintained and is in generally poor condition. Where the surface grades are low (less than approximately 1–2%) the original formation is relatively intact, but where grades are greater and stormwater runoff has been able to concentrate, major gullying has occurred in the formation. The traversing of this road is therefore effectively an ‘off-road’ situation, suitable only for 4WD vehicles and, to a lesser extent, rigid trucks in dry weather. In wet conditions, the road is passable with difficulty by 4WD vehicles.

At The Pines the track follows Rocky Creek and its tributaries northeast for about 9 km along a north-trending shallow, wide valley, with highly discontinuous sand sheets and low dunes, mainly to the west of the creek lines. The subgrade is therefore a mixture of sandy floodplain sediments and gibber terrain. The route crosses the creek three times.

From the last creek crossing, the route follows gibber terrain for about 13 km east then south along a watershed to Site 40a. This section of the route is unformed (vehicle tracks only). The vegetation and gibber cover has not been removed and the road is generally in a stable condition.

The overall length of unsealed track is approximately 35.5 km. The indirect nature of the route is indicated by the contrasting ‘direct’ distance of 20 km.

Site 40a would require about 35.5 km of significant road upgrading works, including 13 km of reconstruction along the old Woomera–Port Augusta Road route, which is primarily gibber terrain. This would involve repairing previous damage and establishing a new road formation over the old formation. Floodways would be required at creek crossings.

The remaining 22.5 km of road upgrading would be along the existing unformed track (about 17.5 km in gibber terrain and 5 km in sandy terrain). This section of works would require removal of vegetation and earthworks over the formation width. Where sharp angle bends occur, the formation width could be increased to accommodate large vehicles.

7.4.3 Access to Site 45a

Site 45a is 131 m above sea-level. The site is approximately 52 km (direct) from Woomera, and 91 km from Woomera via the current access route. Of this distance, 49 km is sealed (Roxby Downs Road) and 42 km unsealed.

From the Roxby Downs Road, the road follows an existing road 29.5 km east through sand dunes towards Andamooka Station. This landform consists of clearly defined but closely spaced linear dunes with swales, which are partially filled with sand. The road is roughly parallel with the east–west-trending dunes, and for most if its length runs along swales. It does, however, cross at least two linear dunes and extensive areas of hummocky sand dunes.

Near Andamooka Station homestead, the station road meets the now unused Woomera–Andamooka Road. The access route then turns south for 12.5 km along the Woomera–Andamooka Road through gibber terrain to Site 45a. The route follows Dromedary Creek with a number of creek crossings for 9 km, before reaching the flatter terrain of the watershed between drainage systems upon which Site 45a is located.

Again, this old Woomera–Andamooka Road is in gibber terrain and, like the Woomera–Port Augusta Road, is in poor condition and suitable only for 4WD vehicles and rigid trucks.

An alternative route is available 14 km north of Woomera along the Roxby Downs Road, via the existing Arcoona–Bosworth Station Road (again part of the old Woomera–Andamooka Road). This route follows the Arcoona Road for 27 km, and then continues on a further 20 km north along the now abandoned and 4WD-only Andamooka Road through gibber terrain to Site 45a. This alternative route would place Site 45a about 71 km from Woomera with 47 km of unsealed road, of which approximately 20 km would require new construction. Thus, although this route is 20 km shorter, it includes 5 km of additional unsealed road.

Site 45a via the current access route would require 12.5 km of road upgrading works in gibber terrain along the old Woomera–Andamooka Road. This would involve repairing previous damage and establishing a new road formation over the old formation. Floodways would be required at creek crossings, with minor earthworks to maintain vertical geometry standards.

The alternative route via Arcoona Station would require approximately 20 km of road upgrading works in gibber terrain.

7.5 Community Consultation

Communities have been consulted on transport issues associated with the national repository project through public reports and information sheets, which have been widely distributed (Section 1.5.3).

In addition, transport issues have been addressed at information days conducted in the central–north region of South Australia in 1998 and 2001, at meetings of the various consultative committees, and at meetings with stakeholder groups (e.g. Aboriginal groups).

Consultation on transport issues has also taken place through qualitative research in the form of group discussions undertaken in 2000 and 2001 by McGregor Tan Research in Port

Augusta (SA), Mildura (Vic) and Broken Hill and Dubbo (NSW). Targeted workshops were held in Broken Hill and Mildura, and transport issues were explored more generally in Port Augusta and Dubbo. These centres were selected as they may be on routes used for transport of radioactive waste to the national repository.

The aim of the qualitative research was to explore people's awareness of, and attitudes and perceptions relating to, the transport of low level and short-lived intermediate level waste through their community. The participants were provided with information concerning the transport of radioactive waste to the national repository in central–north South Australia.

A summary of the outcome of the discussions in the regional centres is outlined below.

7.5.1 Broken Hill

Discussion with Broken Hill residents, through groups engaged for the qualitative research, indicated that transport of waste to the national repository was not a major concern. Some had heard that the Commonwealth Government had plans to dispose of low level radioactive waste. Few knew that the proposed site was in South Australia. Most did not realise that Broken Hill could potentially be on the transport route. For the majority of participants the initial reaction to possibly being on the transport route tended to be one of apprehension or reluctant acceptance.

A number of participants felt that they did not know enough about the issue to be able to pass judgment. Some people felt that it was not necessarily a major issue as they felt dangerous cargo was already transported through Broken Hill, but that the general public was not aware of it.

The greatest perceived risks were associated with the potential for a major accident, and this was enhanced by the fact that the Barrier Highway follows the main roads through the centre of town.

Concerns were also expressed about the capability of the emergency and hazardous material services to be able to cope in the eventuality of such an accident. A number of people did not know what low level waste consists of, how it would be transported and packaged, nor the amount or frequency of transport. They wanted to know what the effect of an accident would be on people and the environment, and what the arrangements would be in the event of an emergency.

Some were of the view that there were more important issues in Broken Hill than the transport of radioactive waste, particularly as they had been living with lead pollution around the town for many years.

As well as the above discussions, consultation on transport issues was conducted in 2000 between the former Department of Industries, Science and Resources (Cwlth) and the Barrier and Darling Environment Group, based in Broken Hill. A teleconference was conducted to respond to questions asked by the group, who were particularly interested in such transport issues as: the amount of waste to be transported, the frequency of transport, the way the waste would be packaged and the contingency plans in the event of an accident.

It was indicated to the group that:

- The transport of radioactive waste to the repository would be infrequent as there was a small quantity of material involved, and that about half of the existing inventory was already stored at Woomera.
- Radioactive material, including waste, is routinely transported every day in Australia and around the world and there is a long record of safe transport.

- Radioactive waste would be transported according to the relevant code of practice, based on international regulations, as well as relevant state and territory safety regulations.
- The type of packaging would depend on the form and level of activity of the waste to be transported. Low level waste generally requires industrial packaging, which meets specified temperature and pressure specifications, drop tests, and water spray and penetration requirements.
- The waste to be transported would be solid, and therefore would not 'spill' in the event of an accident. The package could simply be removed from the scene. Emergency response is the responsibility of the relevant state/territory emergency services, and is covered by existing emergency planning arrangements (see Section 7.6.4).

7.5.2 Mildura

Discussion with Mildura residents, through groups engaged for the qualitative research, indicated that most individuals were not aware of the national repository project. Some had heard of plans to dispose of waste in South Australia. Only one or two people thought that Mildura might be on the transport route.

There was a range of responses to the issue of transport of radioactive waste, from people being uninterested, through those who saw that the waste needed to be transported to a suitable location, to those who expressed reluctant acceptance as long as the material was transported safely. Others were more cautious in their response to the proposal.

Some thought that similarly dangerous material was already transported through Mildura, while others considered that radioactive material had beneficial applications, especially medical, and therefore the transport of such material was necessary. A number of people assumed that safety concerns would be appropriately addressed.

When asked about the perceived risk of transport of radioactive material, the predominant concerns were similar to those raised in Broken Hill, namely the risk associated with an accident, heightened by the fact that the main truck route passes through the middle of Mildura.

A further factor contributing to the degree of concern was the number of trucks that use this route daily and the fact that several parts of the route, especially the Sturt Highway just east of Mildura, are known to be particularly dangerous stretches of road.

7.5.3 Port Augusta

Issues concerning transport raised by the discussion groups in Port Augusta included the need for the vehicles transporting radioactive waste to cross the bridge over Spencer Gulf, and the impact of any potential accident on the bridge. There was a general willingness, however, to accept that the transport of radioactive materials including waste is safely carried out on a regular basis. This was in part due to the fact that uranium from the Olympic Dam operations is routinely transported through Port Augusta.

7.5.4 Dubbo

While the concept of disposing of radioactive waste in a national repository was supported, some were concerned about the transport of the waste. Some wanted more information about the frequency of transport of the material, and safety procedures and precautions, while others considered that too much information might exacerbate concerns.

7.6 Transport Safety

7.6.1 Review of International Accidents

Radioactive material has been transported around the world for more than 40 years, and in that period no transportation-related accidents have occurred involving any significant radiological release or harm to the environment or public health. It is estimated that more than 20 million packages of radioactive material are transported worldwide every year. The majority of these contain only limited amounts of radioactivity used for a variety of purposes, for example isotopes for medical purposes. Only a small number of transport movements actually involve substantial amounts of radioactivity.

Since there have been no major transport accidents involving the release of radioactive material, accurate predictions of likely future accidents are problematic. Therefore, general (non-nuclear) transport accidents have been used as an indicator.

Saricks and Tompkins (2000) compare road and rail transport of hazardous materials (including radioactive materials) in the USA. The report compares statistics from the 1990s with those obtained during the 1980s. There was a total of approximately 67 billion km of hazardous material truck shipments in 1992, with a total accident rate of 3.2×10^{-7} per truck-km. For rail, the number of hazardous material rail transport shipments is not stated in the report; however, the total accident rate was 2.7×10^{-7} per railcar-km.

Thus, accident rates for rail and road are similar but are about 20% higher for road transport, on a per truck-km versus a per railcar-km basis. The rates for road and rail crashes were higher in the 1990s than the 1980s. The report concludes that the following factors contribute to accidents:

- increased road speed
- minor roads, which are worse than large roads
- cold weather in both road and rail transport
- hot weather in rail transport
- rail infrastructure when poorly planned or maintained.

Many organisations collect and publish statistics of international road traffic accidents. In most countries the number of fatalities per 100,000 population, and per registered vehicle, have been reducing every year since the 1960s. This is generally considered to be because vehicles have better safety features (e.g. compulsory seat belts, air bags, side impact protection, anti-skid brakes) and road accident black-spots are designed out.

In a road traffic accident involving radioactive cargo, the cargo is not the cause of death/injury. Such a cargo has a very low hazard potential in normal road traffic accidents; it is simply a heavy load like any other. The principal hazard is physical impact, which is independent of the contents of the load. If appropriately packaged, the radioactive contents are contained within the packaging and are not released to the environment. The transport of radioactive materials is considerably less hazardous than the transport of flammable and other hazardous chemicals that are routinely transported by road.

A comparison of international transport fatality rates by Monash University compares Australia with selected major industrial countries over recent years, and shows that Australia is slightly better than the average in terms of fatality rates, with 1.45 fatalities per 10,000 vehicles, and 9.4 fatalities per 100,000 population. The USA has the highest fatality rate and Sweden the lowest. Data from the international road traffic and accident database, which compares Australia with a much wider selection of countries (for the year 1999), show that Australia has a lower rate than the international average in terms of fatalities. Korea is considered to have the highest fatality rate and the UK the lowest.

Davies (2000) reports on railway safety figures for the UK over the last 10 years. Statistics are given for a variety of accident types, including fatalities and major injuries for passengers, the workforce and the public; catastrophic accidents; signals passed at danger; suicide; and vandalism. The set of statistics most relevant to the Australian national repository relates to collisions and derailments. The average over the last five years has been 0.14 collisions or derailments per million train-km.

7.6.2 Likelihood of Incidental Exposure

The transport of radioactive waste to the repository would take place mostly by road. After the initial campaign to dispose of the current inventory of waste, movement of waste to the repository would be infrequent. The most normal form of transport would be by road in a dedicated truck. Dedicated means that the truck would only carry radioactive waste for the repository on this journey, and the driver would be suitably qualified and experienced.

Stringent controls and procedures such as driver selection and training, careful choice of contractor by safety record, good maintenance and condition of trucks, pre-planned road routes, emergency planning, and trained and equipped escorts would reduce the number of accidents from road transport. However, accidents cannot be ruled out altogether.

What makes the proposed transport safe are the characteristics of the waste to be transported, the design/selection/testing of the packaging and the strict adherence to Australian Transport Regulations.

The risks associated with the proposed transport arrangements are acceptably low because of the:

- characteristics of the radioactive waste to be transported (solid / low level and short-lived intermediate level; see Sections 4.1 and 4.2)
- design/selection/testing of the packaging (see Sections 3.2.3 and 4.3)
- strict adherence to IAEA and Australian Transport Regulations (see Sections 3.1 and 3.2.3).

In the unlikely event of an accident, the solid waste form, and multiple packaging for sealed sources (an inner shielded container, the 205 L drum, and finally the 6 m ISO standard container) would help ensure that radioactive material was not widely distributed around the accident site.

Radiation exposure risks during transport are discussed in Sections 12.4.3 and 12.9. An assessment of the risk of a traffic accident follows.

7.6.3 Risk of Truck Accidents

The potential risk of accidents involving trucks carrying radioactive waste to the repository has been assessed through a three-stage process:

- derivation of average truck accident rates per section of the alternative truck routes
- estimation of the indicative number of truck movements needed to transport the waste from the respective states and territories
- estimation of truck accident risk by applying the accident rates to the indicative numbers of truck movements.

As described below, the accident potential for trucks carrying waste is low, due to a combination of relatively small numbers of truck movements and low probable accident risks involving trucks on the regional Australian highway network.

Port Augusta forms a confluence of truck routes from all states and territories (excluding the Northern Territory). Routes pass through the city and across the bridge over northern

Spencer Gulf. Consideration of truck accident potential within Port Augusta is separately considered.

Derivation of Accident Rates

The approach adopted in assessing truck accident potential was to define average truck accident rates by section of route, as a function of historical accident levels and traffic volumes. This approach obviated the need to undertake detailed accident analyses in each town and city along the respective routes, especially given high level of uncertainty in the logistics of moving the waste (regional pick-ups and truck types).

Average truck accident rates were derived in terms of the number of truck accidents per million vehicle kilometres of travel (all vehicles) per year, based on:

- average annual truck accidents recorded over the past five years. These included accidents in towns and cities along the respective routes, but excluded accident incidence on the outlying sections of higher trafficked capital city roads where accident rates are generally much higher. Typically, accidents were sourced from the respective road authorities over the period 1996–2000.
- average annual daily traffic over each route section. The respective road authorities provided values for 2000 (or 1999 depending on data availability).

Summary average rates thus derived are shown in Table 7.3.

The results of the accident analysis reported in Table 7.3 confirm that accident rates involving trucks on the defined national and state highway routes are low. It is expected that the corresponding incidence of accidents involving trucks carrying the radioactive waste material would also be low, as demonstrated in the following section.

Estimation of Truck Accident Potential

Indicative estimates of accidents involving waste-carrying trucks were derived based on the following set of assumptions:

- Accident rates for a single selected route between each respective capital city and the repository were used. Alternative routes may be chosen with differing accident rates but, for the purpose of this analysis, a single route provides representative accident estimates.
- All accumulated waste material from each state or territory would be carried out within a 12-month period, from the respective capital city to the repository (actually it would occur within a limited time interval within the first year of operation of the repository.
- Numbers of truck movements required to carry the accumulated waste were derived using the assumptions described in Section 7.2.7. Note that these movements are based on a standardised truck carrying a container with a load of material of standard volume of 10 m^3 in 205 L drums (see Section 7.2.7). The actual numbers of truck movements may change depending on the logistical arrangements put into place, but the analysis below provides an indicative estimate of accident potential.

Table 7.4 summarises the estimated numbers of accidents for waste material transported separately from each state/territory to the repository in the initial disposal campaign.

A separate analysis for the transport of the CSIRO waste already stored at Woomera indicates an accident rate of 0.001 for Site 52a and up to 0.006 for the alternative sites, that is a negligible additional amount.

Table 7.4 indicates that less than one accident involving trucks carrying the accumulated waste from the respective states and territories to the repository might be expected. The potential number of accidents involving trucks carrying future waste (expected to total up to some 50 m^3 per year) would be negligible.

TABLE 7.3 Average truck accident rates

State of origin/ capital city	Section of route	Accident rate (accidents x 10-6/vkt/year)(1)
SA/Adelaide	*Port Wakefield Road*	
	■ Adelaide–Port Wakefield	0.20
	■ Port Wakefield–Port Pirie	0.55
	■ Port Pirie–Port Augusta	0.50
	Stuart Highway	
	■ Port Augusta–Pimba (Woomera)	0.25
	■ NT Border–Pimba	0.35
NT/Darwin	*Stuart Highway*	
	■ Darwin–Katherine	1.05
	■ Katherine–Tennant Creek	0.50
	■ Tennant Creek–Alice Springs	0.20
	■ Alice Springs–SA Border	0.10
Queensland/Brisbane	*Cunningham Highway (Option 1)*	
	■ Ipswich–Goondiwindi	1.75
	Gore Highway (Option 2)	
	■ Ipswich–Goondiwindi	0.70
	Newell Highway	
	■ Goondiwindi–Dubbo	1.20
	Then Dubbo to repository as per NSW route via Great Western Highway, Mitchell Highway and Barrier Highway	
NSW/Sydney(2)	*Option 1*	
	Via Great Western Highway	
	■ Katoomba–Orange	1.12
	Mitchell Highway	
	■ Orange–Nyngan	1.22
	Barrier Highway	
	■ Nyngan–Broken Hill	0.50
	■ Broken Hill–Peterborough turnoff (SA)	1.45
	Peterborough turnoff–Port Augusta	2.45
	Then Port Augusta to repository as per SA route via Stuart Highway	
	Option 2	
	Via Hume/Sturt Highways	
	■ Mittagong–Wagga turnoff	0.70
	■ Wagga turnoff –Mildura	0.65
	■ Mildura–SA Border	1.00(3)
	■ SA Border–Lyrup	1.30
	Lyrup to Burra Road	1.30
	Barrier Highway	
	■ Burra–Peterborough turnoff	0.95
	Then to repository as per NSW Option 1 route	
	Option 3	
	Via Silver City Highway from Mildura (Wentworth) to Broken Hill	1.10
Victoria/Melbourne	*Option 1*	
	Via Calder Highway	
	■ Melbourne–Mildura	1.20(3)
	Then to repository as per NSW Option 2 route	
	Option 2	
	Via Western Highway	
	■ Melbourne–Horsham	1.20(3)
	Via Henty/Sunraysia Highways	
	■ Horsham–Mildura	1.40(3)
	Then to repository as per NSW Option 2 route	
Tasmania/Hobart	*Midland Highway*	
	■ Hobart–Launceston	0.35
	Bass Highway	
	■ Launceston–Burnie	0.50
	Then to repository as per Victorian Option 1 route	

(1) VKT = vehicle kilometres of travel
(2) Includes ANSTO facility
(3) Assumed — data not available
Note: Link from ACT via Barton Highway to Hume Highway in NSW at Yass
Source: Consultant analysis

TABLE 7.4 Estimates of truck accidents involving trucks carrying waste

Source of waste	Volume of waste (m^3)	No. of waste shipments[3]	Total distance travelled (km)	No. of accidents (in 1 year)
SA/Adelaide[1]	218	22	490	0.004
NT/Darwin	16	2	2600	0.002
Queensland/ Brisbane	45	5	2100	0.011
NSW/Sydney[2]	1,355	136	1580	0.208
Victoria/Melbourne	33	4	1290	0.006
Tasmania/Hobart	15	2	1610	0.003
Total	**1,682**	**171**		**0.234**

(1) Excludes waste material currently stored at Woomera
(2) Includes waste material from the ACT
(3) Rounded
Source: Consultant analysis

Accident Potential at Port Augusta

The section of national highway through Port Augusta would form a focus for the movement of all trucks carrying waste from the other states and territories, with the exception of the Northern Territory. The potential for accidents within Port Augusta is thus considered separately.

Traffic accident data sourced from Transport SA indicate a total of 26 accidents involving trucks over the period 1996 to 2000 (or five per year on average) over a 23 km section of the Princes Highway between the intersection of the Eyre and Stuart highways and the turnoff to Stirling North on the southern side of the city. This section of highway traverses the length of Port Augusta, including the bridge crossing of Spencer Gulf.

A simple analysis of traffic conditions through Port Augusta indicates that there would be almost negligible potential for increased accidents involving the trucks carrying the waste. This is illustrated at the bridge crossing as follows:

- total daily traffic at the bridge over the northern tip of Spencer Gulf is 14,000 (two-way)
- estimated daily truck movements at the bridge are 760 (two-way)
- potential daily movements of waste-carrying trucks would be in the order of less than 1 truck per working day. This represents less than 0.5% of daily truck movements.

With appropriate transport plans in place, it is expected that there would be minimal risk of accidents involving the trucks carrying the waste.

By way of comparison, WMC Limited have been shipping uranium oxide concentrate through Port Augusta since 1986, and currently have two or three truck movements of this material per week. Over this period, there has not been a single accident or incident involving these WMC trucks (either in Port Augusta or elsewhere along the route from Roxby Downs to Port Adelaide).

7.6.4 Emergency Services

In the unlikely event of a radiation-related accident or incident, emergency response is a matter for the relevant state or territory emergency services and is covered by existing emergency planning arrangements in accordance with the transport code. In most emergency situations, the police, ambulance, fire services and state emergency services (SES) are the first responders. The fire services maintain specialised hazardous materials (HAZMAT) teams trained to deal with chemical, biological and radiological incidents.

In addition, the Commonwealth can provide assistance on request from the states. This assistance is provided through requests from the state SES to Emergency Management Australia (EMA). ARPANSA and ANSTO also maintain trained radiation emergency response teams that can provide assistance on request from the state authorities.

The emergency response plans and procedures of each state for dealing with accidental radioactive waste spillage during transport are covered below.

South Australia

The Department of Human Services (DHS) has overall responsibility for managing emergency responses for any incidents involving spillage/leakage of radioactive materials in SA.

The emergency response to an incident in SA is outlined in *The Blue Book: Emergency Response to a Leakage or Spillage of a Hazardous Material during Transport, Storage or Handling*, published by the SA Government (South Australian Hazardous Materials Standing Committee 1997).

In the event of an incident involving the distribution of radioactive material, the emergency services response is coordinated/managed via the following sequence of activities:

Response

1. Typically the incidence of the distribution of radioactive material would be notified via the 000 emergency phone number, managed by the SA Ambulance Service.
2. Following the initial phone contact, emergency services would be contacted as follows:
   - Within the metropolitan area, the Metropolitan Fire Service (MFS) would be alerted. They would immediately respond to the call, travel to the incident location and make an assessment of the nature of the incident.
   - If the incident took place outside of the metropolitan area, then the Country Fire Service (CFS), coordinated via the SES, would respond similarly.

   The MFS/CFS would initially cordon off the site. SA Police would be in attendance to control vehicle/person movements within the environs of the site and to act as the overall coordinating authority.
3. In the event of a radioactive material incident, the MFS/CFS would contact the DHS, which has responsibility under the response plan to provide expert technical advice. A designated DHS representative would be dispatched to the site, where they would:
   - use appropriate radiation scanning equipment to assess the nature of the incident and type of material, the extent to which the scene should be cordoned off and how the spillage should be treated and the site rehabilitated
   - coordinate with the MFS/CFS to commence a containment and clean-up process.

DHS has a team of 8–10 senior staff experienced in responding to such incidents. This team is rostered to be on a 24-hour response. Response to incidents would vary according to the remoteness of the incident. It is expected that the following times would be typical for more remote incidents:

- initial response by the police and SES/CFS personnel: within 1 hour
- response by DHS specialists: up to 3 hours depending on site remoteness
- response by CFS units having specialised equipment for containing the spillage and for rehabilitating the site: typically up to 2 hours following the DHS site assessment.

Training and Equipment

Training of response staff is provided as follows:

- The nominated DHS staff receive professional training in the handling of radioactive material, and in the use of radiation detection equipment. They undertake in-house training awareness courses, and are familiar with the protocols under which responses are managed. Typically they respond to 2–3 incidents per year.

- The MFS/CFS staff receive routine training in the clean-up of hazardous material spills, including radioactive material. They rely on the expert advice of the DHS personnel in the event of a radioactive material incident.

Equipment available for managing a response to radioactive material incidents comprises the following:

- DHS staff have appropriate radiation detection equipment to determine if radioactive material has been distributed.
- MFS and (selected) CFS staff have comprehensive equipment to handle spillage clean-ups. These include protective suits and handling equipment including containers and other containment devices. All such equipment is brought by the MFS/CFS to each incident. It is noted that not all CFS units have the required equipment, especially those small units in small country towns. Such equipment may need to be brought from further afield.

The CFS advised that the contamination suits are used mainly for chemical spills, and their suitability for radioactive material distribution may depend on the level of radioactivity encountered.

MFS have trained personnel, the necessary protective clothing (breathing and protective clothing) and containment equipment (200 and 360 L drums) at 18 major cities and towns around South Australia. Locations relevant to the shipment of waste material to the repository are:

- Adelaide
- Berri
- Burra
- Loxton
- Peterborough
- Port Augusta
- Port Pirie
- Renmark
- Whyalla.

The CFS has trained firefighting staff in most main country towns in South Australia. HAZMAT brigades, trained and equipped to handle hazardous material spills including radioactive materials, are located in only a limited number of regional centres. Along the proposed transport routes, these centres are:

- Burra
- Jamestown
- Port Wakefield
- Stirling North
- Waikerie
- Woomera
- Yunta.

Emergency Clean-up and Rehabilitation Programs

No formal protocols are in place for the clean-up/rehabilitation of radioactive material distribution. This is largely as a consequence of the potentially wide range of types of incidents. There are procedures in place, however, for differing events. Each specific incident is assessed on its own merits by DHS experts on the scene, who then determine a range of clean-up and rehabilitation treatment programs depending on the nature of the incident. These programs would differ according to the type of material, the level of radioactivity, and the extent of the distribution of radioactive material. The highly variable nature of potential incidents effectively precludes the prescription of detailed programs.

Australian Capital Territory

The ACT Emergency Response Plan deals with incidents involving hazardous substances and radioactive materials. The Radiation Safety Section (RSS, Department of Health, Housing and Community Care) maintain an on-call technical advisory service capable of responding to radiation emergencies, and provide timely technical advice and resources in relation to hazards associated with materials involved in such incidents.

Response

1. The police or ACT Fire Brigade is the first point of contact.
2. The fire brigade would coordinate the response and be responsible for inner perimeter control and notification of other relevant agencies, such as RSS in the case of radioactive substances. They would secure the incident site until the radiation adviser arrives.
3. The RSS would assess the nature of the incident and define what treatment is required, and would be responsible for containment, in collaboration with other relevant agencies.

Typical response times to incidents are:

- initial response by fire brigade: within 10 minutes
- response from the RSS: within 1 hour.

Training and Equipment

There are 260 officers and firefighters in the ACT Fire Brigade. They are located at seven fire stations, two joint emergency services complexes, communications and headquarters.

Staff are trained at EMA in Mt Macedon and all necessary equipment is kept in an emergency vehicle maintained by the RSS. Emergency response exercises are held regularly but response to radiation emergencies has not been tested within the last five years.

Emergency Clean-Up and Rehabilitation Programs

The RSS is responsible for rehabilitation of any incidents involving radioactive materials.

New South Wales

The NSW State Disaster Plan (DISPLAN) and relevant sub-plans, NSW Hazardous Materials Emergency Sub-plan (HAZMATPLAN) in particular, details emergency response procedures for hazardous and radioactive material incidents.

The Radiation Control Section of the Environment Protection Authority (NSW EPA) manages radiation control in New South Wales. Emergency response obligations are managed through a memorandum of understanding with the Hazardous Materials Unit (HAZMAT) of the NSW Fire Brigade (NSWFB).

Response

1. First response to an incident would be by HAZMAT (NSWFB) who responds to all incidents involving hazardous materials (including radioactive material); if assistance was required they would call the EPA. This occurs whether it is a metropolitan or regional area. The NSWFB's role includes containment of any hazardous materials involved.
2. The NSW Police Service would assume control of the emergency site, in support of NSWFB, and coordinate the support required by the HAZMAT Controller.

3. The EPA would attend the scene but would not have the authority to control the scene; rather they would provide assistance and advice. The scene would be managed by HAZMAT.
4. The Roads and Traffic Authority and Ambulance Service would provide assistance with traffic management and injuries at the emergency site, respectively.

HAZMAT has a 24-hour incidents response line.

Training and Equipment

NSWFB has 330 fire stations throughout the state, protecting the public of NSW by providing emergency response vehicles, equipment and personnel 24 hours a day, 365 days per year. They respond to approximately 112,000 emergency incidents a year, of which over 12,000 are spillages, leaks or other HAZMAT incidents.

HAZMAT stations, located at Greenacre (Sydney), Newcastle and Wollongong, are staffed by 90 firefighters. Eight additional units are located in major regional centres, and provide 24-hour emergency response service to any hazardous materials incident within the state. Through training and experience, the firefighters attached to the units are able to provide expert advice and operate specialised hazardous material equipment.

There are 17 response vehicles, which carry a wide range of specialised equipment used to render safe any hazardous materials incident.

The specialised equipment carried includes:

- breathing apparatus
- chemical protective clothing
- gas detection units
- oxygen resuscitators
- compressed air and oxygen cylinders
- containment and recovery equipment
- absorbents and neutralisers
- radiation meters
- laptop computer (containing a chemical database).

In addition to land-based incidents, NSWFB is also responsible for spillages on inland waterways including creeks, lakes, drains and others. To assist in combatting incidents on water, the HAZMAT unit maintains a rigid hulled inflatable boat at Greenacre. This vessel responds to combat waterway spills, deploy booms, take readings or samples and carry out other duties.

A Breathing Apparatus and HAZMAT Training Centre is located within the Alexandria Campus of the NSW Fire Brigade Training College. The centre provides training to all members of the brigades throughout the state in the use and application of breathing apparatus and hazardous materials response.

A mobile breathing apparatus and HAZMAT training and response vehicle facilitates training and servicing in country areas.

The NSW EPA Radiation Control Section has radiation monitoring and response equipment available to cover incidents involving alpha, beta, gamma and neutron emitting sources of radiation.

The Radiation Control Section also participates in emergency response exercises held by ANSTO. Major ANSTO exercises are held approximately every two years, with lower scale complementary exercises held on a more regular basis. These exercises involve a number of participants, such as NSWFB, NSW Ambulance Service and the NSW EPA.

Emergency Clean-Up and Rehabilitation Programs

The EPA Radiation Control Section would control the environmental monitoring (in consultation with the HAZMAT Controller), the disposal of any radioactive waste and the clean-up and rehabilitation of the accident scene and affected land. Generally, if an owner can be identified they are responsible for the clean-up.

The Roads and Traffic Authority provides clean-up assistance to NSWFB, NSW EPA and Health Services as required on its roads.

Northern Territory

Northern Territory Counter Disaster Plans exist at local and regional level. Radiation incidents are not specifically covered in the plans but the relevant agencies are listed. The NT Police is the control agency for all emergency situations.

Safe transport of radioactive materials, including transport emergencies, has primarily been the responsibility of the duly authorised transport provider.

Response

1. The police are the first point of contact and would notify the appropriate response agency.
2. The Fire Service would respond at the scene of the incident. They, however, have limited capability.
3. The NT Police and Radiation Health Section of the Territory Health Services would assess the nature of the incident and define the treatment required.
4. Due to limited resources, Defence and ARPANSA would be asked to assist with containment.

Typical response times to incidents are:

- metropolitan area: within 10–15 minutes
- regional areas are reached at approximately 100 km/h.

Training and Equipment

All staff at main fire stations are trained in hazardous materials response. Some monitoring equipment is held by the NT Emergency Service in Darwin. Large incidents would require Defence and ARPANSA equipment and facilities.

No radiation emergency response exercises have been held due to the low probability of major radiation transport incidents and insufficient resources available to the NT radiation regulation agency.

Emergency Clean-up and Rehabilitation Programs

Defence and ARPANSA would be asked to assist with any rehabilitation and clean-up associated with radiation incidents.

Queensland

The State Radiological Disaster Plan details emergency response procedures for radioactive incidents. Radiation Health of the Department of Environment and Health (Queensland Department of Health) is the overarching authority on radiation and responsible for radioactive incidents. They are available on 24-hour call for advice on radiation-related accidents. All radioactive material transport licensees have their own Radiation Protection Plans.

Response

1. If an incident involved radioactive material transport licensees, they would contact Radiation Health and instigate the State Radiological Disaster Plan. If the police were notified, they would inform either Response Advice for Chemical Emergencies (RACE) or Radiation Health for advice on chemical and radioactive materials, respectively.
2. The police are the overall controller at an emergency scene and would rely on guidance from Radiation Health or RACE. Radiation Health would be called out to the scene if radioactive materials were involved. The fire brigade would provide assistance where needed.
3. Radiation Health would advise the police on managing the incident site, while the Queensland health services would manage any injuries or health issues.

Typical response times from the emergency services for the majority of incidents within metropolitan areas would be within a few minutes. RACE or Radiation Health response times would depend on where the incident occurred. Should an incident occur within an isolated rural area, local physicist expertise would be called upon from the nearest hospital or related facility.

Training and Equipment

Radiation Health and RACE have radiation monitoring and protection equipment for dealing with hazardous materials. Both Radiation Health and RACE are located in metropolitan Brisbane. Emergency services are located in all cities and most rural towns.

The emergency services undergo periodic training in response procedures. Particular attention has been given to training prior to the Goodwill Games, held in 2001. Future training exercises have not yet been planned but are likely to occur.

Irregular emergency response training exercises are held for Radiation Health officers in relation to the nuclear powered warship.

Emergency Clean-up and Rehabilitation Programs

Radiation Health is authorised by EPA Queensland, in accordance with the *Radiation Safety Act 1999* (Qld), to be responsible for containment and rehabilitation of any radiation incident.

Queensland is in the process of developing a document for rehabilitation procedures relating to affected land, in accordance with the *Environmental Protection Act 1994* (Qld).

Tasmania

The emergency response within Tasmania is documented as part of the Tasmanian Hazardous Materials Emergency Plan of the State Emergency Services. The Tasmania Fire Service is the lead combat authority for all hazardous materials accidents. The Department of Health and Human Services (DHHS) (Public and Environmental Health) is notified of any hazardous materials incidents.

Response

1. All incidents involving radioactive materials should be reported to the Tasmania Fire Service as the first point of contact, who would then complete a HAZMAT Action Guide.
2. The Tasmania Fire Service would contact DHHS.
3. The Tasmania Fire Service would be responsible for the rescue of personnel, advising ambulance and hospital personnel of possible radioactive contamination procedures, evacuation and isolation of the area, notifying the DHHS of particulars of the incident and radioactive materials, and securing the area until arrival of a relevant officer from the DHHS.

4. The Brigade Chief would assess the seriousness of the incident and pass control over to the Region Disaster Controller, should the situation be deemed appropriate. If the situation were thought to be very serious, the Region Disaster Controller would recommend to the Director of Emergency Services that a state of alert, emergency or disaster be declared.
5. The Tasmanian Hazardous Materials Management Committee (THMMC) is activated during exceptional, protracted hazardous materials emergencies and when consolidated technical advise may be required. Once activated, THMMC would advise the Region Disaster Controller on the technical aspects of the emergency.

Typical response time in the majority of incidents by the Tasmania Fire Service is less than 10 minutes.

Training and Equipment

Chemists, relevant specialists and laboratory facilities for use in the management of hazardous materials emergencies are available at the following organisations:

- Workplace Standards Tasmania
- Department of Primary Industry, Water and Environment
- DHHS
- University of Tasmania.

Exercises involving responses to hazardous materials incidents and emergencies involving release of radioactive materials are held at least once a year.

Emergency Clean-up and Rehabilitation Programs

The Region Disaster Controller must consider potential clean-up and disposal problems at an early stage. Different materials would require different clean-up methods. DHHS would determine the means of collection, transport and disposal of all radioactive materials.

The Waste Management Section (Department of Primary Industry, Water and Environment) would coordinate rehabilitation of the environment due to damage caused by hazardous materials emergencies.

In cases where the THMMC or Regional Disaster Planning Group has been activated, the Region Disaster Controller would convene a debrief on the emergency within one week, during which all THMMC members would submit a detailed report on their organisation's role in the emergency. The State Emergency Service would then make recommendations for improvements to this plan for discussion by the THMMC within four weeks of the debrief.

Victoria

The emergency response within Victoria is documented as part of the Public Health Emergency Management Plan. The Radiation Safety Unit, responsible for administrating the Health (Radiation Safety) Regulations, controls all uses of ionising radiation in Victoria. The unit has a 24-hour response capacity.

Response

1. Initial calls would be received by the police (Division 4).
2. The police would notify the duty officer at the Radiation Safety Unit, who would determine the exact location, extent of damage, number of people exposed and type and extent of exposure.
3. The Unit Manager or deputy would notify the Manager Health Protection, Assistant Director Public Health, Emergency Coordinator, relevant regional director(s) and the Media Unit.

4. An emergency incident report would be completed. The Assistant Director Public Health Branch and the Emergency Coordinator (in consultation with the Chief Radiation Officer, deputy and/or duty officer) would evaluate the situation and the action required.
5. The Chief Radiation Officer, deputy or delegate would assume the role of incident controller and activate call-out procedures, brief unit staff and participating organisations, and delegate tasks.
6. The Chief Radiation Officer, deputy or delegate would ensure that procedures continue until a stand-down announcement is given.

Training and Equipment

The Radiation Safety Unit has specialist radiation monitoring equipment to assess radiation exposures and measure radioactive contamination.

Emergency Clean-up and Rehabilitation Programs

The fire department handles any materials and clean-up under the advice of the Department of Human Services.

The recovery phase following an incident may require follow-up action. There are no specific actions detailed in the Emergency Management Plan for post clean-up procedures. The type and extent of the follow-up action required would vary depending on the specific circumstances of the incident.

PART C

Environmental Assessment

Chapter 8
PHYSICAL ENVIRONMENT

Chapter 9
BIOLOGICAL ENVIRONMENT

Chapter 10
LAND USE PLANNING AND ACTIVITY

Chapter 11
CULTURAL HERITAGE

Chapter 12
RADIATION

Chapter 8
Physical Environment

This chapter describes the existing physical environment of the proposed sites and the potential impacts of the proposal on the physical environment. The physical environment includes:

- geology
- geomorphology
- soils
- surface hydrology
- hydrogeology
- climate
- air quality
- noise
- fire.

8.1 Geology

8.1.1 Regional Geology

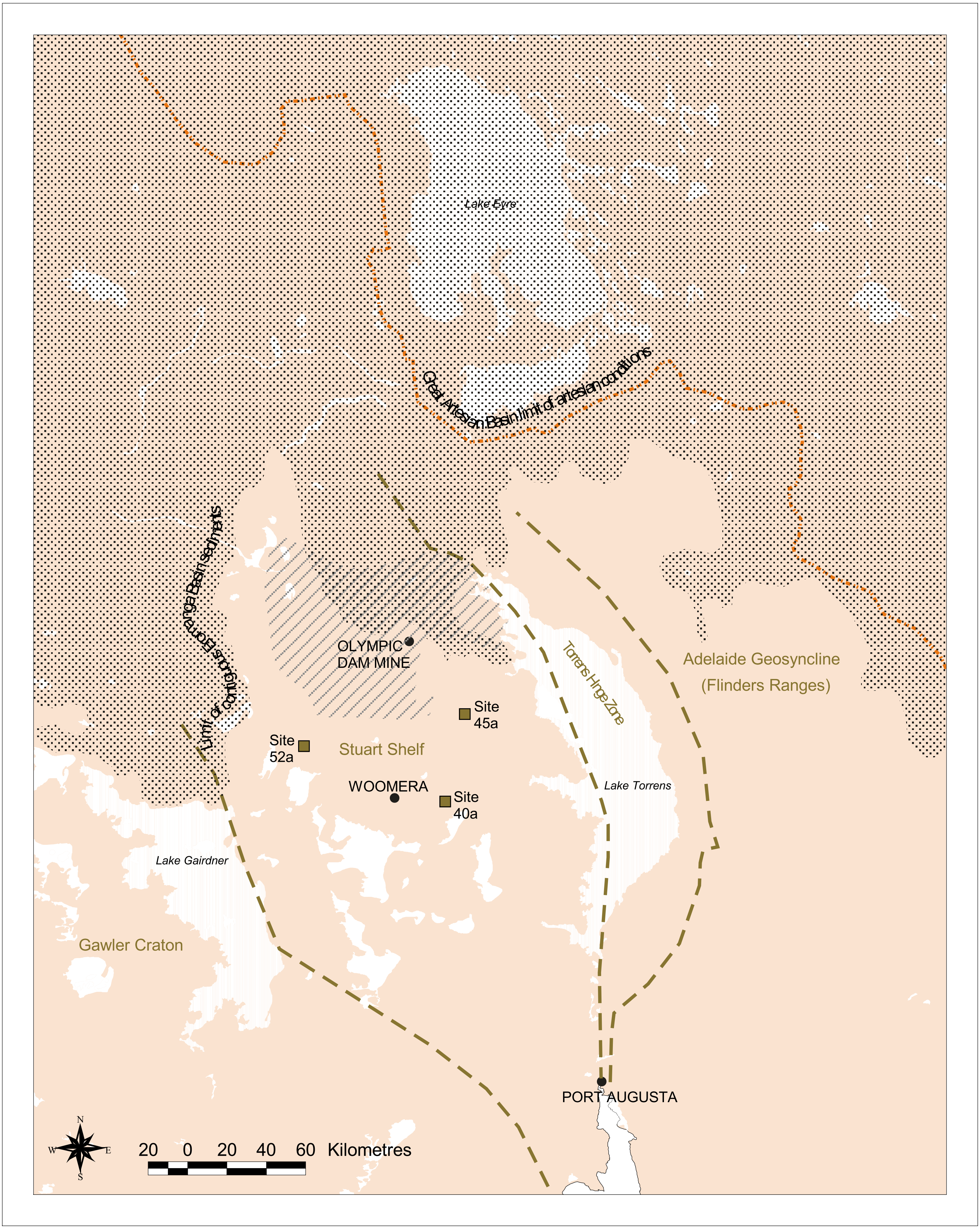
The three proposed sites for the national radioactive waste repository are located in the Stuart Shelf geological province, to the west of Lake Torrens in South Australia. This province comprises incomplete sequences of flat-lying, undeformed Proterozoic (Precambrian) and early Palaeozoic (Cambrian) marine sediments of the Adelaide Geosyncline, overlying the northeastern part of the Archean Gawler Craton. The schematic geology of the area is shown in Figures 8.1 and 8.2.

The Stuart Shelf is bounded to the east and northeast by the Torrens Hinge Zone, a major northerly trending structural feature running beneath Lake Torrens and forming the boundary between the Stuart Shelf and the Adelaide Geosyncline. The northern extension of the shelf is overlain by sediments of the Jurassic/Cretaceous Eromanga Basin. A thin veneer of younger Cainozoic (Tertiary and Quaternary) sediments or in situ deposits (e.g. silcrete or calcrete) is commonly encountered at the landscape surface.

To the north of the Stuart Shelf the Eromanga Basin is the largest and most central of the three depressions that together make up the Great Artesian Basin (the other two are the Carpentaria Basin in northern Queensland and the Surat Basin in southeast Queensland and northeast New South Wales). Although the term ‘Great Artesian Basin’ has obvious hydrological connotations, it is entrenched in geological literature and has been used as a geological term even though the artesian and sedimentary limits are not the same. However, in this report the term Eromanga Basin is preferred, as there is no known or suspected hydraulic connection between the Great Artesian Basin aquifers, as important water resources, and the equivalent sediments in the study area.

The limit of Great Artesian Basin conditions and the limit of contiguous Eromanga Basin sediments in the study area are shown in Figure 8.1 (after Habermehl and Lau 1997).

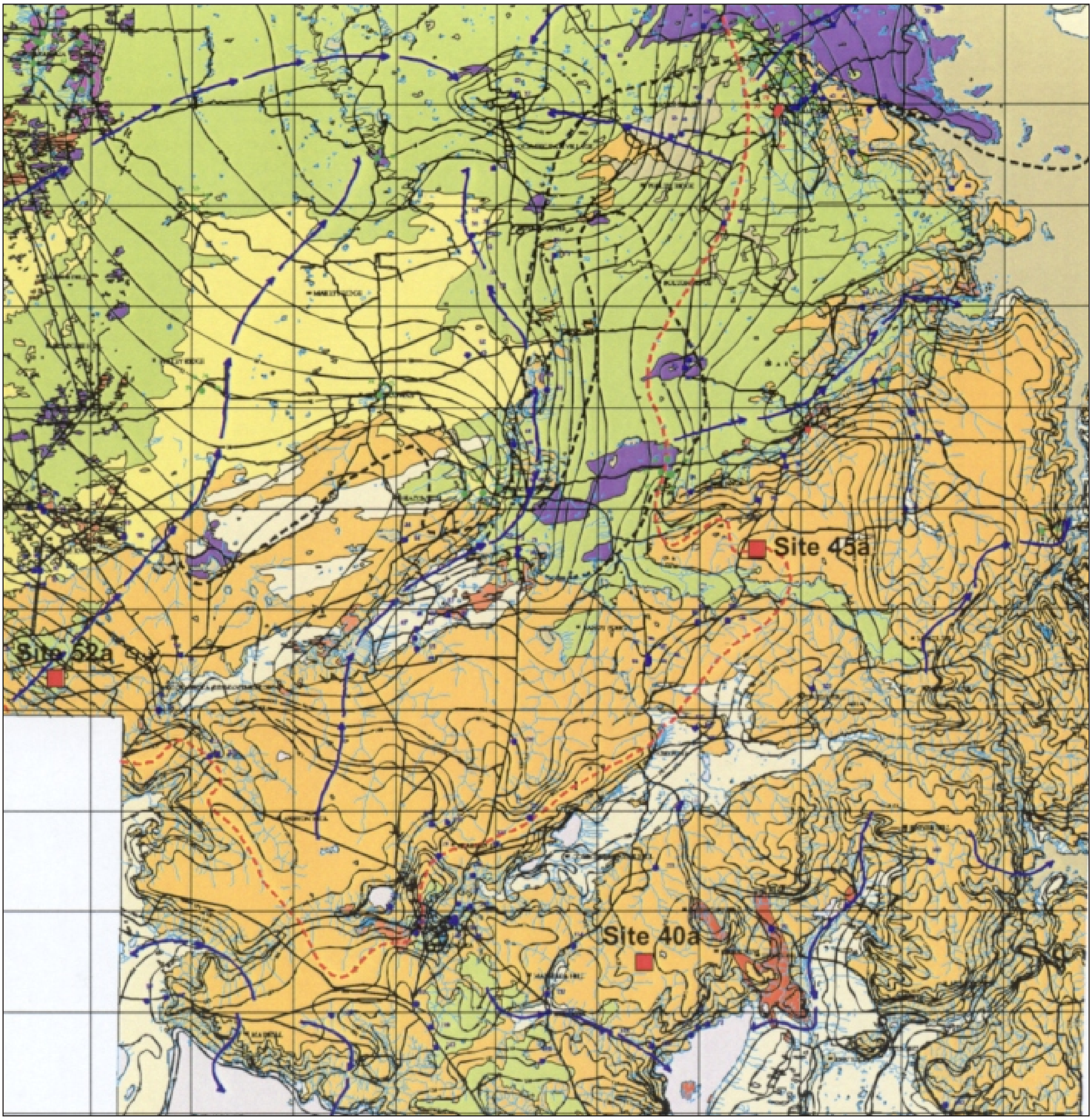
The relationship between rock units, in stratigraphic order, is shown in Table 8.1. As detailed later, not all units are present at all three locations.



Repository waste sites
Great Artesian Basin limit of artesian conditions
Occurrence of Andamooka Limestone
Salt lakes
Eromanga Basin sediments (contiguous)

FIGURE 8.1

Schematic regional geology



0 5 10 15 20
kilometres

Geology

	Qha	Alluvium, of major drainage channels
	Qhs	Sand plains
	Qhl	Lakes: salt, gypsum, gypseous clays
	Qp	Other deposits - Middle Pleistocene
	T	Tertiary
	Kmb	Bulldog Shale
	Kco	Cadna-owie Formation
	Ja	Algebuckina Sandstone
	CP	Arckaringa Basin
	€a	Andamooka Limestone
	€ac	Curdlawindney Siltstone
	€y	Yarrawurta Shale
	Ꝑw	Wilpena Group
	Ꝑb	Late Proterozoic; Umberatana & Burra Group
	Ꝑ	Early to Mid Proterozoic
	qz	Undifferentiated quartz veins/bodies
	fe	Undifferentiated ironstone: ferruginisation
		No data

Bores showing the height above sea-level to which water will rise

- 96 Bores within Kmb aquifer
- 108 Bores within Ja–Kco aquifer
- 78 Bores within €a aquifer
- 105 Bores within Ꝑ–Ꝑb–Ꝑw aquifer
- Limit of geology type
- Surface of drainage features
- Watertable contour
- Groundwater flowline
- Groundwater divide
- Lake Eyre drainage divide
- Roads
- Locality

Projection: Australian Map Grid, Zone 53

Geology derived form the Stuart Shelf Geoscientific GIS Dataset, Minerals & Energy, SA, 1998

Topographic and cultural features after the TOP02150k Dataset, AUSLIG, 1996

Produced by the Land & Water Science Division, BRS, 1999

FIGURE 8.2
Central–north South Australia
Geology and watertable contours

TABLE 8.1 Generalised stratigraphy of study area

Unit/Formation	Geological basin / group	Geological stage	Symbol	Alias: notes
Soil		Cainozoic/ Quaternary	Cz/Qc	Generally clay, often gypsiferous, some loamy soil also
Silcrete		Cainozoic/ Tertiary	Cz/Ts	Some calcrete and ferricrete also, formed in situ
Bulldog Shale	Eromanga Basin	Mesozoic (Cretaceous)	Kmb	Marine shale, upper parts may be moderately to highly weathered[1]
Cadna-owie Formation	Eromanga Basin	Mesozoic (Early Cretaceous)	Kco	Transitional non-marine to marine sediments[1]
Simmens Quartzite	Wilpena Group	Proterozoic (Marionan)	@ws	Arcoona Quartzite[2]
Corraberra Sandstone	Wilpena Group	Proterozoic (Marionan)	@wc	[2]
Woomera Shale	Wilpena Group	Proterozoic (Marionan)	@wm	Tregolana Shale[2]
Nuccaleena Formation	Wilpena Group	Proterozoic (Marionan)		Not encountered during drilling

(1) Krieg and Rogers 1995
(2) Preiss 1993

Note that at some site drillholes the two near-surface Cainozoic formations are distinct and are logged separately as Quaternary clay (Qc) and Tertiary silcrete (Ts), but if not distinct the more general Cz (Cainozoic formations) may be used.

Drilling during the Phase 3 program indicated that sediments underlying the three sites included sediments of the Wilpena Group (all sites) and the Eromanga Basin (Site 52a only).

The Wilpena Group is part of the youngest subdivision (Marinoan) of the Adelaidean succession and records two major transgressive–regressive cycles. Only the Lower Wilpena Group was encountered during the drilling program; the basal unit of the Wilpena Group, the Nuccaleena Formation, a micritic dolomite and interbedded shale unit, was not encountered. This is overlain by the 200 m thick Tent Hill Formation which comprises the Tregolana or Woomera Shale Member, which is overlain by the red beds of the Corraberra Sandstone Member (@wc) and the Simmens or Arcoona Quartzite Member (@ws).

Sediments of the Eromanga Basin extend into the study area (Figure 8.1). The southwestern third of the Eromanga Basin occurs in South Australia as a continuous blanket of sediments over the northeast of the state, where it laps onto older basement blocks and basins to the west and southwest. These sediments partly onlap and are partly in fault contact with elevated Adelaidean rocks including the Wilpena Group of the Stuart Shelf. The stratigraphy of the southwestern margin of the Eromanga Basin includes the non-marine Algebuckina Sandstone (Ja) which is overlain by the Cadna-owie Formation (Kco). Ja was not encountered in any of the investigative drilling programs.

Kco is typically 10–20 m thick around the basin margins and comprises non-marine to marine siltstones and fine-grained sandstones with some coarse-grained sandstones and carbonaceous claystone intervals. Kco is overlain by marine mudstones of Kmb, which has a maximum thickness of approximately 340 m but thins stratigraphically and by erosional stripping toward the southwest. Thicknesses of less than 200 m have been recorded in the Oodnadatta and Marree regions, with outlying remnants recorded in the Andamooka and Woomera areas (not all of which are mapped).

8.1.2 Geology of Sites 40a, 45a and 52a

Stage 3 Assessment Methodology

Following assessment of technical results of Stage 2 drilling of five investigated sites for the national repository (Bureau of Rural Sciences 2001a), and taking into consideration comments received during stakeholder consultation, three sites were selected for further investigation in Stage 3 — Sites 40a, 45a and 52a (Bureau of Rural Sciences 2001b).

In Stage 3 four holes were drilled at an in-fill 750 m spacing around the 1.5 km perimeter and a further eight holes were drilled at a 250 m spacing about an inner 500 m square (Figure 8.3). A total of sixteen holes were drilled at each of the three sites, including two diamond core holes at each site in the Stage 2 drilling, with the remainder by reverse-circulation air-hammer drilling.

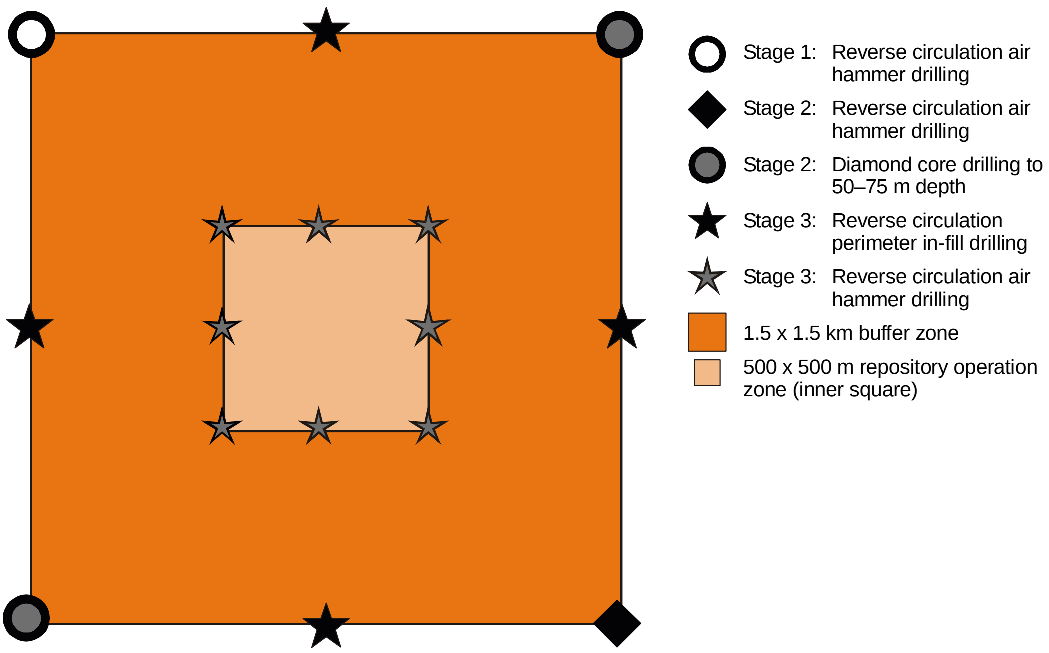


FIGURE 8.3
Drillhole locations

Sampling from the reverse-circulation drilling was done every metre from surface to target depth in the range 70–100 m. The lithology of samples obtained from all percussion holes was described (Bureau of Rural Sciences 2001a, b). Samples were split on site into two large subsamples — one for analytical purposes and the other to be stored in the Department of Defence Hangar B at Woomera. From the residue, material was wet-sieved and then placed into plastic sample trays. Both the percussion hole subsamples and diamond cores were available for inspection at the Bureau of Rural Sciences Land and Water Sciences Division laboratory, Symonston, Canberra.

In addition, the elevation of each drillhole was surveyed. Together these data were used to produce detailed (0.5 m) topographic as well as subsurface (structure) and thickness (isopach) contours of the geological formations. The contours provide an excellent basis for interpreting the three-dimensional configuration of each site. Further details are given in Bureau of Rural Sciences (2001b). Summary figures by the Bureau of Rural Sciences showing topography, watertable levels and stratigraphy are given in Appendix C1.

Site-Specific Geology

Table 8.2 summarises the geology encountered at each site, compiled from Bureau of Rural Sciences (2001b) data. Note that the silcrete layer is discontinuous and may be thinner or partial at some locations within each site.

TABLE 8.2 Summary of geology encountered during Phase 3 assessment

Site 40a		Site 45a		Site 52a	
Max. depth of formation (range)	**Lithology**	**Max. depth of formation (range)**	**Lithology**	**Max. depth of formation (range)**	**Lithology**
2–3.5 m	Clay	2–3 m	Clay	1–3 m	Clay
4–8 m (where present)	Silcrete	4–7 m	Silcrete	2–8 m (where present)	Silcrete
24–44 m	Simmens Quartzite	18–36 m	Simmens Quartzite	13–27 m	Bulldog Shale
69–79 m	Corraberra Sandstone	70+–100+ m	Corraberra Sandstone	38–45 m	Cadna-owie Formation
75+–90+ m	Woomera Shale			65–82 m	Corraberra Sandstone
				70+–100+ m	Woomera Shale

Source: Bureau of Rural Sciences 2001b

The surface clays at each site are generally reddish brown, of medium plasticity, sometimes gypsiferous, becoming more plastic with depth, and with minor calcrete nodules at the base. Tertiary silcrete is also common across the three sites — silcrete at Site 45a occurs as hard bands, whereas massive hard to very hard silcrete is present at Site 40a. The silcrete is generally ferruginised at the top and contains quartzite cobbles in many places. Softer, fractured silcrete and calcrete were observed at Site 52a.

Weathering in @ws is highly variable and the degree of weathering changes across Sites 40a and 45a. Where deeply weathered, it has changed (in bands) to white kaolinitic clay and pale greenish grey clays of low to medium plasticity. Generally, the top half to two-thirds of the clay bands in @ws are gypsiferous.

@ws has been interpreted by the Bureau of Rural Sciences to be a diagenetic weathering surface of @wc, and is not present at Site 52a. The boundary between @ws and @wc is designated primarily on hardness and on lithology (a change to maroon, generally fissile, silicified sandstone with siltstone interbeds typical of the @wc red beds).

Bulldog Shale (Kmb) intersected at Site 52a is a sequence of white massive mudstone and siltstone, grading to pale yellowish brown or grey mudstone at depth. The top is salinised and kaolinised by prolonged and intense weathering (bleaching), and is also highly gypsiferous and ferruginised in the upper part of the section. X-ray diffraction identified amorphous, opaline silica, but there has been no trace of macroscopic opaline material to suggest gem quality or economic worth in material from the diamond cores and percussion chips.

The lower part of Kmb contains well-rounded cobbles and boulders of quartzite. It conformably overlies weakly indurated lithic and quartzose sandstones of Kco, a coarsening-upward sequence from clayey fine sands at the base to fine to medium sands at the top. Bands containing loose sand were encountered at the top of Kco in about half of the holes drilled at Site 52a.

The total thickness of the Mesozoic sequence (Kmb and Kco combined) varies between 35 and 45 m. The Mesozoic sediments at Site 52a are interpreted to represent an isolated outlier of the western Eromanga Basin, based on the presence of outcropping and subcropping Proterozoic rocks within a few kilometres of the buffer zone. Bands of dry, weakly indurated to unconsolidated fine sands occur at the top of Kco and, to a lesser extent, near the base of Kmb. Typically, the bands are a few centimetres thick but individual beds range up to 30 cm in the southwest part of Site 52a.

Geological Host Rock

Table 8.3 summarises the geological host rock at each site, based on the results of the Phase 3 assessment and the proposed repository design, which indicates a trench depth of 15 m (Section 6.2.3).

TABLE 8.3 Geological host rock at each site

Site	Geology encountered by 15 m deep trench
Site 40a	Tertiary clays and silcrete with @ws at base
Site 45a	Tertiary clays and silcrete with @ws at base
Site 52a	Tertiary clays and silcrete with Kmb at base (and Kco at base in northeastern corner of operation zone, if that area is trenched).

Based on Bureau of Rural Sciences (2001b)

8.1.3 Seismicity

The level of seismic activity in Australia is generally considered to be low when compared to the seismically active areas of the world.

The most seismically active areas of South Australia are associated with the Adelaide Geosyncline in an area extending from the Flinders Ranges in the north to Kangaroo Island in the south; the eastern portion of Eyre Peninsula; and the southeastern region of the state around Mt Gambier.

The area between Quorn and Leigh Creek has the highest number of seismic events (considered to be related to zones of crustal weakness), with several earthquakes ranging in magnitude from Richter Local Magnitude (M_L) 4.5 to 5.7 between 1939 and 1983. Activity west of the Torrens Hinge Zone, in the areas of the proposed repository, range from M_L 1 to 2 (with M_L 2 being the lowest magnitude able to be felt). Discussion with the South Australian Office of Minerals and Energy Resources has indicated that the cluster of predominantly M_L 1 recordings are likely to be related to blasting activities associated with mining at Olympic Dam and Mt Gunson.

In Eyre Peninsula the earthquakes appear to be associated with the Lincoln Fault Zone, the highest recording being the 1959 Mambin earthquake of magnitude M_L 4.9. In the South East, seismicity is related to the western margin of the Otway Basin and an onshore volcanic belt. The highest recorded earthquakes are the 1897 Beachport–Kingston earthquake of magnitude M_L 6.5 and the 1948 Robe earthquake of magnitude M_L 5.6.

The Standards Association of Australia AS 1170.4-1993, Minimum Design Loads on Structures, Part 4 Earthquake Loads indicates that a ground acceleration coefficient of 0.08 would be appropriate for Site 52a, and between 0.085 and 0.09 for the eastern sites. There is a 10% probability that the aboveground acceleration levels would be exceeded in a 50-year period.

The repository and buildings would be designed in accordance with AS 1170.4-1993.

8.2 Geomorphology

All three sites are located within the central clay pan and plateau landform and soil region as defined by Laut et al. (1977). This region includes a variety of landforms between Lake Torrens and the Great Victoria Desert. Sites 52a and 40a are located within the Woomera environmental association and are characterised by moderately deep, well-drained red duplex soils. Site 45a is located within the Andamooka environmental association (a gibber covered plateau with shallow well-drained loams).

All three sites lie at elevations of 120–200 m above sea level on broad, elevated gibber plains with clearly defined water drainage courses which eventually fall 60–100 m in height to larger regional drainage systems. Gibber stones vary in composition, size and angularity across and between sites. Gibber at Site 40a is mainly resilicified sandstone, ranging from small cobble to boulder size, with most having a slabby form. At Site 45a the gibber has a similar composition but is typically smaller, with most being large gravel to large cobble size and having a mainly flaggy form. Site 52a is distinctly different, having nodular silcrete and shale flakes smaller than cobble size.

Site 40a is approximately 189 m above sea level at its centre, with a maximum relief of 4 m over the 0.5 km inner square. The surface and drainage features at Site 40a show the greatest variety of the three sites, with a slightly elevated ridge trending approximately north–south, a canegrass swamp on the northeastern boundary, and a subtle drainage depression which drains away from the western margin. There is a small area of water catchment upslope from the site, from which sustained, heavy rainfall could produce run-on to the site.

Site 45a is approximately 131 m above sea level at its centre and has a maximum relief of 8 m over 1.5 km. The surface features define a clear, broad drainage path running from the southeast to the northwest. Of the three sites, Site 45a has the largest upslope catchment area for rainwater run-on, and there is a clear drainage path which conducts runoff from the site. The old Arcoona to Andamooka road crosses the outer northwestern corner, and this concentrates localised rainfall before it joins the larger drainage path.

Site 52a is approximately 158 m above sea level at its centre and has surface features which are the least distinct regarding a surface drainage path. The site has a gentle slope to the east (12 m over 1.5 km) and the smallest catchment area for rainwater run-on. A gravel road lies along the northern edge of the site.

8.3 Soils

Harries et al. (1998) were commissioned to conduct a desk study on vadose zone hydrology and radionuclide retardation in the central–north region of South Australia, which had been proposed as a potential site for the national low-level radioactive waste repository. This report found that the soils and landscapes of the region are well described in the literature; however, the hydraulic and other physical characteristics of the soils are poorly known. In general, the soil hydraulic behaviour was inferred from experience elsewhere.

Three major soil groups were identified within the region. Following the nomenclature in *Handbook of Australian Soils* (Stace et al. 1968), the following soil groups were identified:

- grey brown and red calcareous soils [Map Code 7]
- desert loams [Map Code 8]
- solonised brown soils [Map Code 19].

The soils are old and deeply weathered, and tend to be sodic at the surface with accumulations of calcrete at depth. The surface sodicity results in structural instability during rainfall, which substantially restricts infiltration. The soils range from uniform profiles to gradational ones of medium texture. The desert loams tend to have texture contrast features with sandy loam overlying medium clay. There are significant areas of soil with relatively high amounts of smectite relative to kaolinite. This results, even in this environment, in shrink/swell behaviour and areas of gilgai (the microrelief of the soils, showing localised small depressions). It is not possible to avoid such areas in site selection as the gilgai feature is ubiquitous in this landscape.

In 1998 the Australian Nuclear Science and Technology Organisation (ANSTO) and CSIRO used remote sensing data (enhanced Landsat TM images) to determine the distribution of these soils based on soil surface texture image information. The images suggest that the Woomera–Koolymilka region has quite extensive and relatively uniform areas of similar soils; however, they possibly do not differentiate between soil types. The Woomera–Koolymilka sheet area stretches north and west of Woomera and Pimba, and is bounded in the south by a scarp which borders the large salt Lakes Gairdner, Hart and Island Lagoon. The landscapes north of this scarp are characterised by soils with clay and oxides of iron in the surface. The 'plateau' surface drains sharply to the south and more gently to the north.

Approximately 50 km north of Woomera this surface gives way to soils characterised by broadly spaced, linear, wind deposited sand dunes; low, broadly spaced rolling stony rises; and some small salinas. Soils here are characterised by hardpans, silcrete and calcrete in swales. Some detail on these landscapes is provided by Graetz and Tongway (1980). None of the three candidate sites are located in sand dunes.

Soil surfaces throughout tend to be sodic and structurally unstable. In the south, surfaces are protected by stones (gibbers). The 'dune country' is subject to significant sheet erosion by both water and wind. Milnes and Wright (1993) describe features of the landscape. Thickness of the soils and subsoils is around 2 m on the plateau west and northwest of Woomera, gradually increasing to about 5 m toward the 'dune country'. Preliminary landform data from remotely sensed information suggest that these soils overlie saprolite of unknown thickness which grades into the Arcoona Quartzite. The 'saprolite' overlying the quartzite may consist of several metres of silcrete or calcrete immediately beneath the surface soil profile.

Australian Nuclear Science and Technology Organisation and CSIRO (1999) collected soil samples from two sites near Pimba (not from the study areas) inferred to be 'characteristic' of the site areas. The samples were collected from a range of depths, some from 1.3–1.5 m, some from auger samples of disturbed soil, and some from small undisturbed cores and large cores. They were packed in polythene bags to prevent water loss in transit to the laboratory. Testing of these samples was conducted to confirm the general intuitions about soils of the area as well as to provide a preliminary 'order of magnitude' check on the calculations made by Australian Nuclear Science and Technology Organisation and CSIRO (1998). The samples collected were tested for:

- water content
- bulk density
- hydraulic conductivity
- soil moisture characteristics
- particle size
- coefficient of linear shrinkage
- structural stability
- soil water chemistry
- radionuclide absorption.

The results of the above soil tests indicated the following:

- The pH is consistent with mild sodicity.
- The specific conductivity of the soils indicate saline conditions.
- The soils are 'whole coloured' red (desert loams).
- The field texture is consistent with desert loams.
- Emerson dispersion tests showed that all remoulded samples were stable although some near-surface natural samples showed some dispersion. This was attributed to the presence of gypsum nodules, which do not affect the natural aggregate test because of

their low solubility, but which are distributed through the soil during remoulding and confer stability on the remoulded samples.

- Throughout each profile, soil water contents at the time of sampling were somewhat drier than the wilting point water content.
- The soils contain a high fraction of material in the silt to very fine sand range. Particle size analysis indicated that clay content is low; however, this may be due to inadequate dispersion because of the presence of significant amounts of gypsum and calcium carbonate ($CaCO_3$).
- The soils swell with increasing water content but the cation exchange capacity is low due to the relatively modest clay content.
- Saturated hydraulic conductivity for the soils was measured as 0.06–0.20 cm/h, with the subsoil conductivity slightly less than at the surface.
- The surface soil structure and subsoil structure appear to be stable.
- Shrinkage tests indicated that the soils are quite reactive. Profiles are strongly pedal but do not show strong shear surfaces characteristic of shrink/swell soils.

8.4 Surface Hydrology

There is no permanent surface water in the study area. Ephemeral streams are common, but contain water on an infrequent basis. The description given by Kotwicki (1986) for the nearby Eyre Basin may be applied to the study area also. All streams are characterised by extreme variation in discharge and flow. Very variable seasonal and annual runoff are caused by occasional heavy rainfall (often caused by summer incursions of tropical low-pressure systems) and extended periods of drought.

Surface water drainage, when it occurs, is internal to salt lakes. Named salt lakes in the study area include Lake Torrens in the east, which is over 150 km long, Island Lagoon south of Pimba, and Lakes Windabout and Hart south of Sites 40a and 52a, respectively. However, Sites 40a and 52a fall outside the immediate surface water catchments of these major lakes. Site 40a drains east or north towards an indefinite terminus, while Site 52a drains towards a minor salt lake, Koolymilka Lake. Site 45a appears to drain towards Lake Torrens.

The surface landforms at the three sites indicate that each would shed heavy and sustained rainfall rather than holding water to cause surface flooding. In an extremely heavy and/or sustained rainfall scenario, run-on and runoff would be shed to adjacent drainage lines and very much lower lying areas faster than water can accumulate at any of the sites. The topography of the sites is shown in Appendix C1.

8.4.1 Site 52a

Although close to Lakes Hanson and Hart to the south, Site 52a is north of the surface water divide and drains eventually to the north into Koolymilka Lake near the former township of Koolymilka.

Site 52a has little headward catchment for rainfall to run-on to the site. Gilgai depressions and ‘crabholes’ in calcretes tend to cause minor short-term puddling on-site following rain. The site slopes from the west to the east with a total relief of 12 m over 1.5 km. A small ephemeral stream ‘Wild Dog Creek’ occurs approximately 800 m southeast of the outer square of investigation bores at this site (approximately 1250 m from the inner square).

8.4.2 Site 40a

Although close to Windabout Lake to the southeast, surface drainage at Site 40a is to the northeast towards an area of ill-defined drainage without major salt lakes.

Site 40a contains the greatest surface form diversity. There is a large canegrass swamp on its eastern edge and a subtle surface depression which leads west to the head of Rocky Creek. Overall, the site slopes to the west by 3 m over 1 km although the inner square slopes by 4 m over 0.5 km. A small ephemeral stream 'Bluff Watercourse' occurs approximately 1100 m northeast of the outer square of investigation bores at this site (approximately 1300 m from the inner square).

8.4.3 Site 45a

Site 45a is located close to but apparently immediately east of the surface water divide between the catchment of Lake Torrens to the east and an area of ill-defined drainage without major salt lakes to the southwest.

Site 45a slopes from the south to the northwest with a total relief of 8 m over 1.5 km. There is a small run-on catchment area to the east but there is a clear movement path across the site to shed water. Surface water eventually drains to Lake Torrens.

8.5 Hydrogeology

8.5.1 Broad Regional Hydrogeology

Habermehl and Lau (1997) show the hydraulic extent of the Great Artesian Basin finishing immediately south of Lake Eyre, some 100 km north of the study area. Eromanga Basin sediments are absent from two of the three sites examined here and, where present at Site 52a, are interpreted to be near the southwestern extreme of the Eromanga Basin. These features, as they occur in the study area, are shown in Figure 8.1. Hydrogeologically, the Eromanga Basin sediments, where present in the study area, are part of the Stuart Shelf aquifer system.

A comprehensive regional hydrogeological assessment of the project area and surrounds is provided by Kellett et al. (1999). The report documents a reconnaissance survey of the hydrogeology of an area covering 38,000 km^2 in central–north South Australia. The region has been identified as the preferred site for the national repository, and includes the three sites covered by this draft environmental impact statement (Draft EIS). The specific aims of the study were to:

- determine the location, extent and interrelationship of the significant hydrogeological units in the region
- assess the hydraulic properties of the different units contributing to flow
- estimate average groundwater flow rates, residence times and prevailing directions of groundwater flow
- identify recharge and discharge zones
- determine depths of watertables and estimate their seasonal fluctuations.

Figure 8.4 shows the general hydrogeological relationships in the region in cross-section (but not the Kco–Ja aquifer as it is off-section).

The dominant aquifers in the central part of the study area are sandstones of the Permo-Carboniferous Boorthanna Formation (CPb) and the Cambrian Andamooka Limestone (#a). These two aquifers receive discharge from Kco–Ja and transmit groundwaters to the two major regional sinks — Lake Torrens and the Olympic Dam mine (dewatering of the mine has created a regional groundwater sink — see watertable contours in Figure 8.2). Travel times through Ca may exceed 100,000 years. Total residence times between infiltration at ground surface and ultimate discharge reach up to 200,000 years for the northwest–southeast flowlines. The Ca is not present at Sites 52a, 40a and 45a but occurs further to the north, northeast and northwest. Areas underlain by #a were specifically excluded during the site selection process because of the karstic nature of the limestone.

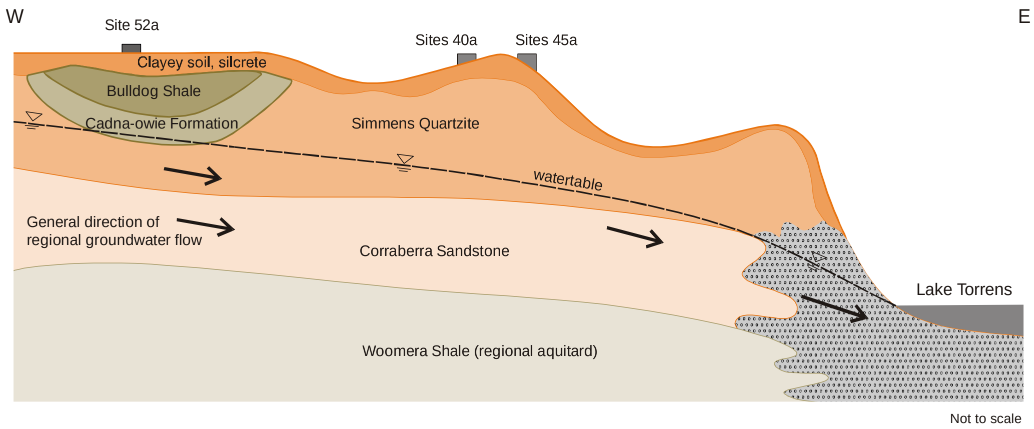


FIGURE 8.4
Generalised schematic hydrogeological section

The Late Proterozoic Simmens (Arcoona) Quartzite–Corraberra Sandstone (@ws–@wc) comprise the fractured rock aquifer of the Andamooka Ranges and Arcoona Plateau of the eastern part of the study area (which incorporates Sites 52a, 40a and 45a). Flow systems in @ws–@wc are localised with flowlines generally shorter than 20 km. Discharge is to the abundant salt lakes of the region and lateral flow velocities vary between 2 and 4 m/yr. Typical residence times between infiltration and discharge in the Proterozoic fractured rocks are from 10,000 to 20,000 years. Groundwater flow directions are shown in Figure 8.4. Note that the regional flowlines on the figure are illustrative and do not represent individual underground ‘streams’.

Depth to watertable exceeds 100 m in some parts of the northwest, and 50 m in most of the northern half of the study area and over much of the Andamooka Ranges and Arcoona Plateau (Figure 8.5). The shallowest watertables occur in the southwest, south and east, where they generally lie within 30 m of ground surface. Watertables lie within 5 m of ground surface in the vicinity of the salt lakes.

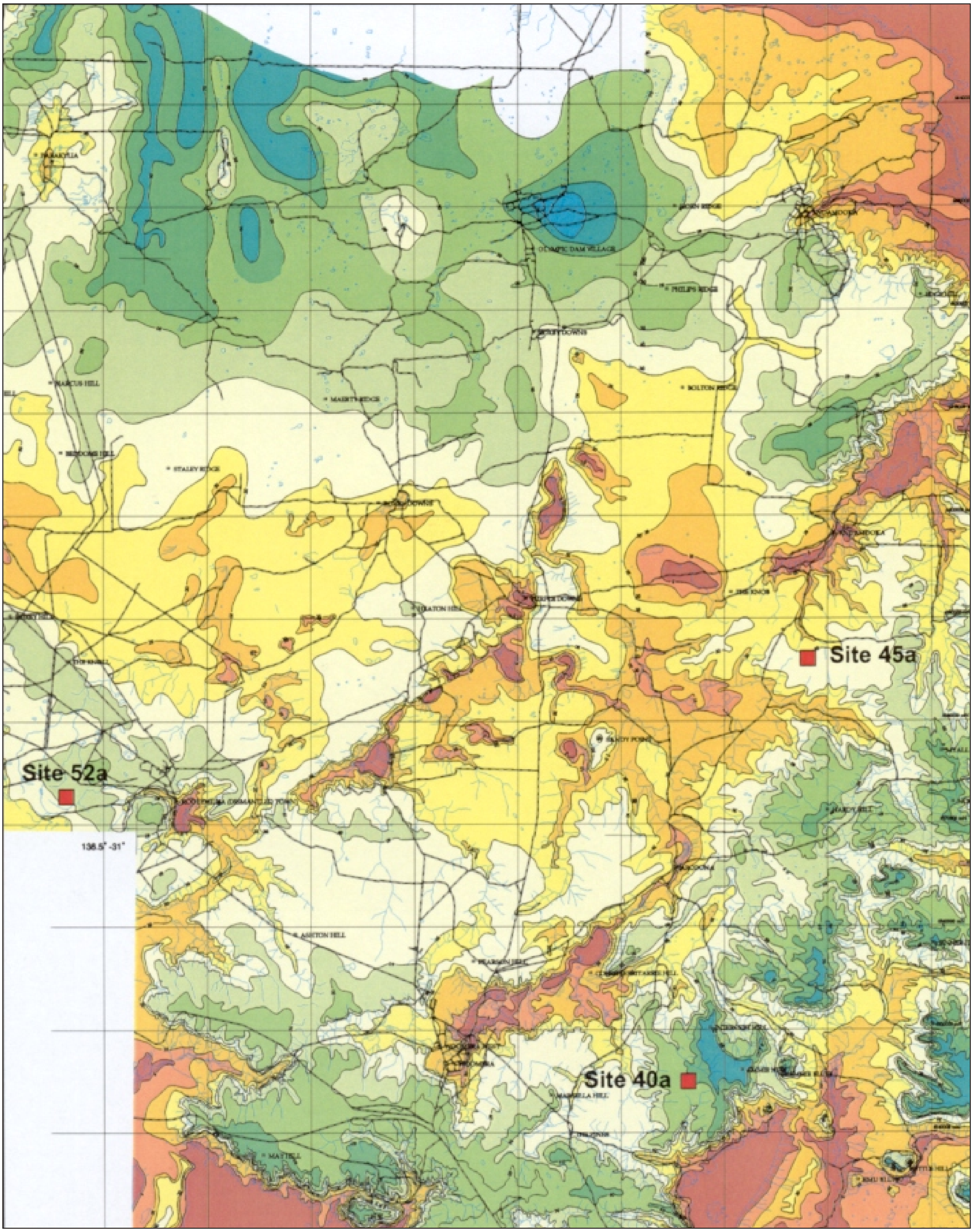
Fresh to brackish stock waters are obtained from the Kco–Ja and CPb aquifers in the west and southwest, but water quality in Kco deteriorates northward toward the Lake Eyre drainage divide, and eastward along regional flowlines in the Permian sediments. The majority of the #a and @ws–@wc aquifers yield waters which are too saline for stock. Distribution of salinity is shown in Figure 8.6 (Kellett et al. 1999).

There are substantial areas in the northwest, central and eastern parts of the study area which satisfy suitability criteria for a repository related to depth of watertable, groundwater salinity and residence times. The area containing Sites 52a, 40a and 45a is in the eastern part of the area studied by Kellett et al. (1999), and is considered in more detail below.

8.5.2 Subregional Hydrogeology

Sites 52a, 40a and 45a are within the geological Stuart Shelf area. The regional brackish to saline aquifer is developed in sedimentary rock of the Stuart Shelf, particularly @ws–@wc. The regional aquifer ultimately discharges into Lake Torrens or smaller salt lakes, or to the Olympic Dam mine. It can reasonably be assumed that the active groundwater flow system does not extend deeper than the top of the Woomera (or Tregona) Shale, the hydraulic conductivity of which appears to be extremely low (Kinhill Engineers 1997).

Although this regional aquifer conducts water mainly though fractures and other preferred pathways, on the scale of the Stuart Shelf it may reasonably be expected to behave as a single, continuous regional flow system rather than a compartmentalised system. Note, however, that on the scale of individual sites the primarily fractured rock aquifer characteristics of these formations may provide a better conceptual guide to local aquifer behaviour.



Depth to watertable

- Less than 5 metres
- 5 to 10 metres
- 10 to 20 metres
- 20 to 30 metres
- 30 to 40 metres
- 40 to 50 metres
- 50 to 60 metres
- 60 to 70 metres
- 70 to 80 metres
- 80 to 90 metres
- 90 to 100 metres
- More than 100 metres
- No more data
- Surface drainage features
- Roads
- Locality

0 5 10 15 20
kilometres

Projection: Australian Map Grid, Zone 53

Geology derived form the Stuart Shelf Geoscientific GIS Dataset, Minerals & Energy, SA, 1998

Topographic and cultural features after the TOP02150k Dataset, AUSLIG 1996

Produced by the Land & Water Science Division, BRS, 1999

FIGURE 8.5
Central–north South Australia
Depth of watertable contours

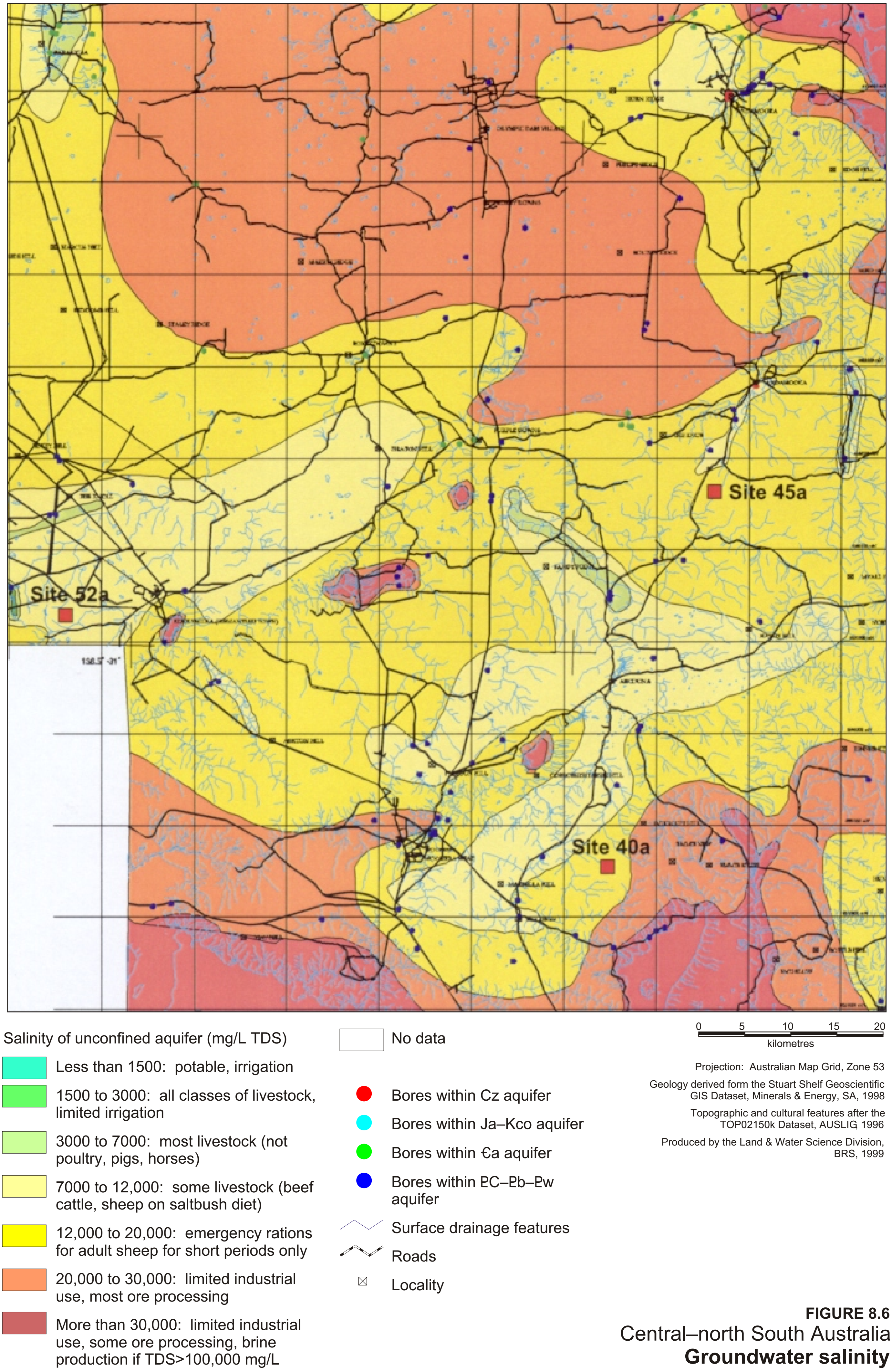


FIGURE 8.6
Central–north South Australia
Groundwater salinity

The regional watertable at all three sites and their surrounds lies generally within the Proterozoic @wc. At Site 52a only, the lower few metres of the overlying Cretaceous Kco is also saturated. This is a local phenomenon and not hydraulically connected to the extensive aquifers of which this formation is part in the Great Artesian Basin to the north.

@wc is underlain by the Woomera (or Tregona) Shale at all sites, although the base of the @wc was not encountered during drilling at Site 45a. The depth to watertable measured in 2000 and 2001 at the three sites is shown in Table 8.4. Note that a smaller number of wells were measured in August 2001 compared to September 2000. At all three sites the watertable was encountered deeper than the 25 m below ground level (bgl) for a 20 m deep disposal trench as required by site criterion b (see Section 5.1.1 and Table 5.2).

TABLE 8.4 Depth to watertable, Sites 52a, 40a and 45a

	Site 52a	Site 40a	Site 45a
September 2000 (inner square)	40.0–44.6 m bgl	63.6–68.7 m bgl	41.8–55.5 m bgl
August 2001	38.8–42.6 m bgl	65.3–68.0 m bgl	51.2–54.2 m bgl

Source: 2000 data courtesy Bureau of Rural Sciences (2001b), 2001 data collected by PPK

Regional groundwater flows preferably through distinct facture zones, and rises in an observation well to equilibrate with the regional watertable. The @wc aquifer is unconfined at Sites 45a and 52a and appears to be partially confined at Site 40a (by lower-permeability zones of the same formation).

Yields from all bores drilled during Stage 3 investigations (Bureau of Rural Sciences 2001b) were low (<1 L/s) and salinities were high, ranging from approximately 8000 to 26,000 mg/L total dissolved solids (TDS), with the majority greater than 20,000 mg/L.

All Sites

As part of Stage 3 Assessment drilling (Bureau of Rural Sciences 2001b) at each of Sites 52a, 40a and 45a, eight geological investigation bores in the inner square were converted to piezometers. Hydraulic tests using the ‘slug test’ method were undertaken at four wells at each site, and interpreted by the Hvorslev (1951) method using Waterloo Hydrogeologic Inc’s AquiferTest software (version 2.01). Full details are given in Appendix C3. The results are summarised below. Where a distinct change in behaviour was apparent, the calculated hydraulic conductivity for both early and late data is provided. Note that slug tests typically underestimate hydraulic conductivity, and results should be considered indicative only.

8.5.3 Site 52a

The groundwater flow direction at Site 52a is southwest to northeast (Appendix C1), sympathetic with the topographic gradient. The head drop is 10 m over 1.5 km with a fairly uniform hydraulic gradient of 1:150 (0.7%), apart from a southwest–northeast groundwater ‘mound’ in the inner square. The mounding develops where the watertable switches from @wc to Kco, and indicates that the fractured @wc is probably more permeable than the basal section of Kco.

Site 52a lies a few kilometres north of a major groundwater divide — the regional flow line through the site is about 100 km long, heading northeast toward Olympic Dam and beyond that to its discharge zone in Lake Torrens. The lateral groundwater velocity beneath Site 52a is estimated to be around 20 m/yr. Airlift yields are reasonably consistent at around 0.4 L/s and the groundwater salinity is uniform over the study area, averaging 16,000 mg/L total dissolved solids. The results of hydraulic tests are summarised in Table 8.5.

TABLE 8.5 Hydraulic test results, Site 52a

Drillhole	Hydraulic conductivity (m/s)	Notes
52a15NW	2.0×10^{-7}	Early data
	1.4×10^{-8}	Late data
52a50E	3.5×10^{-7}	Early data
	2.4×10^{-8}	Late data
52a50W	9.9×10^{-7}	One interpretation only
52a50S	9.4×10^{-8}	Early data
	2.7×10^{-8}	Late data

See Appendix C3 for details

8.5.4 Site 40a

The groundwater potentiometry at Site 40a (Appendix C1) indicates a dominantly southwest groundwater flow. The groundwater level drops by about 5 m over 1500 m, that is an average gradient of approximately 1:300 (0.3%). The gradient appears to be steeper in the southwest compared to the northeast. The salinity across the outer square ranges from about 25,000 mg/L in the north to 15,000 in the southwest. The results of hydraulic tests are summarised in Table 8.6.

TABLE 8.6 Hydraulic test results, Site 40a

Drillhole	Hydraulic conductivity (m/s)	Notes
40a15N	1.6×10^{-7}	One interpretation only
40a50SE	4.9×10^{-7}	Early data
	1.9×10^{-7}	Late data
40a50NE	5.7×10^{-6}	Early data
	3.2×10^{-6}	Late data
40a15NW	8.2×10^{-7}	Early data
	3.2×10^{-7}	Late data

See Appendix C3 for details

8.5.5 Site 45a

The groundwater potentiometry at Site 45a (Appendix C1) indicates a dominantly southwest to northeast and east groundwater flow direction. The flow lines switch from northwest to east along the northern edge of the outer square. Site 45a lies very close to a major groundwater divide in a flow field, with the regional flow direction to the north then northeast and discharge ultimately into Lake Torrens, 25 km to the northeast. There is a head drop of 3 m across the outer square and the hydraulic gradient ranges from 1:170 in the southeast quadrant to 1:400 along the southwest–northeast diagonal.

The change in hydraulic gradient probably reflects a permeability contrast in @wc. The groundwater ‘drain’ running in an arc from drillhole 45a15SW through 45a50NW to 45a15NE (Appendix C1) suggests this is a zone of higher permeability (increased fracturing) because of the low gradient and the comparatively higher airlift yields obtained from these piezometers. Assuming a ‘background’ hydraulic conductivity of 0.05 m/d and 0.1 m/d for the more permeable section, and an effective porosity of 0.01 m^3/m^3, a lateral groundwater velocity of around 10 m/yr is indicated for Site 45a.

The groundwater salinity at Site 45a shows the greatest variation of the three sites investigated. Total dissolved salts range from 23,000 mg/L in the west of the outer square to between 8000 and 9000 mg/L on the eastern side (Appendix C1). The potentiometry indicates that the pod of 'fresher' water in the east cannot represent local recharge — it may be a pulse from an abnormally large rainfall event which occurred over a century ago and has travelled as an unmixed package down gradient, or it may simply be an artefact of less salts available for dissolution in the aquifer in the eastern part of the study area. The results of hydraulic tests are summarised in Table 8.7.

TABLE 8.7 Hydraulic test results, Site 45a

Drillhole	Hydraulic conductivity (m/s)	Notes
45a15SW	2.0×10^{-6}	One interpretation only
45a50E	2.8×10^{-8}	Early data
	1.2×10^{-8}	Late data
45a50NW	3.1×10^{-7}	Early data
	4.2×10^{-8}	Late data
45a15NE	3.8×10^{-7}	One interpretation only

See Appendix C3 for details

8.5.6 Groundwater Recharge

Water Balance Method

Australian Nuclear Science and Technology Organisaiton and CSIRO (1998) undertook water balance calculations for conditions expected in the project area. Three sets of calculations were undertaken using data and properties inferred from two typical soil profiles, and 27 years (1969–96) of daily meteorological data from Woomera. One profile is applicable to a sand-dune system and the other to soils more typical of the three sites of the current project area.

The extensively tested Soil Water Infiltration and Movement (SWIM) model (Verburg et al. 1996) was used to simulate the infiltration of rainfall and its subsequent fate in the root zone of a soil. For each type of climatic data, infiltration was measured in the presence or absence of vegetation and the presence or absence of a cryptogram crust, and in a soil without vegetation. The calculations were restricted to a maximum depth of 1.0 m on the grounds that existing vegetation cannot extract water from below this depth. Movement of water below 1.0 m is assumed to continue, eventually, to the permanent watertable some tens of metres below.

Full results are given in the report by Australian Nuclear Science and Technology Organisaiton and CSIRO (1998). Calculated water balances for the two soils present in the project area, based on the SWIM calculations for the period 1969–96, are given in Table 8.8 below.

The SWIM calculations show low deep infiltration (groundwater recharge) for the two soils under the natural, vegetated state. In the case of no vegetation, a large increase in deep infiltration is predicted for the Solonetz soil (4 orders of magnitude) whilst the increase for the medium clay soil is negligible.

It should be noted that individual wet years account for the majority of runoff calculated for the site over the years examined. For example, during the wettest year in the sequence, 1974, more than 50% of the deep infiltration and 30% of the surface runoff for the entire 27-year period was simulated.

TABLE 8.8 Calculated water balances based on the SWIM calculations for the period 1969–1996, typical soils of the project area

Case	Soil	Deep drainage	Surface runoff
Vegetated	Solonetz soil	0.0016 mm/yr	3.2 mm/yr
	Medium clay soil	0.0015 mm/yr(1)	4.4 mm/yr
No vegetation	Solonetz soil	1.08 mm/yr	3.7 mm/yr
	Medium clay soil	0.0015 mm/yr	16.4 mm/yr

(1) Typographical error in original table by Harries et al. 1998 showed 0.0005 mm/yr.
Source: Australian Nuclear Science and Technology Organisaiton and CSIRO (1998)

The data offer an estimate of the transit time of water moving from the repository if the capped repository acted in a similar manner. Assuming a water content in the unsaturated zone of 0.1 m^3/m^3 and a recharge rate of 0.0015 mm/yr, the transit time for passage of water though 50 m is in the order of 10^6 years. Alternative approaches have confirmed the order of soil water movement and groundwater recharge expected at the sites. The engineered cap of the repository as it would be built is expected to be lower again, with an increased passage time.

Chloride Mass Balance — Saturated Zone

Chloride mass balance in the saturated zone (groundwater) is the simplest technique for recharge estimation. The method assumes one-dimensional piston flow and produces a long-term average. Details are given in Appendix C2, which is an excerpt of Bureau of Rural Sciences 2001b.

The chloride mass balance method gives a recharge rate of 0.06 mm/yr at Sites 40a and 45a, and 0.09 mm/yr at Site 52a. The wetting front velocity is about 6 mm/yr at Sites 40a and 45a, and 3 mm/yr at Site 52a. Hence, it would take 11,000 years for infiltration through the 67 m-thick unsaturated zone at Site 40a, 9000 years to infiltrate the 55 m-thick unsaturated zone at Site 45a and 14,000 years through 41 m of unsaturated zone at Site 52a, based on this estimation method.

Chloride Mass Balance — Unsaturated Zone

Full details of these calculations are given in Appendix C2.

Using the measured chloride and moisture characteristics flow recharge and assuming a constant chloride flux rate through time, a reasonably uniform recharge of 0.02 mm/yr for Site 40a was estimated.

Using the same assumptions, recharge rates of 0.02 mm/yr for drillhole 45a15SE were indicated, whereas 45a15NW gave a recharge rate of 0.02 mm/yr through the surface clay, but an apparent rate of 0.17 mm/yr through @ws. This seems to indicate preferential flow or possibly a different palaeo-recharge regime, a reflection of the marked salinity variations in the unsaturated zone across the site.

At Site 52a, mass balance calculations give a recharge rate of 0.03 mm/yr for drillhole 52a15NE and 0.05 mm/yr for 52a15SW (Kmb and upper Kco).

Groundwater Age Estimation using Isotopes

The radioisotopes chlorine-36 (^{36}Cl) and carbon-14 (^{14}C) have half-lives of 300,000 and 5730 years, respectively. Nine regional groundwaters were analysed for ^{36}Cl by accelerator mass spectrometry at the Australian National University; 10 samples were analysed for ^{14}C by counting at CSIRO (Appendix C2).

In summary, the radioisotopes ^{14}C and ^{36}Cl indicate that groundwater in the region is at least 20,000 years old, with much of it being much older, particularly to the south and east where waters appear to be in excess of 100,000 years old. Within the analytical limits of the measurement techniques, and the inherent variability of radioisotope concentrations in nature, more precise numbers than this cannot be interpreted.

Recharge Processes Indicated by Deviation of the Stable Isotopes δ^{18}O and δD from the Meteoric Water Line

Oxygen-18 (^{18}O) and deuterium (D) are isotopes that occur naturally in all waters and are useful tracers of water movement and history (from Bureau of Rural Sciences 2001b). Results indicate evapotranspiration of infiltrating rainwater prior to recharge of the aquifers. The samples from Site 52a are heavier (i.e. more evaporated) than those from Sites 45a and 40a (there was only one sample collected from Site 40a). This implies lower recharge rates at Site 52a although this cannot be quantified.

Summary of Recharge Rates and Groundwater Residence Times

Comparisons of recharge rates estimated by chloride mass balance in the saturated and unsaturated zones are shown in Table 8.9. Also shown are estimated and observed groundwater ages based on residence times in the unsaturated zone under conditions of one-dimensional vertical piston flow-type recharge.

TABLE 8.9 Recharge rates and groundwater ages / residence times

	Recharge rates (mm/yr)		
Method	**Site 40a**	**Site 45a**	**Site 52a**
Cl mass balance (sat. zone)	0.06	0.06	0.09
Cl mass balance (unsat. zone)	0.02	0.02–0.17(1)	0.03–0.05
	Residence times in unsaturated zone (years)		
Method	**Site 40a**	**Site 45a**	**Site 52a**
Cl mass balance (sat. zone)	11,000	9000	14,000
Cl mass balance (unsat. zone)	33,000	3000(1)–27,000	25,000–42,000
^{14}C	n.a.	>30,000	>30,000 (52aSE) 29,000 (52aNW)
^{36}Cl	n.a.	<100,000	n.a.

(1) Probably via preferential flow path
Source: Bureau of Rural Sciences 2001b (see Appendix C2)

There is a discrepancy between the recharge rates estimated by chloride mass balance in the saturated and unsaturated zones. More credibility should be placed on the unsaturated zone analyses, especially for Site 52a. The chloride and moisture versus depth patterns, and the linearity of the cumulative chloride profile, support the assumption of piston flow-type recharge at Site 52a. These plots also indicate the presence of a diffusion gradient to a fresher watertable.

8.6 Climate

Climatic effects need to be considered in assessing the factors that may influence the integrity and storage of radioactive waste. Climate can affect storage facilities in various ways, for example changes and extremes in rainfall and temperature, variation in soil moisture content, fluctuation in surface and aquifer watertables, and soil erosion by winds and floods (Appendix F). These factors could also influence the vegetation in the region.

The three primary climate issues of particular relevance to the repository are greenhouse-induced climatic change, natural climatic variation and long-term climate perturbations (on the multi-millennium scale) (Appendix F).

Air movements and thermal structure of the local atmosphere may also offer a pathway for any released radionuclides to be transported to residential areas.

8.6.1 Climate and Winds

South Australian seasonal variation of weather is controlled by the position of the subtropical ridge of the high-pressure system. During summer this ridge is located at latitudes south of the Australian continent. Anticyclonic high-pressure systems normally move eastwards along the ridge, resulting in more frequent airstreams from the southeast to east. In autumn the ridge moves north and remains over the continent for most of the colder months, resulting in more frequent northwest to southwest wind directions (Bureau of Meteorology 1998). The climate of South Australia during winter is heavily influenced by cyclonic low pressure fronts associated with this northerly ridge.

The Bureau of Meteorology has been collecting weather data from weather stations at Woomera since the 1940s and Andamooka since the 1960s. The Woomera weather station is the closest to Sites 40a and 52a (approximately 23 km west of 40a and 50 km southeast of 52a). The Andamooka weather station lies approximately 48 km north of Site 45a. Additional weather information is available from five weather stations at the Olympic Dam mine, approximately 50 km north of Site 45a and 30 km west of Andamooka, collected by WMC (Olympic Dam Corporation) and dating back to 1980 (Kinhill Engineers 1997). Figures 7.1 and 7.2 show these locations in relation to the proposed repository sites.

The Bureau of Meteorology weather stations record daily maximum temperatures for 24 hours from 9 am, and daily minimum temperature and rainfall for 24 hours up until 9 pm. A ‘rainday’ is defined as a day with a rainfall of at least 0.2 mm. The median (decile 5) monthly rainfall is given as a preferred and more reliable indicator of ‘average’ rainfall as it is less influenced by the high variability of daily rainfall. Both sites have temperature and rainfall data for at least 30 years. Wind speeds are recorded on three-hourly bases and averaged for each season.

Summaries of the relevant weather data for Woomera and Andamooka are presented in Tables 8.10 and 8.11, respectively. Most elements are calculated for months that have more than 20 days of observations, and not all the variables have been collected for the full period of operation.

The climate of central–north South Australia is generally characterised by low rainfall, low relative humidity, high evaporation and high temperatures during summer. Woomera and Andamooka experience mild to cool winters and warm to hot summers, with annual average maximum and minimum temperatures around 26 °C and 13 °C, respectively.

Rainfall for the general area is irregular, year round and low, with total median rainfall around 177 mm. The average relative humidity in the region is around 43%. Woomera data indicate strong periodicity in evaporation, which is directly related to seasonal temperature and solar radiation levels. On average, the region experiences high evaporation levels of approximately 250 mm per month.

Heavy rainfall events can occur in any month, with a tendency towards highest monthly rainfall occurring mostly during warmer months. Significant rainfall events in the study area are usually a result of large-scale weather systems, involving closed cyclonic circulation in the upper atmosphere and a surface low-pressure system, with the inflow of moist tropical air during summer. Occasional surface anticyclone high-pressure systems can also result in similar rain-producing conditions during winter (Jensen and Wilson 1980).

TABLE 8.10 Summary of atmospheric measurements, Woomera aerodrome, 1949–2001 (Bureau of Meteorology)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (deg C)	34.2	33.6	30.4	25.3	20.4	17.3	16.8	18.7	22.3	26.0	29.5	32.2	25.5
Mean daily minimum temperature (deg C)	19.3	19.3	16.8	12.9	9.4	6.7	5.8	6.7	9.3	12.3	15.1	17.6	12.6
Mean 9 am relative humidity (%)	43	46	50	55	68	76	74	66	53	45	42	42	55
Mean 3 pm relative humidity (%)	22	24	26	32	41	46	43	37	30	26	22	22	31
Mean 3 pm wind speed (km/hr)	17.7	16.6	15.9	15.2	15.9	16.9	18.3	19.9	20.5	20.6	19.1	18.7	17.9
Median (5th decile) monthly rainfall (mm)	9.5	9.9	3.9	6.4	11.5	10.7	11.2	10.2	10.3	8.9	11.2	7.8	175.2 (Total)
Highest monthly rainfall (mm)	93.0	121.2	191.2	68.8	119.4	65.2	64.7	72.6	85.9	82.4	130.6	85.6	
Lowest monthly rainfall (mm)	0	0	0	0	0	0	0	0	0.4	0	0	0	
Mean no. of raindays	3.0	2.5	2.6	2.8	5.1	5.3	6.0	5.5	5.2	4.5	4.4	3.3	50.1 (Total)
Mean daily evaporation (mm)	14.1	13.1	10.2	6.7	4.1	2.9	3.1	4.6	6.7	9.3	11.6	13.2	8.3

TABLE 8.11 Summary of atmospheric measurements, Andamooka, 1965–2001 (Bureau of Meteorology)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature (deg C)	36.1	35.5	32.2	27.0	22.2	18.6	18.3	20.4	24.3	27.9	31.5	34.5	27.4
Mean daily minimum temperature (deg C)	21.0	21.2	18.3	13.7	9.9	6.8	5.8	7.2	10.3	13.5	16.8	19.4	13.7
Mean 9 am relative humidity (%)	40	42	45	49	62	72	70	60	48	41	41	39	51
Mean 3 pm relative humidity (%)	21	24	25	29	39	44	41	34	27	24	23	21	30
Mean 3 pm wind speed (km/hr)	12.4	11.4	10.4	9.6	9.3	9.2	10.9	12.8	13.9	14.3	12.8	12.3	11.6
Median (5th decile) monthly rainfall (mm)	17.0	10.4	5.4	4.1	10.0	7.8	12.2	9.8	7.7	8.6	11.7	10.8	179.2 (Total)
Highest monthly rainfall (mm)	104.5	100.2	231.1	87.6	89.4	66.0	49.3	46.3	43.1	87.6	55.4	125.1	
Lowest monthly rainfall (mm)	0	0	0	0	0	1.4	0	0	0	0	0	0	
Mean no. of raindays	3.6	2.5	2.3	2.3	3.7	4.3	4.6	4.5	4.3	3.9	3.9	3.0	42.9 (Total)

Storm frequency event data have been estimated (Table 8.12) for Woomera using Institution of Engineers Australia methodology (Canterford 1987; Pilgrim 1997).

South Australia has experienced a total of fifteen significant droughts since 1859, most of which were generally restricted to inland areas. Flooding is less common in the generally dry climate and low relief of South Australia (Bureau of Meteorology 1998).

TABLE 8.12 1-in-100-year storm event frequency — Woomera

Duration	Intensity (mm/hr)
5 min	205
1 hr	59.6
12 hr	9.7
24 hr	5.5
72 hr	2.1

Data from the Olympic Dam mine weather stations indicate that barometric pressures do not vary greatly throughout the year but there is a general trend for higher pressures during winter (Kinhill Engineers 1997).

Figures 8.7 and 8.8 represent seasonal wind roses for Woomera (1949–2001) and Andamooka (1969–2001). Autumn is defined as March–May, winter as June–August, spring as September–November and summer as December–February. The size of the central circle on each rose is proportional to the number of calms per season (see scale).

The most frequent wind directions experienced by both stations for summer and autumn are predominantly southerly to southeasterly. During winter and spring winds tend to be more variable, with increased northern and western components during winter. Spring winds are rotating south, shifting towards the summer and autumn conditions, with increased southwesterly and southerly winds. Winds are generally light to variable, with an annual mean wind speed of 17.9 km/hr for Woomera (Table 8.10) and 11.6 km/hr for Andamooka (Table 8.11). In general, Woomera experiences stronger winds and less calms than Andamooka.

8.6.2 Projected Climatic Changes and Potential Impacts on Repository

The Earth's climate fluctuates naturally from year to year and decade to decade, without any anthropogenic or external influences.

The greenhouse effect (global warming) is caused by atmospheric gases trapping heat in the atmosphere, resulting in a steady increase in the Earth's temperature. Increasing concentrations of gases such as carbon dioxide (CO_2), ozone, methane, nitrous oxide and chlorofluorocarbons enhance the greenhouse effect. Of these gases, CO_2 is the most important contributor. It is estimated that six billion tonnes of CO_2 are currently released into the Earth's atmosphere every year (Appendix F). It is further projected that this annual release could triple over the next century, considerably increasing the greenhouse effect.

CSIRO conducted a wide-ranging assessment of the possible range of future climatic changes in the Woomera region, with specific emphasis on the variables relevant to the proposed national repository Appendix F.

Climatic changes were modelled for a range of possible scenarios, to accommodate a range of levels of future atmospheric concentrations of active greenhouse gases (primarily CO_2) The report predicted (with a high level of confidence) an increase in surface temperature of around 4°C (superimposed on interannual natural temperature fluctuations) by the end of this century under an enhanced greenhouse effect.

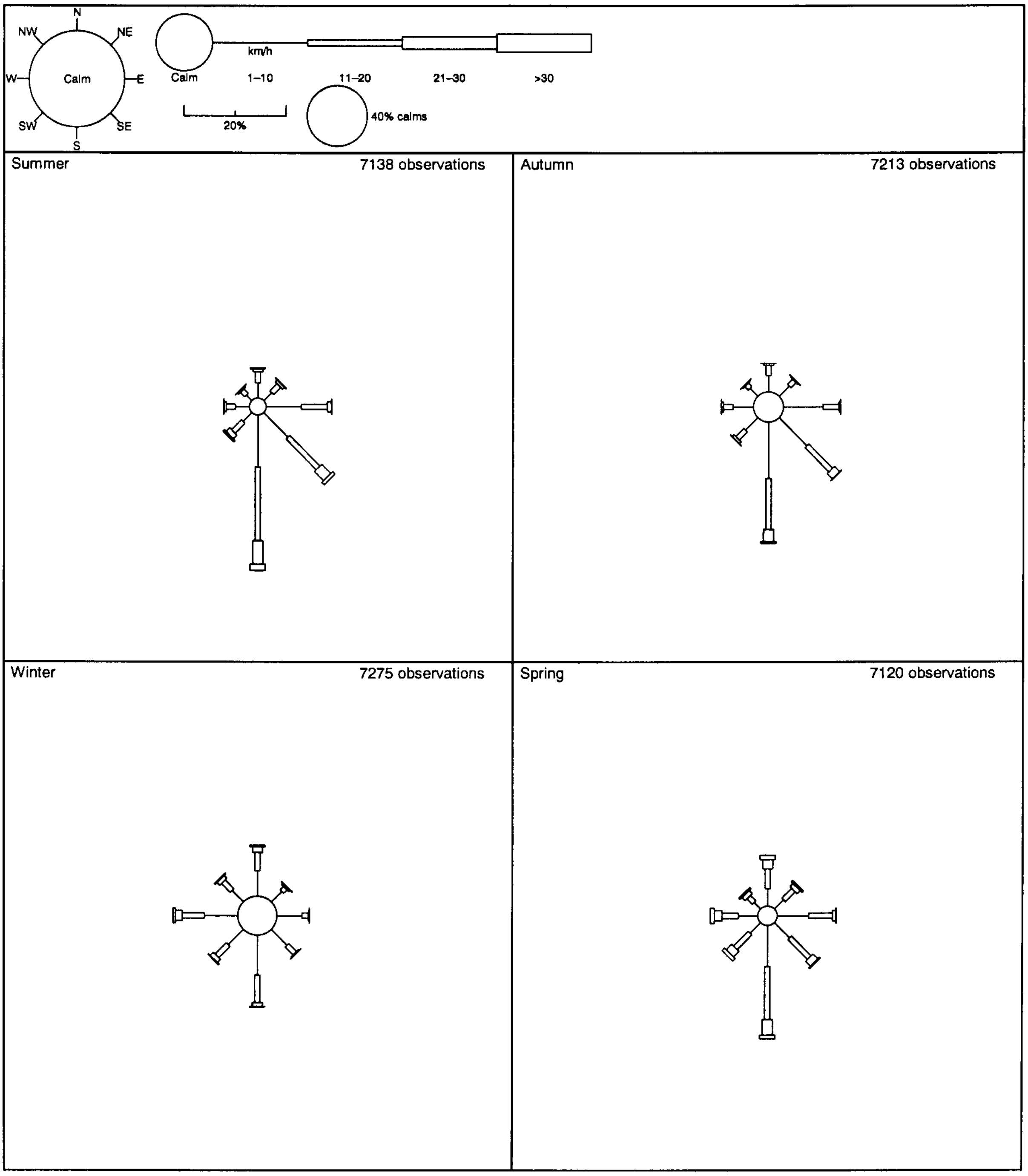


FIGURE 8.7

Wind roses for Andamooka using available data 1969–2001

(Site number 016065, Locality – Andamooka, Opened Jan 1965, Still open, Latitude 30°27'01"S, Longitude 137°10'05"E, Elevation 76 m are included.

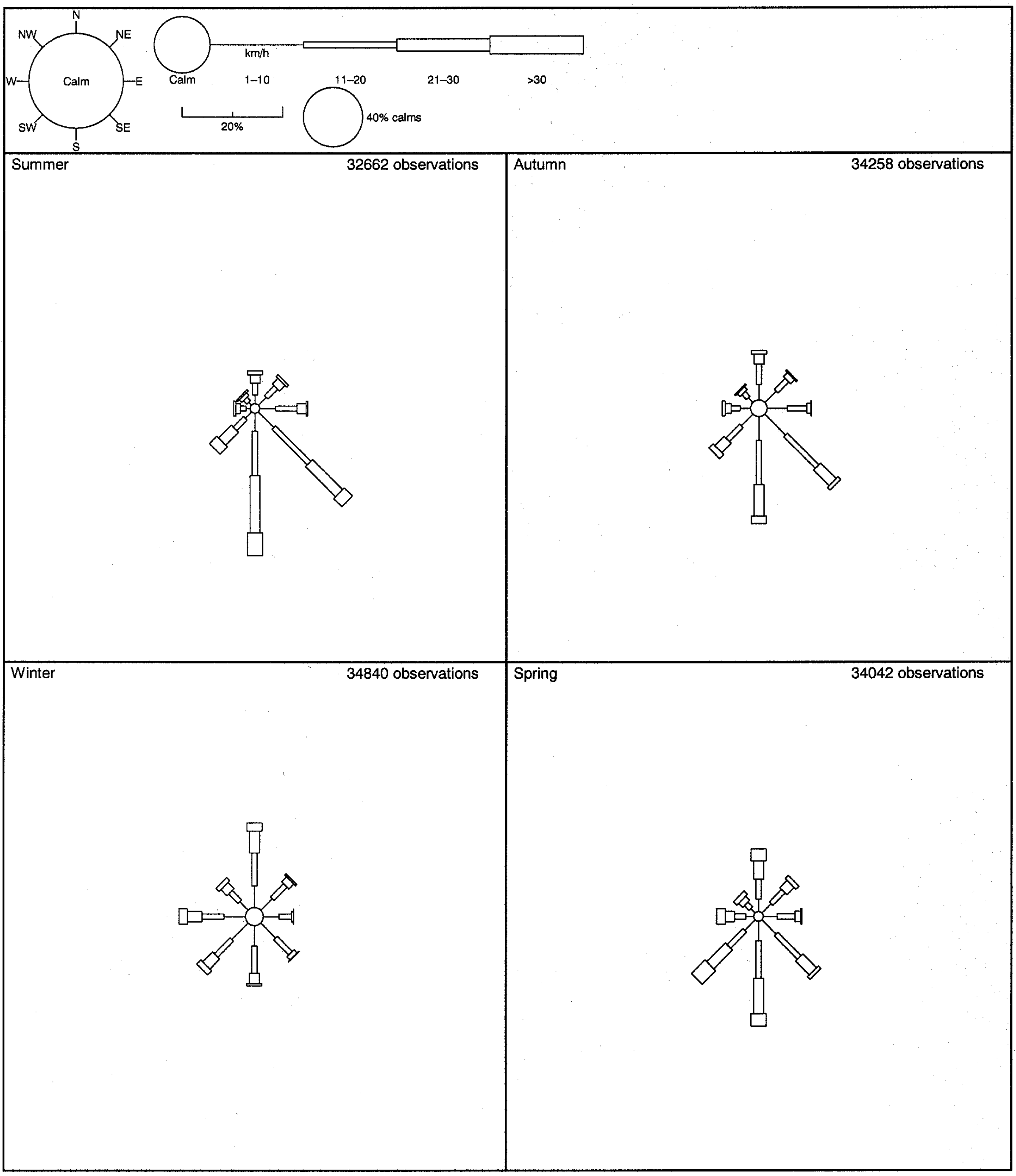


FIGURE 8.8

Wind roses for Woomera aerodrome using available data 1949–2001

(Site Number 016001, Locality – Woomera, opened Jan 1949, still open, Latitude 31°09'26"S, Longitude 136°48'12"E, Elevation 166.6 m are included)

A small increase in rainfall is also projected for the Woomera area. The magnitude of this increase varies considerably with marked interannual variability, depending on the various projected increases in CO_2 that were modelled. An increased frequency of more intense rainfall events is also predicted, which could cause an increase in rain-induced soil erosion compared to present low erosion levels. However, because of the predicted elevated temperatures, the moisture content of the soil is not expected to change markedly, resulting in a continuation of the present marginal vegetative cover.

Mean annual surface-wind velocities are not predicted to increase in the Woomera region. Current levels of wind erosion are therefore not expected to increase under global warming.

Predictions indicate no substantial changes in external forcing mechanisms of climatic variation such as solar perturbations, volcanic eruptions or changes in the Earth's orbital properties within the next 10,000 years. Changes induced by natural climatic variability are unlikely to be sufficient to affect the viability of the proposed repository.

8.7 Air Quality

The vertical air temperature profile also plays an import role in the dispersion and transport of suspended particles (e.g. radionuclides in dust particles). Atmospheric stability influences the horizontal and vertical mixing of air. Stable conditions create vertical stratification with reduced atmospheric mixing, which, in turn, increases the probability of inversion layers. Low level (100–400 m) nocturnal inversion layers have been observed to predominate at Olympic Dam, and are associated with clear night skies and light winds.

Under these conditions, gaseous emissions tend to be concentrated below the inversion layer. As the sun rises, surface heating due to solar radiation generates vertical convective currents, creating unstable ground level conditions. As the ground heats further, this mixed layer grows in height until it reaches the inversion layer and causes the concentrated pollutants to rapidly mix to ground level. Emissions at ground level typically reach their highest concentrations under such conditions.

Air quality data have been collected at the Olympic Dam mine and predictions modelled for the expansion of the mine (Kinhill Engineers 1997).

The proposed sites are all remote from any significant sources of artificial atmospheric pollution. The *Environmental Protection (Air Quality) Policy 1994*, as declared under the *Environment Protection Act 1993*, states the maximum pollution levels for industrial air pollution. The construction and operation of the repository are unlikely to cause any significant air pollution, apart from minor dust emissions during construction. Dust during construction would be controlled by standard methods such as water application in working areas.

Overall, dust emissions during construction would be minor compared with dust generation from a short section of any of the unsealed roads in the arid areas, and is not considered further in this Draft EIS.

The radiological environment and potential impacts of emissions of radionuclides to the atmosphere are discussed in Chapter 12, and an assessment of background levels of atmospheric radioactivity is presented in Appendix E3.

8.8 Noise

The repository site would be remote from all major sources of artificial noise, and noise generated during construction and operation is unlikely to be of any significant disturbance to rural settlements or residential areas.

The *Environment Protection Act 1993*, responsible for the control of excessive noise exposure for people, stipulates that restrictions are imposed on noise levels where industrial activities are located near residential areas. The closest major residential settlements to the proposed sites are approximately 23 km west of Site 40a (Woomera), 50 km southeast of Site 52a (Woomera) and 42 km northwest of Site 45a (Roxby Downs).

Noise generated from the repository would be from the following sources:

- machinery used during digging and construction
- vehicles associated with delivery and transport of waste.

The level of noise generated from the above activities is unlikely to be in excess of noise generated by normal pastoral activities in the region and, in the case of Site 52a, by activities in the Woomera Prohibited Area (WPA), and is not considered further in this Draft EIS.

8.9 Fire Regimes

In arid Australia fire regimes were implemented by Aborigines and Europeans to maintain a vegetation community for a particular purpose, for example hunting and gathering and to enhance grazing by stock (Flannery 1994). These regimes targeted hummock grasslands and savannah woodlands, that is communities whose species are generally adapted to fire.

Within northern South Australia exceptional rainfall was recorded in 1973 and this encouraged exceptional growth of annual and ephemeral plants, especially grasses. After curing, this resulted in the accumulation of a large quantity of inflammable matter across much of the region. Lay (1976) provides a summary of subsequent fires over the period 1974–76.

Within the project area, bushfires occurred near Andamooka Homestead, within the WPA west of Site 52a, and on South Oakden Hills, south of the Stuart Highway, with most occurring in savannah woodland and grassland. No major bushfires have been recorded on the Arcoona Tableland since the 1950s (Donovan 1995). The chenopod low shrubland that dominates the Arcoona Tableland is comparatively inflammable and its component perennial species are not well adapted to fire. McArthur (1972) indicates that fires are extremely infrequent in this community.

In conjunction with Defence, the Pastoral Management Board has undertaken trials on the flammability of saltbush and the propagation, behaviour and management of fire in chenopod shrublands on the WPA (B. Lay, pers. comm. October 2001). These trials recorded that the fire spread slowly through the understorey grasses and dead shrubs and burned only small patches before self-extinguishing. Regeneration of perennial shrub species in the burned areas occurred but was slow.

The potential for fire to have any impact on the repository, given the very low potential combustibility of any of the wastes to be disposed of, is very low. The issue of fire is not considered further in this Draft EIS.

8.10 Impacts, Risks and Safeguards During Construction and Operation

Potential impacts and proposed environmental safeguards associated with development of the repository are included in the following summary table (Table 8.13). Additional details on key areas are provided in Sections 8.10.1, 8.10.2 and 8.10.3.

TABLE 8.13 Potential environmental impacts and safeguards during construction and operation

Issue	Management strategy
Potential impact	
Surface water runoff, soil erosion and siltation of watercourses	▪ Apply water used for dust suppression at a rate that would not generate significant runoff from the application area ▪ Install erosion and sediment control structures to ensure sediment transfer is minimised ▪ Locate soil stockpiles in designated areas away from drainage lines and install appropriate sediment control structures ▪ Carry out washdown of construction equipment on a hardstand within a bunded area and away from drainage lines ▪ Carry out refuelling of equipment on a hardstand away from drainage lines and within a bunded area ▪ Prepare a spill response plan prior to commencement of construction ▪ Construct surface water management ponds to enable storage and evaporation of surface water from construction operations ▪ Pump water that collects in trenches to the storage pond for evaporation ▪ Rehabilitate and revegetate disturbed areas not required for the operational period ▪ Minimise the amount of site disturbance beyond the limit of development works ▪ Minimise disturbance to natural soil profiles and removal of vegetation ▪ Maintain road surface without potholes or 'bulldust' patches ▪ Suspend construction activities following significant rain if additional soil damage is being incurred ▪ Control drainage through diversion to protect exposed areas as required ▪ Install temporary silt traps to remove sediment from site runoff before leaving site
Dust generation	▪ Restrict site access to dedicated roads ▪ Restrict vehicle speeds to 30 km/hr ▪ Apply water or other suitable medium to site roads and soil stockpiles to reduce the potential for dust generation
Noise	▪ Ensure consistency with South Australian Environment Protection Agency (EPA) Industrial Noise Policy ▪ Fit construction equipment with appropriate noise control devices where practical ▪ Ensure regular maintenance of construction equipment
Release of pollutants to soil, surface water or groundwater	▪ Ensure all fuel tanks/drums are stored in bunded areas ▪ Ensure clean-up procedures and equipment are in place and implemented in the event of spills

8.10.1 Slope Stability

During establishment of the repository there are potential risks to site workers associated with the stability of the excavations. A preliminary slope stability assessment indicates that the orientation of the joints would influence the stability of the repository walls. Establishing a slope angle parallel to the dominant dip of the joint would minimise the potential for significant slope failure. As excavation, filling and backfilling of the repository is expected to occur over a short period of time, steeper slope angles are feasible. Temporary support in the form of meshing and rockbolts may be required to ensure the safety of site personnel.

On the basis of information from bore logs, geotechnical testing, rock substance strength and orientation of joints; and on consideration of the short-term period that the excavation would be open, the following preliminary slope design parameters are recommended:

- surface silty gravelly sand, 1:4 (vertical:horizontal)
- sandy clay residual soil and extremely weathered rock, 1:2 (vertical:horizontal)
- rock slope:
  - Site 40a, 80 degrees (parallel to the main joint set)
  - Site 45a, 80 degrees (parallel to the main joint set)
  - Site 52a, 60 degrees.

Additional investigations would be undertaken to provide specific data on the orientation of major defects, to confirm the preliminary design slope angles.

8.10.2 Surface Water Infiltration

Surface water infiltration into the repository can occur from a number of scenarios:

- runoff during construction and operation of the facility
- infiltration of rainfall through the cap
- surface ponding of water on the cap due to settlement and subsequent infiltration.

During construction the surface adjacent to the slope would be graded away from the slope crest to minimise the potential for surface water to discharge into the excavation. Diversion drains would be established to divert up-catchment surface water generated from storm events away from the repository. This would ensure that there is no accumulation of surface water in the vicinity of the buried wastes or entry of surface water into trenches or boreholes both during operations and after closure. Surface drains from operational areas where radioactivity is handled would be led to an evaporation pond within the repository compound, to collect runoff and contain potentially contaminated surface water on site.

The completed repository surface would have a general slope in the order of 10% to minimise the potential for ponding and ensure erosion is not significant over the life of the repository (including the institutional period).

8.10.3 Water Infiltration

Repository Assessment

An assessment was undertaken to assess the possible risks and impacts of water infiltration and to refine the design of the cover material. This included:

- collection and laboratory analysis of soil samples for use as capping material
- hydrological model simulations using the US Environmental Protection Agency approved Hydrological Evaluation of Landfill Performance (HELP) model.

Standard geotechnical tests were conducted including Atterberg Limits (Plastic Limit, Liquid Limit, Plasticity Index, Linear Shrinkage), compaction, particle size distribution, Emerson dispersion and triaxial cell permeability tests.

The results indicate that the gravelly silty sand overburden material and weathered shale could be used to produce a homogeneous earthfill for placing as a cap over the repository. On the basis of the hydraulic conductivity tests this material would not be suitable for constructing a low permeability barrier layer in the cap. On the basis of the Atterberg Limits and particle size distribution it is considered that the sandy clay soil located near the surface should be suitable for use in the construction of a low permeability barrier layer with a permeability expected to be less than $1x10^{-9}$ m/s. Additional sampling and analysis would be undertaken as part of detailed design.

A series of hydrological model simulations using the Waterloo Hydrogeologic Inc. Unsat Visual HELP computer package were undertaken to assess the potential infiltration of rainwater through various capping and base lining system scenarios. The HELP model calculates the movement of water across, through and out of containment facilities.

A number of different capping and liner systems were assessed, including a low permeability clay barrier layer in the cap, a low permeability liner at the base of the repository, a homogeneous earthfill cap and a composite barrier layer in the cap (incorporating a geomembrane and low permeability compacted clay) (Table 8.14).

TABLE 8.14 Summary of cap and liner systems assessed using the HELP model

Case reference	Description	Low permeability liner at base of trench	Drainage layer in cap
1a	Homogeneous soil cap comprising 2.5 m of loamy sand and 2.5 m of sandy loam capping overlying waste	No	No
1b	Homogeneous soil cap comprising 5 m of sandy loam overlying waste with a low permeability clay barrier 0.6 m thick at the base of the trench	Yes	No
2a	Capping layer comprising 1 m of soil, 0.6 m of low permeability clay and 3.4 m of soil overlying the waste	No	No
2b	Capping layer of 1 m of soil overlying a composite liner comprising a geomembrane and 0.6 m clay barrier, and 2.6 m of soil overlying the waste	No	Yes
2c	Capping layer comprising 1 m of soil overlying a 0.6 m thick clay barrier and lateral drainage sand layer, 3.2 m of soil overlying the waste and a 0.6 m thick clay liner at the base of the repository	Yes	Yes
3a	Capping layer comprising 4.4 m of soil overlying a 0.6 m thick clay barrier	No	No
3b	As 3a above, but including a 0.6 m clay barrier at the bottom of the trench	Yes	No
4	Capping layer of 1 m of soil overlying a geomembrane, 4 m of soil overlying the waste, with a 0.6 m clay liner placed at the base of the trench	Yes	Yes

Input parameters for the model included weather data from the Woomera Aerodrome (temperature, precipitation and solar radiation) (see Section 8.6), soil and material parameters from the geotechnical laboratory test results and default parameters from the HELP model.

The assessment indicated low levels of infiltration for all cases examined, with the least infiltration experienced using a composite lining system located at the base of the cover layer. The results are summarised in the attached table (Table 8.15). Essentially, the modelling undertaken as part of the project assessment indicates that rainwater infiltration would be minimal with the assessed alternative covers.

Placement of a compacted clay barrier layer higher in the cover layer would be susceptible to cracking due to prolonged wet/dry cycles. Shallow clay barriers may also be susceptible to burrowing animals.

TABLE 8.15 Summary of annual percolation rates for 10-year modelled period, evaporative zone depth 0.3 m

Case reference	Annual total percolation rates through base of repository (metres)									
	Year									
	1	2	3	4	5	6	7	8	9	10
1a	0	0	0	0.0013	0	0.0013	0.008	0.019	0.012	0.01
1b	0.00015	0.000125	0.00025	0.00031	0.00044	0.00048	0.0006	0.00064	0.00083	0.0023
2a	0.023	0.011	0.0013	0.013	0.001	0.0013	0.018	0.0012	0.009	0.035
2b	0.022	0.011	0.002	0.012	0.01	0.00055	0.019	0.0004	0.009	0.034
2c	0	0	0.0012	0	0.0012	0.0012	0.0012	0.0012	0.0012	0.0026
3a	0.022	0.005	0.009	0.011	0.01	0.0013	0.018	0.0013	0.009	0.026
3b	0.022	0.0117	0.0036	0.011	0.01	0.01	0.0006	0.0004	0.009	0.037
4	0.0004	0.00054	0.0007	0.0009	0.001	0.0011	0.00126	0.00135	0.0014	0.0019

On the basis of the assessment the recommended cover design includes the installation of a composite lining system incorporating a geomembrane liner (high density polyethylene) placed directly onto a compacted clay barrier layer located at the base of the 5 m cover layer. The geomembrane would also serve as a marker layer for the future and minimise potential intrusion by humans and burrowing animals. A geotextile membrane would be placed over the geomembrane to minimise the potential for damage and provide some lateral drainage. As part of the design phase an assessment would be carried out to determine the benefits or otherwise of installing a coarse cobble layer (rock material from the excavations) as an additional deterrent to burrowing animals.

The installation of a compacted clay liner at the base of the repository did not significantly alter the percolation rate through the repository. Nevertheless, it is proposed to compact the base of the repository and grade the finished surface to a sump to collect any free water and direct it to a sampling well.

Unsaturated Zone Assessment

Preliminary modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area suggested a transit time in the order of 60,000 years in the presence of vegetation and 6000 years in the absence of vegetation (Australian Nuclear Science and Technology Organisaiton/CSIRO 1998, 1999). These residence times are very long compared to the half-lives of key radionuclides in typical wastes (e.g. ^{137}Cs is 30 years). The same workers examined the adsorption and retardation characteristics of soil and rock samples. The majority of radionuclides that would be present in buried waste adsorb to a greater or lesser degree on the surfaces of soil and rock particles, which further slows their movement relative to the already slow movement of water through the unsaturated zone towards the watertable.

To further examine the movement of potential contaminants through the unsaturated zone, modelling of the movement of three selected radionuclides was undertaken for Site 52a. This study is presented in full in Appendix C5, and a synopsis is presented here.

The modelling was completed using Chemflo-2000, a one-dimensional water and solute modelling program. Simulations were completed for solute transport from the base of the waste repository during rain and storm periods for up to 100 years. Field and standard reference data were used.

The following radionuclides were modelled, covering the range of physico-chemical properties expected in the conditioned waste that it is proposed will be stored. A nominal (excessive) input concentration of 100 mg/L at the base of the repository was assumed.

- Tritium (^{3}H) is not significantly affected (retarded) by chemical processes, and moves with water flow. It does degrade reasonably quickly, with a half-life of 12.3 years.
- Caesium-137 (^{137}Cs) is relatively mobile, with a half-life of 3 x 10^{6} years.
- Cobalt-60 (^{60}Co) is relatively immobile, with a half-life of 5.27 years.

The modelling results indicate that the amount of solutes originating from the repository reaching the watertable under the conservative scenario of continual low level seepage for 100 years would be so low as to be, to all practical extent, undetectable. Even if 100% of rainfall and stormwater were to penetrate the repository, the modeling results indicate that the amount of solutes reaching the watertable would be less than 10^{-100} mg/L, that is, undetectable. The natural climatic regime of the study region, together with the design and construction of the repository, would provide considerable additional protection for the watertable.

Prediction of this modelling assessment is considered to be due, in large part, to the very low rates of downward percolation that occur under arid conditions, and the thick nature of the unsaturated zone. This allows time for decay of the radionuclides, greatly reducing their concentration before they reach the watertable.

The findings of the modelling correlate with research carried out elsewhere in Australia and the US, which concludes that in desert (arid) areas the dominant direction of water movement in soil is upwards. This upward movement is due to the low level of rainfall and high evaporation rates in these areas. While individual large rainfall events can generate a downward moving wetting front, the dry conditions that follow result in the vast majority of this moisture being drawn back to the surface through evaporation and capillary forces.

Consequently, transport of the nuclides may occur initially as advective (carried by moving water) flow with or behind the wetting front, but this eventually becomes dominated by transport by diffusion and dispersion as the geological profile dries. The dispersion and diffusion rates are generally much lower than the advective rates; hence, the rate of movement of the nuclides is greatly reduced, allowing time for decay to occur.

8.10.4 Radon Emanation

Radon (^{222}Rn) gas from the decay of radium-226 (^{226}Ra) in the waste would diffuse through the waste material and the cover. The concentration of radon in air at ground level would be governed by the radon exhalation rate or flux from the cover material, and by atmospheric dilution, which depends on the prevailing meteorological conditions.

Apart from the ^{226}Ra content of the waste, the resultant radon exhalation rate at the surface of the cover material is a consequence of a number of characteristics of the waste and cover, for example the moisture content, porosity, particle size of the soil, bulk density and thickness of the cover.

If the cover material does not contain significant levels of ^{226}Ra, the main governing parameter for the reduction factor for radon exhalation rate by the cover is the ratio of the cover thickness to the diffusion relaxation length for cover material. This latter parameter effectively is the distance a radon atom travels in the material before decaying. It is related to the radon decay rate (half-life) and the diffusion coefficient for radon in the cover material.

Therefore, the radon diffusion coefficient of the cover material is most important in determining the exhalation rate at the surface. There are significant differences in diffusion coefficients for various soil types. For example, the diffusion coefficient for clay is an order of magnitude less than that for silty sand. The presence of moisture also further reduces the diffusion coefficient, and clay materials have a greater capacity for moisture retention.

A 5 m cover without significant ^{226}Ra content would reduce the exhalation of radon into air by a factor of approximately 100. Attenuation of the surface radon flux from ^{226}Ra in the waste would be further aided by incorporation of a clay layer within the 5 m cover. It has been estimated that, for a 1 m clay layer within the 5 m cover, there is an attenuation factor of 450 for the radon flux at the surface compared to uncovered waste (NHMRC 1997).

8.11 Impacts, Risks and Safeguards During Surveillance, Decommissioning and Institutional Control

Potential impacts and proposed environmental safeguards associated surveillance of the site between disposal campaigns, decommissioning and the institutional control period of the project are presented below (Table 8.16).

TABLE 8.16 Potential environmental impacts and safeguards during surveillance, decommissioning and institutional control

Issue	Management strategy
Potential impact	
Pollution of surface water runoff and erosion	▪ Prepare a surveillance and rehabilitation management plan consistent with South Australian EPA policy ▪ Rehabilitate and revegetate access tracks and other disturbed areas after decommissioning ▪ Remove buildings and infrastructure, then rehabilitate and revegetate the site after decommissioning ▪ Ensure integrity of final cap through revegetation and establishment of appropriate slope grades ▪ Repair and revegetate depressions or erosion channels detected during monitoring according to the design standard
Pollution of groundwater	▪ Ensure the integrity of cap and slope grades are maintained ▪ Repair and revegetate depressions and erosion channels according to the design standard
Potential for release of pollutants to surface water	▪ Maintain natural drainage channels or levees to avoid flooding of site ▪ Maintain cap
Potential for release of pollutants to groundwater	▪ Maintain drainage, preventing ponding of surface water on or near trenches; maintain cap

8.12 Monitoring Programs and Procedures

The monitoring programs listed in Tables 8.17 and 8.18 are proposed to be undertaken as part of the project.

TABLE 8.17 Environmental monitoring requirements during construction and operation

Issue	Monitoring requirement
Physical environment	
Surface water runoff and erosion	▪ Regular inspection of drainage lines for evidence of sediment transport (quarterly during periods without rain and ad hoc following any rain events) ▪ Regular inspections of bunded areas to confirm integrity of bunds ▪ Inspection and maintenance of erosion control measures ▪ Clean-up of areas of accidental spillage of fuels and appropriate disposal of spilled material
Dust	▪ Visual monitoring to determine areas of excessive dust generation and activities creating dust, to ensure that any dust arising is minimal
Noise	▪ Measurement of noise levels during operation to ensure consistency with South Australian EPA Industrial Noise Policy and OH&S requirements
Potential for release of pollutants to soil	▪ Ad hoc inspections following rain events ▪ Ad hoc inspections following any fuel/oil spills and after clean-up activities ▪ Ad hoc inspections following any received waste spills, with waste and affected soil rremoved/repackaged for disposal in trenches/boreholes
Potential for release of pollutants to surface water	▪ Opportunistic sampling of flowing surface water upstream and downstream of site with analysis of salinity, turbidity / total suspended solids and selected radionuclides to build up background dataset ▪ Ad hoc inspections following rain events ▪ Ad hoc inspections following any fuel/oil/waste spills and after clean-up activities
Potential for release of pollutants to groundwater	▪ Quarterly monitoring of water levels in all available drainage layers and groundwater monitoring wells ▪ Ad hoc monitoring of sampling well in basal drainage layer of closed trenches after significant rainfall ▪ Annual groundwater sampling for pH, electrical conductivity / salinity, major ions and selected radionuclides

TABLE 8.18 Environmental monitoring requirements during surveillance, decommissioning and institutional control

Issue	Monitoring requirement
Physical environment	
Surface water and erosion	▪ Preparation of a surveillance and monitoring plan consistent with South Australian EPA policy ▪ Surveillance (yearly or after significant storm events) to assess the integrity of the cap
Potential for soil erosion / siltation of water courses	▪ Annual inspection, reducing to five-yearly after five years ▪ Ad hoc inspections following major rain events (>500 mm/month)
Potential for release of pollutants to soil	▪ Annual inspection, reducing to five-yearly after five years
Potential for release of pollutants to surface water	▪ Annual inspection, reducing to five-yearly after five years ▪ Ad hoc inspections following major rain events (>500 mm/month)

Issue	Monitoring requirement
Potential for release of pollutants to groundwater	▪ Annual monitoring of water levels in all available drainage layers and groundwater monitoring wells, reducing to five-yearly after five years ▪ Ad hoc monitoring of sampling well in basal drainage layer of closed trenches after major rainfall events (>500 mm/month) ▪ Annual groundwater sampling for pH, electrical conductivity / salinity, major ions and selected radionuclides, reducing to five-yearly after five years

Chapter 9
Biological Environment

This chapter reviews the existing biological environment in the region and the project area, and provides an analysis of the predicted project impacts. It includes a brief review of biological diversity, an assessment of the flora and fauna of the region and the project area, and a review of predicted impacts and mitigation.

The discussion in this chapter refers to the following areas (Figure 9.1):

- the project area, which includes all of the land within and adjacent to each of the three potential repository sites
- the Arcoona Tableland as described and delimited by Brandle (1998)
- the region, which comprises all of the Arcoona Tableland and land adjacent to the access route into each of the potential repository sites.

In addition, a wider region is referred to on occasions. This includes the Olympic Dam area to the north of the Arcoona Tableland and includes the Roxby land system.

Much of the region identified and all of the project area lies within the Woomera environmental association of Laut et al. (1977). The remainder of the region is referrable to the Andamooka land system. More recently, the Arcoona Tableland has been recognised as a distinct land system, the Arcoona land system (McDonald 1992). Figure 9.1 shows the locations of land systems within the region.

There have been no previous biological surveys of any of the three potential repository sites or immediately adjacent areas. However, data are available for similar habitats elsewhere on the Arcoona Tableland.

9.1 Biological Diversity

This section provides a brief review of the biological diversity (biodiversity) in the region and the project area.

9.1.1 Biodiversity

Conservation of biodiversity is a foundation of ecologically sustainable development (ESD) and one of the three principal objectives of the *National strategy for ecologically sustainable development* (Environment Australia 1992). Within Australia, the *National strategy for the conservation of Australia's biological diversity* (Department of Environment, Sport and Territories 1996) establishes a link between the current situation and the effective identification, conservation and management of Australia's indigenous biological diversity.

The biological diversity national strategy considers biological diversity at three levels: genetic diversity, species diversity and ecosystem diversity. The strategy contains six target areas:

- conservation of biological diversity across Australia
- integration of biological diversity, conservation and natural resources management
- management of threatening processes
- improvement of knowledge and understanding of biodiversity
- involvement of community
- Australia's international role.

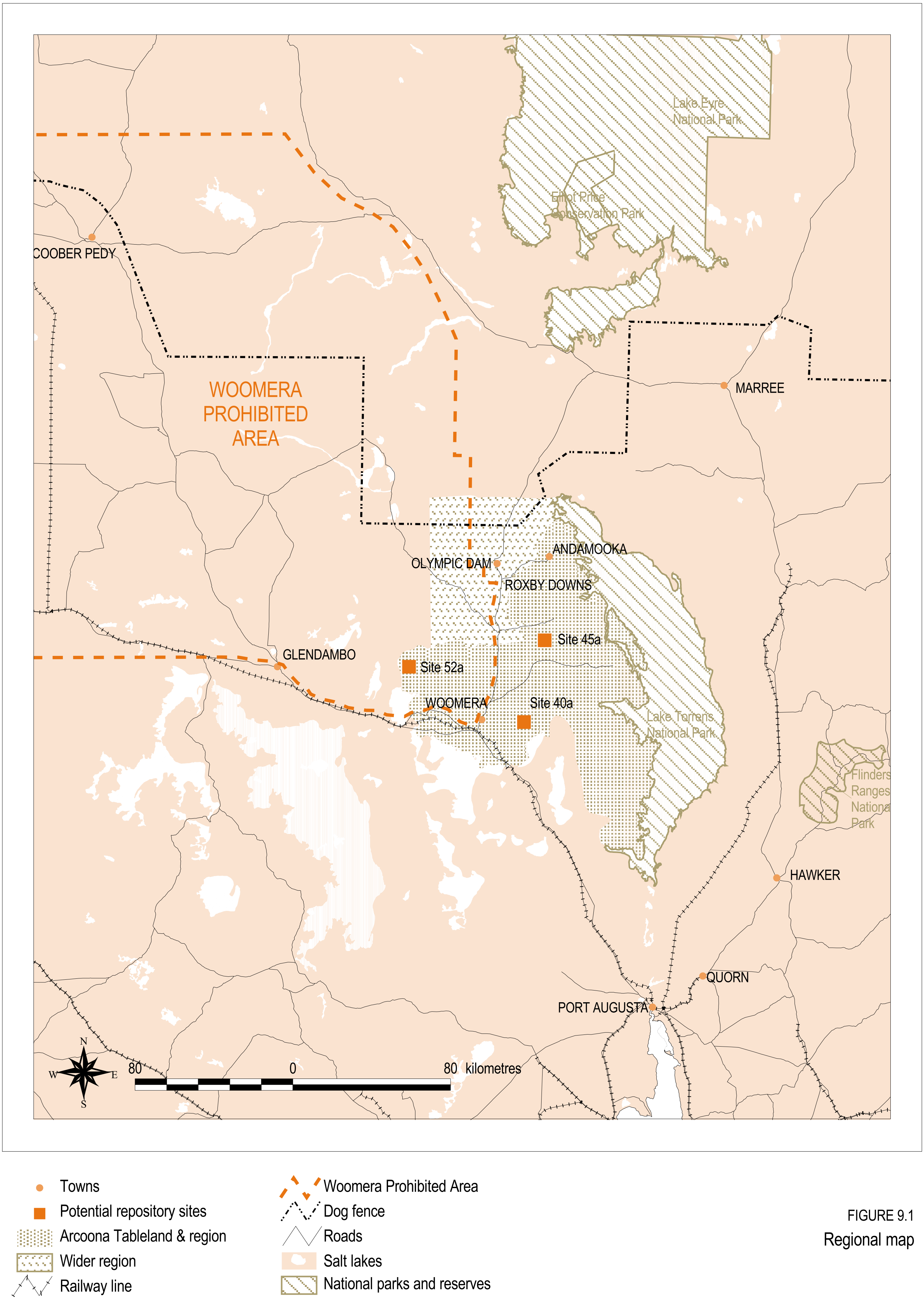


FIGURE 9.1
Regional map

During 2001 the Australian and New Zealand Environment and Conservation Council (ANZECC) published a review of the strategy and defined the national priorities for biodiversity conservation research (ANZECC 2001a, 2001b). In conjunction with the ANZECC reviews, Environment Australia (2001) redefined the ten priority actions, and the attendant objectives and targets for each action, for biodiversity conservation in Australia over 2001–05.

As part of the *National strategy for the conservation of Australia's biological diversity* and the National Land and Water Resources Audit, the South Australian Department for Environment and Heritage (SA DEH) is collating information on the bioregions of the State and preparing regional biodiversity plans. A draft biodiversity plan for the northern part of South Australia, the Rangelands bioregion (which includes the region discussed in this chapter), is expected to be completed by about mid-2002.

Baseline information for the audit is currently being compiled. In compiling information for both projects, SA DEH is primarily considering State information on factors such as threatened species and ecosystems, wetlands of regional and national significance, and areas of conservation (N Neagle, SA DEH, pers. comm. October 2001).

In its management of the national repository, the Department of Education, Science and Training is fully committed to establishing effective management of environmental issues, consistent with the principles of sustainable development. It would comply with relevant State and Commonwealth legislation and policy as a minimum environmental standard.

The environmental monitoring and management plan (EMMP) for the project would adapt elements of environmental management systems designed to improve environmental performance and achieve ESD.

9.2 Vegetation and Flora

This section discusses the terrestrial vegetation present in the region and the project area, the conservation status of the vegetation communities and individual species, introduced (alien) flora, past impacts, potential adverse and beneficial impacts of the proposal and their mitigation, and monitoring programs. The baseline flora report is provided in Appendix D1.

Legislation relevant to the project in relation to vegetation communities and species includes:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act)
- *National Parks and Wildlife Act 1972* (SA) (NP&W Act), especially Schedules 7, 8 and 9 as revised in the *National Parks and Wildlife (Miscellaneous) Amendment Act 2000*
- *Native Vegetation Act 1991* (SA).

International, Commonwealth and State agreements, policies and strategies potentially relevant to vegetation communities and species include the:

- Convention on Biological Diversity (ANZECC 1993) and the *National strategy for the conservation of Australia's biological diversity* (Department of the Environment, Sport and Territories 1996)
- National Conservation Strategy for Australia (Department of Home Affairs and Environment 1983)
- *National strategy for the conservation of Australian species and communities threatened with extinction* (Endangered Species Advisory Committee 1992)
- *National framework for the management and monitoring of Australia's native vegetation* (ANZECC 1999a)
- *National principles and guidelines for rangeland management* (ANZECC 1999b), the draft *National strategy for rangeland management* (ANZECC 1996) and the draft *National land and water resources audit on rangelands* (National Land and Water Resource Audit 2000)

- *National weeds strategy: A strategic approach to weeds problems of national significance* (ANZECC 1999c)
- *Wetlands policy of the Commonwealth Government of Australia* (Environment Australia 1997)
- *Draft threatened species strategy for South Australia* (Department of Environment and Natural Resources 1993).

These documents are also applicable to the review and assessment of the fauna of the project area and region (Section 9.3).

9.2.1 Approach, Methods and Materials

The vegetation study was undertaken in three parts:

- A preliminary desktop study examined existing data from published and unpublished sources, including Commonwealth and State conservation schedules. Quantitative data that could be used for direct comparisons with the present survey data include data from the Stony Deserts Biological Survey (Brandle 1998), data collected during a recent review of the land systems of the Kingoonya Soil Conservation District (Badman 2001) and unpublished data held by Badman.
- During a field survey of the three potential sites in August 2001, quantitative data were collected on species composition and abundance, and 13 quadrats were established and sampled at each potential site as illustrated in Figure 9.2. The field survey also assessed potential impacts that could be caused by access to the sites, including the widening of access tracks and the construction of infrastructure such as boundary fences.
- Field data were entered into an Excel spreadsheet and analysed using the CSIRO 'PATN' data analysis program (Belbin 1992). Data from the field survey were compared against themselves, and against data reported in Brandle (1998) and Badman (2001).

Detailed information about all materials and methods are provided in Appendix D1.

Seasonal conditions at the time of the August 2001 survey were excellent for a flora survey. Good general rains of 75–100 mm fell across the whole of the Arcoona Tableland during late May and early June 2001. Most species were in flower and readily identifiable at the time of the survey. Several species were recorded that had not been seen in the district since the exceptional rainfall events of 1989.

9.2.2 Regional Vegetation

The Arcoona Tableland is a mostly treeless plain, with vegetation dominated by chenopod low shrubland that is less than one metre in height. The densest vegetation usually occurs in the gilgais that are a common feature of the tableland. Gilgais are micro-reliefs of soil produced by expansion and contraction through changes in soil moisture. The undulating surfaces are found in soils that contain large amounts of clay. The few trees that do occur often grow in small clumps. No trees are present at any of the three project area survey sites.

Laut et al. (1977) placed the Arcoona Tableland in the Woomera environmental association. This classification was not concerned primarily with vegetation. More recently, the Arcoona Tableland was recognised as forming a distinct land system, the Arcoona land system, by McDonald (1992), Kingoonya Soil Conservation Board (1996) and Badman (2001). The vegetation of the Arcoona land system has similarities with several other gibber plain land systems in the region (Badman 2001). These are principally the Oodnadatta, Paisley and Breakaway land systems to the northwest, although some small sections of the Ebunbanie land system, which occurs to the southwest, also have similar vegetation.

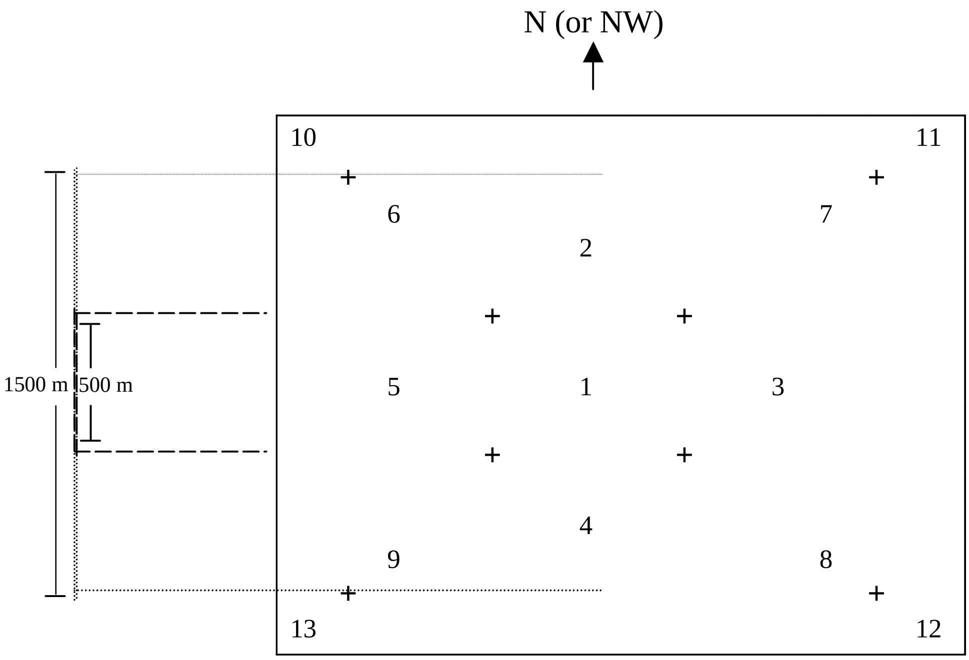


FIGURE 9.2
Sampling strategy for flora quadrats

The vegetation of the Arcoona land system is distinctive, as shown by the analysis of the Kingoonya Soil Conservation District dataset by Badman (2001).

Willis (1981) and Kraehenbuehl (1986) provided a general overview of the history of botanical research in the study area. One of the first publications to mention the plants of the Arcoona Tableland region was that of Cleland (1930) who travelled from Chances Swamp (Roxby Downs homestead) to Andamooka. Murray (1931) gave a more comprehensive report on the vegetation of an area extending as far north as Arcoona. Her studies covered the period 1927–30.

Jessup (1951) established the first quantitative data on the vegetation of the North-West Pastoral District, including the Arcoona Tableland. He listed the plants recorded in various vegetation associations and was the first worker in this region to adopt a vegetation association based approach. Lay (1979) and Maconochie (Maconochie and Lay 1996) subsequently repeated Jessup's surveys.

Preparation of the Environmental Impact Statement for the Olympic Dam Mine (Kinhill-Stearns Roger Joint Venture 1982) provided a focus on the biological values of an area north of the Arcoona Tableland and some northern parts of the tableland. Regional vegetation studies in the early 1980s (Fatchen 1981) were followed by a wide range of subsequent surveys (e.g. Fatchen and Associates 1982; Olympic Dam Operations 1996).

Later studies by or on behalf of WMC that are relevant to the present study include a vegetation survey of a corridor from Olympic Dam to Port Augusta for a new power line (Badman 1992).

Land Systems

Land systems are areas or groups of areas with recurring patterns of differing landforms, soils and vegetation (Christian and Stewart 1953). Each land system contains a combination of land units.

Laut et al. (1977) published a general classification of the environmental associations of South Australia, while McDonald (1992) was the first to publish a detailed description of the land systems of the Kingoonya Soil Conservation District. Kingoonya Soil Conservation Board (1996) made some changes to McDonald's descriptions and Badman (2001) carried out a major review of these land systems.

The three sites that form the project area are entirely within the Arcoona land system. Badman (2001) recently reviewed this land system and his description is given below:

> The gently undulating tableland of the Arcoona land system dominates the south-east of the [Kingoonya Soil Conservation] District on Arcoona, Bosworth, Andamooka, Purple Downs, Roxby Downs, Coondambo (Parakylia South block) and Wirraminna stations. A few low hills and escarpments are included within this system. Soils include stony red duplex and stony brown clay soils of the tablelands, stony clay soils over quartzite on hills, skeletal loams on escarpments and alluvial soils along watercourses.

Chenopod low shrublands dominate this land system, with some trees along watercourses and tall shrublands on isolated dunes. *Atriplex vesicaria* (bladder saltbush) dominates the vegetation, with *Sclerostegia* spp. (glassworts) also common. *Sclerolaena ventricosa* (salt bindyi), *Minuria cunninghamii* (bush minuria), *Frankenia serpyllifolia* (bristly sea heath), *Sclerolaena divaricata* (tangled bindyi), *Dissocarpus paradoxus* (ball bindyi) and *Eragrostis setifolia* (neverfail) are widespread, with *Astrebla pectinata* (barley Mitchell grass), *Sporobolus actinocladus* (ray grass) and *Ixiolaena chloroleuca* and *I. leptolepis* (plover daisies) moderately common in some areas but not common across the whole land system.

Isolated dunes, often with associated calcareous rises, have sparse woodland or tall shrubland vegetation where no single species dominates. *Acacia aneura* (mulga), *A. ligulata* (sandhill wattle) and *A. tetragonophylla* (dead finish) are common. The understorey commonly includes *Aristida holathera* and *A. contorta* (kerosene and mulga grasses). *Maireana sedifolia* (pearl bluebush), *M. pyramidata* (black bluebush), *Sclerolaena tatei* (Tate's bindyi) and *Zygophyllum aurantiacum* (shrubby twinleaf) are common on calcareous rises.

Neither sandy rises nor calcareous rises with *Maireana sedifolia* and *Zygophyllum aurantiacum* occur at or near any of the three potential repository sites.

Introduced Flora

McDouall Stuart did not record any alien species during his crossing of Australia during 1861–62 (Mitchell 1978) and the Horn Expedition recorded only one alien plant in 1894 (Tate 1896). Eardley (1946) listed two naturalised taxa among about 350 species collected by the Madigan expedition while crossing the Simpson Desert in 1939 (Madigan 1946). Mitchell (1979) considered that few weeds of any significance existed in Central Australia before 1954. At least 10% of the regional flora now consists of naturalised taxa (Badman 1995, 1999).

The disproportionately high number of alien species recorded in the Gairdner–Torrens botanical region in the last 20 years, when compared to the numbers for the Lake Eyre and North-West pastoral districts (Badman 1995), probably reflects the lack of work done in this area.

Badman (1995) found that sandy habitats and watercourses supported the greatest number of introduced species and gibber plains have a relatively low incidence of introduced taxa. Disturbed areas are the most prone to invasion by introduced species; establishment and maintenance of a perennial ground cover, particularly of native grasses, prevents their large-scale establishment.

Badman (1995) found that heavy summer rainfall at Olympic Dam in conjunction with conservative management practices could significantly decrease the incidence and cover of introduced species. Once summer growing native grasses, particularly perennial species, become established they occupy the niches that would otherwise have been available for winter growing annual introduced species and prevent these from becoming established in the following winter–spring period. These grasses can remain for several years and continue to exclude introduced species. Several dry years, which can see the elimination of the perennial grasses, followed by a wet winter allow annual introduced species to establish in the niches vacated by the grasses.

9.2.3 Project Area Vegetation and Flora

The August 2001 survey identified 126 individual plant taxa from all three sites (total of 40 monitoring points). These were all recorded from a single habitat on the Arcoona Tableland, the gibber plain. Figure 9.3 illustrates three examples of flora quadrats. (The other significant habitats of watercourses, lake shores and sand dunes were not present in the project area.) This species list represents about 28% of the species listed for all of the Arcoona Tableland (Appendix D1).

The classification and results of the data indicate that the vegetation at all sites be placed into a single floristic assemblage. All monitoring sites at the three potential repository sites fall into the same group as distinguished by Brandle (1998).

There are slight differences between four floristic groups within the single floristic assemblage due to the presence or absence of one (or occasionally more) individual species, as well as to greater or lesser cover scores for individual species. The most obvious difference is in the two adjacent monitoring sites at one corner of Site 52a where the vegetation is dominated by *Maireana astrotricha* rather than *Atriplex vesicaria.* The main differences between the abundance of the most common perennial species at individual sites are shown in Table 9.1.

Most of the common annual and ephemeral species expected to occur were found at all three sites. The only species whose abundance may have influenced the floristic groupings was *Phlegmatospermum cochlearinum*, which was most common at Site 40a and least common at Site 52a.

Comparisons with Other Regional Areas on Similar Landforms

A binary classification (presence or absence of species with no cover scores) carried out on perennial species from sites on the Arcoona Tableland produced similar results to the classification of all species discussed in the previous section. The dendrogram from this classification is shown in Appendix D1.

Ten floristic groups were identified. The level of dissimilarity that distinguished these 10 groups was low, meaning that the vegetation of all of the Arcoona Tableland was similar when classified on the presence or absence of perennial species. The main difference between the first six floristic groups was a paucity of records of *Sclerolaena* spp. among members of these groups, particularly the combination of *Sclerolaena* spp. that was found at most quadrats during the August 2001 survey. Although this genus consists of mainly perennial species, they are short-lived perennials and some or all species may have been absent during the surveys whose data were used in this analysis. None of these past surveys encountered seasonal conditions as good as those of the August 2001 survey.

Similar comments apply to several other short-lived species or genera that were missing from sites that make up the first six groups. These included *Abutilon halophilum, Dissocarpus paradoxus, Euphorbia stevenii* and *Sida* spp. *Maireana appressa* was also missing from the datasets for all the sites in these six groups. This is a shorter-lived species than most of the other members of this genus and its numbers are known to fluctuate in response to seasonal conditions (Badman 2000).

Photo 1: Site 40a, Quadrat 4041

Photo 2: Site 45a, Quadrat 451

Photo 3: Site 52a, Quadrat 52a1

FIGURE 9.3
Three examples of flora quadrats

TABLE 9.1 Comparison of the abundance of the common perennial species at the three sites(1)

Species	Site 40a	Site 45a	Site 52a	Badman (2001)
Astrebla pectinata	Not recorded	Most common	Present	Present
Atriplex vesicaria	Most common	Common	Common	Common
Dissocarpus paradoxus	Present	Present	Least common	Present
Euphorbia stevenii	Present	Present	Least common	Present
Frankenia serpyllifolia	Present	Most common	Least common	Present
Ixiolaena chloroleuca	Not recorded	Most common	Present	Present
Maireana appressa	Present	Present	Least common	Present
Maireana astrotricha	Trace	Present	Present	Present
Minuria cunninghamii	Present	Least common	Most common	Present
Sarcostemma viminale	Not recorded	Not recorded	Present	Present
Sclerolaena brachyptera	Most common	Present	Present	Present
Sclerolaena divaricata	Most common	Present	Least common	Present
Sclerolaena intricata	Present	Present	Least common	Present
Sclerostegia spp.	Most common	Present	Present	Present
Sida spp.	Not recorded	Present	Not recorded	Present

(1) The three potential sites compared to the findings of Badman (2001) for the Arcoona land system as a whole

The ‘control’ sites are representative of the vegetation of the site as a whole.

Comparisons with Different Regional Landforms

A comparison of the floristic data from the three potential repository sites with floristic data from the rest of the Kingoonya Soil Conservation District (Badman 2001) showed distinct similarities between the potential repository sites’ data and several other sites in different land systems.

This classification was based on data for 450 sites and used cover scores for all perennial species. All but three of the vegetation monitoring sites from the August 2001 survey were in the same floristic assemblage (see above).

The three different monitoring sites were all from Site 52a. These were placed in a different floristic group mainly because of their higher cover of *Maireana astrotricha.* Other differences were a greater cover of *Astrebla pectinata, Dissocarpus biflorus* and *Osteocarpum dipterocarpum* than the rest of the August 2001 survey sites, and lower cover of *Eragrostis setifolia*, *Euphorbia stevenii, Frankenia serpyllifolia, Sclerolaena divaricata* and *Sclerolaena intricata.*

Both floristic groups containing the August 2001 vegetation data were almost entirely from the Arcoona land system, with a few representatives from the Paisley, Oodnadatta, Wattiwarriganna and Ebunbanie land systems.

Comparisons with Previous Surveys

Data from three surveys are considered here, namely, those of Jessup (1951), Brandle (1998) and Badman (2001). A comparison of the floristic composition of the vegetation reported by these authors is given in Appendix D1 and a summary of the most numerous species (key or character species) in Table 9.2.

Jessup (1951) described two shrub–steppe vegetation associations from the Arcoona Tableland, the *Atriplex vesicaria–Ixiolaena leptolepis* association and the *Atriplex nummularia* ssp. *omissa* association. The former is the more common, while the latter is largely restricted to northern parts of the tableland.

Jessup (1951) described two vegetation units from the Arcoona Tableland: gilgais and the gibber-covered shelves between the gilgais. He reported that these shelves were mostly devoid of vegetation, a statement that is no longer true. Maconochie and Lay (1996) reported on the improvement in vegetation cover of the country since the time of Jessup's surveys.

It is more difficult to make direct comparisons with Brandle (1998), since this report covered almost 1100 sites from all of the stony deserts of northern South Australia. The floristic groups recognised for the Arcoona Tableland also included data from other areas. Four of Brandle's groups were widespread on the Arcoona Tableland, although none was restricted to this area. These were group 28 (*Sclerolaena ventricosa* low open sub-shrubland), group 34 (*Maireana astrotricha/Atriplex vesicaria/M. pyramidata* low open shrubland), group 35 (*Sclerolaena divaricata/Eragrostis setifolia/Atriplex vesicaria* low open shrubland), and group 36 (*Atriplex vesicaria/Sclerostegia medullosa* low very open shrubland).

Components of all of these groups were found, although, perhaps because of better seasonal conditions, none were found to form separate floristic groups. Brandle's groups 35 and 36 appear to be closest to the vegetation recorded during the current survey.

Seasonal conditions play a large part in the composition of the understorey at any given time. As an example, *Brachycome dichromosomatica* was recorded only once by Brandle (1998) and not at all by Jessup (1951) yet this was one of the most common species during the August 2001 survey. Similarly, *Phlegmatospermum cochlearinum* was not recorded by Jessup or Brandle but was quite common in August 2001. *Erodium crinitum* was also far more common during August 2001 than was reported from these earlier surveys.

Jessup (1951) reported the summer-growing grasses *Astrebla pectinata* and *Eragrostis setifolia* as being more common than in recent surveys. This may be due to subsequent grazing pressure, but is more likely to be due to the fact that none of the latter surveys, including the August 2001 survey, was undertaken after a wet summer. More recent work does not support the 'fairly rare' status of *Eragrostis australasica* reported by Jessup. This species is mainly summer growing but also depends on standing water in swamps which usually occur following heavy summer rainfall. Two shorter-lived grasses, *Panicum decompositum* and *Sporobolus actinocladus,* were also reported to be more common by Jessup than by later workers. This may be due to increased grazing pressure, although the summer rainfall factor may again be the main reason for this.

Several species listed in Table 9.2 have increased in abundance over the past 50 years since Jessup's survey. These include *Euphorbia stevenii, Frankenia serpyllifolia, Maireana aphylla, M. appressa, M. astrotricha, Osteocarpum dipterocarpum, Sclerolaena divaricata, S. intricata* and *S. ventricosa.* The increased abundance of the palatable *Maireana* spp. would suggest a decrease in grazing pressure, while the increase of the less palatable *Sclerolaena* spp. would suggest the opposite.

No introduced taxa were recorded by Jessup (1951). It is not known whether this is because these species were not then present or whether they were just ignored by Jessup. Badman (1995, 1999) reported that many of the present naturalised species were collected in the area before the 1950s but concluded that many of the early workers simply ignored 'weeds' because they did not form part of the native vegetation.

TABLE 9.2 Key species from the Arcoona Tableland

Species	Jessup (1951)	Brandle (1998) group no.				Badman (2001)	This survey		
		28	34	35	36		40a	45a	52a
Abutilon halophilum	FC	C		FC	FC	U	U	U	U
Astrebla pectinata	VC	C		C		FC		C	U
Atriplex vesicaria	D	C	D	D	D	D	D	D	D
Dissocarpus paradoxus	R	C		C	U	C	C	C	FC
Eragrostis australasica	FR	FC				U	FC	FC	U
Eragrostis setifolia	VC	FC	C	D	FC	C	FC	FC	FC
Euphorbia stevenii	FR	FC				U	FC	FC	U
Frankenia serpyllifolia	R	FC		C	C	C	FC	C	FC
Ixiolaena chloroleuca		FC						FC	U
Ixiolaena leptolepis	D(1)	C		U	U	FC		U	
Maireana aphylla	R	C	FC	U		U	U	C	FC
Maireana appressa	VR	+				U	FC	FC	FC
Maireana astrotricha	VR		D		U	FC	U		C
Maireana georgei	VR	+				U	U	U	U
Minuria cunninghamii		FC			C	C	FC	FC	FC
Minuria denticulata	FC	FC					R		
Minuria leptophylla	C								
Osteocarpum dipterocarpum	R	FC				U	FC	FC	FC
Panicum decompositum	VC	+							
Sclerolaena brachyptera	FC	FC	C	FC	FC	C	FC	FC	U
Sclerolaena divaricata	R			D	C	C	C	FC	U
Sclerolaena intricata				C	FC	FC	FC	FC	U
Sclerolaena ventricosa	FR	D	C	C	FC	C	C	C	C
Sclerostegia medullosa		FC	U	C	D		C		C
Sclerostegia sp.				U		C			
Sclerostegia tenuis	C				U			C	
Sida trichopoda	C	C						FC	
Sporobolus actinocladus	VC		FC	FC		FC	U	U	

D = dominant, C = common, FC = fairly common, FR = fairly rare, R = rare, VR = very rare, U = uncommon (see Appendix D for further explanation of how ratings were allocated)
(1) Ixiolaena leptolepis in Jessup's list includes *Ixiolaena chloroleuca*
A complete list of species recorded during the various surveys is given in Appendix D.

9.2.4 Conservation Status of Vegetation Communities

There are no vegetation communities with a recognised conservation status (Davies 1982; Neagle 1995; Specht et al. 1995; Schedules to EPBC Act and NP&W Act) at or near any of the sites examined during the current survey, nor on the Arcoona Tableland as a whole.

9.2.5 Conservation Status of Individual Species

One species, *Frankenia plicata,* is listed as Endangered in Schedule 1 of the EPBC Act. One species that has been recorded from the Arcoona Tableland is listed as Vulnerable under Schedule 8 and six species are listed as Rare under Schedule 9 of the National Parks and Wildlife (Miscellaneous) Amendment Act (SA). The species listed as Vulnerable is *Atriplex kochiana* and the Rare species are *Brachycome eriogona*, *Embadium stagnense, Frankenia plicata, Gratwickia monochaeta, Sclerolaena holtiana* and *Zygophyllum humillimum. Atriplex kochiana, Brachyscome eriogona, Embadium stagnense, Gratwickia monochaeta, Sclerolaena holtiana* and *Zygophyllum humillimum* are listed by Briggs and Leigh (1995) to be of national significance.

Table 9.3 summarises the species of conservation significance recorded from the Arcoona Tableland.

TABLE 9.3 Conservation status of individual species

Species	National Status		
	EPBC Act	Briggs and Leigh (1995)	NP&W Act, NP&WMA Act
Atriplex kochiana		Poorly known	Vulnerable
Brachyscome erogona		Rare	Rare
Embadium stagnense		Poorly known	Rare
Frankenia plicata	Endangered		Rare
Gratwickia monochaeta		Rare	Rare
Sclerolaena holtiana		Poorly known	Rare
Zygophyllum lumillimum		Poorly known	Rare

More detailed information about these species is provided in Appendix D1.

9.2.6 Non-Vascular Plants

A number of non-vascular plants have been recorded in the region, although much of the limited work done on this group of plants has been undertaken north and south of both the region and project area. Groups represented include fungi, cyanobacteria (‘blue-green algae’), algae, lichens, liverworts and mosses. During the field work undertaken for this environmental impact study only lichens, liverworts and mosses were collected.

Compared with vascular plants, there has been very little survey of and interest in these plants, both in the region and Australia-wide. Consequently, there is limited understanding of their taxonomy and ecology.

Catcheside (1980), Filson and Rogers (1979), Flora of Australia (1992, 1994, 2001) Scott (1980), Scott and Stone (1976) and Lumbsch et al. (2001) documented some aspects of the taxonomy of these plants. Rogers (1972a, 1972b, 1982) and more recently Brock (1999), Eldridge (1996) and Eldridge and Tozer (1996, 1997) considered information about the functional ecological values of the non-vascular plants that provide a 'biological soil crust' in the arid zone of Australia.

Within the region there have been a few collections, the most recent of which was well to the north of the project area (Brock 1999). Seppelt, Rogers, Filson and Donner are known to have made collections on or immediately adjacent to the Arcoona Tableland.

The lichen, liverwort and moss flora was collected at each of the sites. In all, 19 taxa of lichen, growing on both soil and rock substrates, were observed. Site 52a exhibited a greater abundance and slightly higher diversity in lichens, with 18 taxa recorded compared to 16 and 8 for Sites 40a and 45a respectively. Site 52a lichen flora was characterised by a large number of species growing on both silcrete and quartzite rock. Site 45a has a slightly lower diversity and lower abundance of soil lichens (five species) than either of the other two sites. The diversity of species growing on rocks was limited at Site 45a.

Liverworts were represented by one species only, *Riccia crystallina,* and this species was confined to canegrass swamp areas. It was present at all three sites.

Two species of moss were recorded from each of Sites 40a and 52a, and one at Site 45a.

These data indicate that the non-vascular plant flora of Site 45a was typical of a site that had been more heavily disturbed and had a less intact soil surface than either of the other sites (Eldridge and Tozer 1997).

No published data are available on the conservation status of arid zone non-vascular flora.

9.2.7 Access Roads

Two land systems would be traversed by the access roads described below. These are the Arcoona land system, described above, and the Roxby land system. (Access routes are also described in Section 7.4 and shown in Figure 7.2). Badman (2001) described the Roxby land system, to the north and west of the Arcoona Tableland on Roxby Downs, Parakylia, Billa Kalina, Andamooka, Purple Downs, Arcoona and Wirraminna stations, as:

> …a large dunefield overlying older alluvial plains or ancient basement limestone. Limestone is often very close to the surface or occurs as outcrops. Red duplex soils or firm calcareous sands overlie the limestone, while siliceous sands occur on dunes and firm calcareous sands occur on rises. Alluvial silts and clays are associated with drainage channels, claypans and swamps.
>
> Mulga *(Acacia aneura)* woodlands are dominant in the main vegetation association, with white cypress pines *(Callitris glaucophylla)* also common on the larger dunes and horse mulga *(Acacia ramulosa)* common on siliceous sands of both large and small dunes. Tall shrublands of sandhill wattle *(Acacia ligulata)*, narrow-leaved hopbush *(Dodonaea viscosa* ssp. *angustissima)* and bullock bush *(Alectryon oleifolius)* are also common on dunes.
>
> Understorey is often dominated by kerosene grass *(Aristida holathera)*, with sand sida *(Sida ammophila)*, ruby saltbush *(Enchylaena tomentosa)* and rosy bluebush *(Maireana erioclada)* all widespread but not common throughout the whole unit. Western myall *(Acacia papyrocarpa)* and mulga woodlands are common in swales and white cypress pine occurs in some swales with deep sandy soils.
>
> Tall shrubland [sic] of senna (*Senna artemisioides* ssp.) are widespread and low shrublands of bladder saltbush (*Atriplex vesicaria*) and low bluebush (*Maireana astrotricha*) are common in the understorey of swales, although these are usually dominated by mulga grass (*Aristida contorta*). Australian boxthorn (*Lycium australe*), ball bindyi (*Dissocarpus paradoxus*), oblique-spined bindyi (*Sclerolaena obliquicuspis*) and desert lantern bush (*Abutilon otocarpum*) are widespread but not common throughout the whole association.

The other floristic groups represent changes in abundance of particular species rather than distinct land units. Small swamps are often bordered by *Melaleuca xerophila* (tea tree) low woodlands and *Eragrostis australasica* (swamp canegrass) is also common in or bordering such places. These areas are usually quite small. Claypans are more common than swamps but very little vegetation grows on them. They are often bordered by halophytic species, particularly chenopods, but these areas usually support the same species as the surrounding swales.

The proposal is for an upgrading of the access roads within the existing disturbed corridor and using existing materials. In this case the biological environmental impacts are likely to be minimal.

All access roads described below begin at the point where they leave the bitumen of the Woomera to Olympic Dam road, having proceeded from Woomera, and are shown in (see Figure 7.2).

Site 40a

The track used for access to this site is nearly twice as long as the straight-line distance between the site and Woomera. It traverses the undulating gibber plains of the Arcoona Tableland (Arcoona land system), a number of tableland escarpments and would also have to cross one large watercourse and several minor ones. Watercourse crossings are sandy.

This route does not encounter any vegetation that is significantly different from that recorded at other monitoring sites on the tableland.

Site 45a

The current access track proceeds along the Andamooka Homestead access road and then the old Arcoona to Andamooka opal field access road. It crosses areas of both the Roxby and Arcoona land systems.

Providing that all road material was obtained from the existing, defined road area only, upgrading the track would be practicable.

Site 52a

The access to this site follows existing major roads through the Woomera Prohibited Area (Arcoona land system). Most of these roads have a bitumen surface or fair to good quality unsealed surface. There would be no effect on native vegetation other than that which already occurs during routine road maintenance activities.

9.2.8 Introduced Plants

Ten of the 126 species (8%) recorded during the August 2001 survey are introduced taxa. This figure is lower than the overall percentage of introduced taxa recorded on the Arcoona Tableland. Appendix D1 lists 453 taxa for the Arcoona Tableland, of which 57 (13%) are introduced. Badman (1999) considered that introduced species made up about 10% of the total flora of northern South Australia (excluding the Flinders Ranges). Badman (1999) also reported 13% of flora as introduced for the Olympic Dam region, just north of the present study area, but including a different land system and greater diversity of habitats.

The low incidence of introduced taxa recorded during the current assessment may be partly due to the relatively undisturbed condition of the study sites. However, none of these sites are completely undisturbed and Laut et al. (1977) described the whole area as being in a ‘disturbed natural’ condition. The whole region has a long history of grazing by native, domestic and feral herbivores, as well as being subject to the operations and infrastructure of sheep and cattle stations. In addition, Site 52a has been heavily disturbed by the operations of the Woomera rocket range, as demonstrated by the many pieces of old infrastructure scattered across and adjacent to the site. Despite this, all of the sites remain relatively undisturbed by ground disturbing activities other than the feet of animals.

9.3 Fauna

This section details the fauna component of the biological environment for the region and the project area including threatened species and the status of threats and threatening processes, pest species, plus predicted impacts and mitigation measures.

9.3.1 Approach, Methods and Materials

The fauna assessment was established in three parts:

- a review and synthesis of published and unpublished data
- field surveys during August and October 2001
- analysis of results from the field information in relation to existing data to provide an assessment of actual and potential impacts of the proposal on faunal habitats and species.

Detailed information on all aspects of the field surveys, including all field data, is provided in Appendix D2.

9.3.2 Existing Information

The broad scale information most relevant to the current study comes from a biological survey of the Stony Deserts (Brandle 1998), and the studies associated with the design, construction, operation and expansion of WMC Limited's Olympic Dam Project from 1981 to present.

The area reviewed by Brandle (1998) encompassed a significant portion of northern South Australia and included all of the Arcoona Tableland. The environmental impact statements for the Olympic Dam mine, and its subsequent expansion, assessed an area approximately 40 km north of Site 45a (Kinhill-Sterns Roger Joint Venture 1982; Kinhill Engineers 1997). However, some of the data are directly relevant to the Arcoona Tableland, especially the assessment of infrastructure corridors south of Olympic Dam. The latter reference also reviewed and summarised the massive amount of baseline data that had been acquired over the previous 16 years of operation and monitoring at Olympic Dam.

In addition, Dr John Read has undertaken a extensive range of ecological studies in the region, both as an employee of WMC and as part of his own research interests (J Read Ecological Horizons, pers. comm. October 2001). The Lake Eyre South Monograph Series (Slaytor 1999a,b) provided detailed environmental information for the arid zone north of Olympic Dam, including the whole of the northeast of South Australia west of the Stuart Highway. However, some of the habitat and species distribution information for vertebrates is directly relevant to the current assessment.

Ehmann and Tynan (1997) provided a useful summary of the native and introduced vertebrate species recorded in the Gawler and Kingoonya soil conservation districts.

The listing of vertebrate species and their distribution for all of South Australia in Robinson et al. (2000) forms the basis of the taxonomy for the fauna species referred to in the section.

These studies and records from various sources, such as SA Museum, SA DEH and Birds Australia databases, form the basis of the predictive model for vertebrates in the project area and region.

(Note: Reference to specific studies and publications about individual areas and species in the region is made in the relevant section of the text.)

Photo 1: Site 40a, Fauna Survey Site No. 3

Photo 2: Site 45a, Fauna Survey Site No. 3

Photo 3: Site 52a, Fauna Survey Site No. 3

FIGURE 9.4
Example fauna survey sites

Although in recent times the quality and quantity of data for vertebrate species and their ecology in the region has significantly increased, little attention has been paid to invertebrate species. This is primarily due to the lack of qualified scientists and amateurs with the interest to undertake the requisite detailed studies into their taxonomy and ecology. Most of WMC's well-documented studies on invertebrates have been associated with the macro-invertebrates of the mound springs.

Extensive collections of terrestrial invertebrates have been made at some sites in the region, and the wider region, and lodged with the SA Museum and specialist taxonomists. These include the work done by Brandle (1998), studies for the Lake Eyre South monograph series, monitoring and research programs by WMC, and specific collections by staff from the SA Museum and the University of Adelaide. However, most of this material remains to be reviewed in detail. Of particular relevance to the current study is the potential use of some groups, primarily ants, as bio-indicators (Andersen 1990, 1993; Greenslade 1979; Read 1996; Read and Andersen 2000).

9.3.3 Regional Perspective

All three sites of the project area are characterised by a flat to gently undulating gibber plain on red duplex soils (Laut et al. 1977). All three potential repository sites are located on gibber plains and are, or have been, grazed by sheep. Sites 40a and 52a are located on gently undulating plains, while the landform of Site 45a is a flat plain with little immediate change in relief, notably to the east and south.

The sites are also characterised by low chenopod shrubland vegetation, with areas of gibber plain, canegrass swamp and gilgai. Figure 9.4 illustrates typical habitats in each of the three sites.

All three sites are similar to each other but differ in several aspects, namely:

- the relative proportion of canegrass swamp, which is greatest at 40a and least at 52a, with 45a being intermediate
- type and extent of gibber cover — Sites 40a and 45a are dominated by quartzite and Site 52a is dominated by silcrete
- the type and size of gilgai — Site 40a has several very large (1–2 ha) powdery, deep cracking gilgais with a large percentage of quartzite cobbles and boulders; Site 45a has smaller areas, with smaller quartzite rocks and often with gypsum in the subsoil; Site 52a gilgai areas are much smaller and often linearly oriented with small silcrete rocks in situ and as a surface scatter
- soil type and distribution, especially the type of soil cracks, with the deepest, widest cracking soils being in Sites 40a and 45a, while Site 52a generally has deep, relatively narrow cracks.

9.3.4 Climate

The climate and weather conditions of the region and, therefore, the project area exert a large influence on the distribution and abundance of the region's wildlife. The regional rainfall regime, in particular, has major implications for the region's faunal groups, often affecting the distribution and abundance of many species, and consequently the region's species richness (Owens and Read 1999; Read and Owens 1999a). The climate of the region is discussed in some detail in Section 8.6.

Large rainfall events are especially critical for seasonal birds, including wetland species, but they also influence the populations of sedentary birds. The heavy rainfall of 1989 highlighted the direct relationships of population and rainfall, and the life history strategies for many species (Read and Ebdon 1998). These events begin a medium term cycle of population growth and reproduction that provides benefits to species higher on the food chain.

Reptile diversity is not only influenced by rainfall but by seasonality, amount of sunshine and evapotranspiration. All are considered to be significant determining factors on diversity and abundance (Read 1995). Mammals, birds and invertebrates are probably also affected by these factors.

9.3.5 Predictive Fauna Model for the Region, Arcoona Tableland and Project Area

This section provides a summary of the actual and potential vertebrate fauna present in the region, Arcoona Tableland and at each of the three potential repository sites.

Mammals

The Australian arid zone fauna has experienced enormous changes in the assemblage of species since European settlement, and particularly since the introduction of *Oryctolagus cuniculus* (European rabbit), *Vulpes vulpes* (red fox), and *Felis catus* (feral cat). WMC (Olympic Dam Corporation) Ltd (1997) indicated that almost half of the arid zone terrestrial mammals were extinct on the Australian mainland and Owens and Read (1999) considered 15 species to be locally extinct. Owens and Read (1999) reported that 35 mammal species were extant for the Lake Eyre South region, while Kinhill Engineers (1997) recorded 26 mammal species for the Olympic Dam expansion project area.

Research by Brandle (1998) on the Arcoona Tableland and Owens and Read (1999) in the Lake Eyre South region found that cracking clay soils supported the highest species richness per site for small mammals, and chenopod shrublands and gibber tablelands supported the highest habitat richness of the six sampled habitat groups.

Short-beaked Echidna

Tachyglossus aculeatus (short-beaked echidna) is sparsely distributed within the region, with Brandle (1998) only recording the species once on the Arcoona Tableland. Furthermore, Kinhill Engineers (1997) recorded it for the first time in the Olympic Dam and Andamooka region in 1996, following 16 years of monitoring. Within arid regions, Strahan (1998) indicated that the species shelters in caves or crevices to avoid temperature extremes. One animal only was recorded at Site 40a.

Dasyurids

Four species of dasyurid, *Planigale gilesi* (paucident planigale), *P. tenuirostris* (narrow-nosed planigale), *Sminthopsis crassicaudata* (fat-tailed dunnart) and *S. macroura* (striped-faced dunnart), are known to occur on the Arcoona Tableland and further north in the Lake Eyre South region.

Cracking clay soils (gilgai) were significant habitat for all species, particularly *Planigale* spp. which were more selective in their habitat requirements (Owens and Read 1999). *Sminthopsis* spp. were more widespread, with *S. macroura* recorded in all habitat types including gibber tableland, sand dunes and chenopod shrubland. *S. crassicaudata* was less selective and was principally recorded on gibber tableland and cracking soils. Field results during the present survey confirmed these habitat preferences.

Kinhill Engineers (1997) and Owens and Read (1999) agreed that *P. gilesi* is locally rare, while both dunnarts appeared to be common.

Within the project area, *P. tenuirostris* was recorded for Sites 40a and 45a, *S. crassicaudata* from Sites 45a and 52a, and *S. macroura* from all three sites. The last species was the most numerous small mammal captured during the survey. *P. gilesi* was not recorded but is likely to be present at Site 40a and probably at Site 45a. The deep cracking soils of gilgais and areas adjacent to canegrass swamps were the preferred habitats.

Kinhill Engineers (1997) suggested that *Antechinomys laniger* (kultarr) was potentially present in the region of Olympic Dam. This species has a preferred habitat of sand dune, gibber tableland and mulga scrub. Consequently, it could also occur further south, although it would be at the very southern limit of its distribution. The species is considered rare over its range; it is noted for being evasive, solitary and nomadic.

Macropods

Macropus fuliginosus (western grey kangaroo), *M. robustus* (euro) and *M. rufus* (red kangaroo) occur in the region. *M. fuliginosus* is abundant in the south-central and south-western portion of Australia and has a secure conservation status. *M. rufus* and *M. robustus* are common but the euro is generally restricted to escarpments and rocky outcrops. The species has also been recorded on cracking soils and woodland, and is essentially solitary. In contrast, *M. rufus* is most abundant in gibber tablelands but occurs in most habitats. Population numbers vary markedly depending upon water supply and seasonal conditions. *M. fuliginosus* and *M. rufus* were common at all sites. *M. robustus* was present adjacent to Site 52a and would be likely to occur in and adjacent to the other sites.

Bats (Molossids and Vespertilids)

Eleven species of bat are known to occur in the region (Ehmann and Tynan 1997; Kinhill Engineers 1997). The Lake Eyre South (Slaytor 1999a,b) surveys recorded four species, none of which were associated with gibber areas. The apparent absence of bats in these habitats was also noted in Brandle (1998).

Woodland habitats, such as myall woodland and mulga scrub, are favoured by many species of bat because roost sites (tree hollows and under tree bark) are available. However, arid zone bats will travel up to 20 km from such habitat to drink from and forage over bodies of fresh water (Reardon 2001). Consequently, gibber habitats would be used during foraging activities but at low densities.

Field surveys in the vicinity of the three sites have confirmed the low abundance and diversity of bats in the region, a consequence of sparsely distributed roosting habitat (Reardon 2001). Species present in the Arcoona Tableland and the project area were *Nyctinomus australis, Mormopterus* sp., *Nyctophilus geoffroyi* and *Vespadelus baverstocki.* All species were recorded over water sources or in suitable roosting habitat adjacent to the sites. The abundance of bats in the project area was comparable to that recorded for the Lake Eyre South region (Owens and Read 1999) and for the Arcoona Tableland (Brandle 1998).

Studies to the north of the project area around Olympic Dam have recorded additional species including *Nyctinomus australis* in woodland habitats (Owens and Read 1999; Kinhill Engineers 1997), while *Chalinolobus gouldii* was recorded equally in rocky outcrop and woodland habitat. *Vespadelus baverstocki* preferentially used woodland habitat with a limited number of records over chenopod shrubland. *Nyctophilus geoffroyi*, a common species, was recorded in sand dune and rocky outcrop habitat.

Many of the bat species recorded at Olympic Dam appear to have a seasonal presence within the region. *Nyctinomus australis* has only been recorded during autumn and winter months; *Mormopterus planiceps* and *Scotorepens greyii* are common in spring; and *Nyctophilus geoffroyi* is common in spring and summer.

Nyctophilus timoriensis (greater long-eared bat) and *Saccolaimus flaviventris* (yellow-bellied sheathtail-bat) are listed as being State Vulnerable and Rare respectively. Both species, although recorded in the wider region, have not previously been recorded on the Arcoona Tableland.

Murids

Seven native murid species potentially occur within the region. Brandle (1998) suggested that *Leggadina forresti* (Forrest's mouse) had a preference for stony plains, but Owens and Read (1999) indicated that cracking soils and chenopod shrubland were favoured. Kinhill Engineers (1997) suggested the preferred habitat was tussock grassland and low chenopod shrubland. Surveys at each potential repository site indicate gilgai–gibber ecotone habitat was locally favoured. Consequently, the species probably occupies a number of habitats across the Arcoona Tableland. The species is recorded to have low capture rates, although this was not evident at Site 45a. *L. forresti* has been secure over its range (Brandle 1998; Lee et al. 1995), although it is listed as Rare under State legislation.

Brandle (1998) recorded *Pseudomys bolami* (Bolam's mouse) and *Pseudomys hermannsburgensis* (sandy inland mouse) on the Arcoona Tableland. Although Brandle (1998) only recorded *P. bolami* on the Arcoona Tableland and in the Lake Eyre South region, its preferred habitat was not gibber plain or gilgai. Owens and Read (1999) recorded the species in low chenopod shrubland and Kinhill Engineers (1997) indicated the habitat to be sandy to loamy soils in sparse mallee or Acacia woodland. It is unlikely that this species occurs in the project area.

P. hermannsburgensis is a species of the gibber plains and sand dunes and, though marginal habitat may be present adjacent to all sites, it would be at the southern-most edge of its distribution. It is unlikely to occur at any of the sites.

Pseudomys australis (plains rat), a nationally Vulnerable species, preferentially inhabits gibber plains and gilgai (Brandle 1998). This species is at risk due to introduced competitors and predators (Lee et al. 1995).

P. australis has been recently recorded at a number of sites north of the region and project area (e.g. Dismal Plain), with the Lake Eyre South region contributing a significant amount of suitable habitat for the species (Owens and Read 1999). The species has also been recorded in the Olympic Dam area (Kinhill Engineers 1997). There is a very recent record for this species in the Woomera Prohibited Area, at Ashton Hill, about 18 km south of Site 52a (A Starkey, Defence, pers. comm. August 2001). The species was not recorded at Site 52a but further research may indicate its presence adjacent to the site.

Until the current field survey, the species had not been recorded in the central area of the tableland in recent history. Specimens were captured in a variety of habitats but particularly on and adjacent to large areas of rocky, cracking clay gilgai. Brandle et al. (1999) considered this to be a secondary type of habitat. However, for the population of Site 40a, gilgai habitat appears to be preferred habitat and required for their continued existence (Appendix D2).

Kinhill Engineers (1997) recorded *Notomys fuscus* (dusky hopping-mouse) from near the Olympic Dam project area. The species is associated with sand dune habitat, and consequently is unlikely to be present at any of the sites under investigation. *Notomys alexis* has recently colonised sand dune habitat around Olympic Dam (J Read, Ecological Horizons, pers. comm. November 2001) but is unlikely to occur at any of the three potential repository sites. Similarly, *Pseudomys desertor* (desert mouse) is a species of the sandplains, dunes and vegetated floodouts well to the north of the project area (Brandle 1998) and is unlikely to be present at the sites. However, suitable habitat for the species is present on the Arcoona Tableland.

Dingo

The study area is just south of the dog fence, and under the *Dog Fence Act 1946* (SA), *Canis lupus dingo* (dingo) and dingo–dog hybrids are classified as vermin. Dingoes are abundant north of the dog fence and, although present in low densities, the species does occur in the region, tableland and project area.

Avifauna

Kinhill Engineers (1997) reported 175 bird species for the Olympic Dam region, while Read and Badman (1999) reported 187 species for Lake Eyre South region. Recent work by Read and Ebdon (1998) on the lakes of the Arcoona Tableland identified 56 species of waterbirds in the five-year period following the filling of many of the lakes (in 1989). Based on all sources of information, 118 bird species have been recorded on the Arcoona Tableland.

The research by Read and Badman (1999) highlights the importance of water bodies and structurally diverse communities in the wider region for bird fauna. Woodland communities, such as those associated with sandy rises, and wetland communities are structurally and compositionally more diverse than the chenopod shrublands of the gibber plains, and consequently provide a greater diversity of niches and habitat for a larger number of species. In contrast, bird assemblages of the gibber plains and cracking clays are reduced in species richness due to the less structurally diverse vegetation.

The lack of habitat complexity associated with the gibber plains and cracking clay soils vegetation suggests that a large proportion of the species recorded are nomadic, vagrant or migratory birds moving between resources or exploiting environmental fluctuations (e.g. flooding of inland lakes).

Table 9.4 summarises the habits of the species recorded for the Arcoona Tableland.

TABLE 9.4 Habit characteristics of Arcoona Tableland bird species

	No. of potential species
Permanent residents	28
Nomadic or with a moderate chance of being resident	67
Migratory or seasonal visitors	18
Vagrant	4
Total	**117**

Of those species recorded on the Arcoona Tableland (SA Museum, Birds Australia and SA DEH database records; Brandle 1998), more than half are considered to be opportunistic or moderately sedentary. Such species include *Charadrius australis* (inland dotterel), *Ardeotis australis* (Australian bustard) and *Epthianura aurifrons* (orange chat) (Brandle 1998). Permanent residents of the gibber tablelands include *Calamanthus campestris* (rufous fieldwren), *Malurus leucopterus* (white-winged fairy-wren), *Anthus novaeseelandiae* (Richard's pipit) and *Cinclosoma cinnamomeum (*cinnamon quail-thrush). The Arcoona Tableland provides key habitat for these species and consequently they will be more affected by development proposals than opportunistic species.

Populations of sedentary bird species experience fluctuations as a result of seasonal and annual variability in the abundance and availability of resources on the tableland. Invertebrate and vertebrate breeding following rains provide indirect benefits for sedentary species of the surrounding tableland as occurred during 2001. Drier years bring lower bird densities and thus less chance of detecting the species' presence. Furthermore, drier years will result in fewer individual opportunistic species, particularly those associated with ephemeral water sources.

The location of the Arcoona Lakes in the region is significant for the presence of many species, particularly waterbirds, migratory species and many opportunistic species. Read and Ebdon (1998) recorded 56 species over a period of five years, 15 of which bred during this time.

A number of species potentially present in the region are of listed conservation significance. Approximately 22% of arid-zone birds have declined since European settlement and 8% are of national conservation significance (WMC (Olympic Dam Operations) Ltd 1997). Most of these species are ground breeding birds and consequently have been heavily impacted by the introduced predators, the feral cat and red fox. However, no arid-zone birds are recorded as being extinct (WMC (Olympic Dam Operations) Ltd 1997). Table 9.5 summarises the conservation rating for bird species of the Arcoona Tableland. Eleven of these species are associated with wetland areas and the project area does not provide suitable habitat. *Ardeotis australis* (Australian bustard) and *Falco peregrinus* (peregrine falcon) are threatened species. Both were observed at or near Site 45a while the former species was also recorded at Site 40a. Both species are unlikely to be breeding in the area and future sightings will probably be infrequent.

In contrast to those species that have declined since European settlement, a number of species have benefited. The establishment of a network of permanent water sources (principally stock watering points) has contributed to the increase in abundance of species such as galah, crested pigeon, yellow-throated miner, Australian raven and white-plumed honeyeater. Water sources have also concentrated the distribution of predators and subsequently those bird species of conservation significance have declined in these immediate localities (Read and Badman 1999).

TABLE 9.5 Bird species and their conservation status

Species name	Common name	EPBC Act	NP&W Act	Distribution status
Anas rhynchotis	Australian shoveler		Rare	N
Ardea intermedia	Intermediate egret		Rare	N
Ardeotis australis	Australian bustard		Vulnerable	N
Biziura lobata	Musk duck		Rare	N
Cacatua leadbeateri(1)	Pink cockatoo		Vulnerable	N
Falco peregrinus(1)	Peregrine falcon	M	Rare	Va
Gallinago hardwickii(1)	Latham’s snipe		Vulnerable	S/Va
Grus rubicunda(1)	Brolga		Vulnerable	Va
Hamirostra melanosternon	Black-breasted buzzard		Rare	N
Neophema chrysostoma	Blue-winged parrot		Vulnerable	N/S
Numenius madagascariensis	Eastern curlew	M	Vulnerable	S/Va
Oxyura australis	Blue-billed duck		Rare	N
Pedionomus torquatus(1)	Plains-wanderer	Vulnerable	Endangered	Va
Phaps histrionica(1)	Flock bronzewing		Vulnerable	N/Va
Plegadis falcinellus	Glossy ibis	M	Rare	N
Podiceps cristatus	Great-crested grebe		Rare	N/Va
Porzana pusilla(1)	Baillon’s crake		Rare	N/Va
Stictonetta naevosa	Freckled duck		Vulnerable	N

N = nomadic, M = migratory species, Va = vagrant, S = seasonal

(1) Not recorded by Brandle (1998), Read and Ebdon (1998), nor SA Museum as occurring on the Arcoona Tableland

Herpetofauna (Reptiles and Amphibians)

Australia’s arid zone is characterised by an abundant and diverse reptile fauna and a few amphibian species.

Kinhill-Stearns Roger Joint Venture (1982) suggested that in the area west of Lake Torrens 63 species of reptiles were found, while studies in the Olympic Dam project area have recorded 41 species. Across all habitats of the Arcoona Tableland, 56 species have been recorded.

Reptile species richness in the region is greatest in sandy habitats; clay soil habitats and those communities with low structural diversity (e.g. some shrublands) have the lowest number of species (Brandle 1998; Read and Owens 1999b). This contrasts to mammals which have the greatest species diversity on clay soils. The low structural complexity and predominance of clay soils suggests that species diversity will be relatively low at sites on the Arcoona Tableland.

No species recorded for the region are listed as being of particular conservation significance under the EPBC Act and NP&W Act or Cogger et al. (1993). However, Brandle (1998) notes that three species maybe of future taxonomic significance: *Cyclodomorphus venustus* (samphire slender-bluetongue), *Ctenotus olympicus* (saltbush ctenotus) and populations of the *Lerista dorsalis* (four-toed slider) from the Arcoona Tableland, which are characterised by a brilliant red-orange tail.

More detailed population genetic studies by WMC on this last species indicate that this is not sufficiently distinctive to be recognised as a new species (Kinhill Engineers 1997).

Brandle (1998) also listed *Antaresia stimsoni* to be of Indeterminate status within South Australia and Uncertain nationally. The species is probably restricted to rocky ranges and is unlikely to occur at any of the proposed sites. It could be present along the rocky water courses adjacent to the access tracks to all project area sites.

Ctenotus taeniatus is also of taxonomic interest, as it is possibly a separate species, currently referred to as *C. brooksi taeniatus* (M Hutchinson, SA Museum, pers. comm. January 2002).

Appendix D2 provides a summary of those species recorded on the Arcoona Tableland and in the region.

Field assessment recorded 12 species at Site 40a and 13 species at each of Sites 45a and 52a. These totals probably underestimate the species diversity and abundance of reptiles, especially at Sites 40a and 45a where the habitat diversity is greater than at Site 52a.

Agamidae

Ctenophorus fordi is a species of sand dunes and is only associated with areas of *Gunniopsis quadrifida* and *Salsola kali* (Read and Owens 1999b). Consequently, it is unlikely that this species will be recorded at the project area, even though it has been recorded on the Arcoona Tableland.

Similarly, *C. pictus* generally inhabits sandy habitats, although it may be found in low shrublands over heavier soils.

Studies by Read and Owens (1999b) suggests that *C. gibba* is a nomadic species and does not burrow as much as other members of the genus. This species inhabits cracking soils and replaces *C. nuchalis* in such areas. The latter species inhabits sandy or loamy soil habitats. The northern areas of gibber, not the Arcoona Tableland, provide critical habitat for *C. gibba* (Brandle 1998).

Of the *Tympanocryptis* species previously recorded on the Arcoona Tableland, *T. tetraporophora* (Eyrean earless dragon) is the most abundant agamid of the gibber plains (Appendix D2). *T. intima* is also widespread on gibber plains, while *T. lineata* occasionally occurs.

Geckonidae

Nine species of gecko have been recorded on the Arcoona Tableland, with a further five species recorded for the region. *Diplodactylus tessellatus* is typically found on rocky, cracking soils; *D. damaeus* and *D. stenodactylus* are located on sandier soils and consequently are unlikely to be present in the project area.

Species of *Gehyra* are unlikely to be found at the proposed sites even through they are known to occur on the Arcoona Tableland. *Gehyra purpurascens* appears to be a tree specialist, while *G. variegata* is associated with woodland and rocky habitats (Brandle 1998) and will colonise infrastructure, such as buildings (J Read, Ecological Horizons, pers. comm. November 2001). Such habitat requirements are not provided within the sites but would be met if the proposal goes ahead.

Heteronotia binoei is a generalist species occupying a large range of habitats but favouring loose surface rock and drainage lines. The species is also commonly found in built structures.

The *Nephrurus* species, *N. levis* and *N. milii* (knob-tailed geckos), have been recorded on the Arcoona Tableland. However, *N. levis* is associated with sandy habitats and is unlikely to occur in gibber areas. *N. milii* is present in rocky habitats and occurs at all three sites.

N. deleanei (Pernatty knob-tailed gecko) is a vulnerable species restricted to dunes along the margin of the Arcoona Tableland. Suitable habitat for the species does not occur at any of the sites.

Pygopodidae

Three species have been recorded both in the region and also on the Arcoona Tableland. The legless lizards of the region appear to be widespread but uncommon. SA Museum records list *Pygopus nigriceps* (black-headed scaly-foot) within the vicinity of all three sites.

Scincidae

Half of the 23 species of skinks recorded on the Arcoona Tableland were probably associated with gibber plains and gilgai soils. *Ctenotus olympicus* and *C. strauchii* are species of such habitats; *Tiliqua rugosa* and *Menetia greyii* are widespread species also occurring in a number of other habitat types. Brandle (1998) also recorded *Eremiascincus richardsonii* as potentially being present.

Lerista dorsalis populations of the southern and central sections of the Arcoona Tableland are distinctively coloured, having bright red tails (Brandle 1998). Similar colouration also occurs in *Lerista bougainvillii*.

Varanidae

Varanus gilleni (pygmy mulga goanna) and *V. gouldii* (sand goanna) are residents of the Arcoona Tableland. Both occur across the project area but the former is uncommon.

Typhlopidae

The blind snakes, *Ramphotyphlops* species, are widespread in the arid zone of South Australia. Two species, *R. bituberculatus* and *R. endoterus*, have been recorded on the Arcoona Tablelands and may be present at the proposed sites.

Boidae

Antaresia stimsoni (Stimson's python) is present on the Arcoona Tableland and has been recorded at Woomera (SA Museum database) and on Andamooka Station (J Read, Ecological Horizons, pers. comm. November 2001). *Aspidites ramsayi* (woma python), although recorded in the region at Olympic Dam, has not been recorded on the Arcoona Tableland.

Elapidae

Six species of Elapidae have been recorded for the Arcoona Tableland, all of which appeared to have been widespread throughout the arid region. Most, if not all, would be expected to occur at each of the three sites.

Leptodactylidae

Amphibian diversity is low for much of the stony desert area (Brandle 1998), including the project area. *Neobatrachus centralis* (trilling frog) is the only species to have been recorded in the region, for the Arcoona Tableland and at all three sites. The species spends a large portion of its life underground (Read and Tyler 1994) with spasmodic breeding events following rain.

Invertebrates

The diversity of invertebrates in the region and Arcoona Tableland is relatively unknown, as most of the previous faunal studies have focused on vertebrates. Specimens collected from past studies are, in general, yet to be identified or studied in detail. Species richness depends on seasonal conditions (Kinhill Engineers 1997) and consequently is in a state of flux. Read and Andersen (2000) provided a useful summary of some of the ant species in the Olympic Dam area and their potential use as bio-indicators

Ants

Shattuck and Barnett (2001) indicated that the Australian arid zone has about 25 ant genera — considered to be a low diversity. None of these genera are endemic to the arid zone, and generally also occur in more coastal areas. The diversity of species is similar to that of the coastal areas, while the semi-arid transition zone appears to have a greater diversity.

Field studies identified nine genera within the project area, representing seven different functional groups (Andersen 1990): dominant Dolichoderinae, associated subordinate Camponotinae, hot climate specialists, cold climate specialists, cryptic species, opportunists, and generalised Myrmicines (Table 9.6).

TABLE 9.6 Ant functional groups in the project area

Functional group	Genera	Relevant features
Dominant Dolichoderinae	*Iridomyrmex*	Abundant, active and aggressive; able to monopolise resources
Generalist Myrmicines	*Monomorium* *Pheidole*	Unspecialised behaviour but successful competitors owing to rapid recruitment and effective defences
Opportunists	*Rhytidoponera* *Odontomachus*	Unspecialised behaviour; poor competitors
Other groups	*Melophorus* *Camponotus* *Prolasius* *Hypoponera*	Variety of subordinate or highly specialised ants, usually with features that reduce interactions with other ants

Functional group distribution for the three sites is comparable to a site with little disturbance (Andersen 1993). Dominant Dolichoderinae (*Iridomyrmex* spp.) are the most abundant species, proportionally followed by opportunistic species (*Rhytidoponera* spp. and *Odontomachus* spp.). Cold climate species (*Prolasius* spp.) were only recorded at Site 52a, and are a group that is generally more abundant in habitat with reduced *Iridomyrmex* (Andersen 1990). Similarly, *Hypoponera* (a cryptic species) was only recorded at Site 52a.

No sub-cryptic or solitary foragers were recorded at any site. Future monitoring will probably increase the number of genera, species and functional group diversity.

Spiders

The arid zone of Australia, and the region, has a large and poorly studied spider fauna. Very few surveys have been undertaken on the Arcoona Tableland and invertebrate specimens collected from the region are yet to be assessed in detail. Table D2.12 provides a summary of the specimens recorded.

Thirteen families of ground-dwelling spiders, with 30 subordinate taxa, have been recorded. Miturgidae (lined spiders) were the most abundant, followed by Lycosidae (wolf spiders). Amaurobiidae and Dictynidae were the least observed, each with only one specimen captured, both at Site 52a. Site 52a was the only site to record at least one specimen for all families represented.

Zodariidae (spotted ground spiders) were the most diverse group with six taxa, followed by Lycosidae, with five taxa. Site 52a supported the greatest spider diversity; Sites 40a and 45a supported lower and similar diversities.

A greater diversity of species is expected at all sites with more extensive sampling. For example, only five species of Lycosidae were collected but more species are expected to be present in the region (D Hirst, South Australian Museum, pers. comm. November 2001). Such spiders have specific habitat requirements and consequently may occupy a range of microhabitats in the region.

A number of specimens collected in the project area are of scientific interest. The Amaurobiidae representative collected at Site 52a has not, apparently, previously been collected. This species is of particular taxonomic interest and may represent a new species. The collection of *Durodamus yeni* at Sites 40a and 52a extends the known distribution of this species from Etadunna Station, 300 km northeast of Woomera.

Species of Zoridae and Prodidomidae are widespread in the northeast of South Australia but are rarely collected. Their collection on the Arcoona Tableland is of biological interest.

Introduced Animals

Eight species of introduced mammal and three species of introduced bird are present in the region and Arcoona Tableland. All are contributing to the decline in many native species.

Of particular concern are *Oryctolagus cuniculus* (European rabbit), *Vulpes vulpes* (red fox) and *Felis catus* (feral cat). The impact of these species on the plant and animal diversity and abundance has been significant. The introduction of rabbit calicivirus disease to the area in 1996 has generated a significant reduction in the arid zone rabbit population, and provided positive flow-on effects for populations of plants (cover and abundance) and small mammals (WMC (Olympic Dam Operations Ltd) 1997).

Red fox is regarded as being evenly distributed over all habitats, while feral cat (and European rabbit) appear to favour dune swale habitat over gibber plains (Read 1994; Read and Bowen 2001).

The predation and competition generated by the presence of red fox and feral cat is a major contributor to the reduction in abundance and distribution of many small mammals and reptiles (Read and Bowen 2001).

The impact of European rabbit is listed under the EPBC Act as a threatening process due to the competition it provides for native herbivores and its contribution to land degradation. Predation by red fox and feral cat on native species has resulted in these two species also being listed as threatening processes under the EPBC Act.

All three species are present or likely to occur at each of the three sites.

Rattus rattus (black rat) and *Mus musculus* (house mouse) have been recorded in the region, and house mouse on the Arcoona Tableland. During good seasons, the numbers of these species can quickly build up and place pressure on the resources available for native species.

Passer domesticus (house sparrow), *Sturnus vulgaris* (common starling) and *Streptopelia chinensis* (spotted turtle-dove) have been recorded for the region and Arcoona Tableland. The former two species were recorded at Koolymilka, the latter was present at Woomera, but none was recorded at any of the three sites.

No introduced invertebrates were recorded at any of the three sites.

9.4 Impacts and Risks — Construction

The principal impacts of the project on the biological environment would be associated with construction activities for the repository. It is anticipated that these activities would include:

- road design and construction, including potential upgrading or realignment of existing roads (depending upon the site chosen), potentially including widening and surface upgrade, and accession of material from borrow pits
- clearing and levelling of part of the final site within the buffer zone for infrastructure and trench development (most of the site would be left as undisturbed buffer)
- construction of perimeter fencing, plus security patrol tracks.

Any potential adverse environmental impacts and risks can be managed and minimised by careful planning before any ground-disturbing work is begun.

9.4.1 Vegetation and Flora

The principal impacts associated with construction activities are the direct and indirect loss of vegetation (as fauna habitat) through clearance and the increased risk of weed introduction and dispersal from construction vehicles and equipment. Vegetation clearance is listed as a key threatening process under the EPBC Act due to its ability to cause a species to become threatened or its threatened status to be upgraded to a higher level of threatened classification. Some minor vegetation clearance would be necessary for road realignment and construction if Sites 40a or 45a were determined to be the preferred site. Furthermore, vegetation clearance within the central 500 x 500 m zone (100 x 100 m of which would be occupied by trenches) would be undertaken for infrastructure and disposal trench/borehole development.

Initial site clearance is expected to only involve the vegetation that must be removed to carry out construction activities. Maintaining native vegetation would minimise dust and erosion problems, as well as the introduction of weeds. Once the repository is established, all future activities would be kept to existing infrastructure areas, such as roads, tracks and hardstand areas.

The extent of vegetation clearance likely to take place at the repository site is a very small area in relation to the distribution of the vegetation communities across the Arcoona Tableland and the existing impacts associated with use of each of the potential sites. Consequently, the impacts of vegetation clearance on the vegetation communities and habitats would be strictly limited.

Introduction of Weeds

Any form of ground disturbance provides an opportunity for the establishment of weed species. However, this can be minimised by good management practices including:

- minimising the area that is disturbed
- preventing the introduction of seeds, particularly of species that are not already present in the area by appropriate cleaning of any plant, machinery or vehicles that are brought on to site during construction.

There are few introduced plant species present at the three potential repository sites but ground disturbance for the construction phase of the project might provide opportunities for weed establishment, which in turn could lead to loss of space and resources for native species, and an increased risk of exotic populations of spreading into surrounding areas. It is planned to minimise such impacts by:

- promoting the establishment of perennial native grasses
- promptly removing weeds, particularly perennial species, before they become established.

Erosion

The potential for accelerated erosion of soils on gibber tablelands is greatest when the protective gibber mantle is removed or disturbed. This is most likely to occur during construction. Any gibbers that are removed from the central repository area would be stockpiled separately from topsoil, subsoil and other material so that they can be replaced following construction or as part of decommissioning. Care would be taken not to alter flows in any drainage channel, either by blocking it or by excavating across or within the channel (this is likely to be a greater problem at Sites 40a and 52a than at 45a).

Soil erosion may be caused by construction activities, through accelerated wind and water erosion, for example by surface deflation, rilling and gullying following removal of the gibber strew from the surface of the stony desert soils. In addition, some of the subsoil at the sites would be dispersive if saturated by water. The removal of the surface strew from gibber plains combined with a heavy rainfall event can result in significant and major accelerated erosion, so this would be avoided.

Topsoil Management

Any topsoil that is removed during construction can be stockpiled for future use, with any cleared vegetation placed on top of the topsoil stockpile in order to provide additional protection of the topsoil from wind and water erosion and also provide a vegetated stockpile that would be an ongoing seed bank. It is anticipated that such topsoil stockpiles could be placed on flat ground wherever possible and if necessary protected from water erosion by the construction of suitable banks and drains.

Dust generated by increased frequency of traffic on tracks and exposure of the soil surface may be sufficient to defoliate perennial shrubs (Kinhill Engineers 1997). Traffic would be largely confined to the time of initial construction and first burial campaign. After that, campaigns are expected to be significantly smaller and only occur once every 2–5 years.

Any amenity plantings of vegetation around the repository would be confined to species indigenous to the Arcoona Tableland.

9.4.2 Fauna

Construction activities and traffic movement pose a hazard to wildlife, either directly or indirectly, through:

- loss of habitat by vegetation clearance or ground disturbance
- increased competition with other animals through displacement from their home ranges
- increased predation due to lack of shelter and displacement stress.

The more sedentary nature of some mammal and retile species, as opposed to bird species, places them at greater risk of impact. The impacts may not be significantly detrimental to species but would negatively impact on local populations.

Five threatened animal species have been recorded within the project area. Of these the most significant is plains rat, which is listed as Vulnerable under the EPBC Act. It is present at Sites 40a and 45a. The population of this species appears to be larger at the former site where it was present at two of the three trapping sites. The distribution of the species outside of the boundaries of Sites 40a and 45a is unknown but suitable, good quality habitat of rocky gilgai is present. Therefore, it is likely that the species would occur elsewhere in the vicinity. Any activity within the buffer zones of Sites 40a and 45a should avoid, as much as is practicable, all key habitat areas actually or potentially occupied and used by this species. Monitoring of the population of the species can address this.

Key threatening processes (predation by foxes and cats, and competition and land degradation by rabbits) may be increased as a result of construction, although this is unlikely if suitable management procedures were established and implemented. This could be accomplished by establishing a perimeter fence and then removing all pest animals.

In order to exclude large fauna from the site, a fence of equal construction to the dog fence would be required, that is one that excludes all medium and large mammals. (Normal station type cattle and sheep fences do not exclude kangaroos, which are able to jump over a fence of this height.) Rabbit netting can exclude rabbits. It is anticipated that the outer fencing would be of such a standard that the area becomes a wildlife refuge similar to, but much smaller than, the Arid Zone Recovery Project at Olympic Dam, which provides a suitable model for this project area.

A rabbit, fox, cat, stock and kangaroo proof fence around the perimeter of the preferred site would establish an exclosure facility for monitoring the recovery of native species without the threats imposed by exotic species and larger native grazing species. Such an exclosure facility may, in future, provide valuable opportunities for management of threatened species and as a reference site for the Pastoral Board. Animals protected by this exclosure would be small enough to get through the fence should their range require it.

The area cleared for fence construction would be the minimum necessary for safe construction and maintenance of the fence.

Animals that enter or fall into the trench during construction would be able to exit up the access ramp. Animals that fall into the boreholes would be removed before daily work began. Construction periods would be quite short (weeks for trenches, days for boreholes) and thus, even if rain fell during construction, there would not be time for a drought refuge for wildlife to form.

9.5 Impacts and Risks — Operation

The activities associated with the operation of the repository would generate fewer impacts on biodiversity. The infrequent operational activities would include:

- transportation of materials to and within the site for burial
- maintenance of facilities and infrastructure, including fire breaks and surface water runoff management
- sewage management and wastewater management, including washdown water
- burial and monitoring of the low-level radioactive waste

- coordination of repository operational and land management activities with Pastoral Board, the adjacent landholder(s) and other stakeholders, particularly in the case of Site 52a, with the Department of Defence and other users of the WPA (e.g. government agencies).

9.5.1 Vegetation and Fauna Habitats

Waste would be transported to the site during the first disposal campaign and then infrequently, possibly every 2–5 years. Activity at the site between the disposal campaigns would only involve monitoring. Times of increased traffic in the area of the preferred site have the potential to increase weed introduction and establishment, along the route and at the site.

Fire is generally not a problem on the chenopod shrublands of the Arcoona Tableland. However, fire may occur in this habitat following exceptional seasons if a substantial fuel load of mainly grasses has built up in the understorey (Kingoonya Soil Conservation Board 1996). However it is anticipated that in between waste burial campaigns there would be no or little infrastructure that can be affected by fire left at the site. For other times of activity, a cleared track two grader blades (8 m) wide around both fences could provide adequate protection from bushfires, which also, under extreme conditions, could be used as a base for back-burning operations to protect the site.

Operational activities are unlikely to cause further disturbances to the lifecycle of plants following construction.

9.5.2 Fauna

It is anticipated that the installation of a vermin-proof fence would continue to restrict the movement of larger species during operation of the waste repository. The resultant benefits provided for small mammals and reptiles would outweigh the restriction of larger animal movements.

The development of a more structurally diverse area may provide habitat for those species that use built structures, particularly some birds, lizards and bats. There is potential to introduce pest vertebrates and invertebrates to the site on vehicles accessing the region from other parts of Australia. This could be managed by appropriate monitoring measures such as vehicle and load hygiene management controls, and appropriate monitoring at the site.

Movement of Radionuclides Baseline Studies

The baseline data for radionuclides have been analysed and are discussed in Section 12.2.1. It is proposed that vegetation and fauna monitoring for the uptake of nuclides be undertaken five yearly.

9.6 Impacts and Risks — Surveillance

It is anticipated that surveillance of the repository site between disposal campaigns may include:

- periodic monitoring of the site between campaigns
- maintenance of access restrictions
- maintenance of infrastructure
- management of repository contents.

9.6.1 Vegetation and Flora

Potential impacts associated with the above activities might include:

- disturbance of vegetation along the edge of the perimeter track
- possible development of some channelled water flows, with the potential for accelerated erosion and weed establishment.

9.6.2 Fauna

Management practices would aim to reduce or minimise and, where possible, avoid impacts of operational activities on fauna associated with any:

- disturbance from human activities
- accidental introduction of pest plants and animals, especially invertebrates.

9.7 Impacts and Risks — Decommissioning and Institutional Control

The recommended end-use of the repository site is as a biological reference area for the Arcoona Tableland. The minimalist approach to vegetation removal and impacts suggested above can help achieve this goal. Depending on the amount of monitoring required for the repository site itself, most hardstand areas might be suitable for rehabilitation. This would require standard rehabilitation techniques including the removal of hardstand, ripping and seeding with locally collected seed.

Associated activities and impacts include:

- closure of trenches/opening of trenches
- removal of infrastructure
- site restoration, including gibber replacement and revegetation with a saltbush community.

9.8 Environmental Safeguards to Minimise Impacts

A number of the impacts generated by the development can be reduced or minimised by developing procedures and safeguards. Table 9.7 summarises the general impacts associated with the proposal and Table 9.8 summarises the environmental safeguards for the impacts and risks considered in the previous section. These requirements would be formalised in an EMP for construction and operation of the repository.

9.9 Monitoring Program and Procedures

9.9.1 Vegetation and Flora

Vegetation monitoring has been established to ensure that four of the monitoring sites at each of the three potential waste repository sites would be outside the outer fence when it is constructed. These monitoring sites would act as control sites to detect any changes in vegetation that may occur inside the fenced area as a result of the construction works and operation of the repository.

TABLE 9.7 Likely and potential general impact areas and risk during construction, operation, surveillance, decommissioning and institutional control

Potential impact	Construction	Operation–surveillance	Decommissioning–institutional control
Disturbance to vegetation	H	L	L
Loss of topsoil	H	L	M
Interception and concentration of surface water flows	M	L	L
Altered drainage patterns to swamps and drainage channels	M	L	L
Accelerated erosion from excavations in drainage channels	L	L	L
Erosion of dispersive soils	M	L	M
Rutting of surface by construction traffic	M	L	M
Dust from trafficked areas	M	L	M
Introduction of weeds	H	M	M
Fire	L	L	L

H = high risk, M = medium risk, L = low risk

TABLE 9.8 Environmental safeguards to minimise the impacts of the proposed repository

Repository phase	Impact or risk	Environmental safeguard
Construction	**Vegetation**	
	Vegetation clearance	Before construction establish detailed photopoints and baseline plans of existing conditions; minimise disturbance by restricting vegetation clearance to only that necessary for building siting and trench development; place cleared vegetation over areas of disturbance following construction
	Weed introduction and dispersal	Keep vehicle hygiene to a high standard i.e. only clean machinery allowed on site Eradicate existing weeds Identify and remove newly established populations of weeds
	Threatened species	Survey access routes for threatened species; maintain a watching brief for presence of rare species within the fenced exclosure; where appropriate clearly mark and avoid all populations (or individuals); implement approved conservation measures for each species
	Accelerated soil erosion	Restrict surface disturbance to that necessary to complete construction; stockpile surface strew and topsoil and replace in appropriate areas or use elsewhere on the site; establish water management techniques as part of construction
	Off-road driving	Prohibit vehicle movement off existing or proposed road alignments and within the buffer zone; restrict vehicle movement within the operational zone to those areas of construction

Repository phase	Impact or risk	Environmental safeguard
	Fauna	
	Direct loss of individuals	Stage the construction to allow fauna adequate time to vacate burrows, roosting and nesting sites; where trenches are constructed, conduct daily checks for trapped animals; capture trapped animals and release nearby; undertake construction activities outside of the main breeding season for sedentary species (particularly threatened species)
	Loss of habitat	Habitat loss is associated with vegetation clearance and surface disturbance: confine disturbance activities to those areas essential for construction
	Increased competition for resources and predation	If practicable, undertake construction outside of dry conditions to reduce the stress on available resources and animals
	Threatened species	Define and avoid habitat critical for threatened species e.g. deep cracking soils and canegrass areas
	Pest species	Undertake control of pest species, particularly red fox, feral cat and European rabbit after fencing; maintain a clean construction site to prevent attracting pest species
		Monitor invertebrate species for the presence of introduced pests
	Fencing	Establish predator and stock proof fencing; maintain its integrity
Operation	**Vegetation**	
	Weed introduction and dispersal	Keep vehicle hygiene to a high standard, i.e. only clean vehicles allowed on site, and provide facilities for washdown
		Remove newly established weed populations
	Movement of radionuclides	Establish baseline monitoring in flora
	Wastewater and sewage management	Control wastewater in a closed environment and dispose of it appropriately to discourage weed establishment and vermin
	Fauna	
	Habitat creation from built structures	Monitor incidence of native and pest species, especially vermin and invertebrates in the latter category
	Movement of radionuclides	Establish a suite of monitoring species
	Non-radioactive waste management	Contain all waste and dispose of it off site; separate recyclable waste and transport it to a recycling depot or other appropriate establishment
Surveillance	Vegetation disturbance	Maintain all programs established above
	Fauna disturbances	Maintain all programs established above
Decommissioning and institutional control	General	Restore the site to as natural a state as practicable; use baseline photographs and plans established at the start of the project

The central vegetation monitoring point of the chosen storage site would probably be destroyed during construction of the storage facility. This would leave eight sites inside the perimeter fence, including four sites midway between the inner and outer fences and four sites near the outer corners, some or all of which can be used for ongoing vegetation monitoring.

There would be little advantage in carrying out annual or more frequent monitoring beyond the first few years after the repository is established (unless there are obvious changes to vegetation inside the fenced area). Monitoring is envisaged after the first few years at intervals in the order of five years. Vegetation monitoring can be staged so as to take advantage of good seasons, especially following summer rainfall. This would allow the compilation of a more complete database on the local vegetation, including the summer-growing grasses that were absent at the time of the August 2001 survey.

Subtle changes in the vegetation that cover a large area would not be detected by these methods but changes can be identified by comparing the baseline data and photos for perennial species at each monitoring site. If such changes are suspected to be occurring and the control sites outside the fence are also in similar condition and thought to be affected, this can be assessed by comparison with the vegetation of several new sites further away from the repository site.

The repository site could form an important reference area for vegetation monitoring programs on the Arcoona Tableland. It could have importance for Commonwealth and State government agencies and for local communities, such as the Council for Sustainable Vegetation Management, Department of Defence, South Australian Rangelands Program and local soil conservation boards.

Elements of the flora monitoring program could include:

- photopoint monitoring and quantitative surveys at the sites established in the field during August
- biodiversity indicator monitoring — based on the quantitative survey data
- pest plant species
- fire fuel loads
- radionuclide monitoring in target species.

After the repository was closed, these programs could be continued annually for five years and then conducted every five years.

9.9.2 Fauna

Elements of faunal monitoring programs may include:

- presence of burrowing animals in repository trenches and other animal species in and around infrastructure
- fauna surveys of invertebrates and vertebrates to be based on the current permanent trapping sites (as detailed in Appendix D2)
- establishment of existing incidence of mutations in trilling frog populations
- maintenance of zero introduced large and medium pest vertebrates, stock and kangaroos within fenced area
- radionuclide monitoring in target species, especially ants.

After the repository was closed, these programs could be continued annually for five years and then conducted every five years.

Chapter 10
Land Use and Activity

10.1 Overview

The land use and activity assessment in this chapter considers the three site options located in the central–north South Australia.

The assessment considers the existing situation of human activity since European settlement, identifies the potential for this situation to change and evaluates possible impacts during the various stages of the national repository's life. The assessment is taken from a primarily non-Aboriginal cultural perspective; issues of indigenous culture, activity and values are addressed in Chapter 11.

The assessment of existing and potential future land use and activity is required in order to establish the extent to which:

- the proposed development might be incompatible with existing activities
- future developments might be incompatible with the proposal.

10.2 Site Planning

10.2.1 State Development Approvals

In most circumstances the *Development Act 1993* controls development and changes of land use throughout South Australia. However, in the case of the national repository, Planning SA, after obtaining Crown legal advice, has advised that no Development Application is required at the State level, as the facility would be constructed on Commonwealth land.

Environmental impact assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Section 1.2 of this document) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) licensing requirements (Section 3.3) satisfy the required land use assessment and approvals requirements for 'controlled activities' such as the waste repository.

Nevertheless, it is noted that the relevant Development Plan and zoning policy for this area present few limitations to the development of this type of facility, provided that environmental and conservation principles are addressed. On the other hand, the zoning does not limit the nature of activities and land uses that might be established in the region in the future.

10.2.2 Nature of the Operation and Facilities

The proposed national repository would have the following features (Sections 6.2 and 6.3):

- an appropriate access road
- security and feral animal-proof fencing
- disposal trenches and/or boreholes that would be filled and capped at the conclusion of each disposal campaign

- support facilities, including an operations building etc (Figure 6.5*)*
- possible other support infrastructure.

The site would be 1.5 x 1.5 km in size, and would largely comprise an undisturbed buffer zone with the disposal structures located in the central 100 x 100 m area of the site. The buffer zone would ensure that there is a space between the disposal structures and any other activity that may occur in the region.

With the construction of feral animal-proof boundary fences and the eradication of feral animals from within, there is potential for the buffer zone to become a native fauna and flora regeneration area (see Section 6.1.5 and 9.4–9.9).

The site of the repository facility and its associated buffer zone would be under the control of the Commonwealth which, in effect, prevents the establishment of other activities in the immediate vicinity and aims to prevent any unauthorised intrusion onto the repository site.

Operation Activity Levels

The level of activity associated with the proposed repository is likely to reach a peak at the construction stage and the following, initial, disposal phase. There would be some small additional activity arising from the establishment of monitoring programs, and from inspections by regulatory authorities and visitors.

Once the initial disposal of waste is completed, it is expected that the facility would generate only limited activity at times when the repository was opened for the disposal of waste, anticipated to be once every few years.

The level of activity at the repository site would probably be restricted to:

- occasional delivery of waste and other materials (during construction and infrequent disposal campaigns)
- on-site handling and disposal of waste (during infrequent disposal campaigns)
- maintenance, monitoring and security activity (between disposal campaigns)
- retrieval of waste if required.

Thus the level of activity directly related to the operation of the facility is likely to be relatively limited.

10.3 Visual and Landscape Considerations

10.3.1 Existing Landscape Character

The existing landscape character has both natural features (e.g. topography, vegetation and colours) and constructed features (e.g. buildings, infrastructure and signs). From the perspective of the viewer, which in the case of this project would be largely from a vehicle or road, the nature of the landscape can be described as an open, flat, gibber desert plain with few features dominating the landscape. It has a notable rich red colour interrupted on occasion by rolling, low-level sand dunes which support vegetation from shrubs to small trees. There are other more limited areas where the desert gives way to drainage lines, which have a more distinctive topography and support more substantial vegetation. The colours of the landscape can be striking, with rich red to yellow sands and the grey–green foliage of the vegetation.

The following observations are relevant to the specific selected sites.

Site 52a

This site (see Figures 9.3 and 9.4) is located within the Woomera Prohibited Area (WPA) and thus access to the area by the public is restricted. The flat plains of the gibber desert are the predominant natural feature, but some lakes break up this landscape, in particular the varied topography around Lake Hart. The landscape is also dotted with various items of Department of Defence (Defence) infrastructure, which is largely associated with its use as the WPA. These structures include a hangar, small offices, overhead lines, pipelines at ground level, roads and concrete remnants of structures.

The access road to the site is partly sealed and partly good all-weather gravel road (see Section 7.4 and Figure 7.2).

Those that experience this landscape are likely to be in the locality for Defence-related business, research or maintenance purposes, and pastoral activity.

Site 45a

Here, the gibber desert is the key feature (see Figures 9.3 and 9.4) but, unlike Site 52a, there is little evidence of constructed features (apart from fences and occasional station buildings). The access track is unsealed and some sections are in poor condition. The access track passes through a number of areas of high landscape value (e.g. sand dunes and vegetated drainage lines) some distance from the site.

Most people who experience this landscape are likely to be associated with local pastoral activity, off-road tourists and Aboriginal people.

Site 40a

This site is dominated by the limited features of the gibber desert plain (see Figures 9.3 and 9.4). The constructed features of the broad area are limited to fences and some ruins in the adjacent landscape. The current access road is an unsealed track and passes through some areas of landscape significance (sand dunes, views to The Pines area to the east and creeks (Figure 7.2)).

Most people who experience this landscape would be associated with the activities described for Site 45a.

10.3.2 Visible Elements of the Proposal

The key visible elements are likely to include (Figures 6.3 – 6.5):

- the access road
- during initial construction, and at subsequent disposal campaigns:
  - trenches or boreholes, which then would be covered and seen only as low relief earth mounds in between campaigns
  - sheds and buildings required to accommodate the various activities of the operation, in particular the operations building, conditioning facility and health physics facility
  - car and truck park areas

- security and feral animal-proof fencing.

The preferred colours, materials and specific design of these facilities have not been identified; however, it is expected that the facilities would be portable buildings for the office and similar facilities, and simple buildings of steel and corrugated iron construction for operational purposes (Section 6.4.2). It is intended that most of the buildings and other on-site infrastructure, apart from the security fencing and any brick buildings or permanent structures, would be removed from the relevant site between disposal operations.

10.4 Land Use and Demographics

10.4.1 Historic and Existing Land Use and Activity

The existing physical and biological environment has been described in detail in the previous chapters. An overview of land uses and attractions is contained in Figure 10.1. This environment establishes a context and certain parameters for human activity and land use. In general terms, the extent of post-European-settlement human activity in this region has been limited to key centres that are either located on transport routes or supporting mining, Defence or research activities. The only other settlements in the area are associated with large rangeland grazing properties; homesteads are sparsely scattered throughout the region.

The lack of obvious, easily accessible and usable water sources, limited transport and urban infrastructure, and the open desert environment have significantly limited human activity in this region since European settlement. Much of this activity, historically and currently, is confined primarily to:

- copper mining at Mount Gunson, copper–gold–silver–uranium mining at Olympic Dam, and opal fields at Andamooka and Coober Pedy
- rangeland grazing activities (primarily sheep and cattle)
- remote area tourism and research activity
- high technology Defence research and trials activity, and other uses of the WPA including those related to the aerospace industry, various types of research, the storage of radioactive waste and the detention of asylum seekers
- a number of townships or service centres and their associated living, recreational, tourism and business activities.

The very environmental conditions that limit human activity, and the relatively remote nature of the area, attracted the most notable activity in the region — the Woomera research and testing facility. The establishment of Woomera in the mid-1940s brought with it an extraordinary level of infrastructure and human activity. At its peak (around 1974) this township accommodated some 4000 people (compared with its present population of around 400). The level of activity associated with Woomera has fluctuated over time and this is likely to be a continuing feature of the town, although population levels are unlikely to reach the previous peak numbers.

The other main centres of activity in the region include:

- Olympic Dam (copper–gold–silver–uranium mining and metallurgical operations) and its service centre Roxby Downs
- opal mining and the associated Andamooka township
- Pimba and Glendambo service centres for Stuart Highway travellers.

Beyond these centres of activity, there are a number of large pastoral properties, which primarily support dry land grazing and stock management.

The most significant population centres are located at Port Augusta to the south of the region (at the head of Spencer Gulf) and Coober Pedy, a well-known opal mining town, located to the northwest of the region on the Stuart Highway.

In the last few years this region has attracted regular protest and demonstration events, which are aimed at displaying opposition to nuclear activity and have been focused on Olympic Dam. In 2002, the focus was on the detention centre for asylum seekers near Woomera. These activities attract a number of participants who require camping facilities and sometimes other services (e.g. medical, police), and can also disrupt access and traffic conditions.

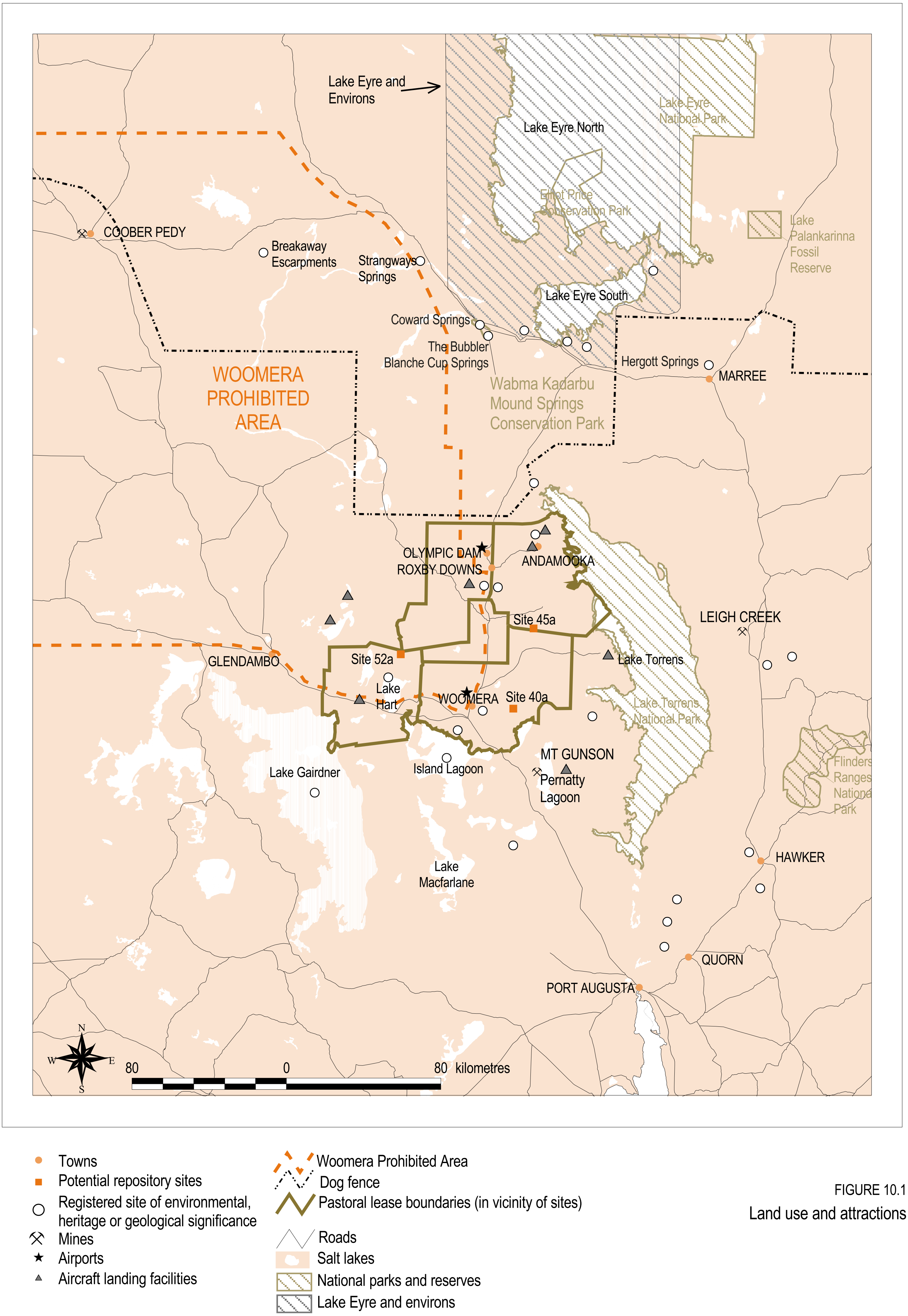


FIGURE 10.1
Land use and attractions

Activity by anti-uranium and anti-nuclear protestors has become part of a regular 'circuit' of demonstration events at other uranium mines, including Honeymoon and Beverley in the east of South Australia (northwest of Broken Hill) and at Ranger in the Northern Territory. The protests have caused minor disruption to activities at these operations, in particular to personnel access, and have also been associated with graffiti and other vandalism, trespass and property damage. Protestor activity is discussed further in Section 12.9.4.

In summary, the current land use and human activity in the region is confined to:

- a limited number of centres of settlement around mining and research facilities
- large scale rangeland grazing operations and associated, scattered homesteads
- Defence-related trials and activities and other uses of the WPA
- remote area tourism
- traffic and transport between centres of activity.

10.4.2 Current Demographics

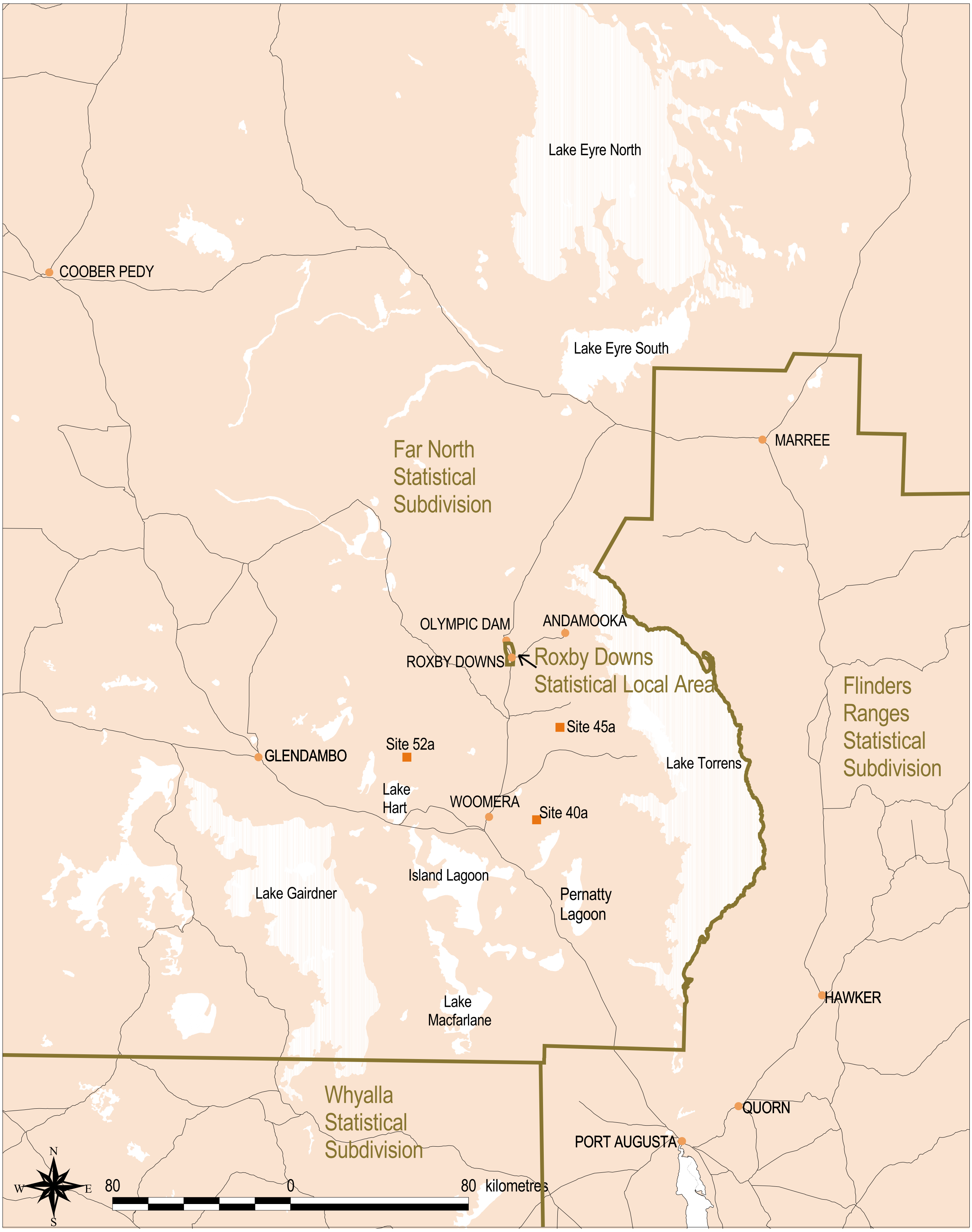
The Far North statistical subdivision (SSD) region is some 800,000 km^2 in area and makes up the bulk of the northern part of the State of South Australia (Figure 10.2). Overall, the Far North region of South Australia has one of the lowest populated densities in Australia, with a total recorded population of 10,693 (in 1996; Australian Bureau of Statistics 1999). In contrast, the Whyalla Local Government Area, to the south of the Far North SSD, has the largest regional population outside the Adelaide statistical division (SD) (Australian Bureau of Statistics 1999).

The estimated Aboriginal population represents 29.2% of the total Far North SSD population, although only a small proportion of these people are located within non-Aboriginal townships. Apart from Aboriginal communities and pastoral stations, most people live in a small number of towns and settlements, the main ones comprising Woomera, Roxby Downs, Coober Pedy and Andamooka.

The demographic statistics highlight the significant diversity of the various communities within this region (Australian Bureau of Statistics 1999, 2001):

- Population growth rates range from relatively high, such as Roxby Downs at 2.4% (the fourth highest rate in the State), to negative rates in other centres.
- The history of erratic population growth rate reflects significant investment projects (e.g. the establishment of Olympic Dam and Roxby Downs, and subsequent expansion) and economic conditions.
- Unemployment rates range from 17.5% at Coober Pedy to 2.1% at Roxby Downs.
- The average income in Roxby Downs ($51,391) and Whyalla ($35,081) were above the State average ($31,964) all other parts of regional South Australia had average incomes below the State average.
- The value of agricultural production is slightly higher than for the Adelaide SD but growth over time has only been marginal.
- Tourism statistics indicate a steady growth in numbers and average length of stay (currently 1.6 days).
- There are more males than females, but the proportion of young families is notably higher than the State average.

The total number of people in this region is relatively small, and significant changes in one location can affect the averages for the whole region. For example, the presence and nature of the Roxby Downs township and its population has a significant influence on average income, population growth rates and age structures for the region as a whole.



Towns
Potential repository sites
ABS statistical divisions
Roads
Salt lakes

FIGURE 10.2

ABS statistical divisions

In more general terms, the projected population change is likely to range from slightly negative to slightly positive, although the region can swing from steady population trends to significant proportional changes, for example, with the establishment or closure of a mine, a research facility or a processing plant.

The demographic trends of the region largely depend on economic and investment factors, primarily driven by global trends. As such it is difficult to predict longer-term trends with any significant level of certainty.

10.4.3 Aircraft Landing Facilities

Generally, aircraft activity in this region is primarily focused on existing centres of activity. The only formal airfields of significance in the vicinity of the site options are located at the Olympic Dam Village (approximately 7 km north of the Roxby Downs township) and Woomera (approximately 5 km north of the township).

The Olympic Dam airfield is some 45 km from the nearest site option (45a) and the Woomera airfield is approximately 20 km from the nearest site option (40a). However, the direction of aircraft approach and take-off does not align with any of the site options. This, combined with the separation distances, suggests that there is a low risk of potential conflict.

The other landing grounds and helipads in the region tend to be focused on centres of activity but their use is less regular and less frequent. Formal landing grounds are located at:

- Andamooka
- Teatree Dam (8 km northeast of Andamooka)
- Chances Swamp (25 km southwest of Roxby Downs)
- Bosworth (80 km east of Woomera)
- Mount Gunson Mine (45 km southeast of Woomera)
- Wirramina (60 km west of Woomera).

Of these landing grounds, the closest is Mount Gunson, which is approximately 30 km southeast of Site 40a. Within the WPA, there is a disused landing ground, Evett's Field, about 10 km from Site 52a. A number of helipads are also located within the WPA but these are located at least 35–40 km from the nearest site option (52a).

10.4.4 The Woomera Prohibited Area

The WPA is located in the northwest pastoral area of South Australia and encloses a region of 127,800 km^2, representing about 13% of the State (Figure 10.1). Its southeastern corner is located approximately 450 km north-northwest of Adelaide. Several small parcels of land within the WPA, including the Defence Support Centre at Woomera and the Woomera Rangehead, are Commonwealth-owned land. About two-thirds of the land is State Crown land, covered by pastoral leases issued by South Australia. Currently, the area comprises 23 pastoral leases, which stock on average approximately 42,000 sheep and 30,000 cattle.

The area of Maralinga Tjarutja freehold land embraces most of the WPA west of 133° E. North of this area, a small portion of Pitjantjatjara freehold land extends into the WPA. Other civil land uses are largely confined to mining and mineral exploration.

Defence administers the WPA.

Within the WPA, Defence has nominated several areas as Defence practice areas where weapons practice and trials activities can be conducted. The primary practice areas are Lake Hart, the Woomera Instrumented Range (WIR) and, within the WIR, the Range E target area.

Lake Hart is located immediately to the south of the southeastern corner of the WIR. It is an air weapons range, used for testing live ordnance released from aircraft. The Lake Hart range is located approximately 15 km south of Site 52a.

The WIR is the most significant range with respect to the repository. It has a spatial extent of approximately 50 x 40 km orientated along the range centre line of 305 N degrees north (Figure 10.3). The Woomera Rangehead is located at the southeast corner of the WIR. Site 52a is located within the southwest corner of the WIR with the centre of the site located a little over 3000 m from the Range E target. The rangehead is Commonwealth land and the WIR is grazing land (i.e. supports non-Defence activity).

Legislation/Regulations

The WPA was first formally established in April 1949 under Regulation 5 of the Supply and Development (Long-Range Weapons) Regulations to facilitate the development of long range weapons jointly by the UK and Australia. The WPA was expanded as there was need for large range areas for missile testing, with the necessary gazettals being made under Regulation 90 (1) of the *Supply and Development Act 1939* (Cwlth). The Emu and Maralinga areas were included in the WPA in March 1953 and March 1955, respectively.

In September 1972 the WPA was reduced in area from about 267,000 km^2 to about 127,800 km^2. The reduction in size released the opal mining areas near Coober Pedy from the WPA. A further variation took place in September 1980, when an area within the eastern boundary was excised to facilitate development of the Olympic Dam mining venture and Roxby Downs township.

Following the disbanding of the then Department of Supply in the mid-1970s, responsibility for Woomera and the WPA passed to Defence. Amendments to the Defence Force Regulations in February 1976 included a new Regulation (DFR 35) enabling the Minister for Defence to declare a place to be a prohibited area.

In 1978 the Minister declared the existing WPA to be a prohibited area under DFR 35:

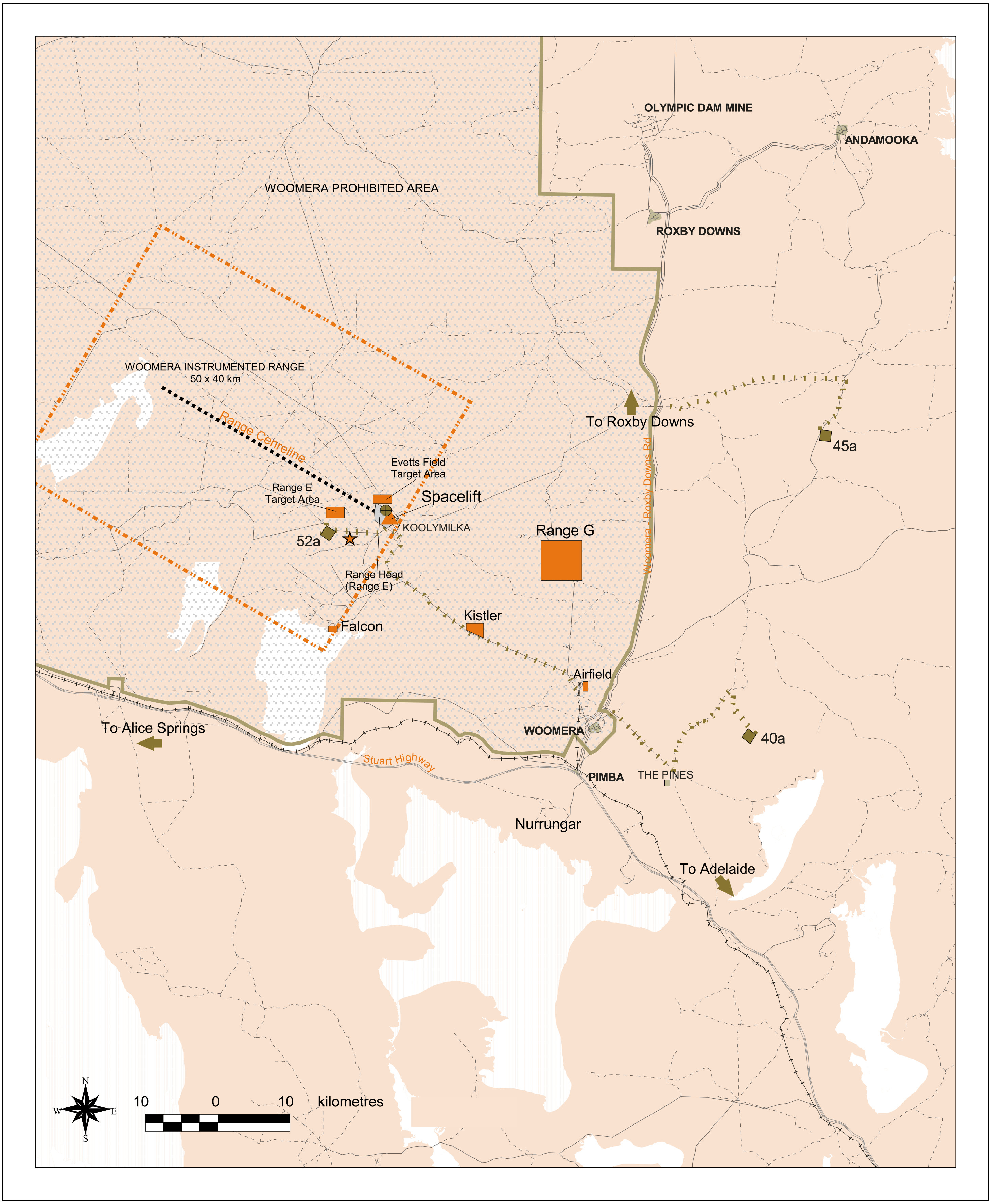
1. the Minister may, by notice published in the Gazette, declare a place to be a prohibited area for the purposes of this regulation;
2. the Minister shall not declare a place to be a prohibited area unless:

a) it is an undertaking; or
b) it is a place which is necessary or expedient in the interests of the safety of defence of Australia:
   (i) to carry out operations for the testing of war material;
   (ii) that special precautions be taken to prevent the entry of unauthorised persons into that place.

Current and Planned Activities

The general function of the WPA is to provide Defence with a secure environment for the safe operation, development, testing, trialling and assessment of experimental or operational ordnance and delivery systems, and associated resources and material. In addition, the WPA is used for operational training and evaluation of elements of the Australian Defence Force.

As well as its uses for military activities, Defence policy is that the WPA be available for use by all elements of the Defence Organisation; non-Defence government, scientific and commercial organisations; and international military and non-Defence users. The area is particularly suitable for a wide range of non-Defence programs, especially those requiring stringent safety precautions and the unique attributes of the WPA (Department of Defence 2001).



Repository waste sites
Access roads
Woomera prohibited area
Salt lakes
Towns/settlements

Existing stores
Bunker Intermediate level waste Launch Area 5
Low level Fishermans Bend Soil

Major road
Sealed secondary road
Minor road
Track

FIGURE 10.3

Woomera prohibited area - uses

Over recent years there has been significant diversification at the WPA and it is used for various research projects, the storage of radioactive waste and the detention of asylum seekers. There are also various proposals to launch commercial satellites from the WPA. All activities within the WPA have been undertaken alongside the various military uses of the range, pastoral activities and habitation. Defence routinely incorporates the various uses in the overall management and use of the area.

A comprehensive Environmental Review (Woodward-Clyde 2000) covers the defence activities at the WPA.

Defence Trials

The Royal Australian Air Force (RAAF) is currently the primary Defence user of the WPA, and typically conducts one or two campaigns per year, each of 2–3 weeks duration.

The Aircraft Research and Development Unit (ARDU) of the RAAF conducts the following activities:

- aircraft operations concerned with navigation and sensor systems
- global positioning system (GPS) interference and signature measurement
- aircraft-launched weapons with trajectory measurements and impact scoring
- ground-launched weapons such as surface-to-air and surface-to-surface missiles
- ground tests involving ordnance detonation and other explosive testing.

The main category of ARDU activity that could impact on the repository is air-launched weapons, which commonly use the Range E target area. These weapons include:

- ballistic weapons (i.e. aerial bombs that are either dropped vertically or lobbed onto the target): even if not filled with high explosive (explosive filled weapons are not used on the WIR) the bombs weigh between 500–2000 pounds (about 230–910 kg)
- air to air weapons: these are not fired at ground targets and become a concern only if they lose control or miss the aerial target; they are relatively small weapons that have small warheads designed to inflict damage on airframes, for example the AIM9 Sidewinder has a warhead weighing only 9.8 kg including the fragmenting casing
- stand-off weapons: these are air-to-ground missiles designed to destroy major infrastructure targets — the largest are often referred to as ‘cruise missiles’; they can have a significant range (i.e. from tens to hundreds of kilometres) and can weigh in the vicinity of 1000 kg; however, these weapons are extremely expensive (often in the order of US$1m) and are fired very rarely for test and evaluation, even by major users such as the US; they are also noted for their very sophisticated guidance systems which sometimes include television and imaging infra-red control (known as ‘man in the loop’).

The Australian Army conducts trials of the Rapier surface-to-air missile, parachute-training drops over Woomera Airfield, infantry exercises in the desert environment, environmental testing and other trials involving military equipment.

The Defence Science and Technology Organisation (DSTO) uses the WPA for various programs including trials of explosives and GPS jamming trials.

Other Uses

Trials (non-Department of Defence)

Various non-Defence trials have been undertaken on the WPA in recent years, including:

- NASA sounding rocket firings
- testing of Japanese rocket propellant

- flight trials for Japanese experimental aircraft
- UK Ministry of Defence anti-armour missile trials
- Australian Space Research Institute trials (rocket firings)
- Commercial trials by the chemical company ORICA, which has used the Lake Hart disposal area for the safe destruction of mining explosives and for the measurement of blast effects
- University of Queensland scramjet test flights.

Commercial Satellite Launching

The Commonwealth government has implemented a number of initiatives to encourage the commercial launch of satellites from Australian territory. It has enacted the *Space Activities Act 1998* to regulate commercial space launch operations in Australia. The Act aims to protect public safety and property during the conduct of launches. Broad approaches to protecting public life and property are adopted under the space-licensing regime.

In launching a rocket, the operator proposes a flight path designed to deliver the satellite (payload) to the owner's target position in space. In some cases the preferred flight path may include overflight of population centres or high value assets. The Space Activities Act requires that the Minister be satisfied as to the safety of the proposed launch along this flight path. Otherwise an alternative flight path needs to be proposed.

The proposed satellite launch activities are (see Figure 10.3):

- Kistler Aerospace Corporation
- Spacelift Australia Ltd
- Falcon Project.

Kistler

Kistler Aerospace Corporation has selected the WPA for the launch and recovery of a two-stage liquid fuel vehicle, which would be used to deploy communications and other satellites into low earth orbit. Kistler is progressing towards the finalisation of finances and is expected to begin construction of the launch pad when these are secured.

A site midway between Woomera Airfield and the Woomera Rangehead at Ashton Hill has been approved for construction. Launches would be in a north-northeasterly direction. The maximum number of launches is estimated to be no more than 25 per year.

Only Site 45a is within the Kistler safety zone.

Spacelift

Spacelift Australia Ltd has a proposal to launch light payloads into low earth orbit using Russian rockets, and is progressing towards finalising its finances. It originally intended to establish its facilities near Range E, but is now investigating a site north of Woomera Airfield, near Range G. When established, Spacelift intends launching along a set of trajectories between north-northwest and northeast with the specific trajectories dependent on customer requirements and safety considerations. The number of launches is estimated to be no more than 12 per year.

Spacelift's activities would not be expected to affect the preferred site or alternatives.

Falcon

The Falcon project is intending to establish facilities at Woomera, and plans to reactivate the launch pad 6a on the shores of Lake Hart, launching along a trajectory of approximately –55 and –10 degrees. Site 52a may be within the safety template. The status of the project is, however, unclear. The number of launches is estimated to be no more than 12 per year.

Radioactive Waste Storage on the WPA

A significant proportion of Australia's holdings of both low and intermediate level waste is currently stored in the WPA, close to Site 52a, and has been stored there since 1994–95 without incident.

More than half of the national holdings of low level and short-lived intermediate level radioactive waste are stored in a corrugated iron annexe attached to an aircraft hanger at the Rangehead, 10 km to the east of Site 52a and close to a target area (Figure 10.3). This material consists of contaminated soil, which originated from the clean-up of a site at Fishermans Bend, Victoria, and belongs to the CSIRO.

This contaminated soil amounts to about 2010 m^3 and is stored in 9276 drums of 207 L capacity (Section 4.1). The drums were moved safely from Sydney to the annexe between November 1994 and January 1995. The transfer required about 120 truck movements. The same number of truck movements is likely to be necessary to transfer the drums from the annexe to the repository.

Some 35 m^3 of conditioned short and long-lived intermediate level waste is stored in a concrete bunker at Launch Area 5, which is 3 km to the south of Site 52a and within the WIR. The location is within 5000 m of the Range E target. This waste is the responsibility of Defence and was moved safely to the WPA from Sydney, in May 1995.

Radioactive waste is also located at the former Maralinga test site, buried in near-surface trenches.

Matters relevant to the siting of the national repository at the preferred site, Site 52a in the WPA, include the following:

- The 1.5 x 1.5 km (2.25 km^2 or 225 hectares) site required for the repository is insignificant compared with the size of the WPA (127,800 km^2). Much of the site would be a large buffer zone with restricted access, with the repository trenches or boreholes located in a central 100 x 100 m area.
- Waste would be buried under at least 5 m of clean cover.
- After the initial campaign to dispose of accumulated waste, the repository would only be open to take waste for a limited time every few years (see Section 6.1.4). Otherwise the trenches would be covered and there would be no activity at the site, apart from monitoring and surveillance. The timing of disposal activities could be coordinated with Defence so as not to overlap with other uses of the range.
- As the WPA is an area of restricted public access, members of the general public would not be allowed near the repository site.
- Site 52a is the closest of the three sites to the building in which more than half of the national holding of low level and short-lived intermediate level radioactive waste is now stored. Thus the use of Site 52a for the repository would minimise the transport risks associated with moving the national holdings of waste to the facility.
- Defence's operational activities in the WIR since 1994 have taken place without any incident related to the existing radioactive waste stored in the WIR. The truck movements for transfer of the radioactive waste to the rangehead were harmonised with activities in the WPA, and operational activities since then have been able to take account of the two above-ground structures in which the waste is stored.

10.5 Planning Policy

The prediction of potential future activity in this part of South Australia is particulary difficult. The infrustructre, land tenure and climatic conditions are generally a major barrier for additional, more intensive activites. However, technological advances and changes in global economic conditions and markets can prompt major investment in activities such as research and mining. In particular, there are a number of potentially significant mining project prospects in the region which, should they occur, could have major impacts on the level and nature of activity in the region.

This section provides an overview of the key development policy documents that provide insight into current expectations of future development. The nature and trends associated with the key land use types are also assessed.

10.5.1 South Australian Government Planning Strategy

A revised draft of the South Australian Government's *Planning strategy for the development of regional South Australia* (Planning SA 2001) was released in August 2001. This document is recognised by the South Australian *Development Act 1993* and has the role of providing broad strategic direction. While it has no direct influence on the assessment of specific development proposals, it does influence and guide future Development Plan and zoning policy.

The planning strategy divides the State into key regions. The Outback Planning and Development Area includes most of the northern region of the State and is the area of relevance to this proposal. The key strategies identified for the outback area focus on supporting economic development, conserving and managing natural resources; supporting existing communities; and providing improved infrastructure. The planning strategy fundamentally acknowledges the existing land use activities but the introduction of new land use activities is not specifically envisaged.

Mining, defence and aerospace activities (including their support industries) are considered the key areas for potential economic growth and future development. Tourism (based on adventure, four-wheel drive, heritage and Aboriginal culture themes) is also considered a potential growth area. The strategic emphasis for rangeland grazing is one of adjusting practices to achieve a greater level of sustainability.

The potential for a radioactive waste repository is recognised in the planning strategy. The existence of a buffer zone on the repository site around the repository trenches and boreholes would ensure a safe distance between the facility and other activities that may be undertaken in the surrounding area.

In summary, the implications of the strategies on future development patterns and level of activity are likely to be as follows:

- Centres of development activity would be generally be limited to existing areas.
- Rangeland grazing activity is unlikely to become more intensive.
- Mining activity and associated support industries could establish in new areas (new ventures).
- Improved approaches to infrastructure and service delivery (water, energy, transport and communications) are unlikely to change significantly the existing patterns of settlement but should support community and business operating conditions.
- Improvement to infrastructure and services may encourage a greater level of remote area tourism (e.g. improved mobile phone service).

10.5.2 Development Plan and Zoning Policy

The relevant Development Plan provides an indication of the type and nature of land uses that are envisaged for the area. The 'Land Not Within A Council Area (Far North)' Development Plan applies to that area indicated in Figure 10.4.

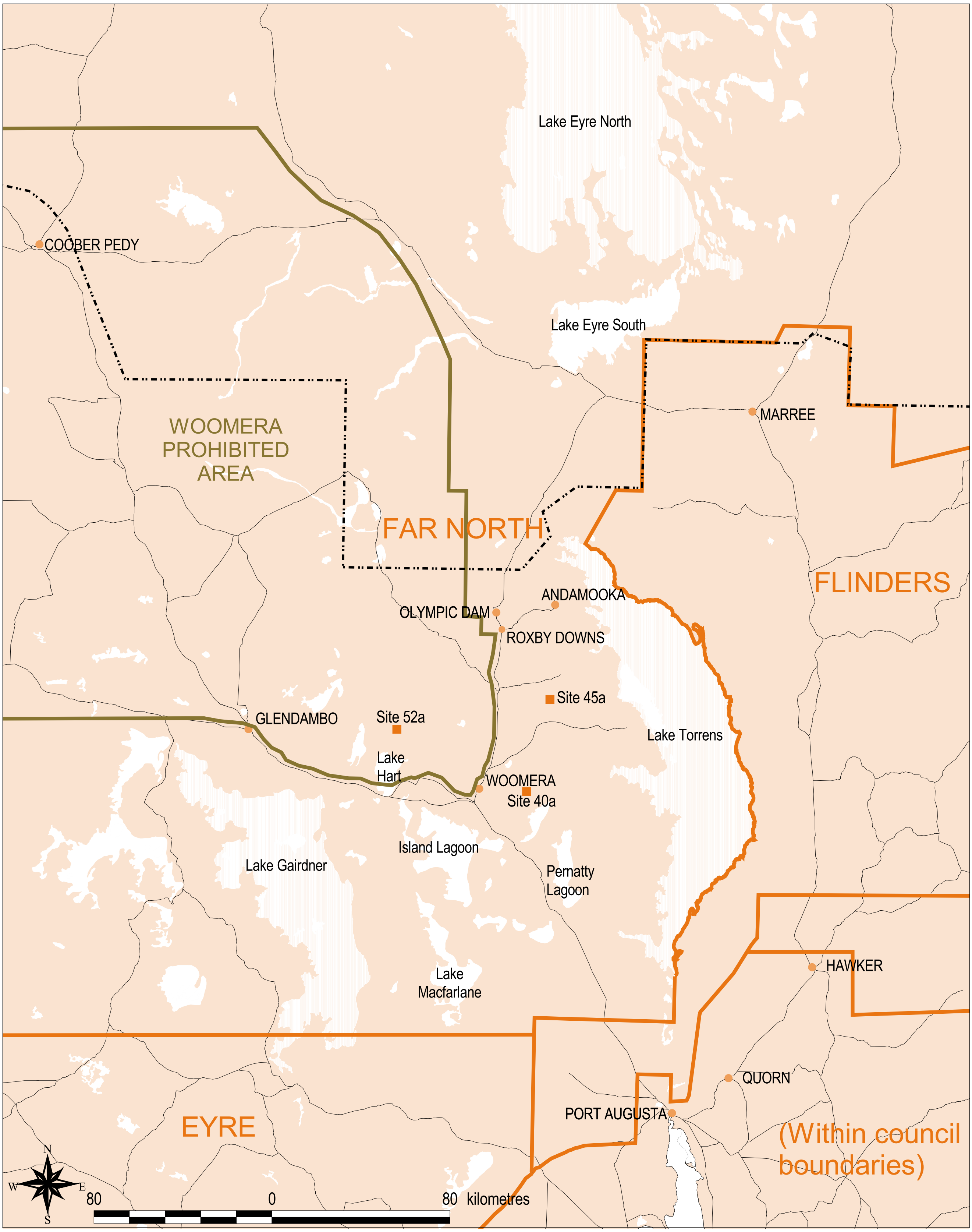


FIGURE 10.4

Development plan areas

Given the recent release of the revised draft planning strategy for the region, it is expected that the Development Plan polices may eventually be amended to align with the intentions of the planning strategy.

Current policies within the Development Plan recognise the remote and diverse nature of this region as a whole. While the policies allow a wide range of forms of development, they also require recognition of environmental and conservation principles. The policies support tourism, mining and township development. Apart from some forms of advertising, no form of development is listed as either complying or non-complying.

Thus, provided a development can supply the infrastructure it requires and addresses environmental and conservation issues, there is little within the Development Plan to prevent any type of development occurring within any part of this region.

10.6 Future Activity Assessment

10.6.1 Access

There is good bitumen road access to the region running north from the Stuart Highway turnoff at Pimba including to Woomera, Roxby Downs and Andamooka from the Pimba turnoff. The Trans Australia Railway also passes though the region. Travel through the remainder of the region is limited by the quality of road infrastructure beyond these townships. Travel is generally restricted to the limited network of public roads and highways unless specific approval has been sought to access pastoral properties, Aboriginal lands and other reserve and restricted areas.

New road infrastructure, particularly that of a higher standard than the current off-road tracks, has the potential to increase the amount of movement through the area. However, it is unlikely to be established unless it is associated with a specific development or facility. On present indications, other than infrastructure required for the repository, other types of development that might require such infrastructure are likely to be confined to new mining operations.

Similarly, the establishment of new aircraft landing facilities is unlikely unless associated with a major new centre of activity such as a new mining operation.

10.6.2 Woomera

Defence maintains a program of activity at the Woomera facility within the WPA for a range of research and testing activities. The facility is also used by commercial organisations. As part of its operational responsibilities, the department maintains safety and exclusion zones and separation requirements to ensure that activity occurs in a safe manner, including controls over access and the nature of activity that can occur within the WPA.

The potential interaction between the repository if sited on Site 52a and Defence and other uses of the WPA is discussed further in Chapter 12.

10.6.3 Tourism

Tourism is a growing element of activity in the remote areas of Australia. Organised, commercial tours and the growth of off-road vehicle use has increased the ability of tourists to access remote and wilderness areas. This has led to an increase in the level of conflict between existing activities (particularly rangeland grazing and mining uses) and tourist activity. It has also created additional environmental management issues when tourists access sensitive and fragile areas.

The key attraction of remote area tourism is the notion of 'getting away from it all' and this type of tourism tends to involve:

- small groups of people
- unpredictable timing and duration of activity
- unpredictable destination estimates
- participants who may not be well trained or versed in the nature and sensitivities of the destination area
- misunderstandings about access rights and cultural practices.

Management and control of the impacts of this type of tourism is particularly difficult as the numbers of people involved, their destinations and level of knowledge are not known. The South Australian Pastoral Board has established a Public Access Coordinating Committee to further consider this issue. The committee includes representatives of the South Australian Government, SA Farmers Federation, the 4WD Association and the Conservation Council.

While not purely a 'tourism' activity, the protest and demonstration events staged at Olympic Dam and Woomera have similar impacts on community infrastructure to tourism. These activities brings 'visitors' to the area, who place pressure on accommodation, facilities and community services, and may discourage other tourists from visiting such areas. This type of activity is not expected to diminish in the near future.

10.6.4 Pastoral Activity

Rangeland grazing is the most extensive land use in the region, but the arid climate and low and erratic rainfall limit the intensity of this activity. A greater understanding and appreciation of land and resource management is also changing the nature of such activities. Inappropriate management practices in the past have affected the productivity of some areas, and international economic trends have further influenced the viability of some operations.

The nature of pastoral activity is now better understood and more easily controlled as there are relatively few individuals involved, their behaviour is more predictable and they are more likely to be receptive to sustainable management practices. Regional soil boards, such as the Kingoonya Soil Board (relevant to this region) advise pastoralists on land management practices.

10.6.5 Mining

The region is recognised as an area with high potential for mining activity. Operations such as Olympic Dam introduce a substantial level of new infrastructure and activity which is not restricted to mining operations alone but includes new communities (employees) service centres supporting industrial activities, transport and logistics activities, and associated infrastructure.

The establishment, expansion and timing of such ventures heavily depend on technological and global economic conditions, making predictions about future land use and activity very difficult.

Other potential mining projects in the area include: the AuIron Energy Ingomar project south of Coober Pedy, based on coal and iron ore; Dominion Mining Ltd's Challenger gold project southwest of Coober Pedy; Pima Mining NL's Andamooka Island prospect with copper–gold–uranium mineralisation (on the western side of Lake Torrens); Gunson Resources Ltd–Billiton Australia copper prospect near Mount Gunson; Grenfell Resources Ltd copper–gold prospect near Tarcoola; and Minotaur Resources Ltd copper–gold–uranium prospect near Mount Woods (between Olympic Dam and Coober Pedy).

10.7 Evaluation of Impacts and Risks

Australia's national repository would be a relatively small facility compared with the land required for other activities in the region. Disposal operations are expected to be conducted infrequently. Therefore, land use impacts would be expected to be small and primarily limited to the 'active' phases (i.e. during construction, operation and decommissioning).

Establishment of the repository would have minor positive impacts including:

- short-term local opportunities for employment and for the sale of goods and services, primarily during construction and operating campaigns
- possible up-grade of road infrastructure (only for Sites 40a and 45a)
- conservation benefits arising from regeneration of flora and fauna as a result of the exclusion of feral animals from the site
- visual impact as a result of the regeneration of flora.

Outside the region, there would be significant positive impacts arising from removing radioactive waste from temporary, non-purpose-built accommodation at many sites around Australia. Any possible hazard from the present storage activities would be eliminated when the sites were decommissioned. Once decommissioned, these sites would be available for uses more appropriate to their surrounding environments.

The main negative land use impacts associated with the proposal are relatively minor or of a short term duration and include:

- upgrading of existing road infrastructure (only for Sites 40a and 45a) which, if undertaken, would provide improved access to these areas
- activities associated with the construction and operation of the repository, such as the establishment of support facilities, and excavation and filling of disposal structures
- visual impact, primarily during construction and operating campaigns
- minor increases in traffic and pressure on local services during construction and operating campaigns
- minor effect on existing land uses at the repository site (including pastoral activities)
- potential to exacerbate the level of 'demonstration' activity and place pressure on local camping facilities and police resources.

It is not proposed to install power and water service infrastructure to the repository site (Section 6.3.6).

It has been argued that public perceptions about the facility would have negative impacts on the image of the region, which in turn would have a related negative economic impact. However, the transfer of radioactive waste for storage in the WPA in 1994–95 received considerable media coverage at the time, and the fact of its storage has been mentioned in the media and other public forums on many occasions since, as has the proposal to locate the repository in this region. In these circumstances, it is unlikely that construction of the repository would give rise to any new adverse impact on perceptions about the region or the regional economy.

The risk that a weapon or projectile from a Defence trial at the WIR might strike Site 52a is discussed in some detail below, and risk reduction measures are identified. The other sites are not subject to this class of risk.

Radiological risks are discussed separately, in Sections 12.5 and 12.8.

The other risks that need to be addressed relate to possible unauthorised intrusion and security breaches. Because of its location within the WPA, these risks would be lower at Site 52a than at either Site 40a or Site 45a.

The establishment of the repository would have minor positive impacts including:

- short-term local employment and purchase of goods and services
- possible up-grade of road infrastructure (local use).

10.7.1 Visual Impact

The nature of the visible elements of the national repository would comprise the security and feral-animal-proof fencing, and the operations and other buildings (Figures 6.2–6.3). During campaigns (which would be infrequent and undertaken over a relatively short period) there would be additional construction and earth moving equipment on site, and one or more trenches or boreholes could be open.

In between campaigns, the disposal trenches (or boreholes) would be covered and capped, and evident only as low mounds. As the disposal area would be a considerable distance from the perimeter fence, regenerated flora in the buffer zone would tend to hide (from the fence) any evidence of surface disturbance, apart from the access road.

Most if not all of the buildings and most other infrastructure, apart from fences, roads etc, would be removed from the repository site between campaigns (see Section 6.4.2). The size, scale, colours, materials and design styles of permanent buildings has yet to be decided. In this context the following assessment is relevant to the potential visual impact.

For Site 52a, the facilities, equipment and activities would not be dissimilar to other facilities, equipment and activities presently on the WPA and would be consistent with the existing landscape character. In addition, the restricted access would limit the numbers and types of people who might experience this landscape. Thus, assuming that appropriate colours and materials are used (e.g. non-reflective), the impact on the existing landscape would therefore be minimal, and this site is preferred for visual impact.

For the alternative sites, 40a and 45a, the landscape context is different. While there is some evidence of human activity in these areas, this tends to be limited in nature and scale (e.g. fence lines, and domestic and agricultural scale buildings). The proposed facilities, equipment and activities would be different from the existing pastoral activities, and would introduce a new visual element. In addition, there is a potential that a greater range of people could experience this landscape as access is not as restricted as in the WPA. It is possible to address the potential impact on the landscape using appropriate designs, colours and materials similar to other buildings commonly found in outback areas.

10.7.2 Access

There would be some impact on the transportation network in the region but, given the relatively small amount of activity during the construction, operation and closure phases, it is not expected that there would be any significant disruption of road traffic from activities relating to the repository. This is discussed in Chapter 7.

Given the limited road infrastructure within the region, a consideration would be the potential conflict between construction traffic and regional activity. The regional transport and traffic activity includes:

- access to shopping and medical centres (Whyalla, Port Augusta, Adelaide)
- freight transport (including road trains)
- tourist traffic (camping and off-road)
- business traffic (suppliers, contractors and service providers to the mining and research industries).

The construction phase has the potential for minor and short-term disruption of access arrangements for these remote areas, which depend on road access for a range of services and activities. However, owing to the relatively small scale of the construction activity, these issues are not considered to be significant.

The amount of operational traffic generated is described in Chapter 7. Overall, the traffic generated would not be significant, even during the first disposal campaign when the accumulated materials are transferred to the facility.

The use of Site 52a for the repository would minimise the transport distance, risks and any possible traffic disruption associated with moving the national holdings of waste to the repository. This is because Site 52a is the closest of the three sites to the building in which more than half of the national holdings of low level and short-lived intermediate level radioactive waste are now stored. The waste now stored in the WPA would be moved on roads not accessible to the public and which would be unlikely to any carry other traffic.

However, in the case of Sites 45a and 40a, the existing access roads would need to be upgraded (Section 7.4, Figure 7.2). The improved road infrastructure might improve accessibility to areas that were previously relatively protected from activity such as tourism and camping. Some areas along these routes are scenically attractive but also sensitive to human intrusion and activity. Such issues would not arise for Site 52a, where access to the WPA is already restricted.

In terms of domestic air traffic it is considered that the potential for conflict from a land use perspective is likely to be low. The limited level of air traffic, the landing and take-off directions of this traffic and the distances from the site options combine to limit the risk of potential conflict. However, of the three sites, 52a is generally the most remote from these facilities and Site 45a is the closest.

10.7.3 Site Suitability and Land Use

Based on the operational characteristics of the proposed facility alone, all three sites are suitable from a site planning perspective in that the proposal could be established at either the preferred or alternative sites provided that suitable buffers are established to address security, risk of intrusion and future land use activity concerns.

Current State zoning has little provision to limit the establishment of land uses and activities in the vicinity of the facility in the future. However, for the foreseeable future it is likely that pastoral activities would occur in the areas around the sites and, in the case of Site 52a, military and other uses of the WPA would also continue around the site. A further possibility is that a ‘major project’ (e.g. a mining venture) could be established in the region following the establishment of the proposed facility.

Given the size of the repository site, the impact on existing land use is expected to be minimal and, in relative terms, only a small amount of land would be removed from pastoral use. In addition, the site area and layout is such that a buffer has been included around the repository to ensure that the disposal trenches are suitably distant from both current and possible future land uses. The use of the buffer as a regeneration area is unlikely to conflict with other land use types.

From a practical, security and infrastructure perspective, Site 52a offers several site planning and other advantages over the two alternative sites:

- The level and standard of existing infrastructure is significantly higher.
- Its location within the WPA offers additional security advantages to address inadvertent or deliberate intrusion.
- It offers better existing access, which would significantly assist the construction stage.

- The use of Site 52a would avoid the significant road access consideration that would be required for the alternative sites.
- The longer-term land use activity is already subject to some control by the Commonwealth.
- Radioactive waste is already stored in the WPA.

10.7.4 Approaches, Programs and Procedures to Minimise Impacts

Various approaches could be adopted to minimise negative impacts of the national repository on the natural environment, existing land uses and the socio-economic environment. There may be some minor positive impacts from the siting of the facility.

Visual Environment

Minimising the structures left on the site between disposal campaigns would reduce minor visual impacts. In the case of Site 52a in particular, the structures on the site during disposal operations would not be dissimilar to the infrastructure already located on the WPA.

For Sites 45a and 40a, appropriate scale, design, colours and materials would be adopted, similar in character to typical ‘outback’ buildings, and this would assist to limit the visual impact.

At whichever site is selected, between campaigns, the growth of flora would tend to hide (from the fence) any evidence of surface disturbance apart from the access road.

Land Use

Potential impacts from the relatively small volume of traffic expected during construction and operation of the facility could be minimised by careful planning of activities. This would include consolidation of waste loads so that the number of trucks required is minimised.

Given the level of infrastructure already in existence in the vicinity of Site 52a, the siting of the repository at this location would minimise the need for the construction and upgrading of existing infrastructure such as roads.

To minimise the effect of construction and disposal operations on existing land use, the timing of these activities could be scheduled so as not to coincide with other uses of the WPA (in the case of Site 52a), or with particular pastoral activities such as lambing.

As for potential impact on diversification or expansion of military, aerospace or other use of the WPA, current activities on the WPA have co-existed with the storage of radioactive waste in above-ground facilities since 1994, without inhibiting activities aimed at diversification or expansion.

In comparison with present circumstances, the repository should, when operational, reduce concerns for diversification or expansion, because waste in the repository would be buried below ground, and the facility would pose a lesser hazard than the current storage arrangements.

Access

Access to the 1.5 x 1.5 km national repository site would be limited through appropriate security measures. Security fencing and other surveillance and monitoring would deter intrusion by people or relatively large animals.

Site 52a, within the WPA, would have in-built public access restrictions and other security coverage, and offer security advantages to the alternative sites.

In the case of Sites 45a and 40a, the upgraded road infrastructure could facilitate public access (e.g. tourists) to areas previously protected by the poor standard of these roads. Should either of Sites 45a or 40a be selected, measures would be adopted to minimise public access to the new roads by the use of locked gates, bollards, signage and fencing as deterrents.

10.7.5 Location of the Repository within the Woomera Instrumented Range

Location of the repository within the WIR presents a small risk that a weapon projectile fired at a target within the WIR, most particularly at the Range E target, could strike the repository site. Smaller, low velocity projectiles can be expected to fragment on impact with only limited ground penetration and are likely to damage only surface features or structures. However, larger or higher velocity weapons may strike with sufficient kinetic energy to penetrate the 5 m soil cover proposed for the repository (Section 6.2.5).

For an impact of this nature to represent a risk to human health or the environment, the impact would have to result in the release of radioactive material into the environment, including the surrounding or underlying ground, groundwater, vegetation or the atmosphere. The radiological risks of such an incident and release are discussed in Sections 12.5 and 12.8.

However, even if no radioactive material is released, the risk of impact of a weapon on the repository is an issue that should be considered.

Risk Assessment

A means of assessing the risk of such an occurrence is presented by *US Department of Defense Military Standard 882D, Standard Practice — System Safety, 1999* (MIL-STD-882D).

MIL-STD-882D provides a method of applying system safety that ‘has proven effective in the management of environmental, safety and health mishap risks encountered during the development, test, production, use and disposal of Government systems, subsystems, equipment and facilities’. The MIL-STD ‘provides a consistent means of evaluating identified risks. Mishap risk must be identified, evaluated and mitigated to a level acceptable (as defined by the system user or customer) to the appropriate authority and compliant with federal laws and regulations.’

MIL-STD-882D is recognised by the Australian Defence Force ADF as an appropriate basis for risk assessment and control. Defence aviation risk management principles require ARDU to ensure that risk assessment and control techniques based on MIL-STD-882D are promulgated and implemented in the planning and conduct of ARDU activities (Department of Defence, pers. comm. 2001). The methodology presented in MIL-STD-882D is similar to that used in *Australian Standard AS/NZS 4360/1999, Risk Management*, although different terminology is used. However, the US MIL-STD-882D is the standard directly applicable to ADF aviation risk management.

Methodology

An ‘assessment of mishap risk’ is made by ‘assess[ing] the severity and probability of the risk associated with each identified hazard, i.e. determine the potential impact of the hazard on the personnel, facilities, equipment, operations, the public or environment, as well as on the system itself’. To aid in the achievement of the objective of system safety, mishap risks are characterised as to mishap severity and mishap probability.

Identifying the Risk

As discussed in preceding paragraphs, the risk to be assessed is the risk that a weapon fired at a target within the WIR would strike the repository site with sufficient force to penetrate at least 5 m into the ground, which is sufficient to breach the capping material above the radioactive waste. High explosives are not used on the WIR — the energy required to achieve soil penetration is therefore kinetic energy only, not explosive.

Analysing the Risk

Mishap Probability

The likelihood being assessed is that of an impact of a weapon with sufficient impact energy to penetrate the soil covering the repository to a depth of 5 m. These weapons are taken to be large bombs and missiles in excess of 250 kg impact mass.

Defence advises that there are on average 60 weapons firings per year that could potentially strike the repository. These are weapons for which the firing template, that is the area within which the weapon may fall if it veers off course, overlaps Site 52a. These weapons are predominantly fired at the Range E target, which is located just over 3000 m from the centre of Site 52a.

Defence advises that, of the 60 weapons releases discussed above, 42 have the potential to penetrate to a depth of 5 m.

However, it is also understood that many of the heavier mass weapons fired at the Range E Target are cluster bombs.

While cluster bombs may weigh up to 500 kg in total, they are a cylindrical clamshell casing that contains 200 or more small bomblets each generally less than 1.5 kg in weight. The weapon is designed so that the clamshell casing splits open in the air and releases the bomblets, which are not massive enough to penetrate the depth to the repository cover. If the weapon casing failed to open in the air, the entire weapon may strike the ground. However, it is likely that the casing would shatter on impact, without significant penetration.

The risk assessment that follows has been based on the firing of 42 weapons per year that have the potential to penetrate to a depth of 5m, without an allowance for use of cluster bombs. This provides for a conservative risk assessment.

Methods of Calculating Likelihood

A method of calculating likelihood of impact is to note that the weapons safety templates used by Defence are based on a probability of an impact from an individual weapon release of 1×10^{-6} at the template boundary, increasing to approach unity at the target point. Information provided by Defence for weapons releases at the Range E target area indicates that the repository is located in an area where the risk is 1×10^{-6}. It is therefore reasonable to assume that the probability of an individual weapon release striking the repository site is 1×10^{-6}.

Based on 42 releases per year of weapons with potential to penetrate to a depth of 5 m, the resultant annual likelihood of an impact in the vicinity of the template boundary can therefore be calculated as $42 \times 1 \times 10^{-6} = 4.2 \times 10^{-5}$ per year.

An alternative method is that used in Section 12.5 in the assessment of radiological risks. This method makes the conservative assumption that each weapon has an equal probability of landing in any given square metre of the WPA. It is further assumed that any strike within 100 m of the central repository area of 100 x 100 m (0.01 km^2) would cause disruption to the wastes, that is the total area that could be possibly affected is approximately 0.09 km^2. The ratio of this to the total WPA is therefore multiplied by the number of releases of weapons potentially disruptive to the repository, resulting in a figure for weapon impact of 3.0 x 10^{-5} per year. This method also includes the possibility of an aircraft crash and calculates the probability of a military aircraft crash on the site, based on UK data, at 7.0 x 10^{-8} per year.

Mishap Probability Level

The mishap probability levels are presented in Table 10.1.

Based on the figures discussed above the mishap probability for an impact of a weapon that could penetrate to a depth of 5 m can be assigned a level of D Remote, as the probability is assessed as being between 10^{-3} and 10^{-6}. The risk level rating does not vary whether the central part of the repository site is evaluated or whether the entire 1.5 x 1.5 km site is assessed.

TABLE 10.1 Mishap probability levels

Description	Level	Specific individual item	Fleet or inventory
Frequent	A	Likely to occur often in the life of an item, with an occurrence greater than 10^{-1} in that life.	Continuously experienced
Probable	B	Will occur several times in the life of an item, with an probability of occurrence less than 10^{-1} but greater than 10^{-2} in that life	Will occur frequently
Occasional	C	Likely to occur some time in the life of an item, with a probability of occurrence less than 10^{-2} but greater than 10^{-3} in that life	Will occur several times
Remote	D	Unlikely but possible to occur some time in the life of an item, with a probability of occurrence less than 10^{-3} but greater than 10^{-6} in that life	Unlikely, but can reasonably be expected to occur
Improbable	E	So unlikely it can be assumed occurrence may not be experienced, with a probability of occurrence of less than 10^{-6}	Unlikely to occur, but possible

Source: MIL-STD-882D

Mishap Severity

Mishap severity categories are presented in Table 10.2.

TABLE 10.2 Mishap severity categories

Description	Category	Criteria
Catastrophic	I	Could result in death, permanent total disability, loss exceeding US $1 million, or irreversible severe environmental damage that violates law or regulation
Critical	II	Could result in permanent partial disability, injuries or occupational illness that may result in the hospitalisation of at least three people, loss exceeding US $200,000 but less than US $1 million, or reversible environmental damage causing a violation of law or regulation.
Marginal	III	Could result in injury or occupational illness resulting in one or more lost work days, loss exceeding US $10,000 but less than US $200,000, or mitigatible environmental damage without violation of law or regulation where restoration activities can be accomplished
Negligible	IV	Could result in injury or illness not resulting in a lost work day, loss exceeding US $2,000 but less than US $10,000, or minimal environmental damage not violating law or regulation

Source: MIL-STD-882D

As discussed in Chapter 12, the human health and environmental risks (the first criterion) posed by a release of radioactive material from the repository are remote and the chance of causing death or injury is low. In injury or illness terms, therefore, the severity can be classified as Negligible.

The second criterion relates to the financial cost of the mishap. For the repository operator, the financial cost of an impact on the repository would include the cost of clean-up and repair of any breach of the repository cover. Given the nature of the repository and the remote human health and environmental risks posed by a release of radioactive material from the repository, it is unlikely that the costs of rectification would be substantial. While a cost figure for this was not estimated, a severity classification of Marginal was considered appropriate.

An impact on the repository could cause delays to Defence operations at the WIR while an investigation into the cause and consequences of the incident is conducted. However, the actual costs incurred would depend on the nature of the mishap, the type of weapon being tested and the point in the testing program at which the mishap occurred. Further, it is likely that Defence would incur these delay costs in any event, as any mishap of this nature would require investigation irrespective of whether the repository was struck.

The third criterion relates to environmental damage. The repository would be licensed by ARPANSA in accordance with Commonwealth laws and regulations (see Sections 3.2 and 3.3). As discussed in Chapter 12, remediation and mitigation treatments could be applied if a weapon of concern penetrated the repository. This would imply a category of Marginal.

Looking at a balanced definition of severity across all relevant criteria, it was considered that the most appropriate categorisation overall is Marginal.

Risk Assessment

The risk assessment matrix is presented in Table 10.3 and the consequent risk category in Table 10.4.

TABLE 10.3 Risk assessment matrix

	Catastrophic	Critical	Marginal	Negligible
Frequent	1	3	7	13
Probable	2	5	9	16
Occasional	4	6	11	18
Remote	8	10	**14**	19
Improbable	12	15	17	20

Source: MIL-STD-882D

TABLE 10.4 Risk category definition

Mishap risk assessment value	Risk category
1–5	High
6–9	Serious
10–17	Medium
18–20	Low

Source: MIL-STD-882D

With a mishap probability of Remote and a mishap severity of Marginal, the risk category is Medium. Activities in this category are permissible in accordance with military risk assessment protocols, and Medium is the second lowest risk category presented by MIL-STD-882D.

Mishap Risk Mitigation

MIL-STD-882D then requires that potential mishap risk mitigation alternatives be identified. A number of alternatives exist, including:

- engineering and constructing the cover material to the waste to increase its resistance to penetration
- altering the orientation or lines of approach to the Range E target area to further decrease the probability of a weapon strike on the repository
- reviewing all new weapon system templates to determine whether templates can be developed that place the repository at minimum risk of impact.

Residual Risk

The residual risk is defined by MIL-STD-882D as the risk that remains after all planned mishap risk mitigation or management measures have been implemented.

The residual risk is categorised by MIL-STD-882D in Table 10.5.

TABLE 10.5 Residual risk categories

Category probability	Catastrophic	Critical	Marginal	Negligible
Frequent	High	High	Serious	Serious
Probable	High	High	Serious	Low
Occasional	High	Serious	Low	Low
Remote	Serious	Low	Low	Low
Improbable	Serious	Low	Low	Low

The implementation of mishap risk mitigation alternatives would reduce the risk category. For a risk probability of Remote and a severity category of Marginal, the residual risk is categorised as Low. Thus the operations at the WIR can be conducted at low residual risk, provided that the planning and management of operations takes into account the presence of the repository.

Existing Defence Waste

It was noted in earlier discussion that short-lived and long-lived intermediate level waste belonging to the Department of Defence was moved to the WPA in 1995 and that the waste has been stored since then in an above-ground structure at Launch Area 5, some 5000 m from the Range E target. Site 52a is some 3000 m from the target. Since the time of the transfer, Defence's operational activities have been able to take account of the structure and location in which the waste is stored.

Chapter 11
Cultural Heritage

This chapter describes the Aboriginal and European cultural heritage aspects of the proposed national repository.

The extensive consultation process with the Aboriginal people has sought their views on sites selected for investigation for the national repository project. Heritage surveys and clearance processes have been undertaken in consultation with the relevant Aboriginal groups for the sites and their access routes.

Information about the national repository project has been provided in response to questions from Aboriginal groups. The preferred site and two alternatives have been identified by Aboriginal groups as not containing areas of significance for Aboriginal cultural heritage, and have been cleared for all works associated with the construction and operation of the national repository. An assessment of the potential impact and risks of the repository on Aboriginal heritage and community aspirations is provided.

This chapter describes the European development of the area, including early European exploration and pastoral settlement and land use, as well as the use of the Woomera Prohibited Area (WPA) for Department of Defence (Defence) and research use following World War II. The potential impacts on European heritage are also assessed.

11.1 Aboriginal Community Consultation and Views

11.1.1 Aboriginal Consultation

Once the 67,000 km central–north region of South Australia had been selected for further study for the possible siting of a national repository, a wide-ranging consultation process began with communities and community organisations in and around the region. This consultation process is described in Section 1.5.3.

As part of this process a number of Aboriginal organisations were contacted by the former (Commonwealth) Department of Primary Industries and Energy (which had responsibility for the project until October 1998), in conjunction with community information days about the proposal, which were held in different centres starting in February 1998. In particular, meetings were held with the following Aboriginal community groups:

- Port Augusta Native Title Working Group (which represented at the time of the consultation) the Kokotha People's Committee, the Barngala Aboriginal Council, the Kuyani Association (Aboriginal Corporation) and the Nukunu People's Council
- Andamooka Land Council
- Kupti Piti Kingka Tjuta Aboriginal Corporation
- Nullakarinka Wanga Association.

The Commonwealth consulted with relevant parties such as the South Australian Department of State Aboriginal Affairs, the Aboriginal Legal Rights Movement and the Native Title Tribunal to determine which Aboriginal groups claimed an interest in the area. In doing so, the Commonwealth noted that some groups that did not have a native title claim over the region may still claim a heritage interest in the land.

At the time the central–north region of South Australia was selected, the following applications for native title claims covering parts of the study area had been accepted by the Native Title Tribunal (Figure 11.1):

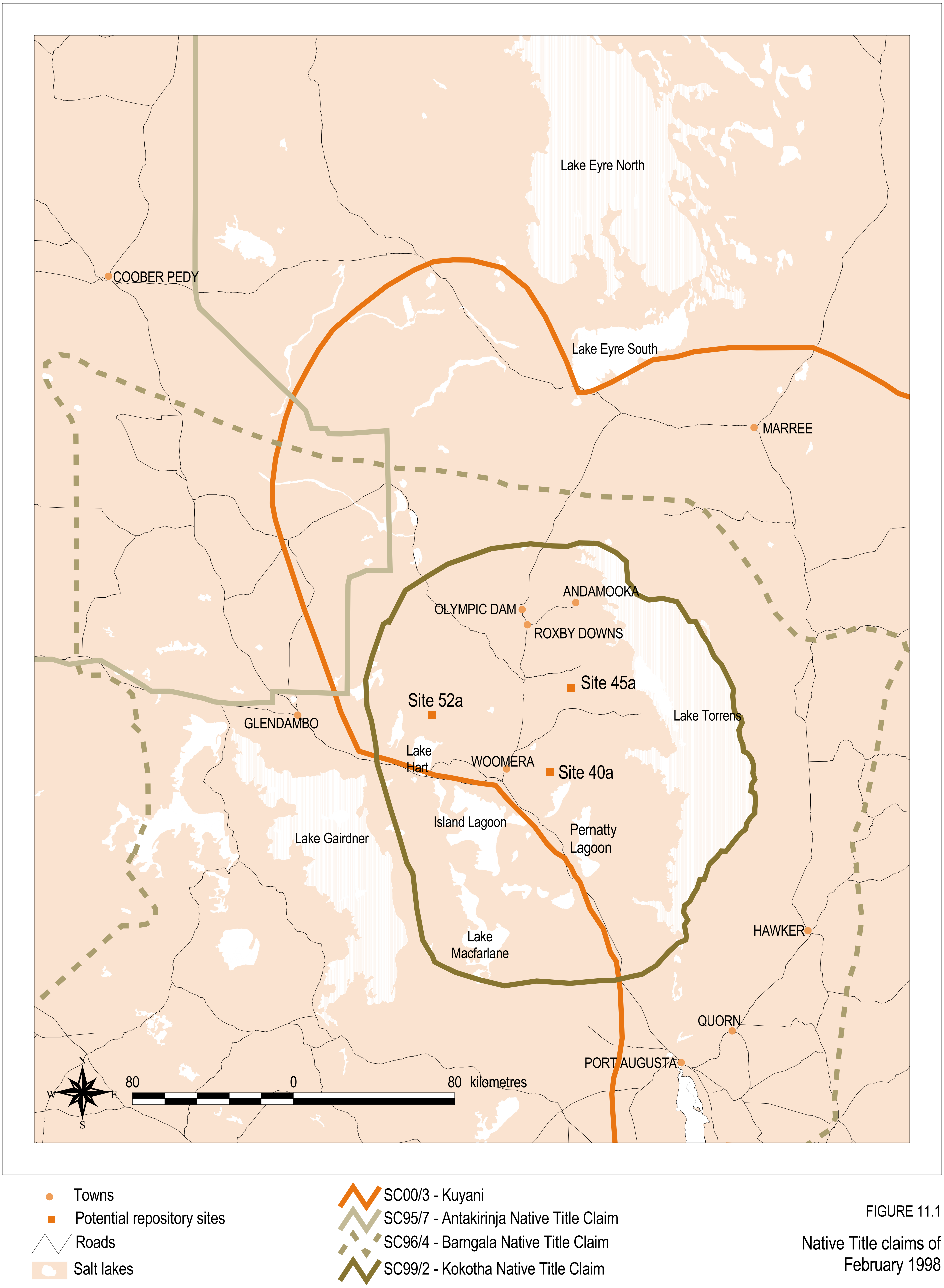


FIGURE 11.1

Native Title claims of February 1998

▪ Kuyani #2	SC95/4
▪ Antakirinja Mutuntjarra	SC95/7
▪ Barngala	SC96/4
▪ Kokotha	SC96/6.

The Kuyani native title claim boundaries were later revised such that their claim area lay to the east of, and no longer overlapped, the national repository project area. However the Kuyani continued to assert their connections to lands in the project area. In 2000, the Kuyani had a new claim, SC00/3, which overlapped the repository project area, accepted by the tribunal. A native title claim application by the Andamooka Land Council Association (Kokotha Gardi–SC98/5) was not accepted by the Tribunal. Subsequently the two groups of Kokotha claimants submitted and had accepted by the Tribunal application SC99/2, which incorporated SC96/6 and SC98/5 (Figure 11.2).

The Regional Consultative Committee (RCC) was established shortly after the announcement that site selection studies for the national repository would be conducted in the central–north region, to facilitate information exchange between the Commonwealth and regional stakeholders. The RCC has members from local and State government, pastoralist groups, townships in the region and local industry groups as well as Aboriginal groups (see Section 1.5.3).

At the initial meetings with the various Aboriginal groups, the Commonwealth and expert consultants explained: the site selection process; what the national repository would look like; how it would operate; what types of waste it would accept; the measures to be taken to ensure that the effect of the facility on the environment would be minimal; how transport of the waste to the site would be managed to ensure its safety; and how the repository would be designed so as to not pose a risk to groundwater and fauna and flora.

Written questions were submitted to the Commonwealth through the legal representatives of the various Aboriginal groups, and these were responded to in writing and at face-to-face meetings. Discussions began on undertaking cultural heritage investigations. The Commonwealth noted that the chosen region contained large areas of potential suitability, and indicated that it was their intention to investigate sites that were not ‘areas of significance’ to Aboriginal people.

Negotiating the contractual arrangements for undertaking these heritage investigations was a major focus of subsequent meetings and correspondence with the Aboriginal groups and their legal representatives.

11.1.2 Aboriginal Views about and Aspirations for the Project

Aboriginal Use of the Land and Resources in the Region

Almost all of the potential repository sites considered in this study were located on pastoral leases, including the three under consideration in this draft environmental impact statement (Draft EIS). The Aboriginal people who claim connections with the lands now under pastoral lease mostly live in towns in or adjacent to the region (e.g. Port Augusta, Coober Pedy and Whyalla) or further afield. Some reside on Aboriginal lands to the west of the study area.

As far as can be determined, few if any Aboriginal people in the claimant groups gain an income from the pastoral industry in the project area, except perhaps through casual station work. However there are older people in these communities who worked on these stations up until the 1970s and even later or who are, or were, employed in other industries such as in road transport, on the railways, by the (then) South Australian Highways Department, or by local, State or Commonwealth government agencies. Thus in a variety of ways Aboriginal people have had a continuing presence in the region.

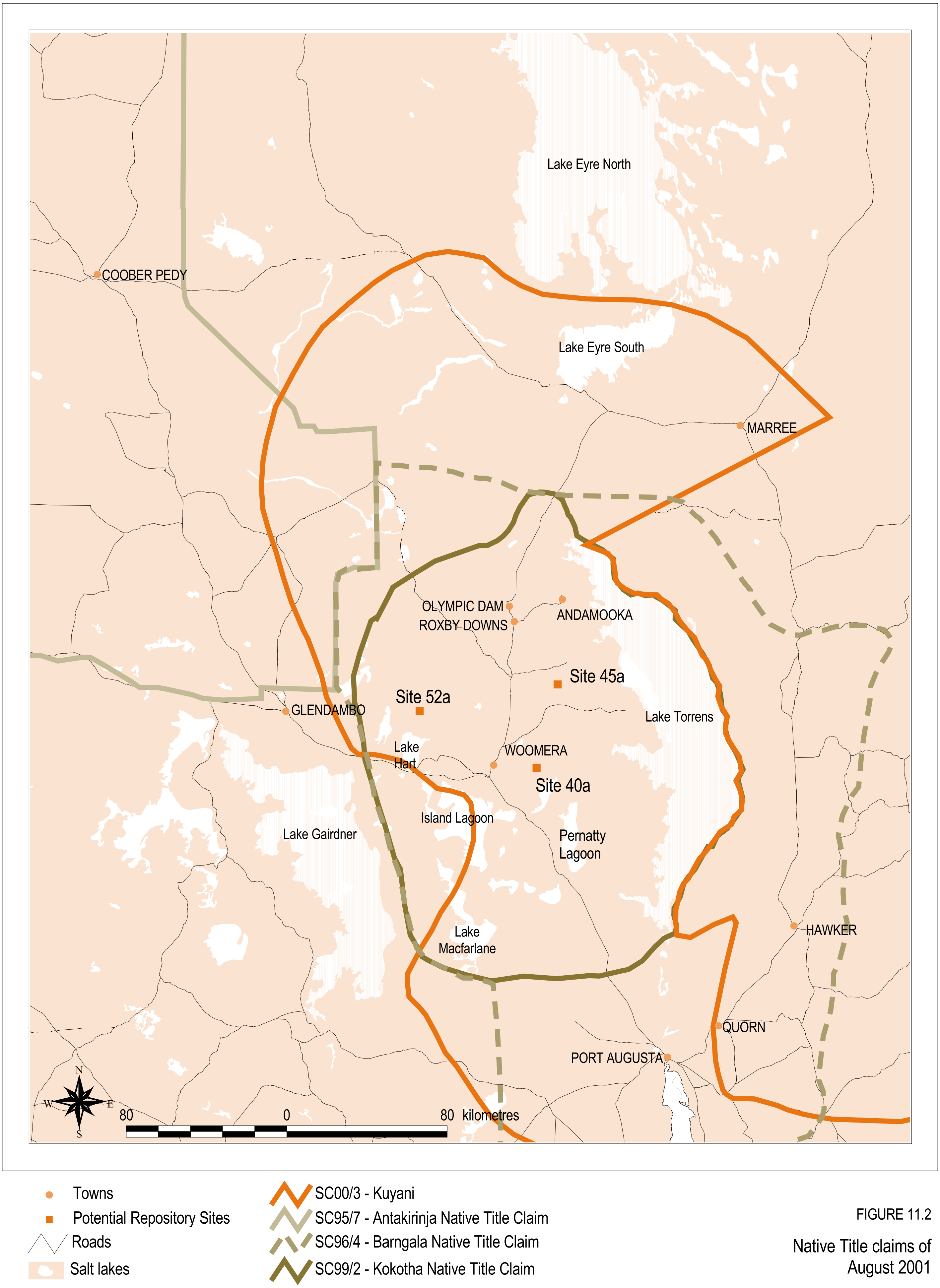


FIGURE 11.2

Native Title claims of August 2001

Aboriginal Attitudes to the Project

Attitudes expressed at meetings and in writing varied between and within groups and ranged from opposition to the proposal to guarded neutrality conditional on cultural heritage issues being assessed appropriately, and landscapes and places of spiritual and cultural significance being properly protected.

The issue of radioactive materials is a particularly sensitive matter for Aboriginal people in the region, in part due to the historical legacy of the atomic tests carried out at Maralinga during the 1950s and 1960s (e.g. see Palmer 1990; Palmer and Brady 1991). As pointed out in one of the work area clearance reports, many older people, including several members of the various field teams, recall the tests and their consequences.

In various consultations with Aboriginal groups, the Commonwealth noted that the disposal of waste in a purpose-built, well managed, below-surface disposal facility was in no way similar to the atmospheric testing of atomic weapons. In addition, the Commonwealth indicated that both low and intermediate level radioactive waste was already stored in above ground accommodation on the WPA in the region, and moving the low level waste to a disposal facility would improve the safety and the management of the material.

In common with other community groups, organisations and individuals, concern was expressed about the risks to people and the environment from the operation of the repository and by the transport of radioactive materials to the repository. Of specific concern to Aboriginal groups was the potential of the project to adversely affect the values that the landscape of the central–north region of South Australia has for them.

These values include most importantly cultural heritage values, not expressed solely as sites or places that might be physically avoided, but in a number of religious narratives, generically called *Tjukurrpa*, that incorporate different parts of the regional landscape. The Commonwealth and expert consultants responded to these issues in face-to-face meetings, and through written correspondence.

11.1.3 Aboriginal Heritage

Heritage Clearance Process

Heritage assessment surveys were conducted separately by each of the three groups under separately negotiated heritage clearance agreements (HCAs). The groups were:

- Antakirinja, Barngala and Kokotha Native Title Claimant Groups, working jointly under the same HCA and with the same legal representatives
- Andamooka Land Council Association, with separate legal representation
- Kuyani Association, represented by an adviser.

The aim of the surveys was to determine whether potentially suitable sites nominated by the Commonwealth, or suggested by the Aboriginal groups, were ‘areas of significance’, that is, whether an area is of cultural, social or spiritual significance to Aboriginal people traditionally responsible for that area, and within the definition of ‘Aboriginal site’ as defined in the *Aboriginal Heritage Act 1988* (SA) and ‘significant Aboriginal area’ as defined in the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Cwlth).

Work on negotiating the HCAs (which were broadly similar in content) began in mid to late 1998 but they were not concluded and signed until April 1999 by the Kuyani Association; May 1999 by the Antakirinja, Barngala and Kokotha claimants; and June 1999 by the Andamooka Land Council Association. However, some clearance work was undertaken by some groups before the finalisation of the relevant heritage agreements.

Following the clearance of sites for investigation and drilling in stage 1 (one drill hole was placed on the corner of 11 potential repository sites), Aboriginal groups were asked to clear sites for stages 2 and 3, which involved placing additional holes on five and three sites respectively.

Following the failure to obtain clearance from some groups for work in stages 2 and 3, in November 1999 the Commonwealth referred a number of potential repository sites to the SA Minister for Aboriginal Affairs under Section 12 (4) of the Aboriginal Heritage Act (SA), for determination of their heritage significance. The South Australia Government then started an assessment process, which involved public consultation.

Before the end of the process, however, a second HCA was concluded in May 2000 with the Antakirinja, Barngala and Kokotha claimants to clear five sites for stage 2 and 3 drilling, and the construction of the national repository. It was agreed that the Commonwealth would nominate a number of sites and during the field clearances alternatives could be nominated, either by the Commonwealth's representative or by the field teams nominated by the claimants.

Under the HCAs the field teams nominated by the various groups inspected and assessed (clearance work) the various proposed repository sites and their access routes (work areas) and in written reports advised the Commonwealth of the details of each work area inspected, assessed and cleared or not cleared by the field team. An area was only to be identified as not cleared for works if it was an area of significance. No specific information was supplied in the reports about the nature of any areas of significance.

The HCAs contained a provision that in the event a work area was not cleared the Commonwealth was able to nominate alternative work areas and to consult with the field teams to endeavor to identify alternative work areas away from areas of significance. In several cases the Aboriginal groups designated alternative areas that were contiguous with or close to the original area. All three repository sites under consideration in this Draft EIS were identified through this process.

All field teams included representatives of the group concerned who were considered by the group to have relevant traditional knowledge of the country and who could speak for the land. The field teams commissioned by the Antakirinja, Barngala and Kokotha claimant groups and the Andamooka Land Council Association also included specialists with expertise in anthropology and archaeology.

The field inspections were undertaken in four phases as summarised in Table 11.1. In total over 40 potential repository sites were inspected by one or more of the groups

TABLE 11.1 Program of heritage clearance surveys

	Date of inspection			
	1st	**2nd**	**3rd**	**4th**
Antakirinja, Barngala and Kokotha claimants	January 1999	June 1999	October 1999	May 2000
Andamooka Land Council Association	October 1998	June–July 1999	November 1999	April 2000
Kuyani Association	April 1999	June 1999	October 1999	April 2000

Heritage Context

The three potential repository sites under consideration are situated in a region that contains locations of significance to Aboriginal people. As described in two of the work area clearance reports, many of the region's landscape features have important spiritual associations. Numerous spiritual pathways or *Tjukurrpa* trails extend for hundreds of kilometres, linking this region with the central desert areas and to cultural areas north and west. They also link to the eastern lakes and Flinders Ranges region. In this respect the area of investigation straddles an area of particular cultural interest.

The interconnected nature of the cultural environment means that to the Aboriginal groups concerned, the locations proposed for the potential repository sites, even though very small, cannot be viewed as isolated entities, but need to be considered within the broader cultural perspective of Aboriginal beliefs. The gibber plains are commonly associated with significant *Tjukurrpa* and the fact that almost all of the work areas (including the three under consideration) were located on gibber plains made their clearance for development more difficult.

It was for these and other reasons that the work area clearance process was deemed to be difficult in the Woomera area, especially for the Antakirinja, Barngala and Kokotha claimant groups. It was also for these reasons that the field teams selected by those claimant groups for the final work area clearance were composed of initiated men, senior women and included senior holders of the law from the Maralinga and Anangu Pitjantjatjara Lands. These people were deemed to have the authority to make land determinations in the context of the law, without upsetting traditional social and political associations and customary rights to land.

There is also abundant archaeological evidence of occupation and resource exploitation of the Woomera region. In the course of archaeological investigations over the past 20 years (e.g. see Hughes and Sullivan 1984) in arid landscapes in northeast South Australia investigated to date (including around Woomera), the largest and archaeologically most impressive sites found are campsites that occur on sand dunes adjacent to large water holding depressions such as large claypans and canegrass swamps, and to creek lines. These sites have very high densities of artefacts (200+/m^2) comprising a wide range of raw materials and with a wide range of artefact types. Sites of this type commonly contain hundreds of thousands and occasionally millions of artefacts.

Stone artefact scatters have been the most common types of site found in the region, and with few exceptions they were located on sand dunes and/or in close proximity to fresh water sources or sources of raw material for flaking. Virtually every isolated dune or small cluster of dunes on gibber plains has surface scatters of stone artefacts on them, demonstrating that these landforms provided a focus for use in otherwise generally featureless landscapes. These dune sites contain a diverse range of raw materials and artefact types.

Silcrete and quartzite were the dominant raw materials used for flaking, but small amounts of quartz (both opaque and crystal), and a variety of chert rocks were also used. As well as flakes and cores, backed artefacts, unifacial points and tulas have been observed. Hammerstones have been recorded on many sites, as have whole and fragmented grinding stones (mainly sandstone). Hearth stones, which served as heat retainers, also have been found on some sites.

Suitable outcrops of silicified rock (especially silcrete and quartzite) were quarried for the raw materials for the manufacture of stone artefacts. These quarries typically have large numbers of flakes and cores that represent the early stages of artefact manufacture.

The gibber plains have very much lower amounts of archaeological material than sand dunes. These plains have a background scatter of stone artefacts, generally at densities of less than 1 artefact/1000–10000 m^2, but densities are locally higher where good quality raw material (usually silcrete or quartzite) occurs. Where good flaking quality rock occurs (again usually silcrete or quartzite) knapping floors can be found where stone has been worked on the spot.

Results of the Work Area Clearance Surveys

All three sites (40a, 45a and 52a) and access to them have been cleared for all works associated with the construction and operation of a waste repository. Certain conditions have been placed on these clearances as described in the next section. The access roads and tracks from Woomera to the sites are described in Section 7.4 and shown on Figure 7.2.

In undertaking their clearance work, all three groups were concerned principally to ensure that areas that were of cultural, social or spiritual significance were not adversely impacted to an unacceptable degree. Archaeological materials and sites were generally treated more peripherally, especially in the reports presented by the Antakirinja, Barngala and Kokotha claimant groups and the Kuyani Association.

The reports by the Andamooka Land Council Association contained archaeological descriptions of the repository sites examined. The field teams commissioned by all three groups were highly familiar with the archaeological landscape of the region. In addition, the teams fielded by the Antakirinja, Barngala and Kokotha claimant groups and the Andamooka Land Council Association included archaeologists.

No archaeological constraints were identified with any of the three proposed repository areas. Part of the access track to Site 40a was described as having extensive archaeological material associated with creeks along the route, and it was suggested that management recommendations should be formulated to minimise damage to and interference with this material.

In the various reports on the proposed repository sites, frequent observations referred to creeks and dunes with associated stone artefact scatters and quarries. It was implicit (and at times explicit) in the reports that such areas should be avoided, not only because of their cultural, social and spiritual significance, but also because of their potential archaeological importance.

For planning and design purposes, the Commonwealth commissioned a geomorphological assessment of the terrain of the three sites and their potential access routes to ensure that no landforms of high archaeological potential — such as sand dunes, major water-holding claypans, major rock outcrops, canegrass swamps and creeks — would be affected by the proposed development. The geomorphological assessment is presented in Section 8.2.

11.1.4 Impacts on and Risks to Aboriginal Heritage and Community Aspirations

Aboriginal Cultural and Heritage Values

As noted above all three sites (40a, 45a and 52a) and access to them (see Figure 7.2) have been cleared for all works associated with the construction and operation of a waste repository. Certain conditions have been placed on these clearances as described below. Provided these conditions are adhered to, there should be no risks to cultural heritage sites and other values of the land.

In particular the Work Area Clearance Report prepared by the Antakirinja, Barngala and Kokotha claimant groups made specific recommendations concerning access to the three sites in the event that one or other of them was selected for development as the repository

Repository Sites

Several quartzite knapping floors have been observed at Site 52a. All of these are located away from proposed construction areas and would be protected in accordance with management measures presented in the environmental management plan. No areas requiring protection were observed at Sites 40a and 45a.

Site 40a Access

- No access is permitted away from the proposed access track leading to Site 40a.

- In the event that the existing road/track is to be realigned and upgraded to service the project, management recommendations should be formulated once the new alignment has been identified to minimise damage and interference with the extensive cultural material associated with creeks along this route. Specialist archaeological advice may be required. Monitoring of road construction activities and/or salvage archaeology by representatives of the claimants may be required before the road is constructed.
- A new access road could be constructed across the gibber ridge from the track between The Pines and Arcoona Station (at grid ref. 692015 6549213), branching southeast in a straight line across the gibber plain to Site 40a.

Site 45a Access

- Access should be confined to existing tracks and dirt roads. Primary access should follow the old Andamooka Road (from where it joins the Andamooka Station road). Secondary access should be confined to an ungraded track following the existing fence line.
- No access is permitted near or within the sand dune fields adjacent to Site 45a.

Site 52a Access

- Access should be confined to existing tracks and dirt roads. Primary access should follow the route via Koolymilka.
- If the access road is to be upgraded to service the project, then the representatives of the claimant groups should monitor that upgrade within 15 km of Site 52a.

The proposed access routes are described in more detail in Section 7.4. No changes are proposed to the cleared access routes, or their alignments. Any upgrading of the access routes would involve minor works within the existing alignments such as repairing previous damage, establishing new road formation over old formation, improved floodways at creek crossings, and minor sheeting works. Such works are commonly undertaken during routine road maintenance in South Australia's arid areas.

The proponent has noted the above conditions and the proposals for accessing these three repository sites during the construction and operation phases incorporate commitments to use the existing access roads and tracks cleared by the various groups and, in the case of Site 40a, the potential new access track route defined by the Antakirinja, Barngala and Kokotha claimant groups.

Impacts on Aboriginal Uses of the Land and Resources, and Native Title

The selected repository site would be extremely small in area (1.5 x 1.5 km = 2.25 km^2) and would have negligible impact on the operations of the pastoral station on which it would be located. The repository site is very small compared with the relevant native title claims: the Kokotha claim occupies 34,230 km^2; the Kuyani claim 96,040 km^2; and the Barngala claim 103,780 km^2.

It was confirmed that none of the three potential sites has archaeological constraints. Sites 40a and 45a have extremely low background scatters of stone artefacts and their archaeological potential is low to negligible. Site 52a has a widespread background scatter of artefacts and a few quartzite flaking floors that can be avoided by any of the proposed construction works.

There were no archaeological constraints associated with access to any of the three potential sites, provided that access is confined to existing tracks and dirt roads. Extensive but sparse scatters of stone artefacts associated with creeks were confirmed to occur along parts of the access track to Site 40a, and any proposed change to the alignment would require further consultation. However no changes are proposed to the cleared access routes or their alignments.

The project should have no impact on the ability of Aboriginal communities to generate income from current or future land uses on pastoral leases in the region. It would not affect the ability of these groups to undertake any current or foreseen Aboriginal uses of land and other resources in the region.

The Commonwealth has indicated that it intends to acquire the repository site. Native title would be addressed during this process.

Opportunities Associated with the Proposal

The siting phase has involved consultation with Aboriginal groups on heritage, and the engagement of relevant individuals and advisers to report on the heritage values of possible sites.

Further opportunities for the involvement of Aboriginal people may be available during the construction stage, including involvement in fencing or other works, or through site visits.

After the final site is decided and approval to proceed is obtained, the Commonwealth has indicated that a local consultative committee would be established. Relevant Aboriginal groups would be invited to join the committee.

11.2 European Heritage

11.2.1 Early Exploration

In 1839, Edward John Eyre sighted and named Lake Torrens (see Figure 10.1), and followed 90 km of its eastern shore (Jensen and Wilson 1980). Eyre described the northern parts of the State as a region of brine and desolation (Bowes 1968), and this report was to deter development of this region for nearly 20 years. In 1842, C Dutton followed Eyre’s tracks around the head of Spencer Gulf. Later evidence indicated that he had penetrated as far as the landform now known as Dutton Bluff (Jensen and Wilson 1980).

In 1846, John Horrocks’ expedition to Lake Torrens had the objective of finding good quality pastoral land west of Lake Torrens. Horrocks reached Lake Gill (later renamed Lake Dutton) (Flannery 1998). His expedition found no areas of fresh water or springs, and Horrocks commented ‘…there being a sterile sameness throughout’.

BH Babbage explored the country at the head of Spencer Gulf and to the northwest between Lake Gairdner and Lake Torrens in 1853 (Jensen and Wilson 1980). Indeed, most of the exploration of this area in the 1850s, including Swinden in 1857, and Stuart, Babbage and Warburton in 1858, used a very similar route immediately west of Lake Torrens. While all other expeditions continued to travel to the north of the project area, Swinden only reached Andamooka Waterhole (Gee 2000).

John McDouall Stuart undertook three major expeditions (in 1852–53, 1858 and 1862), which traversed the area to the north of Port Augusta. On the first expedition, his party explored the country at the head of Spencer Gulf and between Lake Gairdner and Lake Torrens. Following this, he led an expedition to Andamooka, Yarra Wurta Cliff, and Stuart Range, and from there south to Denial Bay (where Ceduna is now located) via Mount Eba, Lake Younghusband and the Gawler Ranges, encircling the area traversed by Babbage. His third expedition crossed the continent to the Gulf of Carpentaria, again traversing the country to the west of Lake Torrens (Jensen and Wilson 1980).

11.2.2 Pastoral Expansion and Historical Land Use

Pastoral activities began in South Australia in the 1830s. In 1842 a system of issuing an occupation licence or a depasturing licence was established to those wishing to use lands within surveyed 'Hundreds'. During the 1840s, Crown Land outside the surveyed Hundreds was being used for opportunistic grazing, often without a rental fee being paid. Therefore, in 1851 a 14-year pastoral lease was introduced by the Government. This provided pastoralists (as opposed to agriculturalists) an increased degree of security of tenure.

As a consequence of Eyre's reports, it was popularly believed that a ring of salt lakes barred access and the expansion of pastoralism into the north of the State. However, by 1856 Babbage had disproved the 'horseshoe lake myth' and in mid-1857, Goyder reported:

> …vegetation of the most luxuriant kind,…placid waters, disturbed only by the enjoyment of the waterfowl,…and a sheet of fresh water…emanating from a number of delicious springs (Bowes 1968).

Within months of Goyder's reports, pastoralists began moving sheep and cattle into the north. This expansion occurred despite subsequent reports by the Surveyor-General, Colonel Freeling, which were less favourable than Goyder's (Bowes 1968).

By 1860, the country on the eastern side of Lake Torrens had been occupied by pastoralists. At this time, the only knowledge of the area to the northwest of Port Augusta and to the west of Lake Torrens was that provided by Goyder, Swinden, Babbage, Oakden and Hulkes, Warburton, Gregory, Stuart, and others who have left no written record (Bowes 1968; Jensen and Wilson 1980).

In 1859, JF Haywood, William Brown and William Marchant explored the country within a short distance of the western side of Lake Torrens, while Oakden and Hulkes explored the country further westward. Oakden and Hulkes reported good pastoral country and took pastoral leases (including Oakden Hills) as confirmation of their optimism. However, drought forced them to abandon the leases and the country was not leased again until the late 1860s (Cockburn 1925; Richardson 1925; Jensen and Wilson 1980).

The definition of the distribution of the artesian mound springs along the southern edge of Lake Eyre by explorers such as Warburton, Babbage, Stuart and Goyder resulted in the rapid development of pastoralism in those areas that could be serviced by this source of water. Between 1859 and 1862, pastoral leases were taken up in the area bordering the southwestern corner of Lake Eyre from Finniss Springs Station to the current Anna Creek Station (Gee 2000).

By 1864, the pastoral expansion in the northeast had advanced through Angepena, and on to Lake Hope at the northern tip of the Finders Ranges. The northern edge of the pastoral expansion was represented by Mount Margaret Station (now known as Peake) on the shores of Lake Eyre. Isolated stations were located on the western side of Lake Torrens at Pernatty and Arcoona, and further to the west there was a group of stations on the southern shore of Lake Gairdner, the principal one being Yardea.

The rate of pastoral expansion was even more rapid after a new system of leasing pastoral land was introduced in 1863. The expansion of pastoralism into the northwest of South Australia was, in the opinion of Bowes (1968), largely brought about by people who saw the pastoral industry as an area of investment or speculation.

Most pastoral leases in the area northwest of Port Augusta were taken up during the 1860s and 1870s. Pastoral activity reached its peak in the late 1880s and by the 1890s all the original leases in the northwest had expired. Since that time there have been many changes in the ownership and boundaries of the pastoral leases in the area. These changes have generally reflected modification in the economic viability of the various leases caused by perturbations in the regional environment such as drought or the relocation of transportation facilities (Kinhill-Stearns Roger Joint Venture 1982).

In 1875–76, AM Wooldridge took up a pastoral lease over approximately 5100 km^2 of land to the west of Lake Torrens. The lease was then subdivided, with one portion becoming part of Andamooka Station, the northwestern portion being transferred to the Chewings brothers to form Parakylia Station, and the balance forming Arcoona Station (Cockburn 1925; Richardson 1925).

The first Pastoral Act, introduced in 1893, established the Pastoral Board and the system of 42 year pastoral leases. This original legislation was amended significantly in 1927 following a Royal Commission into the pastoral industry. Further significant amendments were made in 1939, when the Pastoral Board was authorised to prevent degradation of the soil and vegetation by controlling livestock numbers on pastoral leases (Vickery et al. 1981).

The development of the pastoral industry for sheep grazing was aided by the construction of the dog fence, a 9660 km fence from western Queensland to the Head of the Bight in South Australia, which restricts the movement of dingos south of the fence (see Figure 10.1). Under the *Dog Fence Act 1946 (SA)* and *Dog Control Act 1979*, dingoes are controlled south of the fence where they are considered vermin and a risk for sheep producers, sheep grazing being the major land use. North of the fence, cattle grazing dominates land use.

Pastoralism remains the dominant land use in the region and Donovan (1995) provides a recent summary of pastoralism and the Pastoral Board’s activities. The South Australian *Pastoral Land Management and Conservation Act 1989* and its companion legislation, the *Soil Conservation and Land Care Act 1989*, established a legislative framework to manage the pastoral lands. All of the project area is within the Kingoonya Soil Conservation District and sustainable land management is a major principle of both Acts and the district plan.

Sheep grazing remains the major pastoral activity on the Arcoona Tableland. Arcoona Station (Site 40a) has recently changed ownership. The lease to Andamooka Station (Site 45a) is held by WMC Limited and with the exception of a few cattle and horses the latter station is currently destocked. Areas of the WPA, including Site 52a, form part of the grazing leases of neighbouring stations.

11.2.3 Woomera Prohibited Area

Following World War II Great Britain sought to develop a Defence facility for weapons research and testing. Sites within Canada and Australia were assessed, with a 480,000 km^2 area north of Adelaide chosen. The area provided a large, remote sparsely populated region for testing. A master plan and project team for the proposal were established in 1946.

The joint project between the United Kingdom and Australia, the Long Range Weapons Organisation, came into existence on 1 April 1947 with the Long Range Weapons Establishment being formally promulgated in the following year. The facilities initially comprised two prohibited areas: a long range weapon impact area in the northwest of Western Australia, and the actual rocket range in the centre of South Australia. The prohibited areas enabled the firing, observation and recovery of long-range weapons. Morton (1989) provides a detailed account of the use of WPA up to 1980.

Facilities developed for the rocket range included airfields, road and water reticulation networks, telecommunications, launch facilities, and a 132 kV transmission line and water supply pipeline to Port Augusta. Personnel were accommodated in a purpose-built town, Woomera, located just north of Pimba.

During the early operational years, nine independent and subsidiary live firing ranges were established. Eight of these ranges were closed by 1957 and resources were concentrated on one main range, Range E (Morton 1989), which was used from 1951 onwards. It was provided with a sealed road and airfield (Evetts Field), and was a world-class facility (see Figure 10.3).

The Range E range head, which included the main launch, plus technical and support facilities, is approximately 40 km northwest of Woomera at Koolymilka (just north of Lake Koolymilka). The danger template for the live firing of weapons included all or part of 21 pastoral leases north and northwest of Woomera.

The WPA and the township of Woomera maintained high security levels during the almost 30 years of weapons testing. Many short and long range weapons and research vehicles were completed and tested at WPA, with the first missile launched almost two years after the establishment of the joint venture. An array of air-to-air, ground-to-air and air-to-ground defensive and offensive unguided and guided weapons was tested. Trials of the latter weapons included Skylark, Black Knight, Blue Streak, Europa, Blood Hound and Zulu Squire.

During the 1960s the functions of the WPA became less focused on weapons, and began to include satellite launches and deep space research. During 1970, construction began of the Joint Defence Facility, Nurrungar, approximately 19 km south of Woomera.

The scaling down of weapons testing in the 1970s and the closure of Nurrungar in the late 1990s saw Woomera's population significantly decline. The area designated for the launching, observation and recovery of guided weapons has significantly reduced since the abolition of long range testing.

The main administrative facilities for WPA are maintained by Defence and its contractors, and continue to be used. However, facilities associated with the launching of rockets are in a disused state with many of the original facilities removed or demolished. The WPA continues to be used for Defence purposes, including research and development of weapons systems, but it incorporates the research and testing of space instruments and vehicles from a wide range of countries. Much of this is on a commercial basis. Further information on the use of the WPA is provided in Section 10.4.4.

Site 52a is located in the WPA, approximately 10 km west of the Range E range head and Evetts Field (Figure 10.3).

11.2.4 Items of Heritage Value

No items of European heritage value for the project area are listed on the Australian Heritage Places Index, a compilation of the various State and Commonwealth heritage databases. John Henry Davies' grave and the Philip Ponds Homestead are sign-posted as sites of local interest along the Woomera to Roxby Downs road, approximately 5 km north of Woomera. No sites of European heritage value were identified as likely to be affected by the project.

Chapter 12 Radiation

In this chapter, current background radiation at the sites is described and the potential radiological impact from construction, operation and closure of the repository assessed.

12.1 Existing Environment

This section assesses natural background radiation levels at the three potential repository sites. Sources of background radiation are discussed and the methods used to measure these are described. The results of the measurement programs are presented and their implications discussed.

12.1.1 Sources of Naturally Occurring Radionuclides

Natural radioactivity, to which humans have always been exposed, arises from both terrestrial and cosmic sources. Cosmic radiation originates from outer space and interacts with the upper atmosphere to produce several radionuclides, of which carbon-14 (^{14}C), tritium (^{3}H) and beryllium-7 (^{7}Be) are the most significant.

The three main terrestrial sources of natural radioactivity in soils and rocks in the Earth's crust are potassium-40 (^{40}K), uranium (predominantly as ^{238}U but also as ^{235}U) and thorium (predominantly as ^{232}Th). Each of these radionuclides has an extremely long half-life, some in excess of 10^9 years. Potassium-40 is associated with stable potassium, which is a very common element in soils and minerals, and decays to a stable nuclide. Natural uranium is comprised of ^{238}U (99% by mass), its radioactive decay product ^{234}U (0.006% by mass) and ^{235}U (0.7% by mass).

Radioactive decay of the radionuclides ^{238}U, ^{235}U and ^{232}Th produces a total of more than 40 radionuclides with half-lives ranging from a fraction of a second to 10^8 years. In each case the end product of the decay process is a stable lead isotope. Some of these radionuclides, such as the radium isotope ^{226}Ra and radon gas ^{222}Rn, are of particular importance in human exposure to radiation. In any radioactive decay process a radionuclide formed by decay of another is termed a 'daughter' product and the original radionuclide is described as the 'parent'.

Normally, these radioactive elements are present in air, water or soil in trace quantities. However, there are situations where industrial or environmental processes can concentrate certain naturally occurring radionuclides, for example in the waste or byproducts of the smelting of tin and aluminium, which concentrate uranium and thorium in the residual slag. Another example of technological enhancement of the levels of naturally occurring radionuclides is in oil and gas production, where ^{226} Ra and its daughters can plate out onto production equipment and storage vessels — activity levels in scales and films in oil or gas production pipes in extreme cases can rise to 10,000 Bq/kg.

Certain foodstuffs can concentrate natural radioactivity by normal environmental processes. The most notable example is Brazil nuts, which can contain 200 Bq/kg of the uranium decay product ^{226}Ra. Another example is shellfish, which can concentrate ^{226}Ra to relatively high levels, up to thousands of Bq/kg.

12.1.2 Sources of Artificially Occurring Radionuclides

Non-naturally occurring radionuclides (sometimes termed anthropogenic) have been created by human activities since the discovery of atomic fission and the subsequent development of nuclear energy and nuclear weapons technologies. From the 1950s through to the early 1970s testing of nuclear weapons was mainly conducted in the atmosphere. The subsequent fallout of fission products and weapons debris from these tests is the main source of artificial radionuclides in the environment, the most important of these being caesium-137 (^{137}Cs) and strontium-90 (^{90}Sr).

12.1.3 Measuring Background Radioactivity

Radionuclides, either natural or artificial, in the environment emit different types of radiation depending on their physical properties. This has been discussed previously in Section 2.1. Gamma (γ)-emitting radionuclides in the environment are the source of external radiation exposure of people, whereas alpha (α) and beta (β) emitting radionuclides lead to internal exposure through ingestion or inhalation of the radioactive material.

The measurement of background radioactivity due to individual radionuclides may require the detection of alpha, beta or gamma radiation depending on the specific radionuclide. The type of radiation emitted will also govern whether or not measurements can be done in the field or in the laboratory on samples collected from the particular location.

Because both alpha and beta radiation have a limited range, or penetration, in situ measurements are probably unreliable. As a result, samples have to be collected and transferred to a laboratory for analysis for specific radionuclides, which would normally require complex chemical separation techniques.

Gamma radiation has a much longer range, or penetration, and radionuclides that emit gamma rays can be measured by detectors either in situ or in a laboratory. In the latter case the analysis would normally require minimal processing of the sample. In situ measurements of gamma-emitting radionuclides provide an average concentration over a relatively large area (5000 m^2) and to a depth of several tens of centimetres. In order to achieve a similar average value, a number of individual samples are usually collected from a measurement location to overcome the possibility of variability of radionuclide concentration at individual sampling points.

The actual radionuclide concentrations in soil or rock at a particular location vary according to the mineral constituents of the material. For example, granite has higher than normal levels of uranium and thorium, while materials like sandstone and limestone are much lower in activity. The background radioactivity in surface soil would also reflect any deposition of radioactivity from the atmosphere, such as that due to natural radionuclides (lead-210 (^{210}Pb) and ^{7}Be) and artificial radionuclides (^{137}Cs and ^{90}Sr) from nuclear weapons tests/accident fallout.

Therefore, in order to determine the average background radioactivity at a site it is necessary to survey a reasonably wide surface area and to measure samples taken from depth.

12.1.4 Radioactivity Measurement Programs

A number of radiological measurements have been undertaken at the proposed and alternative sites. These include:

- a direct gamma measurement survey, and gamma spectroscopy on a series of soil samples taken from cores extracted from the sites

- analysis of rock and soil from two drill cores from each site for a series of radionuclides using high resolution gamma spectrometry (HRGS)
- an air survey comprising collection of dust samples in passive deposition gauges (two for each site for three months), which were analysed for uranium, thorium and selected radionuclides; and monitoring of radon and measurement of radon daughters
- sampling of groundwater and analysis for selected radionuclides, to supplement earlier measurement
- a baseline biota survey of selected radionuclides present in flora (samphire, canegrass and saltbush) and fauna (sheep, rabbit and meat ant).

Direct Gamma Measurement Survey

The Department of Industry, Science and Resources commissioned the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to undertake a gamma survey of the preferred and two alternative sites for the national repository (see Appendix E1). The purpose of this survey was to determine the pre-existing radiological content of the three areas and ensure that none of the proposed sites had an anomalous radioactive content.

The field survey was conducted during October and November 2000. The field monitoring program obtained several high resolution gamma-ray spectra at each site using the purpose-designed vehicle operated by ARPANSA. The vehicle-borne instrumentation allows gamma rays emitted from the soil within a 40 m radius to be detected and analysed. The detector was calibrated for the range of gamma rays emitted by the decay of ^{40}K, and from uranium and thorium decay products, the most common radioactive constituents found in soil.

The activity concentrations of potassium, thorium and uranium within an area of approximately 5000 m^2 could then be determined. Any additional gamma ray emitters not associated with these common radionuclides would also be measured by this technique and therefore could be further investigated. Results obtained indicated that the only other radionuclide detected at a statistically significant level was ^{137}Cs, which is found throughout Australia and the world as a result of atmospheric fallout. Twelve sample spectra were collected from each site.

Five soil samples were also collected from each of two locations within each site. Analysis of samples was used to complement the in situ monitoring.

Results obtained from these surveys indicated that the background radioactivity measurements are typical of worldwide averages, and the radiological content of the soils at these sites is similar to that found in most Australian soils.

Soil and Rock Sampling Program

Further soil and rock analyses were undertaken by ARPANSA. Two drill cores were analysed from each site, varying in total depth from 28.0 m to 34.4 m. All rocks were sedimentary in origin and varied between quartzites / harder sandstones and mudstones / softer sandstones, with an upper topsoil layer.

Three different depth intervals were sampled from the cores: the surface topsoils, 15 m depth and 30 m depth. Additional samples were taken from various depths, in order to test all of the various lithologies present. The samples were then analysed by HRGS for ^{235}U, ^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb, ^{228}Ra, ^{228}Th, ^{137}Cs, cobalt-60 (^{60}Co) and ^{40}K. The only radionuclides detected were gamma-emitters from the natural uranium and thorium series and ^{137}Cs. No other radionuclides were observed.

The results were evaluated with respect to the lithology, depth and site location. Details of the results obtained are presented in Appendix E2. In general, mudstones and soft sandstones are expected to be more permeable to water than the other lithologies. These sample types showed the highest radioactivity concentrations; the harder lithologies such as hard sandstones and quartzites showed lower activities. There were no significant variations with either depth or location.

Air Survey

Determination of background levels of atmospheric radioactivity was undertaken by On Site Technology Pty Ltd between September and December 2001. The report on this work is presented in Appendix E3.

Dustfall samples were collected for 78 days and analysed for uranium and thorium by inductively coupled plasma mass spectrometry, and for ^{226}Ra, ^{210}Pb, actinium-228 (^{228}Ac), ^{228}Th, ^{137}Cs, ^{60}Co and ^{40}K by HRGS. Radon daughter measurements were undertaken on single days in September and December. Average radon levels between September and December were determined using passive track etch samplers. Results were compared with environmental monitoring data from WMC Limited’s Olympic Dam operation, which is about 100 km north of Woomera (Figure 1.1).

The dustfall samples from Site 45a were contaminated with large amounts of dead insects. Rainfall recorded at Site 45a was also significantly higher than at Sites 40a and 52a. Dustfall results at the three sites were comparable to those recorded at the Olympic Dam monitoring sites. Uranium and thorium in the dust was low and typical of the surface soil in the area. There was some evidence that the insects collected at Site 45a were contaminated with local surface soil and this resulted in slightly elevated thorium values in those samples.

The only radionuclides detected in the dust were naturally occurring uranium, thorium and ^{210}Pb. All of these were found at levels that are considered typical for samples from an uncontaminated rural area. Elevated levels of ^{210}Pb (compared to other radionuclides) are a natural phenomenon resulting from the decay of naturally occurring ^{222}Rn in the atmosphere.

For comparison with the radionuclide content of the airborne dust, surface soil from the three sites was also analysed. Radionuclides detected were naturally occurring ^{40}K, uranium and uranium daughter products, and thorium and thorium daughter products. The levels of these nuclides were typical of an uncontaminated environment and comparable to the levels found in the dustfall samples.

Radon and radon daughter products were detected at levels typical of an uncontaminated rural environment. However, the radon daughter results were at the upper range of those found near Olympic Dam. This could be due to the high rainfall recorded at the three sites within a few days of each sampling trip or to the different geomorphology of the sites. The Olympic Dam sampling sites are in sand dune areas and Sites 40a, 45a and 52a are in gibber plains areas.

In summary, no artificial radionuclides were detected in airborne dust at the sites under investigation. Low levels of naturally occurring radionuclides were found at all sites, typical of an uncontaminated environment and comparable to the levels found in the local surface soil. There is no statistical difference between the results from Sites 40a, 45a and 52a.

Groundwater Sampling

Groundwater samples from one borehole at each site were taken in November 2001 and analysed for selected radionuclides. These analyses supplemented earlier measurements of ^{14}C and chlorine-36 (^{36}Cl) which were taken in the context of hydrological tracers. Ten-litre samples were taken using dedicated disposable plastic bailers, with measurements of field parameters to verify that the samples taken were reasonably uniform in composition.

The results (Appendix E5) indicate the baseline levels of radioactivity in groundwater from the Woomera area. The water samples from the boreholes at each of the three sites were tested for gross alpha, beta and gamma-emitting radioactivity for a number of radionuclides.

Results from each of the sites were relatively similar, with the exception of Site 52a, which showed a greater content of ^{228}Ra than the other sites, and Site 40a, which contained a greater concentration of ^{210}Pb. There was no detection of ^{137}Cs in any of the water samples analysed. The levels of radionuclides observed in each of the three water samples are typical for groundwaters from an area of high salt content.

Biota Survey

As noted in Section 9.5, a baseline survey of radionuclides present in flora and fauna for the preferred and two alternative sites has been undertaken. Samples of vegetation from each of the potential sites (samphire, canegrass and saltbush) were analysed for their americium-241 (^{241}Am), ^{226}Ra, ^{137}Cs and ^{60}Co activity by gamma-ray spectroscopy at the Australian Nuclear Science and Technology Organisation (ANSTO). The analysis (Appendix E4) concluded that at all three sites there was no presence of the radionuclides ^{241}Am, ^{60}Co or ^{226}Ra in any of the bladder saltbush, canegrass or samphire samples. Therefore, these have been reported as minimal detectable activities (MDAs).

Measurable levels of ^{137}Cs were detected in more than half of the samples. On Site 40a ^{137}Cs was only detected in the bladder saltbush and canegrass samples; on Site 45a ^{137}Cs was only detected in the bladder saltbush sample; and on Site 52a ^{137}Cs was only detected in the canegrass and samphire samples. The data indicate that the specimens at all sites had not been subjected to any significant quantities of radioactive fallout and the traces of ^{137}Cs can be considered as consistent with background levels.

Similarly, sheep, rabbit and meat ant (*Irodomyruex purpureus*) tissue from each of the potential repository sites, as well as underground water collected from boreholes at the sites, has undergone high resolution gamma spectroscopy analysis at ARPANSA. The data indicate that no traces of artificial radionuclides were detected in the samples taken from rabbits, sheep and ants from all three sites.

The samples were also tested for levels of ^{137}Cs and ^{60}Co. Where no traces were detected the results have been reported as MDAs. ^{137}Cs is present in the Australian environment due to fallout from atmospheric nuclear tests.

With the exception of a few cases, the naturally occurring radionuclides ^{238}U and ^{232}Th were not detected and were also reported as being MDAs. ^{40}K was detected in all samples, with levels fluctuating with the normal variation in potassium content of the samples.

12.1.5 Conclusion

The background radiation of all three sites has been measured by a combination of in situ measurement and laboratory analysis. Results from these measurements indicate that levels of activity of the naturally occurring radionuclides are typical of these types of materials. The level of ^{137}Cs is low compared with levels in Europe, where there is a greater amount of the radionuclide from past atmospheric testing of nuclear weapons and from the reactor accident at Chernobyl in 1986.

The results from both programs of soil measurements are broadly consistent. As would be expected, the analysis of individual samples indicates a greater range of radionuclide concentrations than the in situ measurements.

Similarly, the levels of radionuclides in the groundwater and biota samples are typical of these types of materials in this region.

Dustfall results at the three sites were comparable to those recorded for some years at Olympic Dam, which is about 100 km north of Woomera. Surface soil samples were typical of an uncontaminated environment and radionuclide concentrations are comparable to the levels found in the dustfall samples. Radon and radon daughter products were detected at levels typical of an uncontaminated rural environment; however, the radon daughter results were at the upper range of those found near Olympic Dam.

The local environment would be routinely sampled throughout the operational and monitoring periods of the repository and measurements of radioactivity made. This would enable the regulator to determine whether operations at the site were having any impact on the natural environmental levels of radioactivity as established by these radiological measurement programs.

12.2 Radiation Pathway Analysis

The radioactive waste arriving at the site would be conditioned to comply with the waste acceptance criteria (WAC) that would be established for the repository. These criteria are designed to allow the safe transport, handling and disposal of the radioactive material. The WAC are discussed in detail in Section 4.3.

The WAC would be developed to minimise potential releases of radioactivity at the disposal site by ensuring that the waste is in a solid, stable form and that it is packaged to prevent any loss of radioactive material through potential damage during transport and handling; and also to allow the repository to attain a mechanically stable structure (e.g. no voidage, gas production, explosions).

Waste packages would be tested for external contamination before transport. The packages would also be checked on arrival. In principle, therefore, only conditioned, externally uncontaminated, packaged radioactive material would be present at the site. However, there would be facilities at the site for the repackaging of waste if required. In the operational phase of the repository, when waste is being received, assayed and emplaced in the trenches or boreholes, there is unlikely to be any mechanism by which radioactivity could be discharged or dispersed from the repository buffer zone.

There may be some discharge of radon radionuclides that have been generated from decay of uranium and thorium parents. However, these are very short lived, with a longest half-life of 3.5 days. The potential for radon radionuclide production and emanation would be considered in developing the WAC.

In the event of an incident where, for example, an improperly conditioned package arrived at the site and a release of radioactivity did occur, this would be identified and remediated without any radioactive material leaving the site.

Following emplacement of radioactive waste in the trenches and boreholes, and closure of the facility (after a minimum operating life of 50 years) there would be an institutional control period of 200 years, during which access would be restricted. In this period, and beyond, the waste form and waste packages would degrade and infiltration by rainwater may occur. There may then be a number of release pathways by which radioactive material might be transferred to the general environment.

12.2.1 Release Pathways

Discharge to Air

The WAC would restrict the presence of gaseous materials in the waste packages. However, some gaseous material might form over time. For example, ^{14}C might become incorporated in methane (CH_4) or carbon dioxide (CO_2) as a result of microbial activity, and

^{3}H might be converted to hydrogen (H_2) gas or to tritiated water vapour. The naturally occurring isotopes of uranium, thorium and radium (all present in the waste) decay to form gaseous radon isotopes, and these emanate from the waste when the integrity of the packaging is lost.

Such gases would percolate through the trench cap materials and be discharged at the surface. The emanation of radon from the repository is discussed in Section 8.10.4. The release of these small quantities of radioactive gases over time would be indistinguishable from background radiation.

Discharge to Groundwater

One aspect, among others, of selection of the repository site was the very low rainfall and high evaporation in the region. However, the trench would still be designed to withstand periodic high rainfall events and to divert water flow away from the wastes. The selection of the site is also based on the considerable distance from the surface to groundwater (38.8–68.7 m, depending on the site — see Table 8.4), over which any infiltrating water would need to travel before the watertable is reached.

Hydrological model simulations (Section 8.10.3) assessed the potential infiltration of rainwater through various capping and base lining system scenarios. The assessment indicated rainwater infiltration to be minimal for all cases examined, including an assessment under adverse climatic conditions.

Modelling of the potential movement of radionuclides through the unsaturated zone below the repository was also undertaken (Section 8.10.3). The results indicate that the amount of solutes originating from the repository which would reach the watertable under the conservative scenario of continual low-level seepage for 100 years would be so low as to be, to all practical extent, undetectable. Even if 100% of rainfall and stormwater were to penetrate the repository, the amount of solutes reaching the watertable would be less than 10^{-100} mg/L.

The natural arid climatic regime of the study region, together with the design and construction of the repository, would provide considerable additional protection for the watertable. The groundwater under each site is highly saline (greater than 20,000 mg/L) and is unsuitable for direct use for domestic or stock purposes, or for irrigation (Section 8.2).

Contamination of Surface Environment

There would be a 5 m-thick cover over the radioactive wastes in the repository. The cap would be designed to deter intrusion by flora or fauna and there would be monitoring and security at the site. These factors, coupled with the remote location of the site, would also deter any intrusion from human activities.

There is a possibility that activities at the nearby Woomera Instrumented Range (WIR) might affect the trench. For example, in the unlikely event of a missile or aircraft crashing onto the site, it is possible that this might remove the cover material and expose the wastes. However, only some of the weapons tested at the WIR would be capable of causing this amount of damage. This potential route for release of radionuclides to the surface environment from weapons testing is considered in detail in Section 12.5.1.

In the longer term, when institutional control of the site has ceased, there are a number of ways in which release of material to the surface environment, and subsequent radiation exposure, may occur. These are usually considered either as **human intrusion events** or **natural disruptive events**. For example, human intrusion events could include the drilling of boreholes through the trench for exploration purposes or archaeological digs; natural disruptive events could include seismic events (earthquakes) or erosion. The site selection criteria include conditions to minimise both human intrusion and natural disruptive events.

There are no mineral resources associated with the site, which should preclude borehole drilling, and the site is extremely geologically stable.

In some cases these events could be combined. For example, road building after a period of erosion over thousands of years could expose the wastes. A change in climate to a wetter state could result in the area becoming more suitable for settling and more intensive farming, which might result in small communities using groundwater (possibly by use of desalination technology) for irrigation and consumption.

Once the radioactive wastes are exposed to the surface environment, by any mechanism, radiation exposure could occur through a variety of ways. These would include direct external radiation from gamma-emitting radionuclides, internal irradiation from ingestion or inhalation of contaminated dust, and internal irradiation from ingestion of contaminated foodstuffs or drinking water.

For radiation exposure to occur, people must be living near the site and using the area in some way. One of the site selection criteria was for the repository to be located in an area of low population density with limited resources.

12.2.2 Radiation Dose and Risk Assessment

During the operation of a near-surface repository, radiation exposure of the repository workers can reasonably be predicted, as the times of exposure are known and other controlling factors such as beta and gamma dose rates can be measured.

In such situations, where an exposure is actually occurring or is certain to occur, the International Commission on Radiation Protection (ICRP) recommends the use of a dose assessment and associated dose limits as a basis for assessment of the safety of the facility (International Commission on Radiological Protection 1991). As discussed in Section 3.1, these recommendations have been formally adopted in Australia as the *National standard for limiting occupational exposure to ionizing radiation* (National Health and Medical Research Council and National Occupational Health and Safety Commission 1995).

For members of the public, the dose limit in this national standard is an annual effective dose of 1 mSv above the ambient background dose rate, excluding exposure from medical procedures. For occupationally exposed workers, the dose limit is 20 mSv/yr, averaged over a five-year period.

It is more difficult to predict exposures that would occur in the future after the near-surface repository is closed. These exposures are not certain to occur, and would probably be the result of specific actions on the part of those who are exposed. In such cases, the ICRP recommends the use of a risk-based assessment and risk limits for assessment of the safety of the facility.

Radiological risk is defined as follows:

$$R = rPH$$

where:
- R (yr^{-1}) is the individual risk
- H (Sv) is the effective dose assuming the event takes place
- r (Sv^{-1}) is the dose-to-risk conversion factor
- P (yr^{-1}) is the probability of exposure in any one year.

It should be noted that this expression, strictly speaking, is only valid for low levels of radiation exposure, where stochastic effects of radiation predominate, as opposed to deterministic effects (i.e. effective doses less than about 0.5 Sv). Risk is normally expressed as an annual probability; the factor *rH* is the probability of inducing a fatal cancer or serious hereditary effect, given that the exposure occurs.

A description of basic radiation protection issues and the concept of radiation 'dose' and 'exposure' presented in Section 2.1.

In 1992 the National Health and Medical Research Council (NHMRC) released the *Code of practice for the near-surface disposal of radioactive waste in Australia* (NHMRC 1992 Code). The code includes 13 criteria designed to ensure that the selected national repository site has characteristics that would facilitate appropriate isolation of waste and the long-term stability of the repository. The criteria take into account a broad range of social, technical and environmental factors, and are discussed in Section 5.1.1.

In 1997 the NHMRC discussed further the issue of individual dose and risk limits. The following criterion (NHMRC 1997) is relevant:

> The exposure of individuals resulting from a combination of all the relevant practices should be subject to dose limits or to some control of risk in the case of potential exposures (individual dose and risk limit).

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 1×10^{-6}/yr would be desirable (Section 5.3.4). No time cut-off is specified beyond which the radiological consequences of disposal need not be considered.

The location and design of the repository site and its operation (which entails no routine discharges) mean that it is very unlikely that any releases of radioactive material would occur at the site during its operational phase. The monitoring program for the site during the operational and closure phases would identify any potential discharges, and these would be investigated and remediated as necessary. Any remediation would be carried out under the supervision of radiation protection experts and no uncontrolled radiation doses to the workforce or to off-site communities is envisaged.

Any accidental intrusion into the site as a result of Department of Defence (Defence) activities at the WIR would be identified and remediated. Again, this would take place under the supervision of radiation protection experts and no uncontrolled radiation doses to the workforce or to off-site communities is envisaged.

In the longer term, when the site is no longer controlled, at least 200 years into the future, releases of radionuclides to the environment could occur along several pathways as described above. This phase of the repository life has been examined in some detail, and radiation doses and risks of fatal health effects have been assessed for a range of exposure scenarios. These are presented in Section 12.8 and in more detail in Appendix E8.

12.3 Impacts and Risks During Construction

12.3.1 Initial Campaign

The construction phase for the repository would be completed before radioactive waste is moved to the site. Any radiological implications during construction would therefore result from exposure to the natural background radioactivity. Radiological exposures could occur from inhalation of suspended dust, intake of dust or soil, and direct external radiation from radionuclides.

Although any radiation exposure during this phase would be related to the naturally occurring background radiation for the region, it is of interest to calculate these risks and place into context the overall radiological risk associated with the project.

The critical group for this scenario is the excavation workers, who may receive radiation doses during the time that excavation work is taking place. The three exposure pathways listed below were considered:

- external exposure
- inhalation of contaminated dust
- ingestion of contaminated dust.

Effective doses were calculated using simple linear dose models for each of the above pathways. The assessment used the maximum concentrations of ^{238}U, ^{232}Th and ^{40}K found at Site 52a to illustrate the potential radiological implications during construction of the trench. Details of calculations are presented in Appendix E6.

The results show that the total radiation dose from external and internal irradiation is of the order of 1.8×10^{-5} Sv. The most important radionuclides contributing to the dose are the thorium radionuclides, ^{232}Th, ^{230}Th and ^{228}Th. The radiation dose from inhalation of dust is the most significant pathway, and is of the order of 1.5×10^{-5} Sv.

These doses, as may be expected, are a very small addition to the average annual background radiation exposure in Australia of 2 mSv/yr. Using a dose-to-risk conversion factor of 0.06/Sv, this is equivalent to the risk of contracting a fatal cancer of 1 in 10^6 (1 in 1 million).

12.3.2 Subsequent Campaigns

An additional risk for subsequent campaigns would be inadvertent intrusion into the previously constructed trench or trenches. Appropriate record keeping and control of activities at the site should prevent any accidental ingress; however, this risk would be mitigated further by using easily identifiable backfill layers at the boundaries of the active material.

12.4 Impacts and Risks During Operation and Surveillance

12.4.1 Routine Operational Tasks

The following activities have been identified as being likely to be undertaken at the repository site during its operational phase, including the surveillance periods between disposal campaigns:

- transport of radioactive waste to the repository from locations around Australia
- arrival survey of transporter
- unloading of waste packages or overpacks from the transporter
- weighing of packages or overpacks
- receipt survey for individual packages or overpacks
- transfer to temporary store / holding area
- radiological validation of waste consignment by radiography, spectrometry, sampling facilities for waste analysis
- monitoring of packages
- transfer to pre-disposal store
- repacking into overpacks (where appropriate)

- emplacement of waste within trenches or boreholes
- grouting and backfilling of trenches as necessary
- monitoring of trenches
- recovery and repackaging of material previously disposed of in trenches (only if required)
- routine radiological monitoring of all site facilities
- decontamination operations in event of accident or emergency
- filter replacement and disposal for potentially radioactive ventilation and drainage systems
- post-operational clean-out of waste handling and storage facilities prior to decommissioning.

Each of these activities requires detailed systematic analysis in order to identify all credible radiological hazards and to quantify the risk associated with each hazard.

12.4.2 Dose Assessment for Operators

Potentially, the most significant radiological hazards would be the exposure of an individual to external radiation, for example gamma rays, or the inhalation by an individual of airborne radioactive particulate. Other radiological hazard scenarios might include the ingestion of radioactive material through a wound to the skin or via oral intake if standard radiological safety practices are not observed or if there is an accidental release of materials during operations.

In the case of external radiation exposure, the dose assessment is simply the product of the dose rate and the exposure time. For intakes of radioactive material, the situation is more complex but simplistic equations can be derived to enable doses to be estimated using the appropriate exposure models for inhalation and ingestion of radionuclides.

12.4.3 Operational Hazards and Associated Radiation Exposure Scenarios

For each of the operational tasks listed in Section 12.4.1, a simple hazard assessment shows numerous radiological exposure routes and mechanisms. These are summarised in Table 12.1. The table also includes an indication of the significance of each exposure scenario in terms of whether it is likely to give rise to a hazard that is contained within the repository facilities or buildings (I) or is likely to affect the environment outside the repository facilities (O). Mitigating factors to monitor or minimise exposures are also indicated.

TABLE 12.1 Hazard assessment

Operational task	Exposure scenario	Mitigating factor	I/O
Transport of radioactive waste to the repository from locations around Australia	▪ road transport accident ▪ direct gamma radiation ▪ activity leakage from transporter	▪ emergency response plan ▪ ovepack shielding, short exposure time ▪ monitoring of vehicles before and after transport	O
Arrival survey of transporter	▪ contamination of worker	▪ contamination control procedures	I
Unloading of waste packages or overpacks from the transporter	▪ radiation from packages ▪ dropped package releasing radioactive material	▪ real-time dosimetry ▪ local contingency plans ▪ trained operators, contingency plans	I/O

Operational task	Exposure scenario	Mitigating factor	I/O
Weighing of packages or overpacks	▪ dropped package	▪ contingency plans	I/O
Receipt survey for individual packages or overpacks	▪ radiation or contamination	▪ dosimetry / contamination control procedures	I/O
Transfer to temporary store / holding area	▪ dropping or breach of a package	▪ contingency plans and training ▪ minimising distance from floor	I/O
Radiological validation of waste consignment	▪ radiation or contamination during sampling	▪ dosimetry, working instructions for sampling, contamination control procedures	I
Monitoring of packages	▪ radiation	▪ real-time dosimetry	I/O
Transfer to pre-disposal store	▪ radiation ▪ dropped package	▪ dosimetry / dose control ▪ minimising distance from floor during move	I/O
Repacking into overpacks (where appropriate)	▪ radiation ▪ dropped package	▪ dosimetry / dose control ▪ minimising distance from floor during move	I/O
Emplacement of waste within trenches	▪ toppling/dropped drums ▪ radiation from stacked waste	▪ remote working where practicable ▪ dosimetry ▪ shielded equipment	O
Grouting and backfilling of trenches as necessary	▪ radiation from waste ▪ inadvertent damage to underlying waste	▪ grout/backfill providing shielding ▪ weight limit for loads placed on trench	O
Monitoring of trenches	▪ radiation	▪ dosimetry	O
Recovery and re-packaging of material previously disposed of in trenches (if required)	▪ breach of waste packages ▪ contamination ▪ radiation	▪ temporary containment over work area so far as practicable ▪ use of PPE/RPE(1) ▪ dosimetry and contamination controls	O
Routine radiological monitoring of all site facilities	▪ radiation and contamination		I/O
Decontamination operations (potentially at several locations)	▪ contamination ▪ spreading of activity ▪ radiation	▪ barrier controls and other contamination control procedures	I/O
Filter replacement and disposal for potentially radioactive ventilation and drainage systems	▪ radiation and contamination	▪ standard working procedure, dosimetry and contamination controls ▪ use of PPE/RPE	I
Post-operational clean-out of waste handling and storage facilities, prior to decommissioning	▪ radiation and contamination ▪ decontamination tools and techniques spreading activity	▪ dosimetry and contamination control ▪ task-specific working instructions and training ▪ use of PPE/RPE	I

(1) PPE = personal protection equipment; RPE = radiation protection equipment

All operations at the site would be conducted under a radiological protection regime consistent with regulatory requirements as required by ARPANSA, and worker exposure would be as low as reasonably achievable (ALARA) and within the relevant dose constraints.

12.5 Accidental Intrusion during WPA Activities

12.5.1 Defence Activities

Activity Exposure Scenarios

It is possible that activities at the Woomera Prohibited Area (WPA) could result in accidental intrusion into the repository. The potential exposures arising from such an event have been assessed and are presented in Appendix E7 and summarised here. It has been assumed that the repository would not be manned during any period of weapons testing at the WPA and that there would therefore be no direct risk to the workforce at the time of a weapons impact.

The approach taken for the assessment is to initially identify ways in which an individual may subsequently become exposed to radiation as a result of the event, and receive a radiation dose. This is termed an 'exposure scenario'. In this assessment the sole concern is with risks to users of the Woomera facility in the relatively near future, during the operational and surveillance periods of the repository. Sections 12.8.2 and 12.9.3 address possible exposure scenarios and release pathways for the site in the more distant future, which may potentially arise as a result of climate change or when restricted access to the site is removed.

Having identified an exposure scenario, for example 'a missile crashes onto the site penetrating the cover material and exposing the waste', the 'critical group' is identified. The critical group are those individuals who, by the nature of their lifestyle or occupation, would be most exposed to radiation or radioactive materials in this scenario. The specific habits of the critical group are then defined, for example exposure times or intake rates.

Radiation doses to the critical groups can then be calculated. Risks to the critical groups of serious health effects are also calculated, taking into account the relationship between radiation exposure and health effects and also the probability of the event described occurring.

Scenario Assessment Approach

The assessment approach is demonstrated in the following example, in which the dose to an individual who is investigating a missile crash at the repository site, but who is unaware that the site is a nuclear repository and has taken no protective measure, might be 5 mSv (5×10^{-3} Sv). This may be compared with the annual dose limit for a member of the public of 1 mSv/yr, or for a classified radiation worker of 20 mSv/yr averaged over 5 years (Section 3.2.2).

Using a dose-to-risk conversion factor of 0.06/Sv and this assumed dose, the individual would have a 3×10^{-4} (3 in 10,000) chance of incurring a fatal cancer as a result of this exposure. This is approximately equivalent to a risk of serious health effects (National Radiological Protection Board 1992) (typically a fatal cancer or serious hereditary effects), and can be compared to other risk factors for fatalities, for example driving, smoking and obesity.

In addition, the probability of this event occurring needs to be considered. If a missile crashes in an uncontrolled manner on the WPA, for example once a year, then, given the proportion of the repository disposal area (100 x 100 m, or 0.01 km^2) to the total WPA (127,800 km^2), the risk of a missile hitting the actual repository itself or within 100 m of it (about 9 times the area of the repository) is 7.0×10^{-7} hits per year. Therefore, the overall risk to an individual of incurring a fatal cancer would be $(3 \times 10^{-4}) \times (7.0 \times 10^{-7})$, which is 2.1×10^{-10}/yr, or about a 2 in 10,000,000,000 chance of incurring a fatal cancer from this scenario in a year.

The assessment approach can therefore be summarised in the following steps:

- Select a number of exposure scenarios.
- Define the critical group(s) appropriate to each scenario.
- Define the exposure pathways for each critical group (i.e. the ways in which the critical group is exposed to radiation and radioactive material, e.g. the inhalation of contaminated dust).
- Define the behaviour of the critical group in terms of exposure times, intake rates, etc.
- Evaluate doses and risks to the critical groups, and compare them with appropriate target dose and risk values.

12.5.2 Scenarios and Critical Groups

After due consideration of the conditions likely to prevail at the WPA site and experience with previous near-surface assessments, it was decided that the following exposure scenarios should be considered in this assessment:

- the effects of a missile crash from the nearby WIR onto the repository site
- the effects of an aircraft crash (associated with Defence activities at the WPA) onto the repository site.

Information on Defence activities in the WPA and the WIR is provided in Section 10.4.4, and an assessment of risks (non-radiological) in Section 10.7.5.

The term ‘missile’ refers to any type of weapon or projectile used at the site. It also includes satellites and associated propulsion systems. The distinction between ‘missile’ and ‘aircraft’ is generally one of size (the potential for disruption of the repository site) and the length of time for any investigation and recovery operations.

It is not claimed that these scenarios comprise a comprehensive or exhaustive description of possible future happenings at the site. However, they broadly scope the range of consequences that might be expected to arise. There are a number of ways in which critical groups can receive a radiation dose from materials disposed of in the repository. These exposure pathways include:

- external irradiation (from gamma-emitting radionuclides)
- inhalation of contaminated dust
- ingestion of contaminated soils and dust.

Once the critical groups for each of the scenarios have been identified, it is necessary to define their behaviour in terms of parameter values that can be used in dose equations. It is these critical groups that would be expected to receive the highest doses; the two most important quantities are exposure times and intake rates. Thus, to calculate external gamma doses, it is necessary to know the amount of time a critical group member spends in the vicinity of contaminated material. Intake rates are required to calculate internal doses.

Radiological doses and risks are obtained by using the equations set out in Appendix E7. All doses are expressed as effective doses; that is, they take account of the distribution of the radionuclides within the body and of the relative sensitivity of different organs to radiation effects.

In the first scenario of a missile crash occurring at the repository site, it is assumed that the effect of the crash is to penetrate the cap materials, thus exposing the wastes and distributing these over the surrounding area. The critical group is a recovery team which investigates the crash and comes into contact with the radioactive wastes.

In the second scenario of an aircraft crash occurring at the repository site, the critical group is the aircraft recovery team which comes to investigate the accident and clear up the debris. It is known that it can take up to two days to clear the debris, and so the exposure time is taken as 25 hours, corresponding to about two 12-hour working days.

It is assumed in both scenarios that it is not immediately realized that the impact site is the repository and therefore no precautions (e.g. the use of protective equipment or health physics monitoring) are taken by the team. The crash recovery team comes to the site from outside, and leaves the site once their work is done.

The two scenarios are very similar. The main distinction between them is the amount of radioactive material that might be exposed and released to the surface and the probability of the event occurring.

12.5.3 Scenario Probabilities

In order to estimate radiological risks, it is necessary to estimate probabilities of occurrence for the scenarios. Usually these are expressed on the basis of an annual probability or frequency of occurrence. Probabilities of this type are dimensionless.

Missile Crash

According to information supplied by Defence, of the weapons fired on the Woomera test site in the last ten years, about 42 per annum are capable of penetrating to a depth of 5 m. Therefore, it is assumed that about 42 missiles potentially disruptive to the repository hit the ground in the WPA every year.

If it is assumed that these 42 missiles land at random positions on the test site (an assumption that may not be valid, if the missiles are fired within a limited range of trajectory and velocity values), then an estimate of frequency of impact on the repository can be made. The total area of the WPA is 127,800 km^2 and the repository has a plan area of 0.01 km^2. If it is further assumed that any strike within 100 m of the repository causes disruption to the wastes, an area approximately nine times the repository disposal area, then the frequency of strike is approximately:

$$f(\text{missile}) = (42 \times 9 \times 10^{-2}) \div (1.28 \times 10^{5}) = 3.0 \times 10^{-5} \text{ disruptions per year.}$$

Aircraft Crash

The probability of an aircraft crash into the repository can be estimated from consideration of aircraft crash data. According to Defence, one aircraft crash has occurred at the WPA over the last 10 years.

As with the missile crashes, the best way to proceed is to assume that aircraft crashes occur at random locations on the test site. The target area for which a crash can disturb the repository wastes is taken to be the same as that for missiles; that is, any impact within 100 m of the repository location, an area approximately nine times the repository disposal area, would be considered to disturb the wastes.

From this, the frequency of a disruptive aircraft impact is approximately:

$$f(\text{aircraft}) = (0.1 \times 9 \times 10^{-2}) \div (1.28 \times 10^{5}) = 7.0 \times 10^{-8} \text{ crashes per year.}$$

12.5.4 Results of the Assessment

The equations and parameter values used to calculate the radiation dose are presented in Appendix E6. The results of the assessment are summarised here.

Missile Crash

For a recovery team exposed to the radioactive wastes after a missile crash at the repository site, maximum doses would be attained if the crash occurred immediately after the repository was filled. This would mean that the inventory was at the maximum value and little radioactive decay had occurred. For simplicity, we have assumed that the repository is filled with the entire inventory (expected over 50 years) in year zero. This is a conservative assumption as we might expect significant decay of ^{60}Co (half-life of 5 years) over the 50-year operating period.

We have also considered two cases, the first where the wastes are exposed and unmixed with any cover material; that is, dilution is zero. The second case assumes that the radioactive wastes are diluted with the cover material, by a dilution factor of 0.66.

Case 1 — No Dilution

For this case the dose is around 3.8×10^{-3} Sv (3.8 mSv), with the most significant radionuclides being ^{241}Am, ^{137}Cs and ^{60}Co. External irradiation is the most significant exposure pathway, with ^{60}Co and ^{137}Cs being the most significant contributors. Inhalation of contaminated dust (^{241} Am) is the next most significant exposure pathway.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of missile crashes, the individual risk is around 6.9×10^{-9}/yr for a missile crash immediately after the repository is full, which is well within the risk target of 1×10^{-6}/yr.

Thus, the assessed dose exceeds the annual public dose limit of 1 mSv/yr but is well within the annual dose limit for a classified radiation worker of 20 mSv/yr (averaged over 5 years), and the low probability of occurrence ensures that individual risks are small. In fact, in the case of the missile crash, the true frequency of occurrence would probably be considerably less than the value of 3.0×10^{-5}/yr assumed in this study.

It should be noted that these doses would only be incurred if it has not been recognised that the crashes occurred at the repository site and the recovery team uses no protective equipment. As the radioactive waste trenches or boreholes would be within a larger buffer zone, with clear markings and delineation recording the presence of radioactive material, it is unlikely that such an event could occur whilst the site is under institutional control.

Case 2 — Dilution of Radioactive Wastes with Cover Material

For this case the dose is slightly lower, at around 2.5×10^{-3} Sv (2.5 mSv), with the most significant radionuclides being ^{241}Am, ^{137}Cs and ^{60}Co. External irradiation is the most significant exposure pathway, with ^{60}Co and ^{137}Cs again being the most significant contributors. Inhalation of contaminated dust (^{241}Am) is the next most significant exposure pathway.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of missile crashes, the individual risk is around 4.6×10^{-9}/yr for a missile crash immediately after the repository is full, which is well within the risk target of 1×10^{-6}/yr.

Thus, the assessed dose exceeds the annual public dose limit of 1 mSv/yr but is well within the annual dose limit for a classified radiation worker of 20 mSv/yr (averaged over 5 years), and the low probability of occurrence ensures that the individual risks are small. In fact, in the case of the missile crash, the true frequency of occurrence would probably be considerably less than the value of 3.0×10^{-5}/yr assumed in this study.

Aircraft Crash

Case 1 — No Asbestos Detected Dilution

For an aircraft recovery team that clears up debris lying on exposed wastes after an aircraft crash, maximum doses would be attained if the crash occurred immediately after the repository is filled. This dose is around 9.6 x 10^{-3} Sv (9.6 mSv) and therefore higher than that associated with the missile crash due to the longer exposure time assumed for the recovery team. External irradiation is the most significant exposure pathway, with ^{60}Co and ^{137}Cs being the most significant contributors. Inhalation of contaminated dust (^{241}Am) is the next most significant exposure pathway.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of aircraft crashes, the individual risk is around 4.0 x 10^{-11}/yr for an aircraft crash.

Thus, the assessed dose exceeds the annual public dose limit of 1 mSv/yr but is well within the annual dose limit for a classified radiation worker of 20 mSv/yr (averaged over 5 years), and the low probability of occurrence ensures that the individual risks are small. This risk value is comfortably within the risk target of 1 x 10^{-6}/yr.

Case 2 — Dilution of Radioactive Wastes with Cover Material

For the aircraft recovery team that clears up aircraft debris lying on exposed wastes after an aircraft crash, maximum doses would be attained if the crash occurred immediately after the repository is filled. This dose is around 6.3 x 10^{-3} Sv. External irradiation is the most significant exposure pathway, with ^{60}Co and ^{137}Cs being the most significant contributor. Inhalation of contaminated dust (^{241}Am) is the next most significant exposure pathway.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of aircraft crashes, the individual risk is around 2.7 x 10^{-11}/yr for an aircraft crash.

Thus, the assessed dose exceeds the annual public dose limit of 1 mSv/yr but is well within the annual dose limit for a classified radiation worker of 20 mSv/yr (averaged over 5 years), and the low probability of occurrence ensures that the individual risks are small. This risk value is comfortably within the risk target of 1 x 10^{-6}/yr.

Conclusions

This assessment of radiological risk from Defence activities at Woomera has shown that the risk of serious health effects associated with disturbance of repository material and subsequent investigation is very low and within the risk target proposed for the repository. The associated risks range from 2.7 x 10^{-11}/yr to 6.9 x 10^{-9}/yr for the scenarios considered.

The assessment made a number of conservative assumptions. It was assumed in the calculation that the full radionuclide inventory predicted to arise over 50 years was present at year zero and that no radioactive decay had taken place before the exposure occurred.

Very importantly, it was also assumed that the critical group would take no protective measures when investigating an incident at the repository.

The maximum dose should an exposure occur is of the order of a few mSv. This is less than the annual dose limit for a classified radiation worker (20 mSv/yr averaged over 5 years) and represents an annual risk of contracting a fatal cancer of about 5 in 10^{5}.

12.5.5 Commercial Satellite Launching

It is also possible that other users of the site could accidentally intrude into the repository in a similar way. It is planned to use the WPA for commercial satellite launches and it is possible that these may go astray and some components may land on the repository, with similar results to that of the missile or aircraft impact.

As the frequency of satellite launches would be considerably less than that of weapons testing, or overflying of the WPA, these risks have not been assessed explicitly and it is assumed that they would be less than those calculated above for missile and aircraft impact.

12.6 Impacts and Risks of Decommissioning

Before commencement of decommissioning, the repository site and facilities would be radiologically surveyed and no decommissioning activities would take place unless radiation levels throughout the site met the requirements of the regulatory authority.

Any remedial activities required to clean up the site would be conducted under the radiation protection system established for protection of the workforce during operation of the site under the licence conditions. Any radioactive waste generated during the decontamination phase would be disposed of within the facility trench and in accordance with the criteria for waste acceptance and disposal.

Decommissioning activities would carry a lower level of risk than those for construction as no large-scale excavation activities would be necessary and there would be, consequently, less dust generated.

12.7 Impacts and Risks during Institutional Control

From the decommissioning of the repository to the end of the institutional control period (200 years), an ongoing program of monitoring and surveillance of the repository and its environment would be carried out and security of the site would be maintained.

During this period the risks of inadvertent intrusion into the repository would be minimised by these monitoring and security systems. If the monitoring and surveillance program indicated that the repository safety has been compromised for some reason, then a remedial plan (developed in advance) would be put into place.

12.8 Impacts and Risks of Post-Institutional Phase

12.8.1 Assumptions

In this section results are presented of an assessment of the potential risks from radiation exposure once institutional control of the repository site has ceased. The time period starts from 200 years after the closure of the repository. During this time it is assumed that there is no control on activities at the site, some of which may be different from today’s use of the site.

The assessment is based on the repository inventory and design described in Chapters 4 and 6. For most of the calculations it is assumed that the radioactivity in the waste is homogeneously distributed amongst the waste volume. However, it is known that some of the wasteforms, for example the spent sealed sources, would have higher specific activities than others. Therefore, the consequences of recovery of some of the higher activity artefacts that could be disposed of at the site have also been considered.

The assessment allows the identification of key release pathways by which radiation exposure may occur. For these pathways, the sensitivity of the results to the inventory of radionuclides at the repository is examined. That is, the consequences of higher initial levels of radionuclides are assessed.

The assumptions used, the assessment approach and the results of the calculations are given in detail in Appendix E8.

12.8.2 Scenarios and Release Pathways

The assessment has considered scenarios involving releases of radionuclides via the three release pathways considered earlier in Section 12.2, that is discharge to air by gas migration, discharge of radionuclides to groundwater and contamination of the surface environment.

Gas Generation and Migration

There are a number of mechanisms during the natural evolution of a waste repository that can give rise to gas generation and migration upwards and out of the top of the repository. For example, the microbial degradation of cellulose can give rise to carbon dioxide and methane.

There are two principal ways in which gaseous products from the repository can have a radiological impact on the human population. ^{3}H and ^{14}C labelled gases can be incorporated into soils and taken up by plants and animals, which are subsequently used as food produce. In addition, there are the direct effects of gases that emerge out of the repository. In many circumstances, the gases would emerge into the outside environment, and would be rapidly dispersed throughout the atmosphere to negligible levels.

However, if a house, dwelling or other type of building were located on top of the repository, the gases could enter the building, and build up to appreciable levels, alleviated only by removal through ventilation and radioactive decay. ^{222}Rn, which is produced from the decay of ^{226}Ra, is a universal hazard as a consequence of its potential build-up in occupied buildings.

The critical group in this scenario is taken to be a family of settlers who build their house on top of the waste repository, and who occupy the house for 16 hours per day.

The approach adopted in this assessment can be summarised in the following steps.

- Estimate the emanation rate of gases out of the repository.
- Calculate the concentration of gas in the building structure.
- Estimate the radiological impact, based on breathing rates and occupancy.

For ^{3}H, ^{14}C and krypton-85 (^{85}Kr), it is assumed that the entire inventory is released (in gaseous form) within one year at the end of the 200-year institutional control period. This assumption is therefore highly cautious and not appropriate for ^{222}Rn, where the production rate is governed by the decay of ^{226}Ra.

Groundwater Contamination

In many repository assessment contexts, the leaching of contaminants from the repository in groundwater is the main transport pathway of interest. However, present day conditions at the proposed sites indicate an arid environment, with the watertable some 38.8–68.7 m below ground surface (Section 12.2.1). In such circumstances, issues such as repository resaturation and consequent dissolution and leaching of radioactive materials is of lesser importance.

Nevertheless, while future climate studies indicate that there is unlikely to be a transition from an arid to a temperate climate state in the next 10,000 years or so, there is the possibility of localised and short-term storm events that could lead to infiltration through the repository, with radionuclides being leached downwards through the unsaturated zone in the direction of the underlying aquifer.

The postulated scenario investigated is the possibility that radionuclides could reach and contaminate the aquifer, and that water in the aquifer is used for human consumption.

The calculation of groundwater flow and radionuclide transport in unsaturated conditions is somewhat more complex than for fully saturated conditions. The following procedure was followed.

- Obtain the groundwater travel time from the base of the repository to the aquifer.
- Obtain retarded travel times, based on adsorption characteristics of individual radionuclides.
- Compare retarded travel times with radioactive half-lives and assessment timescales.
- Estimate dilution factors for those radionuclides able to reach the aquifer.

The impact of the radionuclide flux to the groundwater has been compared to the naturally occurring levels of radioactivity in groundwater at the site.

For illustrative purposes, doses are calculated on the assumption that the water is potable, which is unlikely to be the case, as salinities in the area are presently of order 20,000 mg/L (Section 8.5.2). Thus the scenario assumes that some form of desalination would occur that does not remove any of the radionuclides that may be present, which again is unlikely to be the case.

Human Intrusion or Natural Disruptive Events

For the human intrusion and natural disruptive event pathway, a range of scenarios has been considered, namely the effects of:

1. drilling and examination of borehole cores
2. bulk excavation at the site
3. building a road that runs across the repository
4. archaeological digging at the site
5. longer-term exposure to materials excavated in scenarios 2 and 3
6. a missile crash from the nearby WIR
7. an aircraft crash onto the repository site
8. a transition to a wetter climate state
9. a gross erosional event
10. site flooding in wetter a climate state
11. consumption of contaminated waters obtained from a well drilled through the wastes
12. artefact recover.

Each of the scenarios described requires the definition of a critical group. Settler, nomadic and transient critical groups need to be taken into account. The last group corresponds neither to the settler nor nomadic groups, as they would be workers who come from outside the area and then leave the area again once their work is complete.

Borehole Drillers

In this scenario, it is assumed that a single borehole core is extracted from the centre of the repository and then examined by a geotechnical worker. It is considered unlikely that more than one core would be extracted from the repository location.

The geotechnical worker would suffer radiation exposure from the following exposure pathways: inhalation of dust, ingestion of dust and external irradiation from gamma-emitting radionuclides.

Excavation Workers

In this scenario it is assumed that bulk excavation occurs at the site for some reason, possibly for materials for use in road building.

The excavation workers would suffer radiation exposure from the same exposure pathways as above.

Road Builders

In this scenario the critical group is the team of workers engaged in building a road that runs across the repository. The team is assumed to spend 50 hours (i.e. about six working days) working on top of the repository site. It might be argued that road builders are unlikely to penetrate the 5 m cap that lies on top of the repository. However, it should be noted that the cap may degrade over time, and may not be present at that thickness several thousand years from now.

The exposure pathways for the road builders are as above.

Archaeologists

In this scenario the critical group is a number of archaeologists who explore the repository site. They are assumed to spend 400 hours at the repository site. This could be considered an over estimate, especially if the archaeologists find nothing of interest at the site. However, many thousand years from now it cannot be assumed that the repository contents would be of no interest to future generations.

The exposure pathways for the archaeologists are as above.

Longer-Term Exposure

In this scenario the critical group consists of those individuals who make use of contaminated materials that were excavated in scenarios 2 or 3 above. Such individuals might remove the excavated materials and use them as topsoil in their gardens, or more compact materials as foundation materials or for ornamental purposes (e.g. a rockery). As the precise usage of such materials is unclear, it has been pessimistically assumed that the critical group members spend up to eight hours per day in contact with the materials (corresponding, for example, to a gardener who uses the materials for topsoil).

The nomadic critical group is likely to be one that sets up camp in the vicinity of, or on top of, the excavated materials. It is unlikely that the group would use the materials for gardening or ornamental purposes, although they may be used for building purposes.

The exposure pathways for longer-term exposures are as above.

Missile Crashes

In this scenario a rocket, missile or satellite crash (from the nearby WIR) occurs at the repository site. For the purposes of assessment, it is assumed that the projectile is not located, and that the effect of the crash is to remove the cap materials, thus exposing the wastes. The critical group is taken to be a group of children who play in or around the exposed wastes at some future time after the WIR is no longer used for weapons trials. They are assumed to spend one hour per day playing at the site.

The critical group derived from nomadic people would be the same as that described above, that is children who play at the site of the exposed wastes.

The exposure pathways for the missile crash are as above.

Aircraft Crashes

In this scenario an aircraft is assumed to crash at the repository site. In contrast to the situation with the missile crash, there would be full knowledge of this accident, and so the critical group is taken to be the aircraft recovery team who come to investigate the accident and clear up the debris. It is known that it can take up to two days to clear the debris, and so the exposure time is taken as 25 hours, corresponding to about two 12-hour working days.

As for the human intrusion scenarios, the critical group defined above is derived neither from the settlers nor the nomadic people. Instead, the crash recovery team comes to the site from outside and leaves the site once their work is done.

The exposure pathways for the aircraft crash are as above.

Climate Change

In this scenario it is assumed that the dry and arid climate that currently prevails at the proposed site is replaced by a much damper climate. At the present time the land is dry and unsuitable for agricultural use, with the watertable lying many tens of metres below the ground surface. The groundwater under each site is presently highly saline (greater than 20,000 mg/L) and is unsuitable for direct use for domestic or stock purposes, or for irrigation (Section 8.5.2); however, with some form of treatment (such as desalination) the water would be useable.

The transition to conditions suitable for agricultural use would require a considerable increase in precipitation levels, sufficient to balance the deficit due to evapotranspiration and raise the level of the watertable.

The CSIRO has undertaken a detailed study of the potential impact of climate change on the repository, and this report is presented in Appendix F. The study considered the effects of future climate change attributable to the greenhouse effect over timescales of the next 100 years, in year 2600 and over 10,000 years. This is discussed further in Section 12.9.3. In the simulation reported in the study, the average soil moisture content did not change significantly. This result suggests there may be limited potential for significant future changes in land use.

The approach taken in this assessment is to assume that the contaminated material in the disposal structures would be exposed and provide soil for farming. The critical group is therefore taken to be a farming or subsistence community that sets up a farm in the vicinity of the repository, and derives all of its food produce from this land. Of course, the size of the repository is such that much of the food would be obtained from uncontaminated land, though some would be obtained from the repository footprint. This is taken into account using appropriate 'dilution' factors.

The critical group derived from nomadic people would be a group that sets up camp on or in the region of the contaminated area, and who occupy that position for a period of a few weeks. Of particular interest is the assumption that such a group would hunt animals (e.g. rabbits or kangaroos) that had been grazing in the contaminated region.

The exposure pathways for the climate change scenario are: inhalation of dust, ingestion of dust, external irradiation from gamma-emitting radionuclides, ingestion of plant foodstuffs and ingestion of animal foodstuffs.

Gross Erosional Events

In this scenario it is assumed that the contents of the repository are removed from their current location and deposited over a larger volume of accessible land. This could arise from the effects of severe wind erosion, or possibly from climatic change events such as glaciation. In either case, the effect would not be seen for many thousands of years into the future.

Because the effect of gross erosion is to place the wastes over a wide area in the accessible environment, the critical group derived from a farming or subsistence community is taken to be the same as that for the climate change scenario described in the previous section. The critical group derived from nomadic people would be the same as that for the climate change scenario.

The exposure pathways for the gross erosion scenario are the same as for climate change.

Site Flooding (Bathtubbing)

Bathtubbing occurs if water builds up within the disposal structures (e.g. because natural or engineered drainage features lose their efficiency) and results in contamination of surface soils and sediments. To occur, it requires an impermeable barrier within or around the disposal structures.

The approach adopted is to assume that surface soils become contaminated to a level equal to that in repository porewater. Again, the critical group derived from a farming or subsistence community is the same as for climate change. The critical group derived from nomadic people would be the same as that for the climate change scenario.

The exposure pathways for the bathtubbing scenario are the same as for climate change.

Consumption of Contaminated Well Waters

In this scenario it is assumed that a well is drilled through the repository footprint and the extracted water is used for drinking purposes. As noted above, the groundwater under each site is presently highly saline (greater than 20,000 mg/L) and is unsuitable for direct use for domestic or stock purposes, or for irrigation (Section 8.5.2); however with some form of treatment (such as desalination) the water would be useable. The assumption is made that a farming community may wish to set up such a well, and use the extracted waters for many purposes, including irrigation, domestic usage and as drinking water for animals.

The critical group for nomadic people is taken to be the same as that for farmers described above, though the water may not necessarily be obtained through well drilling.

The exposure pathway for the contaminated well water scenario is ingestion of contaminated water.

Artefact Recovery

It is assumed that an intrusion in the form of excavation of repository materials has taken place and that a considerable amount of repository material remains in the accessible environment. This would include some or all of the sealed sources that have been disposed of in the repository. It is considered that such sources constitute items of interest, and may be picked up by members of the public walking close by who happen to see them lying on the ground.

The critical group in this scenario is those individuals who handle the sources or are in close proximity to them.

The exposure pathways are external irradiation from gamma-emitting radionuclides and dermal exposure from beta-emitters.

12.8.3 Scenario Probabilities

In order to estimate radiological risks, it is necessary to estimate probabilities of occurrence for the scenarios for the three pathways described above. Usually these are expressed on the basis of an annual probability or frequency of occurrence. However, for scenarios such as climate change, such a quantity is not meaningful, and an overall probability of occurrence is required. Probabilities of this type are dimensionless.

Gas Generation and Migration

Exposures via this scenario would only take place if a dwelling is constructed directly on the surface expression of the repository. The likelihood of this happening has been based on the current housing density on the area. This suggests a probability of a dwelling being constructed on the site of about 10^{-5}/yr.

Groundwater Contamination

The assessment calculates the likelihood of radionuclides reaching the underlying groundwater though consideration of the travel times for water through the unsaturated zone and the retardation properties of the underlying rocks. The amount of radionuclides which could reach the watertable has been calculated to be an extremely small fraction (1 in 10^{-100}) of the original concentration in the trench. Any risk associated with such levels of radioactivity will be negligible.

Borehole Drilling

The most satisfactory means of estimating borehole drilling frequencies is to consider historical data for the region under consideration (assuming that all boreholes drilled were recorded). A cautious estimate of one borehole drilled per square kilometre per hundred years was assumed. Since the area of the repository is 100 x 100 m, (10^{-2} km^2), this leads to a drilling frequency at the repository of:

$$f(\text{borehole}) = 10^{-2} \times 10^{-2} = 10^{-4} \text{ boreholes per year.}$$

Bulk Excavation

As in the case of borehole drilling, historical records provide the best starting point for estimating frequencies of bulk excavation. It is considered that bulk excavation is as probable as borehole excavation, and so the same frequency of occurrence is adopted, namely:

$$f(\text{bulk excavation}) = 10^{-2} \times 10^{-2} = 10^{-4} \text{ excavations per year.}$$

Road Building

The frequency with which a road is constructed and intersects a given disposal structure can be estimated from:

$$f(\text{road}) = \frac{\Delta + w}{Dt}$$

where: Δ (m) is the diameter of the disposal structure

W (m) is the width of a road, which is taken to be 5 m

D (m) is the spacing between roads and is taken to be 10^5 m

t (y) is the time period over which roads in the region are taken to have been built and is assumed to be 50 years.

This is believed to be a pessimistic estimate of the frequency with which contaminated material would be disturbed, since it is unlikely that the road foundations would reach to a depth sufficient to intersect the wastes under the 5 m cap. In the distant future (i.e. in a few thousand years from repository closure), when the cap may have eroded to some extent, it may be possible that road foundations could intersect the wastes. It is important to note this when interpreting the results of the dose calculation; while disruptive road-building practices cannot be ruled out at earlier times, it is probable that several thousand years of erosion would be required before this operation can realistically be expected to expose the wastes.

Assuming that Δ = 100 m, w = 5 m, $D = 10^5$ m and t = 50 yr, this gives a frequency of:

$f(\text{road}) = 2.1 \times 10^{-5}$ roads per year.

Archaeological Digging

Assessing the probable frequency of archaeological digs is not straightforward. A conservative estimate of one dig per square kilometre per hundred years has been taken. This leads to:

$f(\text{archaeology}) = 10^{-2} \times 10^{-2} = 10^{-4}$ digs per year.

Longer-Term Exposure

Exposures in the longer term arising from the use of excavated materials requires that two events occur: that an intrusion occurs and, subsequently, that a small population resides in the vicinity of or on the contaminated material. The probability at any one time that a community lives on top of contaminated ground can be derived by considering the density of population centres in the surrounding area. The density has been taken to be one community per thousand square kilometres (i.e. the linear separation of communities is around 30 km).

The probability of this scenario applying at any time is the probability of there being a community (assumed area 0.1 km^2) on top of the contaminated region at that time. Assuming that the cumulative probability that an intrusion event has already occurred is 1.0, this gives the probability of a longer-term exposure as:

$P(\text{longer-term exposure}) = 10^{-2} \times 10^{-1} = 10^{-3}$.

Note that the risk calculated using this probability would still be an annual risk, as the long-term nature of the exposures in this scenario means that effective dose rates would be calculated.

Missile Crashes

According to information supplied by Defence, of the weapons fired on the Woomera test site in the last ten years, about 42 per annum are capable of penetrating to a depth of 5 m. Therefore, it is assumed that about 42 missiles potentially disruptive to the repository hit the ground in the WPA every year.

If it is assumed that these 42 missiles land at random positions on the test site (an assumption that may not be valid, if the missiles are fired within a limited range of trajectory and velocity values), then an estimate of frequency of impact on the repository can be made. The total area of the WPA is 127,800 km^2 and the repository has a cross-sectional area of 10^{-2} km^2. If it is further assumed that any strike within 100 m of the repository causes disruption to the wastes, an area approximately nine times the repository disposal area, then the frequency of strike is approximately:

$$f(\text{missile}) = (42 \times 9 \times 10^{-2}) \div 1.28 \text{ x } 10^{5} = 3.0 \text{ x } 10^{-5} \text{ disruptions per year.}$$

Aircraft Crash

The probability of an aircraft crash into the repository can be estimated from consideration of aircraft crash data. According to Defence, one aircraft crash has occurred at the WPA over the last ten years.

As with the missile crashes, the best way to proceed is to assume that aircraft crashes occur at random locations on the test site. The target area for which a crash can disturb the repository wastes would be taken to be the same as that for missiles; that is, any impact within 100 m of the repository location, an area approximately nine times the repository disposal area, would be considered to disturb the wastes.

From this, the frequency of a disruptive aircraft impact is approximately:

$$f(\text{aircraft}) = (0.1 \text{ x } 9 \text{ x } 10^{-2}) \div (1.28 \text{ x } 10^{5}) = 7.0 \text{ x } 10^{-8} \text{ crashes per year.}$$

Climate Change

Assessing the probability that a transition to a wetter climate state will occur is very difficult. However, computer modelling has been carried out by CSIRO (Appendix F), which indicates that a transition to a wetter climate state in the Woomera area is unlikely to occur in the next 10,000 years. The detailed conclusions of this report can be stated as follows:

1. The greenhouse effect will lead to a gradual increase of surface temperature in the Woomera region.
2. The greenhouse effect may lead to a slight increase in rainfall in the Woomera region.
3. Under greenhouse conditions, the frequency of intense periods of rainfall will increase.
4. Soil moisture shows no increasing trend, except in one of the variant scenarios for atmospheric CO_2.
5. Surface winds are unlikely to increase.
6. Over a 10,000-year timescale, climate change may arise from natural climatic variability, though this is difficult (if not impossible) to predict.

With regard to item 6, it can be suggested that wetter climate states could occur, in the same way that the 'Little Ice Age' came and went, but it cannot be stated that such change would definitely occur. Therefore, the degree of belief for this scenario is less than unity.

However, owing to the difficulty of making plausible estimates of the degree of belief, the probability of a climate change is taken as unity. The radiological safety of the facility would be judged on the basis of conditional risks obtained in the assessment calculation. Thus:

P(wetter climate) = 1.

Gross Erosional Events

In the previous subsection it was noted that the frequency of intense periods of rainfall might increase over time. Therefore, it is possible that rain-induced soil erosion rates may increase over time. However, wind-induced erosion is not likely to increase, as surface wind velocities are not expected to increase (item 5).

As for the transition to a wetter climate state, it is assumed that gross erosion (by whatever means) would eventually remove the repository contents and disperse them over an area of the accessible environment, so that the degree of belief for this scenario is taken to be unity. The difficulty in this case is deciding on what timescale this would occur. In interpreting the assessment results, it is assumed that at least 5000 years passes before this situation arises.

P(gross erosion) = 1.

Site Flooding (Bathtubbing)

Bathtubbing is most likely to occur if the transition to a wetter climate state occurs, though the phenomenon cannot be ruled out in the absence of a wetter climate (depending on the local hydrogeology, etc). It would also require a failure of the drainage systems in place at the repository. These are difficult to estimate and so, as for the wetter climate state and gross erosion scenarios, the probability of occurrence is taken as unity. The radiological safety of the facility would be judged on the basis of conditional risks obtained in the assessment calculation.

P(bathtubbing) = 1.

Consumption of Contaminated Well Waters

The probability of a well intersecting the repository can be obtained from historical knowledge of the frequency with which wells are drilled in the surrounding area (if such information exists). It is assumed that a farmer who has set up a farm at the repository site during wetter climate conditions would drill such a well. If it is assumed that the farmer owns 1 km^2 of land and drills a well somewhere on his land once every ten years (a somewhat pessimistic assumption), then the frequency of well drilling on contaminated land is:

f(well) = $10^3 \div (10^6 \times 10) = 10^{-4}$ wells per year.

It should be noted that this scenario can only occur during a wetter climate (in order for the watertable to be sufficiently close to the ground surface to make well drilling practical), and so this estimate of well-drilling frequency is also contingent on the occurrence of climate change. The estimate is therefore somewhat pessimistic.

Artefact Recovery

An estimation of the probability that members of the public would recover such sources requires both an excavation event and the presence of a community within a distance of (for example) 1 km of the repository site. That is, a population centre is required within an area of around 3 km^2, centred on the repository location.

In other calculations presented in this assessment, it has been estimated that the frequency of excavation events at the repository location is around 10^{-4}/yr. Similarly, the probability of a community being located within a given area of 3 km^2 is 0.001 × 3 = 0.003. This latter calculation assumes one community per 1000 km^2, with the community size being much smaller than the target area. Thus, the probability of someone picking up such a source is approximately:

$$P(\text{pick up source}) = 10^{-4} \times 3 \times 10^{-3} = 3 \times 10^{-7}/\text{yr}.$$

This is a very small estimated probability.

12.8.4 Radiological Dose Estimates

Gas Generation and Migration

Annual effective doses from the release of radioactive gases from the repository have been calculated, using a number of conservative assumptions, to be:

^{3}H	2×10^{-4} mSv
^{14}C	2×10^{-6} mSv
^{85}Kr	3×10^{-9} mSv
^{220}Rn	0 mSv
^{222}Rn	up to 130 mSv.

With the exception of ^{222}Rn, these calculated annual doses are all very much smaller than the dose limit of 1 mSv/yr.

A simple estimate of the likelihood of a house being constructed over the repository, based on the area and current population of the WPA, suggests the probability would be about 10^{-5}. The effective dose rate from ^{222}Rn and its progeny, in the worst case assumption of no covering materials and a house built on top of the facility, is around 130 mSv/yr.

In risk terms this equates to an individual risk of around 8×10^{-8}/yr, when the probability of building a house on top of the repository is taken into account. The calculation also shows that the use of backfilling materials of low diffusivity would reduce the dose considerably, even if the cap ceases to be present at some stage in the future.

An engineered, multi-layer cap of 5 m thickness and backfill material would substantially mitigate the effects of ^{222}Rn emanation from the repository. However, this conclusion is contingent on the cap not acquiring fissures or cracks, which might provide a preferential leakage pathway out of the repository.

Groundwater Contamination

Radionuclides could be released from the repository in infiltrating groundwater through the unsaturated zone towards the aquifer below. Diffusion and dispersion would spread the release, and sorption on to the rocks would be expected to slow the progress of most of the radionuclides. Any activity reaching the aquifer would mix with the infiltrating water into the aquifer water and be carried towards the outlet. Again, diffusion, dispersion and sorption would occur, with similar outcomes.

The consequence of the long travel time for groundwater to travel through the unsaturated zone, estimated to be 10,000 years, is that most radionuclides in the inventory would decay long before reaching the underlying aquifer.

The remaining radionuclides of interest are ^{238}U and daughters, ^{232}Th and daughters, ^{241}Am and daughters, ^{14}C, iodine-129 (^{129}I) and holmium-166 (^{166}Ho). Retarded travel times were calculated for these radionuclides through the unsaturated zone, that is taking account of the sorption of the radionuclides into the rocks.

Examining the estimated travel times shows that, with the exception of ^{129}I, all of the other species require at least 1 million years to travel through the unsaturated zone. Uranium requires nearly 10 million years, and thorium and radium require around 50 million years or more. ^{241}Am, ^{14}C and ^{166}Ho would decay away completely within their travel times.

Thus, with the exception of ^{129}I, no radionuclides would emerge into the aquifer within 10,000 years.

For ^{129}I, the impact of discharge to the aquifer may be assessed with the following simple calculation. Assume that all of the ^{129}I present in the repository is discharged into the aquifer, and mixes to a depth of 1 m. This leads to a concentration in aquifer water of around 0.1 Bq/L. For someone who drinks aquifer water to the extent of 1000 litres per year, the intake is 100 Bq of ^{129}I, which corresponds to a committed effective dose of around 1 x 10^{-5} Sv/yr. This is a negligible dose, derived on extreme assumptions.

The potential impact of ^{238}U and its daughters reaching the aquifer can be obtained from the following very simple dilution argument. In the repository the maximum concentration of ^{238}U in porewater would be defined by the solubility limit of uranium. In a high pH environment a typical value could be in the order of 10^{-3} mol/m^3. In terms of activity concentrations, this is equivalent to 3 Bq/L.

Analyses of groundwater indicate that ^{210}Pb is present in porewater in the general area of the repository at concentrations of between 0.2 and 0.8 Bq/L. Assuming that secular equilibrium has been reached as ^{238}U in repository porewater makes its way through the unsaturated zone, it follows that a dilution factor of between 10 and 40 is required, to ensure that ^{210}Pb levels derived from the repository do not exceed natural levels in porewater.

This requires that the flow rate in the aquifer (in m^3/sec) should exceed the flow rate from the unsaturated zone to the aquifer by a factor of 10 to 40. Bearing in mind the extremely low recharge levels in the unsaturated zone, this level of dilution should be achieved with ease.

Borehole Drillers

For borehole drillers maximum doses would be attained if the intrusion occurred immediately after the end of the institutional control period. This dose is around 1.7 x 10^{-6} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of contaminated dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of borehole drilling, the individual risk is around 1.0 x 10^{-11}/yr which is comfortably within the risk target of 1 x 10^{-6}/yr.

Excavation Workers

For excavation workers maximum doses would be attained if the intrusion occurred immediately after the end of the institutional control period. This dose is around 3.5 x 10^{-5} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of contaminated dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times ^{238}U and its decay products ^{230}Th, ^{226}Ra and polonium 210 (^{210}Po) provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of excavations, the individual risk is around 2.1 x 10^{-10}/yr which is comfortably within the risk target of 1 x 10^{-6}/yr.

Road Builders

For road builders the maximum dose is around 1.5 x 10^{-5} Sv, with the most significant radionuclide being ^{226}Ra. Inhalation of dust is the most significant exposure pathway. At later times ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of road building, the individual risk is around 1. 9 x 10^{-11}/yr for an intrusion that occurs after sufficient erosion has taken place to allow the trench contents to be removed (about 4000 years). This risk value is comfortably within the risk target of 1 x 10^{-6}/yr.

Archaeologists

For archaeologists maximum doses would be attained if the archaeological work occurred immediately after the end of the institutional control period. This dose is around 1.7 x 10^{-3} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of archaeological digging, the individual risk is around 1.1 x 10^{-8}/yr, which is comfortably within the risk target of 1 x 10^{-6}/yr. Thus, even though the assessed dose is slightly higher than the level specified as the public dose limit by many authorities, the low probability of occurrence ensures that the individual risks are small.

Exposure of Future Inhabitants

For future inhabitants settled in the area who make use of excavated materials, maximum doses would be attained if the excavation intrusion occurred immediately after the end of the institutional control period. This dose would be attained in the earliest years of material usage, and is around 1.5 x 10^{-3} Sv, with the most significant radionuclide being ^{226}Ra. External irradiation is the most significant exposure pathway, with ^{226}Ra being the most significant contributor.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of usage of excavated materials, the individual risk is around 8.6 x 10^{-8}/yr, which is within the risk target of 1 x 10^{-6}/yr. Thus, the assessed dose is slightly higher than that specified as the public dose limit by many authorities, and the low probability of occurrence ensures that the individual risks are small.

For nomadic users of the area, who make use of excavated materials, maximum doses would be attained if the excavation intrusion occurred immediately after the end of the institutional control period. This dose would be attained in the earliest years of material usage, and is around 6.8 x 10^{-4} Sv, with the most significant radionuclide being ^{226}Ra. Ingestion is the most significant exposure pathway, with ^{210}Po being the most significant contributor.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of such usage of excavated materials, the individual risk is around 4.1x10^{-8}/yr, which is within the risk target of 1 x 10^{-6}/yr. Thus, the assessed dose is less than that specified as the public dose limit by many authorities, and the low probability of occurrence ensures that the individual risks are small.

Missile Crashes

For children in settled communities who play on exposed wastes after a missile crash at the repository site, maximum doses would be attained if the crash occurred immediately after the end of the institutional control period. This dose is around 9.6×10^{-4} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times, ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of rocket crashes, the individual risk is around 1.7×10^{-9}/yr, which is comfortably within the risk target of 1×10^{-6}/yr. Thus, even though the assessed dose is at the level specified as the public dose limit by many authorities, the low probability of occurrence ensures that the individual risks are small. In fact, in the case of the missile crash the true frequency of occurrence would probably be considerably less than the value of 3.0×10^{-5}/yr assumed in this study.

For children in nomadic communities who play on exposed wastes after a missile crash at the repository site, maximum doses would be attained if the crash occurred immediately after the end of the institutional control period. This dose is around 1.6×10^{-4} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of contaminated dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times, ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of missile crashes, the individual risk is around 3.0×10^{-10}/yr, which is comfortably within the risk target of 1×10^{-6}/yr. Thus, the assessed dose is less than that specified as the public dose limit by many authorities, and the low probability of occurrence ensures that the individual risks are small. In fact, in the case of the missile crash, the true frequency of occurrence would probably be considerably less than the value of 3.0×10^{-5}/yr assumed in this study.

Aircraft Crashes

For an aircraft recovery team that clears up debris lying on exposed wastes after an aircraft crash, maximum doses would be attained if the crash occurred immediately after the end of the institutional control period. This dose is around 6.9×10^{-5} Sv, with the most significant radionuclide being ^{241}Am. Inhalation of contaminated dust is the most significant exposure pathway, with ^{241}Am again being the most significant contributor. At later times, ^{238}U and its decay products ^{230}Th, ^{226}Ra and ^{210}Po provide the largest contribution to dose.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of aircraft crashes, the individual risk is around 2.9×10^{-13}/yr, which is comfortably within the risk target of 1×10^{-6}/yr.

Climate Change

In interpreting the results for the transition to a wetter climate, it should be borne in mind that such a climate change would happen many hundreds or thousands of years after the end of the institutional control period. It is assumed that the climate change has been manifested, and a critical group established in the vicinity of the repository 5000 years after repository closure.

At this time the assessed effective dose rate to critical group members in a settled community would be about 4.61×10^{-5} Sv/yr. The largest single contribution is made by ^{210}Po, and the most important exposure pathway is ingestion of plants.

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 2.8 x 10^{-6}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if the climate change scenario definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such climate change, as this requires more detailed information about the disposal site and its evolution in time.

It can be seen that, if the climate change scenario were definitely to occur, the conditional risk would be similar to the risk target of 1 x 10^{-6}/yr.

The assessed effective dose rate to critical group members in a nomadic community would be about 1.2 x 10^{-5} Sv/yr. The largest single contribution is made by ^{210}Po, and the most important exposure pathway is ingestion.

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 7.1 x 10^{-7}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if the climate change scenario definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such climate change, as this requires more detailed information about the disposal site and its evolution in time.

It can be seen that, if the climate change scenario were definitely to occur, the conditional risk would be within the risk target of 1 x 10^{-6} yr.

Gross Erosional Events

As in the interpretation of results for the transition to a wetter climate, it should be borne in mind that gross erosional events would happen thousands of years after the end of the institutional control period. It is assumed that gross erosion has been manifested, and a critical group established in the vicinity of the repository 5000 years after closure of the repository.

At this time the assessed effective dose rate to critical group members of a settled community would be about 3.6 x 10^{-5} Sv/yr. The largest single contribution is made by ^{238}U, and the most important exposure pathway is ingestion of plants (though ingestion of meat also provides a contribution of similar magnitude).

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 2.1 x 10^{-6}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if gross erosion of the repository definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such an event, as this requires more detailed information about the disposal site and its evolution in time.

It can be seen that, if the climate change scenario were definitely to occur, the conditional risk would be similar to the risk target of 1 x 10^{-6}/yr.

The assessed effective dose rate to critical group members of a nomadic community would be about 4.9 x 10^{-6} Sv/yr. The largest single contribution is made by ^{238}U, and the most important exposure pathway is ingestion of meat.

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 3.0 x 10^{-6}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if gross erosion of the repository definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such an event, as this requires more detailed information about the disposal site and its evolution in time.

It can be seen that, if the climate change scenario were definitely to occur, the conditional risk would be similar to the risk target of 1 x 10^{-6}/yr.

Site Flooding (Bathtubbing)

As in the interpretation of the results for the transition to a wetter climate, it should be borne in mind that site flooding would happen thousands of years after the end of the institutional control period. In addition, it would only occur in a wetter climate state. It is assumed that site flooding has been manifested, and a critical group established in the vicinity of the repository 5000 years after closure of the repository.

At this time the assessed effective dose rate to critical group members of a settled community would be about 3.2×10^{-5} Sv/yr. The largest single contribution is made by ^{210}Po, and the most important exposure pathway is ingestion of plant materials (though ingestion of meat also provides a contribution of similar magnitude).

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 1.9×10^{-6}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if flooding of the repository site definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such an event, as this requires more detailed information about the disposal site and its evolution in time, in particular the properties of natural drainage and any engineered drainage facilities at the site.

It can be seen that, if the site flooding scenario were definitely to occur, the conditional risk would be similar to the risk target of 1×10^{-6}/yr.

The assessed effective dose rate to critical group members of a nomadic community would be about 8.3×10^{-6} Sv/yr. The largest single contribution is made by ^{210}Po, and the most important exposure pathway is ingestion of meat.

The conditional risk is obtained by multiplying this dose by the dose-to-risk conversion factor of 0.06/Sv, leading to a conditional risk of around 5.0×10^{-7}/yr. It is important to note that this is the risk of cancer induction (or serious hereditary effects) that would occur if flooding of the repository site definitely occurs. No attempt has been made to estimate the probability (or degree of belief) of occurrence of such an event, as this requires more detailed information about the disposal site and its evolution in time, in particular the properties of natural drainage and any engineered drainage facilities at the site.

It can be seen that, if the site flooding scenario were definitely to occur, the conditional risk would be within the risk target of 1×10^{-6}/yr.

Consumption of Contaminated Well Waters

The consumption of well waters scenario only applies if the wetter climate state is manifested. Therefore, the results are considered at a time of 5000 years after repository closure. At this time the effective dose from water obtained from a well drilled at the repository site would be around 2.8×10^{-3} Sv/yr, with ^{238}U being the main contributor.

Taking into account the dose-to-risk conversion factor of 0.06/Sv and the frequency of occurrence of well drilling on a farm of area 1 km^2, the individual risk is around 1.87×10^{-7}/yr for consumption of contaminated waters. This risk value is well within the risk target of 1×10^{-6}/yr.

Artefact Recovery

In order to investigate the effects of handling recovered sources, three characteristic sources have been identified from the current inventory which would be disposed of at the repository (all assumed to be a cylinder or diameter 2 cm and length 5 cm):

- a 0.185 GBq source of ^{60}Co
- a 480 GBq source of ^{137}Cs
- a 0.37 GBq source of ^{226}Ra.

It is reasonable to assume that these sources could not be recovered during the period of institutional control due to restrictions on access and maintenance of intrusion barriers. Radioactive decay during that period would reduce the source activities after 200 years to:

- ^{60}Co (half-life 5 yr) 6.3×10^{-4} Bq
- ^{137}Cs (half-life 30 yr) 4.7×10^{9} Bq
- ^{226}Ra (half-life 1600 yr) 3.4×10^{8} Bq.

^{60}Co has almost entirely decayed away and is not considered further. The following dose rates to the hand are obtained for a person holding the ^{137}Cs and ^{226}Ra sources:

- ^{137}Cs absorbed dose rate ~ 250 Gy/hr
- ^{226}Ra absorbed dose rate ~ 46 Gy/hr

For someone standing a short distance away from such a source (e.g. having taken the source home and placed it on a table or mantelpiece), the dose rates at 1 m are:

- ^{137}Cs effective dose rate ~ 0.5 mSv/hr
- ^{226}Ra effective dose rate ~ 0.05 mSv/hr

The doses arising from handling these sealed sources are therefore considerable, in particular the dose arising from the high activity ^{137}Cs source. The doses arising from exposure to a sealed source at a distance of 1 m are much lower.

It is therefore clear that excavation of repository contents could lead to a situation where sealed sources are returned to the accessible environment, with serious consequences for members of the public who pick up and carry around such sources.

However, safety factors such as the cover thickness and the role of the conditioned waste matrix are designed to minimise the potential for discrete sources being accessible. After 200 years, the concrete matrix in the conditioned waste would still be intact. By the time this matrix degrades it is reasonable to assume that the source would also have degraded, with the result that there would no longer be a discrete concentrated source as assumed for these calculations.

Consideration should also be given to the extremely low probability that such sources are removed by members of the public. This has been estimated to be ~ 10^{-7}/yr, a very small probability.

If an exposure time of 100 hrs at 1 m from the source is assumed, this would lead to an annual dose of 50 mSv. However, the associated annual risk would be 3×10^{-10} due to the low probability of the occurrence.

12.8.5 Summary and Discussion

A summary of the peak doses and risks from all of the scenarios considered for the post-institutional phase is given in Table 12.2.

Key Release Pathways

The two key release pathways identified by the analysis, as summarised in Table 12.2, are via the scenarios of gas generation and migration into a dwelling built on the surface on the repository, and artefact recovery. The figures assume these events occur directly after the 200-year post-institutional control period.

TABLE 12.2 Summary of peak doses and risks — post-institutional phase

Scenario	Critical group	Peak dose(1)	Peak risk(2)	Time (yr)(3)	Key nuclide
Gas generation and migration	Occupants of dwelling built on the surface of the repository	1.3×10^{-1}	8.0×10^{-8}	200	^{222}Rn
Groundwater contamination	People using groundwater for drinking (illustrative)	1×10^{-5}	n.a.	0	^{129}I
Borehole drillers	Geotechnical workers	1.7×10^{-6}	1.0×10^{-11}	200	^{241}Am
Excavation workers	Excavation gang	3.5×10^{-5}	2.1×10^{-10}	200	^{241}Am
Road builders	Road building gang	1.5×10^{-5}	1.9×10^{-11}	4000	^{226}Ra
Archaeologists	Group of archaeologists	1.8×10^{-3}	1.1×10^{-8}	200	^{241}Am
Longer-term exposures	Settlers who use excavated materials in gardens	1.5×10^{-3}	8.9×10^{-8}	200	^{226}Ra
Missile crashes	Settler children playing at site	9.6×10^{-4}	1.7×10^{-9}	200	^{241}Am
Aircraft crashes	Aircraft recovery team	6.9×10^{-5}	2.9×10^{-13}	200	^{241}Am
Climate change	Subsistence/farming community	4.6×10^{-5}	2.8×10^{-6}	5000	^{210}Po
Gross erosional events	Subsistence/farming community	3.6×10^{-5}	2.1×10^{-6}	5000	^{238}U
Site flooding (bathtubbing)	Subsistence/farming community	3.2×10^{-5}	1.9×10^{-6}	5000	^{210}Po
Consumption of contaminated well water	Subsistence/farming community	2.8×10^{-3}	1.9×10^{-7}	5000	^{238}U
Artefact recovery	Individuals who encounter sources from bulk excavated waste	5×10^{-2}	3×10^{-10}	200	^{137}Cs

(1) Doses are effective doses, with units of Sv or Sv/yr.
(2) Risks are individual annual risks.
(3) Times are measured in years post-closure.

Assessment of the gas pathway shows that the effective dose rate from ^{222}Rn and its progeny, in the worst case assumption of no covering materials and a house built on top of the facility, is around 130 mSv/yr. However, in risk terms, this equates to an individual risk of around 8×10^{-8}/yr when the probability of building a house on top of the repository is taken into account. The potential impact of this pathway can be mitigated at the detailed design stage for the facility by considering appropriate materials for the conditioned waste, backfill and cap.

The second key release pathway identified for potential future exposures is that of recovery of the more active sources and artefacts in the waste. These sources constitute a very small volume of the waste, and the probability of excavating the bulk waste and recovering the small active sources is considered to be very low. Safety factors such as the cover thickness and the role of the conditioned waste matrix are designed to minimise the potential for discrete sources being accessible.

After 200 years the concrete matrix in the conditioned waste would still be intact. By the time this matrix degrades it is reasonable to assume that the source would also have degraded, with the result that there would no longer be a discrete concentrated source as assumed for these calculations. In addition, most of the active sources would have decayed substantially during the institutional control period. In fact, it is precisely because the potential exposure from uncontrolled access to these sources is so high that disposal of such sources in a remote location, in a conditioned waste form, under at least 5 m of cover has been proposed. This is considered to be a preferable alternative to leaving these sources in surface stores in more densely populated areas in an unconditioned form.

All the scenarios examined result in risks within the regulatory target values, with the exception of those that assumed that major environmental changes would occur, that is climate change to much wetter conditions and gross erosional events. Even when these were assumed to occur, the resultant risks were close to the risk target of 1×10^{-6}/yr. However, in this respect, computer modelling carried out by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) indicates that a transition to a wetter climate in the Woomera area is unlikely to occur in the next 10,000 years.

Key Radionuclides and Inventory

The radionuclides that contribute most to radiation exposure in these scenarios are ^{241}Am, ^{137}Cs (for source recovery only) and ^{238}U and its daughters ^{226}Ra and ^{210}Po. The assessment calculations are linear with respect to the initial inventory of radionuclides in the waste. That is, with a higher initial inventory in terms of Bq per unit mass, the resultant dose and risk are also proportionally higher.

The inventory used for these assessments was based on the amount of radioactive waste that has been identified as suitable for near-surface disposal using the generic assumptions at the present time and on assumptions about future arisings. The present inventory and future arisings are discussed in Sections 4.1 and 4.2, and more detail on the current inventory is provided in Appendix B.

The regulator (ARPANSA) would determine the total radionuclide inventory (both for bulk material and individual sources) acceptable for disposal at the repository. They would take into account the exact location of the site, the detailed repository design and the acceptance and verification of the scenarios and assumptions used in the risk assessments.

Conclusions

It should be noted that these assessments are equally applicable to all three of the candidate sites, with the exception of risks associated with missile and aircraft crashes, which largely apply to Site 52a only.

Overall, it has been shown that the risks that might arise in future years, when the site is no longer under institutional control, are acceptably low and comply with the NHMRC 1992 Code.

12.9 Other Events

12.9.1 Acts of Sabotage

At present radioactive material is distributed in a number of locations across Australia, some of which may have less than ideal security arrangements. Therefore, bringing the waste together into one national repository and storing it permanently under proper security would provide an overall reduction in the risk of sabotage/terrorism. This benefit outweighs the transient risk of sabotage during transport.

From a sabotage perspective, sealed sources are the most hazardous shipments because they comprise discrete, concentrated sources of radioactivity. They could be used by individual or groups of terrorists to expose the public to dangerous levels of radiation, for example by being removed from the shipping container and left in a crowded public place.

It is impossible to calculate the probability of such a deliberate act. Shipments are provided with at least two barriers in the case of soils (the primary barrier is the 205 L drum and the secondary barrier is the ISO standard container) and three barriers for sealed sources (the inner shielded container, the 205 L drum and the ISO standard container). An escort, and not publicising the transport route beforehand, would provide additional protection. Bulk waste in the form of contaminated soil and operational waste would not be as attractive to saboteurs or terrorists, but stealing or dispersing it would generate significant publicity and fear in the community.

12.9.2 Natural Catastrophic Events

Transport Impacts

Earthquakes, floods, cyclones, sandstorms or fire could all have detrimental effects on the shipment of radioactive waste. Any one of these could cause a truck to tip over, potentially allowing the waste to become exposed to the elements in the unlikely event of the relevant containers being damaged. However, the consequences are no worse than the ‘maximum reasonably foreseeable accident scenario’ of Section 7.6.3.

As in fire and sabotage, the sealed sources are relatively the most hazardous shipments and the soil and operational waste less hazardous. As noted above, shipments are provided with at least two barriers in the case of soils (the primary barrier is the 205 L drum and the secondary barrier is the ISO standard container) and three barriers for sealed sources (the inner shielded container, the 205 L drum and the ISO standard container).

The most sensible precaution is that shipments should not begin if any natural extreme climate events are forecast in the area of the repository or transport route, and drivers should be trained to put the truck under shelter in such an event.

Repository Impacts

The impact of erosion and flooding at the repository site has been addressed in Section 12.8. In the short term, during the institutional control period, the repository design, and maintenance of the cap and storm drainage systems if required, would prevent any damage due to erosion or flooding. At later times, assessment has shown that potential radiation exposure and subsequent risk of serious health effects from these events is very low.

12.9.3 Greenhouse Implications

The implications of future climate change impacts on the national repository have been investigated by CSIRO, using a variety of climatic models (Appendix F). The simulations included possible future scenarios for atmospheric carbon dioxide and sulphate aerosol concentrations extending to 2100 AD using the CSIRO global model.

A complementary simulation, extending to 2600 AD, explored longer-term climatic changes assuming atmospheric carbon dioxide concentration had stabilised at double pre-industrial values around 2100 AD. The possibility of extreme climatic anomalies was investigated using a 10,000-year-long simulation for present climatic conditions.

All simulations indicate that a temperature rise of several degrees is to be expected in the Woomera area over the next century. Rainfall changes are more difficult to quantify, with the more accurate models suggesting a small increase in annual rainfall. However, an increase is to be expected of the infrequent, highest rainfall intensity events, which could result in some increase in flood-induced soil erosion.

Soil moisture and surface winds are indicated as essentially invariant at Woomera under climatic change conditions, implying no increase on present rates of wind-induced soil erosion. This stable hydrological situation, when combined with expected increased temperature, suggests that pastoral conditions in the Woomera area might experience some deterioration.

With the possible exception of the extreme situation where the polar ice sheets melt owing to the greenhouse effect, no especially significant climatic perturbations were identified as probable over the next 10,000 years, although it is acknowledged that such an assessment is difficult to make.

In summary, a relatively stable climatic state is predicted for the Woomera area and, as the national repository would be designed to withstand the extremes of present climatic variability, this should provide adequate security against possible future climatic changes. The overall conclusion is that future climatic change or climatic variability would appear to represent a minor factor in the long-term security of the national repository.

12.9.4 Protestor Activity

Activity by anti-uranium and anti-nuclear protestors has become a regular event in the region. In the last few years a regular 'circuit' of demonstration events has taken place at uranium mines, including at the nearby Olympic Dam operation, at Honeymoon and Beverley in the east of South Australia (northwest of Broken Hill) and at Ranger in the Northern Territory. The protests have caused minor disruption to activities at these operations, in particular in relation to personnel access, and have also been associated with graffiti and other vandalism, trespass and property damage.

It may be expected that protestors may also attempt to disrupt activities at the national repository. Access to the 1.5 by 1.5 km national repository site would be limited through appropriate security measures. Security fencing and other surveillance and monitoring would deter intrusion by people. Site 52a, within the WPA, would have inbuilt public-access restrictions and other security coverage, and would offer security advantages over the alternative sites.

Should any protestors gain access to the repository site, there would be very little risk of any radiation exposure from the buried waste, which would be effectively shielded by the 5 m cover material and steel and concrete packaging.

12.9.5 Accidents Involving Fire

Waste that would be transported to the repository is low level and short-lived intermediate level radioactive waste, all in solid form and most of it non-combustible, in sealed drums. Any potentially combustible material would be conditioned using concrete inside sealed drums. The spent sealed sources are solid metal inside a metal container inside concrete-filled drums. In addition, all drums would be contained in a sealed metal ISO standard container during transport. Thus, it is most unlikely that any radioactivity would be released in a fire following a transport accident.

Once at the repository, the drums would be held in store for a short period (days to weeks at most) pending disposal. The non-combustible nature of the drums and their contents would make any potential release of radionuclides to the environment in the event of a fire in the store most unlikely. Once buried in the trenches or boreholes the drums would be secure from fire.

Thus, it is considered most improbable that a fire involving the waste would result in any radioactivity being released into the environment, either during transport or at the repository.

12.10 Environmental Safeguards to Minimise Impacts

Risks can be reduced by appropriate mitigation measures. This section provides an overview of a range of radiation risk reduction strategies that would be implemented at the repository.

Radiological risks at the site could arise at all stages of the repository operations and from all procedures required for the transport, assay, conditioning, storage and disposal of radioactive waste. However, the design of the facility and its operational plan would be developed in accordance with the relevant codes and licensing process (see Sections 3.2 and 3.3) to minimise the radiological risk to the workforce, members of the public and the environment. The radiological risk that is considered in relation to the repository refers to the additional risk from disposal of radioactive waste, not that resulting from exposure to natural background radiation.

Exposure of humans and the environment to radiological risk can occur through two main processes: either from direct external exposure to penetrating gamma radiation; or through internal exposure arising from inhalation of contamination as an aerosol or as resuspended dust in air or by ingestion of contaminated drinking water or foodstuffs.

The fundamental features of the repository design would mitigate external exposure and environmental release of radioactivity that might lead to uptake of radionuclides.

12.10.1 Location

The design and operation of the repository would ensure that, during the operation and surveillance phases, loss of radioactive material would probably not occur. However, after the end of the 200-year control period, there would be unrestricted access to the site and it is possible that either human activities or natural processes could result in the release of radioactive material to the environment.

These activities include possible development of the site for roads or house building, mineral exploration, climate change, erosion of the cap, and impact of weapons or aircraft crashes at the site. However, the remote location of the site and its geological and hydrogeological profile ensure that these potential activities are relatively unlikely to occur and, if they were to occur, radiation exposure to the population would be limited to an acceptable low level of risk.

12.10.2 Mechanisms for Handling Unexpected Releases

A detailed emergency management plan would be established for the site and submitted to ARPANSA for approval (Section 3.3.2).

Waste would be conditioned and packaged prior to transport to the repository. Some additional packaging might occur at the repository. There would also be facilities for minor conditioning of waste, for example concreting, if required. Packages would be checked before transport.

There are a number of ways in which radioactive material could potentially be released during these processes. These are identified below and discussed in the following sections:

- receipt of faulty package (externally contaminated by radioactivity)
- dropping of faulty package (resulting in release of radioactive contents)
- explosion/fire in waste package
- stack collapse in trench
- damage of waste packages in store
- damage of waste packages in trench.

Receipt of Faulty Package

It is possible that a package might be received at the repository that has been improperly prepared or damaged during transport and therefore may have radioactive contamination on the surface. To mitigate this risk, waste packages would be surveyed prior to loading at the waste supplier or unloading at the repository. This would involve external examination to look for signs of damage, radiation dose monitoring and collection of surface contamination swabs.

If a faulty package were suspected, the radiation protection officer (RPO) would be informed, who would instigate its safe recovery using personnel with appropriate training and personal protective equipment. The RPO would also ensure the decontamination of any other surfaces if necessary. Any externally contaminated packages that arrive would be wrapped in polythene and diverted to a separate storage bay prior to decontamination. Any loose material that had spread from the faulty package would be recovered and treated as waste.

Dropping of Faulty Package (Resulting in Release of Radioactive Contents)

The WAC for transport and acceptance of the waste at the repository would ensure that the waste is packaged appropriately to mitigate the impact from potential accidents such as drops. However, in the unlikely event that a package is dropped and releases radioactive material, the incident would be confined to the local area as the waste would be in an inert and immobile solid form (no liquids or gases would be allowed in the waste). The buffer zone around the repository would ensure that no releases of radioactive material, for example through the resuspension of dust, would occur off-site.

In the event of an accidental release of radioactive material, the area would be isolated and the RPO informed. If the material were noticeably dusty, a polythene sheet to prevent dispersion would be used to cover it. The RPO would instigate procedures for the safe recovery of the package and the remediation of any other contaminated surfaces.

Explosion/Fire in Waste Package

The WAC would include a provision that excludes the presence of explosive or combustible materials within a conditioned waste package. Consequently, the effective monitoring of compliance with the WAC would make this an extremely unlikely event.

If a fire or explosion did occur, the area would be evacuated of non-essential personnel, and trained personnel with appropriate protective equipment would extinguish any fire and monitor the surrounding environment. The contaminated areas would be cordoned off and covered if necessary to prevent dispersion before beginning remediation activities.

The buffer zone around the repository would ensure that any off-site releases of radioactive material, for example through the generation of aerosols and/or resuspension of particulate material, are minimised.

Stack Collapse in Trench

It is planned to stack the waste packages on top of each other in the trench. It is possible that, due to a faulty package or mishap during storage, a stack of packages might collapse and be damaged, releasing radioactive material.

In this event, the area would be evacuated of non-essential personnel, and trained personnel with appropriate protective equipment would monitor the surrounding environment. The contaminated areas would be cordoned off and covered if necessary to prevent dispersion before beginning remediation activities.

The scale of the remediation activities would consider the balance between potential risks and exposures to the workforce from recovery and repackaging of material and the radiological impact of leaving the material in situ with some simple containment in place.

Damage to Waste Packages in Store

Some interim storage at the site for a period of days or weeks only may be required before permanent disposal in the trench occurs. The WAC would specify package requirements adequate for this storage period without any deterioration in the package integrity. The packages would be externally inspected to check for obvious signs of deterioration before being removed to the trench for disposal.

If a faulty package were suspected, the RPO would be informed and would instigate its safe recovery, using personnel with appropriate training and personal protective equipment. The RPO would also supervise the remediation of any other contaminated surfaces. Any externally contaminated packages would be wrapped in polythene and diverted to a separate storage bay prior to decontamination. Any loose material that had spread from the faulty package would be recovered and treated as waste.

Damage to Waste Packages in Trench

It is possible that a faulty package may be observed after emplacement in the trench and before backfilling. The package and the surrounding area would be monitored in this instance. If no release of radioactivity had occurred, the feasibility and relative risks of retrieving the package would be assessed and compared to the impact of leaving the package in situ with a degree of further containment (which might simply be backfilling).

If radioactive material had been released, the area would be evacuated of non-essential personnel and the contaminated area would be cordoned off and covered if necessary to prevent dispersion before beginning remediation activities.

12.10.3 Mitigation of Operational Impacts

Occupational Exposure

All radiation exposure would be controlled and monitored and would conform to the ALARA principle as established by the ICRP. As described in Sections 3.2 and 3.3, ARPANSA would regulate the operations and monitoring program. An RPO would be present during any campaigns at the repository. All staff would have appropriate radiological protection training and would be equipped with, and trained to use, personal protective equipment. An environmental and personnel radiation monitoring program would be developed in consultation with ARPANSA and implemented.

12.11 Monitoring Programs and Procedures

A comprehensive program for environmental and radiation safety monitoring would be prepared as part of the ARPANSA licensing process for the facility and in accordance with the NHMRC 1992 Code.

A monitoring system would be established throughout all phases of the repository lifecycle. A comprehensive recording and reporting system would be established which could be audited. Independent verification programs would also be established.

The monitoring system would provide a continuous review of radiation exposures and would demonstrate that all exposures are ALARA and that all dose limits and constraints are met. The monitoring results would be reviewed by both the operator and ARPANSA on a regular basis to determine whether safety and environmental objectives are being met.

The objectives of monitoring are to:

- establish a baseline for the repository environment prior to construction
- provide information for repository design
- demonstrate that operational procedures are effective and that no releases of radioactive contaminants from the repository occur
- demonstrate that radiation protection of the workforce is compliant with objectives and that exposures are within regulatory limits
- demonstrate compliance with the WAC
- demonstrate compliance with performance objectives and regulatory limits.

These aspects are discussed below.

Establish a Baseline for the Repository Environment Prior to Construction

During the operation and post-closure surveillance phases of the repository, environmental monitoring would be conducted to determine whether any releases of radionuclides from the site are occurring and, if so, whether these are within the agreed limits. In order to judge this, the ambient background radiation levels of the site need to be established. The baseline monitoring would address both the surface and subsurface environments. The program would include the following environmental media:

- air
- surface water and groundwater
- soil
- flora
- fauna.

The baseline monitoring would also identify the local ecosystems, and potential pathways for radionuclide transport through the environment and uptake by people.

Provide Information for Repository Design

The trenches or boreholes would be designed such that surface water ingress is minimised (through surface water drainage) and that disturbance of the buried material is minimised for both the short- and long-term future (through the trench/borehole cap design). Current surface water drainage patterns and habits of local flora/fauna and humans would be identified to aid the optimisation of the trench design.

Demonstrate that Operational Procedures are Effective and that No Releases of Radioactive Contaminants from the Repository Occur

Operating procedures at the repository would be established to ensure that no releases of radioactive material to the environment occur. A monitoring program would be established to confirm this and to check that the working environment is being properly controlled with for radiation exposure. This program would include routine measurements of:

- surface contamination (via instrument surveys and surface swabs)
- airborne contamination (via area monitoring with high-volume air samplers and personal air samplers)
- external radiation dose rates (via instrument surveys).

Demonstrate that Radiation Protection of the Workforce is Compliant with Objectives

A personnel dosimetry program would be established for the workforce, which would include use of personal dosimeters and air samplers, and routine urine sampling and analysis.

A dose record would be kept for each employee and reviewed by the RPO, as well as ARPANSA, on a regular basis.

Demonstrate Compliance with WAC

The performance of the repository is reliant on the establishment of, and compliance with, the WAC for the site. A validation program would be established to confirm compliance with the WAC, which would include on-site assay, both indirectly by external gamma monitoring of packages and directly by measurement of a subsample of packages.

Normally, waste assay on approved disposal packages takes place close to the disposal facility. It may be possible to produce the package and assay it before transporting it to the disposal site. In this case, some additional safeguards and procedures would be adopted to prevent any tampering with the contents.

Detailed records of the waste accepted at the repository would be kept in accordance with regulatory requirements. These records would include the location of the waste within the trench, the date of emplacement and the contents of the waste package.

In cases where the source of the waste is well documented (e.g. where it consists of spent sources), a document quality assurance trail may be sufficient to establish the contents of the package, as there would be records documenting the receipt of the source, its use and its storage prior to disposal.

Demonstrate Compliance with Performance Objectives and Regulatory Limits

The repository would be monitored during both the operational and the institutional control (post-closure) phases to ensure that it is performing satisfactorily and meeting all relevant requirements.

The monitoring system would include both sampling of the various media, as described in the baseline survey (i.e. air, surface water and groundwater, biota and soil) and their analysis for key contaminants. In addition, the detailed design of the monitoring system would depend on whether there is a requirement for certain components of the engineered system to be monitored, for example:

- aqueous/colloidal discharges through the repository base
- gas/vapour discharge through the cap/cover.

The requirement for retrievability of the waste also plays an important part in the design of the monitoring system, which may need to monitor subsections of the repository rather than the entire facility. Similarly, internal monitoring for dose rate, ^{14}C, ^{3}H and ^{222}Rn could be undertaken and compared with acceptable values.

The logistics of sample collection and analysis would be optimised. Analysis could take place on-site or off-site, with an on-site facility requiring appropriate infrastructure availability.

PART D

Environmental Management

Chapter 13

OVERVIEW OF ENVIRONMENTAL MANAGEMENT AND MONITORING

Chapter 13
Overview of Environmental Management and Monitoring

13.1 Preparation of the Environmental Management and Monitoring Plan

An environmental management and monitoring plan (EMMP) is required for operations at the national repository, covering both general environmental issues and the specific requirements of legislation and codes of practice on radiation and near surface repositories. Development of the EMMP would take into account issues and responses raised in the EIS process, as well as formal regulatory requirements.

The general aims of the EMMP would be to establish:

- management processes and procedures that would ensure environmental impacts are minimised during construction, operation, surveillance and decommissioning
- ongoing monitoring and reporting processes to follow the impacts of the operation on the surrounding environment
- monitoring and surveillance activities for the post-closure institutional control period to provide assurance that the waste remains contained and isolated in accordance with the safety requirements
- audit processes for checking the implementation and effectiveness of management and monitoring systems.

13.2 Management and Monitoring Approaches

A number of management and monitoring approaches have been recommended in Part C of this draft environmental impact statement (Draft EIS), which focuses on environmental assessment. Generally recommendations are provided against the five key phases of the proposal: during construction, during operation, during surveillance periods between disposal campaigns, during decommissioning, and during institutional control. The following sections provide a summary of the information presented in Part C of the Draft EIS. The recommendations outlined would form the basis of the EMMP.

13.2.1 Management and Monitoring During Construction

This section provides a summary of management (Table 13.1) and monitoring (Table 13.2) requirements during construction.

TABLE 13.1 Environmental management requirements during construction

Issue	Management strategy
Physical environment	
Surface water runoff, soil erosion and siltation of water courses	▪ Apply water used for dust suppression at a rate that would not generate significant runoff from the application area ▪ Install erosion and sediment control structures to ensure sediment transfer is minimised ▪ Locate soil stockpiles in designated areas away from drainage lines and have appropriate sediment control structures ▪ Carry out wash down of construction equipment on a hardstand within a bunded area and away from drainage lines ▪ Carry out refuelling of equipment on a hardstand away from drainage lines and within a bunded area ▪ Prepare a spill response plan before construction begins ▪ Construct surface water management ponds to enable storage and evaporation of surface water from construction operations ▪ Pump water that collects in trenches to the storage pond for evaporation ▪ Rehabilitate and revegetate disturbed areas not required for the operational period ▪ Minimise the amount of site disturbance beyond the limit of development works ▪ Minimise disturbance to natural soil profiles and removal of vegetation ▪ Maintain road surface without potholes or 'bulldust' patches ▪ Suspend construction activities following significant rain if additional soil damage is being incurred ▪ Control drainage through diversion to protect exposed areas as required ▪ Install temporary silt traps to remove sediment from site runoff before leaving site
Dust generation	▪ Impose speed restrictions ▪ Apply water or other suitable medium to site roads and soil stockpiles to reduce the potential for dust generation
Noise	▪ Ensure compliance with South Australian Environment Protection Agency (EPA) Industrial Noise Policy ▪ Fit construction equipment with appropriate noise control devices where practical ▪ Ensure construction equipment is regularly maintained
Release of pollutants to soil, surface water or groundwater	▪ Ensure all fuel tanks/drums are stored in bunded areas ▪ Ensure cleanup procedures and equipment are in place and implemented in the event of any spills
Vegetation and flora	
Potential for introduction and dispersal of weeds	▪ Minimise the disturbed area ▪ Prevent the introduction of seeds by thoroughly cleaning any plant machinery or vehicles that are brought on to the site during construction ▪ Eradicate existing weeds ▪ Promote the establishment of perennial native grasses ▪ Develop an ongoing weed removal program to remove weeds before they become established
Damage/removal of native vegetation	▪ Minimise disturbance by restricting vegetation clearance to only that necessary for building site and trench development ▪ Place cleared vegetation over areas of disturbance following construction
Threatened species	▪ Survey access routes for threatened species ▪ Where appropriate clearly mark and avoid all populations (or individuals) ▪ Implement approved conservation measures for each species

Issue	Management strategy
Off-road driving	■ Prohibit vehicle movement off existing or proposed road alignments and within the buffer zone ■ Restrict vehicle movement within the operational zone to areas of construction
Fauna	
Direct loss of individuals	■ Stage the construction to allow fauna adequate time to vacate burrows, roosting and nesting sites ■ Undertake construction activities outside the main breeding season for sedentary species (particularly threatened species)
Loss of habitat	■ Confine disturbance activities to those areas essential for construction (habitat loss is associated with vegetation clearance and surface disturbance)
Increased competition for resources and predation	■ If practicable, undertake construction outside of dry conditions to reduce the stress on available resources and animals
Threatened species	■ Define and avoid habitat critical for threatened species (e.g. deep cracking soils and canegrass areas)
Pest species	■ Undertake control of pest species, particularly red fox, feral cat and European rabbit after fencing ■ Maintain a clean construction site to prevent attracting pest species
Fencing	■ Establish and maintain predator and stock-proof fencing
Socio-economic	
Construction vehicle traffic	■ Manage peak construction vehicle levels to minimise access restrictions for surrounding community
Demonstrations and protests	■ Manage protest and demonstration events by providing suitable security infrastructure and response procedures
Land use conflicts	■ Minimise potential for future land use conflict by seeking a state level land use rezoning
Cultural heritage	
Consultation with claimant groups	■ Develop the cultural heritage component of the EMMP in consultation with claimant groups
Access to the repository sites	■ Ensure that access roads and tracks are designed and located in accordance with the specific recommendations of the claimant groups in the Work Area Clearance Report ■ For areas along these roads and tracks where ground disturbance is required beyond the present road/track limits, undertake archaeological investigations and implement a field monitoring program involving representatives of the claimant groups, where warranted, and in accordance with the EMMP ■ Develop specific cultural heritage management plans for any archaeological sites requiring protection and management during the construction and operations phases
Infrastructure and access within Site 52a	■ If deemed necessary by the claimant groups, fence the known knapping floor complexes to ensure they are not inadvertently damaged during construction and subsequent phases (Site 52a has an extensive background scatter of stone artefacts and knapping floors were located in the course of the fauna and geomorphology surveys) ■ If ground-disturbing works are proposed outside the central area (e.g. buildings, new access tracks or fences) archaeologically survey the areas to be impacted
Infrastructure and access within Sites 40a and 45a	■ Sites 40a and 45a have extremely low background scatters of artefacts and there are no monitoring requirements
Radiation	
Initial construction phase	■ At the construction stage no radioactive waste would be present at the site and therefore there would be no radiological concerns ■ Conduct a background radiation survey to establish the pre-construction conditions

Issue	Management strategy
Subsequent trench construction	■ Additional trenches may be constructed in future years: clearly identify the boundaries of the existing trench(es) by appropriate signage and the use of unambiguous marker material at the boundaries of the active wastes disposal areas ■ Specify the environmental management plan how new trench excavations would be planned and constructed to mitigate the risk of intrusion into existing trench(es)

TABLE 13.2 Environmental monitoring requirements during construction

Issue	Monitoring requirement
Physical environment	
Surface water runoff, soil erosion and siltation of watercourses	■ Regularly inspect drainage lines for evidence of sediment transport ■ Inspect bunded areas regularly to confirm integrity of bunds ■ Inspect and maintain erosion control measures ■ Clean up areas of accidental spillage of fuels and dispose of appropriately
Dust	■ Visually monitor to determine areas of excessive dust generation and activities creating dust to ensure that dust does not discharge from the site
Noise	■ Measure noise levels during construction to ensure compliance with SA EPA Industrial Noise Policy and occupational health and safety (OHS) requirements
Potential for release of pollutants to soil and surface water	■ Carry out ad hoc inspections following rain events ■ Carry out ad hoc inspections following any fuel/oil spills and after cleanup activities ■ Opportunistically sample flowing surface water upstream and downstream of the site and analyse salinity, turbidity/total suspended solids and selected radionuclides to build up background data set
Potential for release of pollutants to groundwater	■ Unless contamination is introduced directly into existing monitoring wells, no specific groundwater monitoring is required during construction
Vegetation and flora	
Potential for introduction and dispersal of weeds	■ Survey disturbed areas to identify pest plants before and after construction
Damage/removal of native vegetation	■ Establish photopoint monitoring sites and baseline plans of existing conditions before construction ■ Undertake quantitative surveys to establish biodiversity indicators (including non-vascular plants) for future monitoring
Threatened species	■ Maintain a watching brief for presence of rare species within the site ■ Monitor delineated populations (or individuals) for disturbance ■ Monitor implemented conservation measures for level of success
Accelerated soil erosion	■ Undertake pre- and post-construction surveys to identify areas of potential erosion ■ Monitor the effectiveness of water management techniques
Off-road driving	■ Monitor vehicle movement in and around the site and identify areas of impact
Fauna	
Direct loss of individuals	■ Monitor the presence of fauna in and around construction activities ■ Where trenches are constructed, conduct daily checks for trapped animals; capture and release trapped animals nearby
Loss of habitat	■ Monitor as per vegetation and flora above

Issue	Monitoring requirement
Threatened species	■ Monitor areas defined as no-go areas for impacts on threatened species
Pest species	■ Monitor the site for vertebrate and invertebrate pests
Socio-economic	
Demonstrations and protests	■ Maintain a record of protest and demonstration events and security breaches
Radiation	
Initial construction phase	■ Address both the surface and subsurface environments in the baseline monitoring include the following environmental media in the program: ▸ air ▸ surface and groundwater ▸ soil ▸ flora ▸ fauna ■ In the baseline monitoring also identify the local ecosystems and potential pathways for radionuclide transport through the environment and uptake by people
Subsequent trench construction	■ Maintain the signage indicating the trench position(s) and buffer zones ■ Maintain a record of the precise location(s) of trenches and the disposed wastes

13.2.2 Management and Monitoring During Operation

This section provides a summary of management (Table 13.3) and monitoring (Table 13.4) requirements during the operational period of the repository, expected to be approximately 50 years, after which there would be a review of operations.

TABLE 13.3 Environmental management requirements during operation

Issue	Management strategy
Physical environment	
Surface water runoff and erosion	■ Apply water used for dust suppression at a rate that would not generate significant runoff from the application area ■ Maintain and upgrade erosion and sediment control structures if necessary to ensure sediment transfer is minimised ■ Locate soil stockpiles in designated areas away from drainage lines and ensure appropriate sediment control structures ■ Carry out wash down of site operation equipment on a hardstand within a bunded area and away from drainage lines ■ Refuel site operation equipment on hardstand away from drainage lines and within a bunded area ■ Prepare a spill response plan for the operation period ■ Maintain surface water management ponds and, if necessary, upgrade for expected flow conditions ■ Pump water that collects in trench to the storage pond for evaporation ■ Divert and separate clean water from water that has collected in the trench ■ Progressively rehabilitate and revegetate repository trenches and other disturbed areas ■ Minimise the amount of site disturbance beyond the limit of operational works ■ Maintain road surface without potholes or ‘bulldust’ patches

Issue	Management strategy
	■ Suspend transport activities following significant rain if additional soil damage is being incurred ■ Control non-contaminated drainage by diverting to protect exposed areas as required ■ Maintain silt traps to remove sediment from clean site runoff
Dust generation	■ Restrict vehicle speeds to 30 km/h ■ Restrict site access to dedicated roads ■ Apply water or other suitable medium to site roads and soil stockpiles to reduce the potential for dust generation ■ Apply at a rate that minimises the potential for surface water runoff ■ Progressively rehabilitate and revegetate repository trenches and other disturbed areas
Noise	■ Ensure compliance with SA EPA Industrial Noise Policy ■ Fit operation plant and equipment with appropriate noise control devices where practical ■ Maintain plant and equipment regularly
Potential for release of pollutants to soil	■ Place fuel tanks/drums in bunded areas ■ Ensure cleanup procedures and equipment are in place and implement them in the event of any spills
Potential for release of pollutants to surface water	■ Do not allow surface water to accumulate in the vicinity of the buried wastes or entry of surface waters into trenches ■ Direct drains from operational areas where radioactivity is handled to an evaporation pond within the repository compound ■ Place fuel tanks/drums in bunded areas ■ Install silt traps to remove sediment from clean site runoff before it leaves the site
Potential for release of pollutants to groundwater	■ Install facilities to collect rainwater that accumulates in open trenches and transfer it to evaporation ponds ■ Install drainage layer with sampling well in trenches to collect free water seepage should it occur
Vegetation and flora	
Weed introduction and dispersal	■ Keep vehicle hygiene to a high standard i.e. allow only clean vehicles on site and provide facilities for washdown ■ Remove newly established weed populations
Movement of radionuclides	■ Establish baseline monitoring in flora
Wastewater and sewage management	■ Control wastewater in a closed environment and dispose of it appropriately to discourage weed establishment and vermin
Fire management	■ Maintain a cleared track around both fences to provide for fire protection
Fauna	
Pest species	■ Undertake control of pest species, particularly red fox, feral cat and European rabbit ■ Maintain a clean site to prevent attracting pest species
Disturbance associated with human activities	■ Limit activities to the operational area
Movement of radionuclide	■ Establish a suite of monitoring species
Wastewater and sewage management	■ Control wastewater in a closed environment and dispose of it appropriately to discourage weed establishment and vermin
Non-radioactive waste management	■ Contain all waste and dispose of it off site ■ Separate recyclable waste and transport it to a recycling depot or other appropriate establishment
Socio-economic	
Protests and demonstrations	■ Maintain ongoing management of protests and demonstrations or security breaches
Human intrusion	■ Manage risk of human intrusion by using security fences and surveillance

Issue	Management strategy
Impacts of tourists on surrounding areas	▪ Manage tourist access to sensitive areas by using barriers/bollards and gates
Cultural heritage	
Consultation with claimant groups	▪ Develop the cultural heritage component of the EMMP in consultation with the claimant groups
Access to and within the repository sites	▪ Except for flora and fauna monitoring, strictly confine vehicle access to designated roads and tracks ▪ Implement the requirements of any specific cultural heritage management plans for archaeological sites adjacent to the road that might be affected by road maintenance works
Radiation	
Waste acceptance at the site	▪ The performance of the repository is reliant on the establishment of, and compliance with, the waste acceptance criteria (WAC) for the site: Establish a validation program would be established to confirm compliance with the WAC
Routine operations	▪ Establish operating procedures at the repository to ensure that no releases of radioactive material to the environment occur; establish a monitoring program to confirm this and to ensure that radiation exposures in the working environment are being properly controlled ▪ Ensure all radiation exposure is controlled and monitored and conforms to the ALARA principle as established by the International Commission on Radiological Protection; the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) regulates the operations and monitoring program; a radiation protection officer is present during any campaigns a the repository; all staff have appropriate radiological protection training and are equipped with, and trained to use, personal protective equipment; and an environmental personal radiation-monitoring program is developed in consultation with ARPANSA, and implemented
Unexpected events	▪ Establish a detailed emergency management plan for the site and submit it to all relevant regulatory authorities for approval; include the following aspects in the plan: ‣ receipt of faulty package (externally contaminated by radioactivity) ‣ dropping of faulty package (resulting in release of radioactive contents) ‣ explosion/fire in waste package ‣ stack collapse in trench

TABLE 13.4 Environmental monitoring requirements during operation

Issue	Monitoring requirement
Physical environment	
Surface water runoff and erosion	▪ Regularly inspect drainage lines for evidence of sediment transport quarterly during periods without rain and ad hoc inspections following any rain events) ▪ Inspect bunded areas regularly to confirm integrity of bunds ▪ Inspect and maintain erosion control measures ▪ Clean up areas of accidental spillage of fuels and dispose appropriately
Dust	▪ Visually monitor to determine areas of excessive dust generation and activities creating dust to ensure that dust does not discharge from the site
Noise	▪ Measure noise levels during operation to ensure compliance with SA EPA Industrial Noise Policy and OHS requirements

Issue	Monitoring requirement
Potential for release of pollutants to soil	▪ Carry out ad hoc inspections following rain events ▪ Carry out ad hoc inspections following any fuel/oil spills and after cleanup activities ▪ Carry out ad hoc inspections following any received waste spills, with waste and affected soil removed/repackaged for disposal in trench
Potential for release of pollutants to surface water	▪ Opportunistically sample flowing surface water up stream and downstream of site and analyse of salinity, turbidity/total suspended solids and selected radionuclides to build up background data set ▪ Carry out ad hoc inspections following rain events ▪ Carry out ad hoc inspections following any fuel/oil/waste spills and after cleanup activities
Potential for release of pollutants to groundwater	▪ Carry out quarterly monitoring of water levels in all available drainage layer and groundwater monitoring wells ▪ Carry out ad hoc monitoring of sampling well in basal drainage layer of closed trenches after significant rainfall ▪ Carry out annual groundwater sampling for pH, electrical conductivity/salinity, major ions and selected radionuclides
Vegetation and flora	
Introduction and dispersal of weeds	▪ Undertake annual (spring) and opportunistic (e.g. following summer rains) monitoring
Native vegetation and threatened species	▪ Undertake photopoint monitoring and quantitative surveys every 4–5 years ▪ Undertake biodiversity indicator monitoring (including non-vascular plants) based upon the quantitative survey data
Fire management	▪ Monitor fire fuel loads annually
Movement of radionuclides	▪ Monitor radionuclide in target species five yearly
Fauna	
Fauna and threatened species	▪ Monitor quarterly the presence of burrowing animals in repository trenches and other animals species in and around infrastructure ▪ Conduct a complete biennial survey of invertebrate and vertebrates based upon the current permanent trapping sites ▪ Undertake biodiversity indicator monitoring based upon fauna surveying data
Habitat creation from built structures	▪ Monitor incidence of native and pest species, especially vermin and invertebrates in the latter category
Pest species	▪ Monitor the site five yearly for vertebrate and invertebrate pests, stock and kangaroos within fenced area
Movement of radionuclides	▪ Monitor radionuclides annually in target species, including ants ▪ Establish the existing incidence of mutations in *Neobatrachus centralis* populations in the first year (weather dependent)
Socio-economic	
Impacts of tourists on surrounding areas	▪ For Sites 40a and 45a monitor impacts of off-road tourist activity accessed via new road infrastructure
Radiation	
waste acceptance	▪ Include on-site assay by external gamma monitoring of packages in the validation program ▪ It may be possible to assay packages before transporting it to the disposal site: adopt additional safeguards and procedures to prevent any tampering with the contents; in cases where the source of the waste is well documented (e.g. where it consists of spent sources) establish a document quality assurance trail sufficient to establish the contents of the package (there would be records from the receipt of the source, its use and its storage, before disposal)

Issue	Monitoring requirement
	■ Keep detailed records of the waste accepted at the repository in accordance with regulatory requirements; ensure the records included the location of the waste within the trench, the date of emplacement and the contents of the waste package
Routine operations	■ Establish a monitoring program to confirm that no releases of radioactive material to the environment occur and that radiation exposures in the working environment are being properly controlled including routine measurements of: ▸ surface contamination (via instrument surveys and surface swabs) ▸ airborne contamination (via area monitoring with high volume air samplers and personal air samplers) ▸ external radiation dose rates (via instrument surveys) ■ Demonstrate, through the monitoring program, that environmental impacts are compliant with objectives and regulatory limits ■ Monitor the repository during both the operational and surveillance phases to ensure that it is performing satisfactorily and meeting all relevant requirements ■ Ensure the monitoring system includes both sampling of the various media as described in the baseline survey and their analysis for key contaminants, and covers air, surface and groundwater, biota and soil; match the detailed design of the monitoring systems to whether there is a requirement for certain components of the engineered system to be monitored, for example: ▸ aqueous/colloidal discharges through the repository base ▸ gas/vapour discharge through the cap/cover ■ Take the requirement for retrievability of the waste into account in designing the monitoring system ■ Optimise the logistics of the sample collection and analyses; consider that analyses could take place on-site or off-site, and that an on-site facility would require appropriate infrastructure availability

13.2.3 Management and Monitoring During Surveillance

This section provides a summary of management (Table 13.5) and monitoring (Table 13.6) requirements during surveillance in between waste disposal campaigns during the operational period.

TABLE 13.5 Environmental management requirements during surveillance

Issue	Management strategy
Physical environment	
Surface water runoff and erosion	■ Prepare a surveillance and rehabilitation management plan to the satisfaction of SA EPA ■ Rehabilitate and revegetate access tracks and other disturbed areas ■ Remove buildings and infrastructure as appropriate ■ Ensure integrity of final cap through revegetation and establishment of appropriate grades ■ Repair and revegetate depressions or erosion channels detected during monitoring to the design standard

Issue	Management strategy
Groundwater	▪ Ensure integrity of cap and slope grades are maintained ▪ Repair and revegetate depressions and erosion channels to design standard
Potential for release of pollutants to surface water	▪ Maintain natural drainage channels or levees to avoid flooding of site ▪ Maintain cap
Potential for release of pollutants to groundwater	▪ Maintain drainage preventing ponding of surface water on or near trenches; maintain cap
Vegetation and flora	
Weed introduction and dispersal	▪ Maintain all programs as per operation phase
Fire management	▪ Maintain all programs as per operation phase
Fauna	
Disturbance associated with human activities	▪ Maintain all programs as per operation phase
Pest species	▪ Maintain all programs as per operation phase
Socio-economic	
	▪ As per operations phase
Cultural heritage	
Consultation with claimant groups	▪ Develop the cultural heritage component of the EMMP in consultation with the claimant groups
Access to and within the repository sites	▪ Except for flora and fauna monitoring, confine vehicle access to designated roads and tracks
Radiation	
Routine surveillance	▪ Continue the established environmental monitoring plan

TABLE 13.6 Environmental monitoring requirements during surveillance

Issue	Monitoring requirement
Physical environment	
Surface water and erosion	▪ Prepare a surveillance and monitoring plan to the satisfaction of SA EPA ▪ Survey annually or after significant storm events to assess the integrity of the cap
Potential for soil erosion / siltation of water courses	▪ Conduct annual inspection reducing to five yearly after five years ▪ Conduct ad hoc inspections following major rain events (>500 mm/month)
Potential for release of pollutants to soil	▪ Conduct annual inspections reducing to five yearly after five years
Potential for release of pollutants to surface water	▪ Conduct annual inspection reducing to five yearly after five years ▪ Conduct ad hoc inspections following major rain events (>300 mm/month)
Potential for release of pollutants to ground water	▪ Monitor water levels annually in all available drainage layer and groundwater monitoring wells reducing to five yearly after five years ▪ Conduct ad hoc monitoring of sampling well in basal drainage layer of closed trenches after major rainfall (>500 mm/month) ▪ Sample groundwater annually for pH, electrical conductivity/salinity, major ions and selected radionuclides, reducing to five yearly after five years
Vegetation and flora	
Weed introduction and dispersal	▪ Maintain all programs as per operation phase
Native vegetation and threatened species	▪ Maintain all programs as per operation phase
Fire management	▪ Maintain all programs as per operation phase

Issue	Monitoring requirement
Movement of radionuclides	■ Maintain all programs as per operation phase
Fauna	
Fauna and threatened species	■ Maintain all programs as per operation phase
Pest species	■ Maintain all programs as per operation phase
Movement of radionuclides	■ Maintain all programs as per operation phase
Socio-economic	
	■ As per operations phase
Radiation	
Routine surveillance	■ Maintain all programs as per operation phase

13.2.4 Management and Monitoring During Decommissioning

This section provides a summary of management (Table 13.7) and monitoring (Table 13.8) requirements during decommissioning of the repository.

TABLE 13.7 Environmental management requirements during decommissioning

Issue	Management strategy
Physical environment	
Surface water runoff and erosion	■ Prepare a surveillance and rehabilitation management plan to the satisfaction of SA EPA
	■ Rehabilitate and revegetate access tracks and other disturbed areas
	■ Ensure integrity of final cap by revegetating and establishing appropriate grades
	■ Repair and revegetate depressions or erosion channels detected during monitoring to the design standard
Groundwater	■ Ensure integrity of cap and slope grades are maintained
	■ Repair and revegetate depressions and erosion channels to the design standard
Potential for release of pollutants to surface water	■ Maintain natural drainage channels or levees to avoid flooding of site
	■ Maintain cap
Potential for release of pollutants to groundwater	■ Maintain drainage preventing ponding of surface water on or near trenches; maintain cap
Vegetation and flora	
Weed introduction and dispersal	■ Maintain all programs as per operation phase
Fire management	■ Maintain all programs as per operation phase
Fauna	
Disturbance associated with human activities	■ Maintain all programs as per operation phase
Pest species	■ Maintain all programs as per operation phase
Non-radioactive waste management	■ Maintain all programs as per operation phase
Cultural heritage	
Consultation with claimant groups	■ Develop the cultural heritage component of the EMMP in consultation with the claimant groups
Access to and within the repository sites	■ Confine vehicle access to designated roads and tracks

Issue	Management strategy
Radiation	
Routine operations	▪ Before decommissioning begins, radiologically survey the repository site and facilities and halt decommissioning activities unless the radiation levels throughout the site met the requirements of the regulatory authority ▪ Conduct any remedial activities required to clean up the site under the radiation protection system established for protection of the workforce for the operation of the site under the licence conditions ▪ Dispose of any radioactive waste generated during the decontamination phase within the facility trench and in accordance with the criteria for waste acceptance and disposal

TABLE 13.8 Environmental monitoring requirements during decommissioning

Issue	Monitoring requirement
Physical environment	
Soil	▪ Maintain all programs as per operation phase
Surface water	▪ Maintain all programs as per operation phase
Groundwater	▪ Maintain all programs as per operation phase
Vegetation and flora	
Introduction and dispersal of weeds	▪ Maintain all programs as per operation phase
Native vegetation and threatened species	▪ Maintain all programs as per operation phase
Fire management	▪ Maintain all programs as per operation phase
Movement of radionuclides	▪ Maintain all programs as per operation phase
Fauna	
Fauna and threatened species	▪ Maintain all programs as per operation phase
Pest species	▪ Maintain all programs as per operation phase
Movement of radionuclides	▪ Maintain all programs as per operation phase
Radiation	
Routine operations	▪ Maintain all programs as per operation phase

13.2.5 Management and Monitoring During Institutional Control

This section provides a summary of the management (Table 13.9) and monitoring (Table 13.10) requirements during the 200-year post-closure institutional control period. During this period, in addition to the preservation of controls to limit access and restrict land use, a program of monitoring and site maintenance would be implemented.

Such active measures would be subject to regular review to ascertain their effectiveness and to take into account the long-term behavior of the barriers for the isolation of the waste. The management and monitoring requirements for this period would be similar to that for the surveillance during the period in between waste disposal regimes but with reduced time schedules after five years. Monitoring programs would be subject to review by the regulator at the time.

TABLE 13.9 Environmental management requirements during institutional control

Issue	Management strategy
Physical environment	
Surface water runoff and erosion	▪ Prepare a surveillance and rehabilitation management plan to the satisfaction of SA EPA ▪ Rehabilitate and revegetate access tracks and other disturbed areas ▪ Ensure integrity of final cap by revegetating and establishing appropriate grades ▪ Repair and revegetate depressions or erosion channels detected during monitoring to the design standard
Groundwater	▪ Ensure integrity of cap and slope grades are maintained ▪ Repair and revegetate depressions and erosion channels to the design standard
Potential for release of pollutants to surface water	▪ Maintain natural drainage channels or levees to avoid flooding of site ▪ Maintain cap
Potential for release of pollutants to groundwater	▪ Maintain drainage preventing ponding of surface water on or near trenches; maintain cap
Vegetation and flora	
Weed introduction and dispersal	▪ Maintain all programs as per surveillance phase
Fire management	▪ Maintain all programs as per surveillance phase
Fauna	
Disturbance associated with human activities	▪ Maintain all programs as per surveillance phase
Pest species	▪ Maintain all programs as per surveillance phase
Socio-economic	
	▪ As per surveillance phase
Cultural heritage	
Consultation with claimant groups	▪ Maintain the cultural heritage component of the EMMP in consultation with the claimant groups
Access to and within the repository sites	▪ Except for flora and fauna monitoring, confine vehicle access to designated roads and tracks
Radiation	
Routine surveillance	▪ Implement a long-term environmental monitoring plan subject to periodic review

TABLE 13.10 Environmental monitoring requirements during institutional control

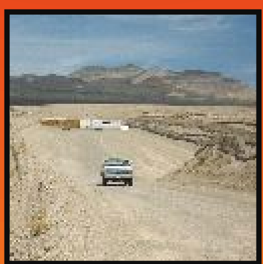
Issue	Monitoring requirement
Physical environment	
Surface water and erosion	▪ Prepare a surveillance and monitoring plan to the satisfaction of SA EPA ▪ Conduct surveillance annually or after significant storm events to assess the integrity of the cap
Potential for soil erosion / siltation of water courses	▪ Inspect annually reducing to five yearly after five years ▪ Carry out ad hoc inspections following major rain events (>500 mm/month)
Potential for release of pollutants to soil	▪ Inspect annually reducing to five yearly after five years
Potential for release of pollutants to surface water	▪ Inspect annually reducing to five yearly after five years ▪ Carry out ad hoc inspections following major rain events (>300 mm/month)

Issue	Monitoring requirement
Potential for release of pollutants to groundwater	▪ Monitor water levels annually in all available drainage layers and groundwater monitoring wells reducing to five yearly after five years ▪ Carry out ad hoc monitoring of sampling well in basal drainage layer of closed trenches after major rainfall (>500 mm/month) ▪ Sample groundwater annually for pH, electrical conductivity/salinity, major ions and selected radionuclides, reducing to five yearly after five years
Vegetation and flora	
Weed introduction and dispersal	▪ Inspect annually reducing to five yearly after five years
Native vegetation and threatened species	▪ Monitor annually reducing to five yearly after five years
Fire management	▪ Inspect annually reducing to five yearly after five years
Movement of radionuclides	▪ Monitor five yearly
Fauna	
Fauna and threatened species	▪ Inspect annually reducing to five yearly after five years
Pest species	▪ Inspect annually reducing to five yearly after five years
Movement of radionuclides	▪ Monitor five yearly
Socio-economic	
	▪ As per surveillance phase
Radiation	
Routine surveillance	▪ Inspect annually reducing to five yearly after five years

PART E

Conclusions

Chapter 14
CONCLUSIONS



Chapter 14 Conclusions

14.1 Background

14.1.1 The Waste Issue

Australia's use of radioactive materials for medical, industrial and scientific purposes results in small amounts of radioactive waste, including low level and short-lived intermediate level radioactive waste such as lightly contaminated soil, plastic, paper, laboratory equipment, smoke detectors, exit signs and gauges.

At present, this waste is temporarily stored at more than 100 urban and rural locations around Australia, much of it in buildings that were neither designed nor located for the long-term storage of radioactive material and that are nearing or have reached capacity. Storage locations include hospitals, research institutions, and industry and government stores.

Storing such waste in many locations in non-purpose built facilities potentially poses greater risk to the environment and people than disposing of the material in a national, purpose-built repository where the material can be safely managed and monitored.

This practice is clearly unsatisfactory from a public health and safety perspective as well as not being in the interests of public security from possible theft and misuse by terrorists.

Australia has about 3700 m^3 of low level and short-lived intermediate level waste in these storage locations. Over half this total is 2010 m^3 of slightly contaminated soil stored near Woomera, which arose from Commonwealth Scientific, Industrial and Research Organisation (CSIRO) research into the processing of radioactive ores during the 1950s and 1960s. Another major component is 1320 m^3 of Australian Nuclear Science and Technology Organisation (ANSTO) operational waste, including clothing, paper and glassware, stored at Lucas Heights near Sydney.

Defence has 210 m^3, consisting of contaminated soils from land remediation, sealed sources, gauges, electron tubes, equipment (watches and compass parts) and some aircraft ballast, which is held at a number of locations around the country. The remaining waste, approximately 160 m^3 (allowing for conditioning), comprises spent sealed sources and miscellaneous laboratory waste from hospitals, universities, industrial activities and other 'small users', and is distributed throughout the country.

Australia currently produces about 40 m^3 (conditioned volume) of this type of waste annually and there would be an ongoing need to dispose of these wastes safely.

Compared with the amount of similar wastes disposed of in countries with nuclear power programs, the accumulated and expected future amounts of this waste arising 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 (ANDRA website 2001). Near-surface disposal has been practised since the 1940s and there are more than 100 near-surface repositories for low level and short-lived intermediate level radioactive waste either operating or being established in over 30 countries around the world (Table 2.2).

Conclusion

A national repository is required to dispose of Australia's accumulated and expected future low level and short-lived intermediate level radioactive waste. Without a national repository, radioactive waste would continue to be stored in over 100 sites around Australia, largely in facilities that were not purpose built, and continue to pose public health, safety and security risks. Alternatively, each state and territory would need to establish its own repository for a very small quantity of waste, which would be an inefficient and unnecessary use of resources.

14.1.2 The Proposal

It is proposed to construct a national near-surface repository at either the preferred site on the Woomera Prohibited Area (WPA), or on one of the two nearby alternative sites, to dispose of the existing low level and short-lived intermediate level radioactive waste and future waste. The proponent is the Commonwealth Department of Education, Science and Training (DEST).

The facility is not intended for the disposal of naturally occurring radioactive waste from mining or mineral processing. A national store for long-lived intermediate level waste would not be co-located on the same site as the national repository.

All three sites are located in central–north South Australia, approximately 400 km north of Adelaide, between the townships of Woomera and Roxby Downs (Figure 1.1). The sites are located in stony desert country with sparse saltbush and were identified through an extensive site selection process (Section 1.5).

The objectives of the national repository are to:

- strengthen Australia's radioactive waste management arrangements by promoting the safe and environmentally sound management of low level and short-lived intermediate level radioactive waste
- provide safe containment of these wastes until the radioactivity has decayed to background levels.

14.2 The Investigation Process

An extensive site selection process began in 1992 with Phase 1, the development of the methodology for siting a national repository.

In Phase 2, which began in 1994, this methodology was applied to identify eight broad regions of Australia likely to contain suitable sites. The Great Artesian Basin and the Murray–Darling Basin were excluded from the search areas.

Phase 3 of the study began in 1998, with the selection of central–north South Australia, as the preferred area for more detailed investigation. The region, which covers approximately 67,000 km^2, contained the largest area potentially suitable for siting the repository, based on the available data.

The selection criteria were then applied to the central–north region on a local scale. Desktop studies and community consultation identified 1.5 x 1.5 km sites within the region suitable for further investigation. All were located on raised, stony desert plateaux. In a three-stage drilling program 11 sites were drilled in Stage 1 in 1999, five of these sites were more extensively drilled in Stage 2 in 2000; and three of these sites further investigated in Stage 3.

In January 2001 the former Minister for Industry, Science and Resources announced the selection of the preferred site at Evetts Field West (Site 52a) and two alternative sites (Sites 45a and 40a) in the central–north region of SA (Figure 1.1) — based on advice from technical experts in the Technical Assessment Group and the National Repository Advisory Committee — for further investigation in an environmental assessment process.

Public consultation throughout the site selection process included the national release of public discussion papers and the establishment of a toll-free information line and internet site to consult with regional stakeholders. In central–north South Australia information days, a regional information office and a newsletter kept consultation active, and a Regional Consultative Committee (RCC), with members from soil conservation boards, Aboriginal groups, local industry, and local and State government, was formed. Issues raised during consultations were addressed in publications, letters and at meetings. For a summary of consultations see Section 1.5.3 and Appendix G.

Conclusion

The comprehensive investigation and extensive consultation processes have extended over a period of 10 years.

14.3 Regulatory Framework

Australia's radioactive waste is managed in accordance with national regulatory requirements, and where applicable, internationally accepted procedures and practices. The Commonwealth's environmental impact statement (EIS) approval process is also applicable to the repository proposal.

International Organisations and Conventions

Australia is an active member of international organisations that encourage the safe use and management of radioactive materials. The International Atomic Energy Agency (IAEA), of which Australia is a member, has developed a series of Radiation and Waste Safety Standards, which are followed by most countries including Australia. The standards identify the basic principles for the regulatory, safety and technical requirements for radioactive waste repositories.

Australia's Regulatory Framework

Each of the states and territories has its own legislation to regulate the use of radioactive materials. In the case of the Commonwealth, in 1999, the *Australian Radiation Protection and Nuclear Safety Act 1998* (ARPANS Act) established the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which regulates the Commonwealth's use of radioactive materials, and provides advice on the use and management of radioactive substances. Specifically ARPANSA is responsible for:

- promoting uniformity of radiation protection and nuclear safety policy and practices across Australia
- providing advice to government and the community on radiation protection and nuclear safety
- undertaking research and providing services on radiation protection, nuclear safety and medical exposures to radiation
- regulating all Commonwealth entities (including departments, agencies and bodies corporate, including contractors to these organisations) involved in radiation or nuclear activities or dealings.

The ARPANS Act makes reference to 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). The code is intended to encourage uniform practice in Australia for the near-surface disposal of radioactive waste. It is also consistent with current IAEA philosophy and recommendations on the safety requirements for radioactive waste management.

Approvals and Licences

Approval is required under the ARPANS Act for each stage of the repository project including siting, construction, operation and decommissioning of the facility. Detailed plans and arrangements for protection and safety would be assessed in licence applications, including the:

- safety management plan
- radiation protection plan
- radioactive waste management plan
- strategies for the decommissioning, disposal or abandoning of the facilities and/or the site
- security plan
- emergency plan for the controlled facility.

The regulatory branch of ARPANSA would review the monitoring results from the repository regularly to ensure its safety and compliance with licence conditions.

The repository site would be acquired by the Commonwealth using the *Lands Acquisition Act 1989* (Cwlth).

The EIS Approval Process

A principal object of the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is to ensure that matters potentially significantly affecting the environment are fully examined and taken into account in decisions made by the Commonwealth Government. Under the Act, an action will require approval from the Minister of Environment and Heritage if it has, will have, or is likely to have a significant impact on a matter of national environmental significance.

The national repository was determined to require ministerial approval under the EPBC Act, and the proponent (DEST) was requested to prepare an EIS to assist in the decision process. Guidelines prepared by Environment Australia outlined the requirements for the EIS.

Conclusion

The regulatory process in place is in accordance with accepted international practice, and the approval and licencing process is both comprehensive and rigorous.

14.4 The Repository Design

A preliminary design layout and an outline of operational concepts are presented in Chapter 6. Details of this concept plan would be further refined during the detailed design phase of the project, which would start at the completion of the EIS process. A brief overview of key aspects of the design follows.

Design Basis

A multi-barrier approach would be used for the national repository, including physical containment provided by some, or all, of the:

- conditioned waste packages
- waste form
- trench/borehole design including the cover
- host rocks, arid environment, and groundwater and surface water characteristics of the site.

Operational Usage and Institutional Control Periods

The operating life of the repository is expected to be approximately 50 years, after which operations would be reviewed. The low generation rate of radioactive waste in Australia means that once the existing waste has been disposed of, disposal campaigns would be separated by periods of two to five years when no disposal would occur. At the end of each disposal campaign, the disposal structure (trench or borehole) would be closed and securely contained to prevent intrusion and minimise the ingress of rainwater.

The institutional control period (once the facility has ceased operations) would be 200 years. At the end of the institutional control period the radioactivity in the disposed waste would have decayed to low enough levels to allow unrestricted land uses.

Repository Layout

The repository would be on a site measuring 1.5 x 1.5 km, with the waste buried in the central 100 x100 m part of the site in trenches or boreholes.

The repository would be designed to meet the licence requirements of ARPANSA, and the performance criteria and safety requirements of the NHMRC 1992 Code. The facility would contain a number of disposal trenches and boreholes, designed and sized to account for different waste types.

Conclusion

The design of the proposed repository is in accordance with applicable national standards and codes of practice, as well as accepted international practice.

14.5 Transport of Waste

The transport of radioactive substances within Australia routinely takes place for a variety of commercial and industrial applications. Over the past 40 years there have been no accidents where there has been any significant radiological release harmful to the environment or public health. Shipments of such substances are strictly governed by relevant Australian and international regulations and codes which define how waste should be packaged, what warning signs must be placed on vehicles, and what instructions must be provided to carriers for safe operating procedures.

Transport Modes and Routes

It is expected that the waste material would be transported to the repository by road, as this provides a safe, flexible, secure and cost effective mode of transport, considering:

- the location of waste at over 100 sites around Australia
- most sites have only small quantities of waste, thus requiring some load consolidation
- trucks have flexible load capacity to facilitate load consolidation at intermediate storage locations
- the need to maintain continuous chain of custody of material during transport.

Rail offers an inherently lower risk of accidents en route, but its main disadvantages include additional handling, more inefficient transport arrangements for the relatively small volumes of material and, in particular, the security of chain of custody when compared with road transport.

Water-borne transport is generally not relevant to the proposed national repository, apart from the specific case of Tasmania from where a small amount of waste would need to be shipped to the mainland. Airborne transport would only be considered where it is a practical alternative, for example, possibly for the small quantities of waste from Tasmania.

Possible road routes to the national repository have been identified. Route alternatives were defined between each state or territory and the repository in a hierarchical approach, which sought to maximise the use of national highways, supplemented with state highways. Secondary roads were only selected as connections between highways. This approach was designed to reduce the impacts of truck movements on communities along each route.

Quantities to be Transported

The total national volume of accumulated waste to be shipped to the repository is low, with total conditioned waste requiring transport (i.e. not already in Woomera) estimated to total 1690 m^3 (Table 7.1). Assuming that this material is packed in 205 L drums, which would then be double stacked into standard 6 m shipping containers for transport, the total number of shipments needed to clear the accumulated waste backlog is estimated to be 171 truckloads — a very small number of truck movements over the road network.

Shipments of future waste are also expected to be very low, equivalent to about five 6 m shipping container loads per year nationally. In practice, transport would be expected to be only for disposal campaigns every 2–5 years after the initial campaign.

Consultation

Communities at selected locations (Port Augusta (SA), Mildura (Vic), Broken Hill and Dubbo (NSW)) along the proposed route network were consulted through a series of group discussions to seek their views on the transport issues.

The responses to the issue of transport of radioactive waste ranged from people being uninterested, through those who saw that the waste needed to be transported to a suitable location, to those who expressed reluctant acceptance, as long as the material was transported safely. Others were more cautious in their response. The Port Augusta group accepted that radioactive materials, in the form of uranium oxide ore from Olympic Dam to Adelaide, are already transported through the city safely on a regular basis.

Safety

A review of international transport experience confirmed a low likelihood of incidental exposure to radioactive materials as a result of shipments by road. The stringent international controls and procedures placed on shipments are largely responsible for the excellent safety record over the past 40 years.

The potential for accidents involving trucks carrying waste to the repository was quantified, considering the individual transport routes, the numbers of truck movements, and historical accident rates and traffic conditions prevailing on the routes (see Section 7.6.3). The rate of less than one expected accident when transporting the total accumulated waste inventory indicates a low accident likelihood.

In the unlikely event of an accident, the solid waste form and multiple packaging comprising an inner shielded container (for sealed sources), the 205 L drum, and finally the standard 6 m container would help ensure that radioactive material was not widely distributed around the accident site.

Emergency Services

All states and territories have in place emergency response plans in case of accidents or incidents involving radioactive (or other hazardous) materials. In most emergency cases, the police, ambulance, fire services and state emergency services are the first responders. In addition, the Commonwealth can provide assistance if required.

The state and territory teams have the required level of training, protective clothing and equipment needed to identify the nature of the hazard, and to retrieve material. Resources located in country centres around each state enable rapid responses to incidents at relatively short notice.

Conclusion

The transport of waste to the proposed national repository would be in accordance with relevant Australian and international regulations and codes. The proposed mode of transport, principally by truck, is the preferred means. The risk of an accident during transport is low. The solid waste would be packaged in accordance with the relevant codes and regulations. In the unlikely event of an accident, the solid waste form, and multiple packaging for sealed sources would help to ensure that radioactive material was not widely distributed around the accident site.

14.6 Physical Environment

The three proposed sites for the national repository are located in the Stuart Shelf geological province, to the west of Lake Torrens in South Australia. This province contains incomplete sequences of flat-lying marine sediments of the Adelaide Geosyncline, overlying the northeastern part of the Archean Gawler Craton. The northern extension of the shelf is overlain by sediments of the Jurassic/Cretaceous Eromanga Basin, and a thin veneer of younger sediments or in situ deposits (such as silcrete or calcrete) commonly encountered at the landscape surface (Figure 8.2).

The Eromanga Basin is the largest and most central of the three depressions that together make up the Great Artesian Basin (Figure 8.1).

Eromanga Basin sediments are absent from Sites 40a and 45a and, where present at Site 52a, are interpreted to be near the southwestern extreme of the Eromanga Basin. Hydrogeologically the Eromanga Basin sediments, where present in the study area, are hydraulically part of the Stuart Shelf aquifer system and there is no known or suspected hydraulic connection of this part of the Eromanga Basin with the Great Artesian Basin aquifers.

For detailed information on the geology, geomorphology, hydrology, hydrogeology and climatology of the sites see Chapter 8. The preferred and two alternative sites have been extensively studied through drilling investigations in the repository site selection process (see Section 1.5) and further investigations as part of the EIS process.

These investigations included a series of hydrological model simulations to assess the potential infiltration of rainwater through various capping and base lining system scenarios, and modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area. The capping and base lining systems included low permeability clay barrier layer in the cap, low permeability liner at the base of the repository, homogeneous earthfill cap and a composite barrier layer in the cap (incorporating a geomembrane and low permeability compacted clay).

The assessment indicated rainwater infiltration to be minimal for all cases examined, with a composite lining system located at the base of the cover layer allowing the least infiltration. Alternative design proposals would be investigated further in the design phase as would the benefits or otherwise of installing a coarse cobble layer (rock material from the excavations) as an additional deterrent to burrowing animals.

A compacted clay liner installed at the base of the repository would not significantly alter the percolation rate through the repository. Notwithstanding this, it is proposed to compact the base of the repository and grade the finished surface to a sump to collect any free water and direct it to a sampling well.

The modelling of the movement of water through the unsaturated zone of soil and rock between the ground surface and the watertable in the project area has suggested a transit time in the order of 60,000 years in the presence of vegetation and 6000 years in the absence of vegetation (ANSTO–CSIRO 1998, 1999) — very long residence times compared to the half-lives of key radionuclides in typical wastes (e.g. ^{137}Cs, 30 years).

The adsorption and retardation characteristics of soil and rock samples were also investigated. Most radionuclides present in the buried waste would adsorb to a greater or lesser degree on the surfaces of the soil and rock particles, which would further slow their movement relative to the already slow movement of water through the unsaturated zone towards the watertable.

The movement of three selected radionuclides through the unsaturated zone was further modified for Site 52a (see Section 8.10.3 and Appendix C5). Simulations were completed for solute transport from the base of the waste repository during rain and storm periods, for up to 100 years.

The modelling results indicate that the amount of solutes originating from the repository reaching the watertable under the conservative scenario of continual low-level seepage for 100 years would be so low as to be, to all practical extent, undetectable. Even if 100% of rainfall and stormwater were to penetrate the repository the modelling indicates that the amount of solutes reaching the watertable would not be detectable. The natural arid climatic regime of the study region, together with the construction of the repository, would provide considerable additional protection for the watertable.

These findings correlate with Australian and USA research which concluded that in desert (arid) areas the dominant direction of water movement in soil is upwards due to the low level of rainfall and high evaporative rates. So while individual large rainfall events can generate a downward moving wetting front, the following dry conditions result in the vast majority of this moisture being drawn back to the surface through evaporation and capillary forces.

Conclusion

There is no known or suspected hydraulic connection of the Eromanga Basin sediments at Site 52a with the Great Artesian Basin aquifers. All three sites are hydraulically part of the Stuart Shelf aquifer system. Sites 40a and 45a are located outside of the Eromanga Basin sediments. The Bulldog Shale at Site 52a provides a good base for the proposed repository trench.

The hydrological model simulations indicated that a composite lining system located at the base of the cover layer would allow the lease rainwater infiltration. Alternative design proposals would be investigated further in the design phase.

Although a compacted clay liner at the base of the repository would not significantly alter the percolation rate through the repository, the base would be compacted and graded to a sump to collect any free water and direct it to a sampling well.

The modelling of the movement of water suggested a transit time from ground surface to watertable in the order of 60,000 years in the presence of vegetation and 6000 years in the absence of vegetation — very much longer residence times than the half-lives of key radionuclides in typical wastes.

Additional modelling of the movement of three selected radionuclides from all three sites over 100 years would yield undetectable levels at the watertable even under conditions of continual low-level seepage. The natural and climatic regime of the study region, together with the construction of the repository, would provide considerable additional protection for the watertable.

14.7 Biological Environment

The preferred and two alternative potential repository sites lie within the Arcoona Tableland, which has been recognised as a distinct land system, the Arcoona land system (see Chapter 9). There have been no previous biological surveys of any of the three potential repository sites or adjacent areas.

Flora

The Arcoona Tableland is primarily a treeless plain dominated by low chenopod shrubland. The region has had a long history of grazing by native, domestic and feral herbivores, as well as being subjected to the operations and infrastructure of sheep and cattle stations and the construction and operation of Woomera Rocket Range.

The field survey for this project, in August 2001, coincided with above average field conditions. Classification of the data collected shows that the vegetation communities of the three sites are relatively homogenous. At lower levels of dissimilarity, minor differences were present (based on slightly different floristic groups). All vegetation communities are in relatively good condition.

There are no vegetation communities with recognised conservation status at any of the three sites or on the Arcoona Tableland generally. Seven plant species from the Arcoona Tableland have recognised State or national conservation status but none were recorded during the field survey.

Eight percent of the species recorded during the field survey were identified as being introduced. This figure is slightly lower than the overall figure recorded on the Arcoona Tableland, which could be a result of the relatively undisturbed condition of the study sites. Control of introduced species and prevention of the introduction of new species would be a key land management issue at the selected site.

Qualitative vegetation assessments along access roads to all three potential sites show that access to Site 52a would cause the least environmental impact. However, impacts to the biological environment of Sites 40a and 45a would be minimal if access roads were upgraded within, and using existing materials from, the existing disturbed corridor.

Fauna

The results of field surveys in August and October 2001 reflected the exceptional seasonal conditions following well above average rainfall during late May and early June.

Canegrass swamp, gilgai and low open chenopod shrubland, the three major habitats that comprise the Arcoona Tableland, were assessed and a diversity of vertebrate and invertebrate species typical of the Arcoona Tableland was present at all three sites. All sites exhibited slight differences in species diversity and abundance.

Site 52a had the greatest faunal diversity (57 species of vertebrates, 8 genera of ants and 17 taxa of spiders) but the lowest mammal diversity, richness and abundance, with two species of small mammals compared to four at the other two sites. Site 45a contained the highest diversity of vertebrates. The assessment recorded 12 reptile species at Site 40a and 13 at each of Sites 45a and 52a. These totals probably underestimate the species diversity and abundance of reptiles in the project area.

The most abundant mammal species captured for all sites was the stripe-face dunnart; this is consistent with other recent findings for the region. In comparison, the fat-tailed dunnart was the least trapped species; however, this species is widespread within the region. Low bat diversity and abundance (4 species) at each site is consistent with previous surveys in the area. Bird diversity was greatest at Sites 45a and 52a.

European settlement and the introduction of stock and pest species such as European rabbit, red fox and feral cat have changed the assemblage of native species in the Australian arid zone. There are eight introduced mammal species and three species of birds recorded in the region. All contribute to the decline of native species. Providing that suitable management actions are undertaken, key threatening processes would not increase as a result of construction and operation of the waste repository

Five threatened animal species were recorded within the project area. Of these, the most significant is the plains rat, which is listed as vulnerable under the EPBC Act. It is present at Sites 40a and 45a. The other four species are vagrant or nomadic bird species. A number of other bird and reptile species are of regional significance and may be of future taxonomic and conservation significance.

The principal impacts of the project on the biological environment would be associated with construction and can be managed or minimised through careful planning and monitoring. Impacts of vegetation clearance on the vegetation communities and habitats would be limited due to the small area to be cleared in relation to the large distribution of the vegetation communities across the Arcoona Tableland. Development of stock, pest animal and kangaroo-proof fencing around the preferred site and elimination of pest species from within the fenced area would probably delineate a very useful ecological exclosure and reference area.

Conclusion

The preferred and two alternative potential repository sites lie within the Arcoona Tableland, which has been recognised as a distinct land system, the Arcoona land system. Site 52a would have the lowest potential biological impact particularly as only minimal road construction works would be required. However Sites 40a and 45a would be acceptable subject to implementation of suitable management procedures.

14.8 Land Use and Activity

The nature of human activity since European settlement, including issues such as land use and activity, demographics and landscape character, was assessed for the three sites and the region. The proposed facility was assessed for visual impact, site suitability and the potential for land use conflict now and in the future.

Historical and current land use activities in the region include:

- mining copper at Mount Gunson, copper–gold–silver–uranium at Olympic Dam and opal fields at Andamooka and Coober Pedy)
- rangeland grazing activities (primarily sheep and cattle)
- remote area tourism and research activity
- high technology Defence research and trials activity, and other uses of the WPA including those related to the aerospace industry, various types of research, the storage of radioactive waste and the detention of asylum seekers
- a number of townships or service centres and their associated living, recreational, tourism and business activities.

The physical components and infrastructure (e.g. buildings, equipment, roads) of the proposed facility are considered to be relatively minor particularly when compared to other land uses in the region (e.g. Olympic Dam). Over the life of the facility, the level of activity that it is likely to generate is considered to be relatively low.

The 100 x 100 m disposal site would be enclosed in 1.5 x 1.5 km site, which would provide an extensive buffer and separate the operation from potentially incompatible land uses now and in the future. Security fencing would prevent unauthorised intrusion into the repository site.

The South Australian Government’s draft Planning Strategy for the region acknowledges the existing land use activities but the introduction of new land use activities is not specifically envisaged.

Mining, defence and aerospace activities (including their support industries) are considered the key areas for potential economic growth and future development. Tourism (based on adventure, four-wheel drive, heritage and Aboriginal culture themes) is also considered a potential growth area. The strategic emphasis for rangeland grazing is one of adjusting practices to achieve a greater level of sustainability.

The location of the repository within the Woomera Instrumented Range (WIR) presents a small risk that a missile fired at a target within the WIR, most particularly at the Range E target, could strike the repository site. Smaller, low velocity projectiles can be expected to fragment on impact with only limited ground penetration and are likely to damage only surface features or structures. However, larger or higher velocity weapons may strike with sufficient kinetic energy to penetrate the 5 m soil cover of the waste.

An assessment of the risk of such an occurrence, using US Department of Defence methodology (see Section 10.7.5) which considers ‘the management of environmental, safety and health mishap risks encountered during the development, test, production, use and disposal of government systems, subsystems, equipment and facilities’, concluded that the risk category is Medium, which is the second lowest risk category presented by the relevant standard. Risk mitigation measures would reduce the risk to a risk category of Low.

Site 52a is the preferred site with respect to land use and activity for the following main reasons:

- the access to the WPA is already restricted, which would help address the potential for unauthorised intrusion
- the visual impact of the proposed facility, its buildings and infrastructure would be minimal given the range of buildings, towers and other infrastructure already in the WPA.

The development of the facility at Sites 40a and 45a would:

- need to up-grade road access, which may also improve public access to sensitive and fragile environments
- introduce of a new visual element and land use into predominantly pastoral areas.

Peak traffic generation during the construction stage would need to be managed to avoid conflict with local peak traffic times. Sensitive design of permanent structures at the facility would minimise the visual impact and the proposed buffer is likely to minimise potential conflict with adjacent land uses.

Conclusion

The proposed repository is consistent with the existing land use, and the South Australian Government’s Planning Strategy for the region. The existing use includes the storage within the WPA of 2010 m^3 of the total of 3700 m^3 of radioactive waste requiring disposal.

A risk assessment concluded that the risk associated with the use of the WIR was Medium, the second lowest category, and that risk mitigation measures could reduce the risk to a risk category of Low. The timing of construction and disposal activities could be scheduled so as to not coincide with other uses of the WPA.

14.9 Cultural Heritage

14.9.1 Aboriginal Community Consultation and Views

The relevant Aboriginal claimant groups have cleared the preferred site and two alternatives and the access to them for all works associated with the construction and operation of a waste repository. Certain conditions have been placed on these clearances. In undertaking their clearance work, all claimant groups were concerned principally with ensuring that areas of cultural, social or spiritual significance to them were not adversely impacted to an unacceptable extent.

Sites 40a and 45a have extremely low background scatters of stone artefacts and their archaeological potential is low to negligible. Site 52a has a widespread background scatter of artefacts and a few quartzite flaking floors, but the proposed activities of the repository would avoid these flaking floors.

Sparse scatters of stone artefacts occur in the dunefield section of the access track to Site 45a. Extensive but sparse scatters of stone artefacts associated with creeks were confirmed to occur along parts of the access track to Site 40a. The claimant groups defined a potential new access track route to Site 40a.

Provided that conditions agreed with the claimant groups are adhered to, there should be no risks to cultural heritage sites and values of the land. The quartzite knapping floors observed at Site 52a would be avoided and protected in accordance with management measures. If the access road to Site 45a through the dunefield section requires road works with the potential to affect archaeological sites, then archaeological investigations and monitoring would be undertaken.

Conclusion

No archaeological constraints with any of the three proposed repository areas were identified during the work area clearances. All sites had a low background scatter of stone artefacts. The quartzite flaking floors identified on Site 52a would be avoided. Part of the access tracks to Sites 40a and 45a had scatters of archaeological material and it was recommended that management strategies be formulated to minimise damage to and interference with this material.

14.9.2 European Heritage

Early Explorers and Pastoral Expansion

Early European explorers reported that the region was desolate, which deterred initial development.

Pastoral activities began in South Australia in the 1830s, with licences issued to those wishing to use land for pastoralism. In 1851 the government introduced 14-year pastoral leases for Crown Land, which increased security for pastoralists. The definition and expansion of cropping and pastoral lands was considerably influenced by Goyder and by 1864 the northern edge of the pastoral expansion extended to the shores of Lake Eyre. Since the 1880s there have been many changes in the ownership and boundaries of pastoral leases in the area.

The development of the pastoral industry for sheep was aided by the construction of the dog fence that extended from western Queensland to the Head of the Bight in South Australia. Pastoralism is the dominant land use in the region, with sheep grazing remaining the major pastoral activity on the Arcoona Tableland.

Woomera Prohibited Area

Following World War II Great Britain sought to develop a facility for weapons research and testing. A 480,000 km^2 area north of Adelaide was chosen and the Long Range Weapons Organisation was established in 1947 as a joint venture of the British and Australian governments to undertake the firing, observation and recovery of long-range weapons. Facilities developed for the rocket range included airfields, road and water reticulation networks, telecommunications, launch facilities, and a 132 kV transmission line and water supply pipeline. Personnel were accommodated in a purpose-built town, Woomera.

Eight of the nine independent and subsidiary live firing ranges initially established had closed by 1957. Resources were then concentrated on one main range, Range E, a world-class facility for weapons testing.

Many short and long range weapons and research vehicles were completed and tested at WPA, with the first missile launched almost two years after the establishment of the joint venture. During the 1960s, and subsequently, the functions of the WPA became less focused on weapons, and began to include research on a wide range of subjects, including satellite launches and deep space research. The prohibited area is now a much smaller portion of the original WPA.

Site 52a is located within the WPA, approximately 10 km west-southwest of the Range E range head. Sites 40a and 45a are to the east of the eastern edge of the WPA. A summary of the risk assessment of the use of the WPA for the repository is provided in Section 14.7, and the detailed assessment is provided in Section 10.7.5.

Conclusion

No items of European heritage value for the project area are listed on the Australian Heritage Places Index. No impact on items of European heritage is predicted.

14.10 Radiation

Existing background radiation at the sites has been evaluated from a series of measurements of radionuclide concentrations in the soil (both surface and underground), air, groundwater, plants and animals. All of these measurements indicate that the levels observed are typical of the region. There are no unusually high values of either naturally occurring radionuclides (e.g. uranium or thorium) or artificial radionuclides (e.g. ^{137}Cs from weapons testing). This natural background radiation would be the baseline against which the environmental monitoring program of the repository would be judged.

Initial construction of the repository trench would require that the excavation workers be exposed to the natural levels of radiation at the site. The radiological impact for workers has been assessed and found to be very low, at about 20 μSv, which is a very small addition to the average background radiation exposure in Australia of 2 mSv/yr. Should subsequent excavation be required at the site for future disposal campaigns, there would be an additional risk that the construction workers might inadvertently expose the previously buried wastes. However, appropriate design and management controls would mitigate this risk, as would a borehole rather than a trench.

During the operation of the repository, radioactive waste would be brought to the site in an approved waste form and using approved waste packages. The packages would be assayed in accordance with a validation program to confirm their compliance with the waste acceptance criteria. The waste would then be disposed of in the trench. There is therefore no operation at the site that involves the opening of these packages or the direct handling of radioactive materials. There would therefore be no routine radioactive discharges from the site.

Potential accidents at the site, for example an externally contaminated package or a dropped package spilling radioactive material, would be mitigated by the application of the waste acceptance criteria and would be confined to the repository buffer zone and remediated immediately. All operations at the site would be conducted under a radiological protection regime consistent with the regulatory requirements, and worker exposure will be as low as reasonably achievable and within the relevant dose constraints.

A potential accident scenario in the operational/closure phase of the repository that has been considered in some detail is the potential radiological impact resulting from a missile or aircraft crashing into the site from the nearby Woomera testing range. The assessment shows that the highest radiation exposures would be to a recovery team which, unaware of the fact that the repository had been hit, began their operations without taking any precautions and without any radiation protection supervision. The potential doses in such a case are of the order of a few mSv, which is well within the annual dose limit for a classified radiation worker (20 mSv averaged over 5 years).

After the wastes have been disposed of, the trench (or borehole) capped and the facility decommissioned, the repository area would be monitored and access controlled for 200 years. During this period any release of radioactivity from the site would be detected and remedial action taken if required.

In future years, when the repository site is no longer under institutional control and the waste form and waste packages have degraded, radioactivity could be released to the environment via a number of pathways. This aspect of the repository lifecycle has been considered in some detail. The potential pathways by which radionuclides may be released to the environment are discussed. The radiological impacts from such releases have been assessed. The exposure pathways and scenarios that have been considered include:

- radioactive gaseous discharges and exposures to people living in dwellings over the repository site
- releases to groundwater through infiltration of rainwater and dissolution of the waste
- the effects of drilling and examination of borehole cores
- bulk excavation at the site
- the effects of building a road that runs across the repository
- the effects of archaeological digging at the site
- the longer term effects arising from exposure to excavated materials
- the effects of a rocket crash from the nearby Woomera test site
- the effects of an aircraft crash onto the repository site
- the effects of a transition to a wetter climate state
- the effects of a gross erosional event
- the effects of site flooding in a wetter climate state
- the effects of consuming contaminated waters obtained from a well drilled through the wastes
- the recovery from excavated materials of some of the more active sources or artefacts disposed of in the repository.

The radionuclides that contribute most to radiation exposure in these scenarios are ^{241}Am, ^{137}Cs (for source recovery only) and ^{238}U and its daughters, ^{226}Ra and ^{210}Po. The most significant postulated scenarios in terms of exposure are those of gas migration into a dwelling built on the repository site and of recovery of the more active sealed sources from the waste.

The conclusion from these assessments is that the risks are very low, and within the risk target value, for all of the scenarios other than major climate changes and gross erosional events, for which the risks are only slightly higher than the risk target. However, CSIRO computer modelling indicates that a transition to a wetter climate in the Woomera area is unlikely in the next 10,000 years.

The total radionuclide inventory (both for bulk material and for individual sources) that would be acceptable for disposal at the repository would be determined by the regulator, who would take into account the exact location of the site, the detailed repository design and the acceptance and verification of the scenarios and assumptions used in risk assessment.

It should be noted that these assessments are equally applicable to all three of the candidate sites. Overall, it has been shown that the risks which might arise in future years, when the site is no longer under institutional control, are acceptably low and comply with the NHMRC 1992 Code.

Conclusion

Overall the radiation risks during construction, operation and which might arise in future years, when the site is no longer under institutional control are acceptably low and are in accordance with the NHMRC 1992 Code.

14.11 Environmental Management and Monitoring

An environmental management and monitoring plan (EMMP) is required for both construction and operations at the national repository, covering general environmental issues and also the specific legislative requirements for radiation and near surface repositories. Development of the EMMP would take into account issues and responses raised in the EIS process, as well as formal regulatory requirements.

The general aims of the EMMP would be to establish:

- management processes and procedures to ensure environmental impacts are minimised during construction, operation, surveillance and decommissioning
- ongoing monitoring and reporting processes to evaluate any impacts of the operation on the surrounding environment
- audit processes for checking the implementation and effectiveness of management and monitoring systems.

Proposed management and monitoring strategies broadly address the following areas:

- physical environment
- biological environment
- radiation
- land use planning conflicts
- consultation with Aboriginal groups.

Conclusion

An EMMP would be prepared for both construction and operations at the repository, covering general environmental issues and also specific legislative requirements for radiation and near surface repositories. Development of the EMMP would take into account issues and responses raised in the EIS process, as well as formal regulatory requirements.

14.12 Comparison of Sites

The comparison of key advantages and disadvantages of the preferred and two alternative sites in Table 14.1 is provided here to determine if the preferred site as identified following the previous phases of the site selection process remains as the preferred site after the environmental assessment process.

TABLE 14.1 Advantages and disadvantages of the preferred and two alternative sites

Potential Issue	Site 52a (Preferred)	Site 40a (Alternative)	Site 45a (Alternative)
Construction	Need to coordinate with Defence use of WPA	Access road upgrade required prior to works (see below)	Access road upgrade required prior to works (see below)
Operation	Need to coordinate with Defence use of WPA	No significant issue identified	No significant issue identified
Access roads from Woomera	Good access using existing roads; 1.5 km requires minor upgrade	Requires 35.5 km of road upgrade construction through sensitive environment	Requires 12.5 km of road upgrade construction
Transport of waste to site	No significant issue identified; approx half the waste is presently 10 km from Site 52a	No significant issue identified	No significant issue identified
Geology	No significant issue identified; mud and siltstones on site provide better fill and cover characteristics than Sites 40a and 45a	No significant issue identified; may require blasting during construction	No significant issue identified; may require blasting during construction
Hydrology and hydrogeology	Presence of shale provides lower permeability material for trench base; favourable surface drainage features	Greatest depth to groundwater; large canegrass swamp near the site	Depth to groundwater intermediate compared with other two sites; favourable surface drainage features
Biology	No significant issue identified; this site has least biological impact	No significant issue identified; 35.5 km of road upgrade construction required	Site has high biodiversity; 12.5 km of road upgrade construction required
Land use (including activities on the WPA)	Limited impact on WPA activities and pastoral usage	Limited impact on pastoral usage	Limited impact on pastoral usage
Heritage	Two knapping floors to be avoided on the site	Potential archaeological sites to be avoided during access road upgrade	Potential archaeological sites to be avoided during access road upgrade
Radiation	No significant issue identified	No significant issue identified	No significant issue identified
Security	Good; in Commonwealth protected area	Requires additional security measures to 52a	Requires additional security measures to 52a

Site 52a, within the WPA, remains the preferred site following the environmental assessment process. It has good existing access and superior security compared with the two alternative sites. The presence of shale provides lower permeability material for the trench base, and it has favourable surface drainage features. Its main disadvantage compared with the two alternative sites is its potential impact on the activities within the WPA. However the assessment has indicated that any such impacts can be managed.

The alternative Sites 40a and 45a remain as acceptable sites subject to the implementation of certain additional management procedures. These procedures relate to site security, and to construction and operational management to protect possible archaeological sites along the access roads to Sites 40a and 45a, and to protect biodiversity at Site 45a.

Site 45a has a significantly shorter length of required road construction than Site 40a. Site 45a has a higher biodiversity than site 40a in terms of vertebrates and birds, although the footprint of the repository is small. Overall, of the alternative sites, Site 45a would be preferred over Site 40a, but both remain acceptable alternatives.

Chapter 14
Conclusions

GLOSSARY

Glossary

Glossary of Terms

Aeolian	Descriptive of soil deposited by wind.
Alluvial	Descriptive of soil deposited by river or flood water.
Alpha emitter	A radioisotope that emits an alpha particle (q.v.) when it decays.
Alpha particle	A positively charged particle containing two protons and two neutrons which is emitted by certain radioisotopes. It is the least penetrating of the three main forms of radiation (alpha, beta and gamma) in that it may be stopped by a sheet of paper.
Aquifer	A permeable rock formation that stores and transmits sufficient groundwater to yield economically significant quantities of water to wells, bores or springs.
Aquitard	A confining bed that retards, but does not prevent, the water flow to or from an adjacent aquifer.
Artesian water	Groundwater under sufficient hydrostatic pressure to rise above the level at which it is encountered by a well.
Bathtubbing	Build up of water within a containment structure (e.g. because natural or engineered drainage features lose their efficiency) resulting in contamination of surface soils or sediments.
Batter	The slope from bottom to top of the face of a retaining wall or pier.
Becquerel (Bq)	The SI unit of measurement of radioactivity defined as one radioactive disintegration per second.
Beta emitter	A radioisotope that emits a beta particle (q.v.) when it decays.
Beta particle	An electron or positron emitted by the nucleus of a radionuclide during radioactive decay. Beta particles may pass through paper but are stopped by a thin sheet of metal.
Borrow pits	Excavations that provide extra soil, rock, gravel, clay or sand for construction activity.
Buffer zone	A zone of restricted access, which is controlled by the operator, between the operational site boundary and any structure within the facility, to ensure that there is a sufficient distance between the facility and any area accessible to members of the public.
Bund	An earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids.
Bulldog Shale	One of the strata of the Eromanga Basin, which commonly forms an aquitard in the Great Artesian Basin but also occurs elsewhere. It is a grey marine mudstone that weathers to white or brown where it outcrops.
Cainozoic (Cenozoic)	The last of the four eras of geologic time, extending from the close of the Mesozoic (q.v.) up to and including the present.
Calcrete	Friable to hard calcareous material of secondary accumulation found near or on the surface, and composed largely of crusts of soluble calcium salts intermixed with gravel, sand, salt and clay.
Cambrian	The earliest period of the Palaeozoic Era. It spanned the geological time between 500 and 570 million years ago.
Category A waste	Waste containing short-lived radionuclides (half-lives of around 30 years or less) mainly emitting beta or gamma radiation. Long-lived radionuclides emitting alpha radiation are present in very low concentrations. Under the NHMRC *1992 Code of practice for the*

	near-surface disposal of radioactive waste in Australia, category A waste requires at least 2 metres of cover.
Category B waste	Waste emitting considerably higher levels of beta or gamma radiation than category A waste, but still at relatively low levels. Under the NHMRC *1992 Code of practice for the near-surface disposal of radioactive waste in Australia*, category B waste requires at least 5 metres of cover.
Category C waste	Bulk waste of similar activity to category B waste.
Category S waste	Waste with activity concentrations greater than in category A, B or C waste.
Chenopod	A member of a family of mostly herbaceous plants and shrubs, mainly of saline and semi-arid regions; includes bluebushes, saltbushes and samphires.
Class A pan	A standard pan used for measuring rates of evaporation.
Conditioning	Those operations that produce a waste package suitable for handling, storage and/or disposal. Conditioning may include converting the waste to a solid waste form, enclosure of the waste in containers and, if necessary, providing an overpack.
Consignment	Generally taken to mean a transport package or a disposal package and its contents of waste.
Containment	Methods of use of physical structures that prevent the dispersion of radionuclides.
Cretaceous	The final, third period of the Mesozoic Era. It spanned the geological time between 65 and 135 million years ago.
Criteria	Conditions on which a decision or judgement can be based. They may be qualitative or quantitative and should result from established principles and standards. In radioactive waste management, criteria and requirements are set by a regulatory body and may result from specific application of a more general principle.
Decay product	The product of the spontaneous radioactive decay of a nuclide (q.v.). A nuclide such as uranium-238 decays through a sequence of steps and has associated with it a number of successive decay products in a decay series.
Deuterium	An isotope of hydrogen, with 1 proton and 1 neutron in its nucleus: also referred to as ^{2}H, hydrogen-2 or, sometimes, D.
Decommissioning waste	Radioactive waste from decommissioning activities.
Disposal package	A waste package used for disposal.
Disposal	The emplacement of waste in an approved, specified facility without the intention of retrieval.
Dog fence	A dingo-proof fence in the Australian outback, extending from the Great Australian Bight to the east coast of Australia.
Dose equivalent	The mathematical product of the absorbed dose, the quality factor and any other specified modifying factors. The quality factor accounts for the effectiveness of energy transfer of the ionising radiation in producing a biological detriment. Modifying factors are those which may act to modify the effect of the energy imparted to the matter.
Dose	The radiation energy absorbed in a unit mass of material.
Drum crushing	A method of waste compaction that involves pressing an entire drum and its contents into a smaller volume. Several crushed drums can then be placed into a larger drum or container.

Drum	A type of waste container similar in appearance to an oil drum which may be sealed by a fitted lid.
Ecotype	A recognisable local form of a plant species which has become genetically adapted to certain environmental conditions.
Emplacement	The placement of a waste package in a designated location for storage disposal.
Encapsulation	Immobilisation of solid waste by surrounding it with a matrix material in order to produce a waste form.
Engineered barrier	A feature made or altered by humans that delays or prevents radionuclide migration from the waste or the disposal structure into its surroundings; it may be part of the waste package or part of the disposal structure.
Epiclastic	Descriptive of mechanically deposited sediments consisting of weathered products of older rocks.
Evapotranspiration	The total water loss by evaporation from a particular area, being the sum of evaporation from the soil and transpiration from vegetation.
Flow-on effects	The effects on other areas of an economy as a result of a change in activity in a particular industry sector.
Forb	Any herb other than a grass.
Free liquid	That liquid which is present as a separate phase (including that which is physically absorbed onto a solid matrix rather than chemically combined).
Gamma radiation	A form of electromagnetic radiation similar to light or X-rays, distinguished by its high energy and penetrating power. Gamma radiation is emitted after nuclear reactions or by radioactive atoms when the nucleus is left in an excited state after the emission of an alpha or beta particle.
Geosyncline	A large, generally linear trough that has subsided deeply over a long time interval and in which thick sequences of sedimentary and volcanic rocks have accumulated.
Gibbers	Fragments of stone on the surface of tableland, formed by weathering of the top layer of rock.
Gilgai	The microrelief of soils produced by expansion and contraction with changes in moisture, found in soils that contain large amounts of clay. It is characterised by a markedly undulating surface with mounds and depressions.
Great Artesian Basin	A groundwater basin covering about one-fifth of Australia that includes an artesian aquifer whose potentiometric surface is above the land surface in topographically lower parts of the area.
Groundwater	Underground water contained within a saturated zone or rock (aquifer (q.v.)).
Gypcrete	A gypsum-cemented crust or rock found in some playa (q.v.) lake beachrock environments in arid climates.
High force compaction	The application of pressure of at least 20,000 kN/m^2.
High level waste	Waste containing high levels of beta and gamma radiation emitters and significant levels of alpha emitters, and generating significant amounts of heat (>2 kW/m^3) as defined in the IAEA Safety Guide, number 111-G-1.1. Such waste requires careful handling, substantial shielding, provision for dissipation of heat generated by the decay of radioactive material, and long-term immobilisation and isolation from

	the biosphere. High level waste is generated by nuclear power reactors. No high level waste is generated in Australia.
Hydraulic conductivity	A measure of the ability of a medium to transmit water.
Hydraulic gradient	The change in static head or hydraulic potential per unit of distance in a given direction.
Hydrogeology	The science dealing with groundwater and related geological aspects of surface water.
Hydrostatic head	The water pressure at the bottom of a vertical column of water of a specified height above an assumed surface used as a reference surface for the measurement of reduced levels.
In-drum compaction	The compaction of waste in a drum. In practice, after initial compaction more waste is added and the process is repeated until the drum is filled to the desired level.
Inaccessible voidage	That voidage within a disposal package which will not be readily penetrated by in-fill stabilisation medium, for example grout, sand, soil or clay.
Institutional control	The control of a former waste disposal site by the appropriate authority in order to restrict access to, and use of, the site and to ensure an ongoing knowledge that the site has been used for the disposal of radioactive waste.
Intermediate level waste	Waste containing significant levels of beta and gamma emitting radionuclides that could also contain significant levels of alpha emitters. The waste requires special shielding during handling and transport. Short-lived intermediate level waste corresponds to Category A, B, and C waste in the NHMRC 1992 *Code of practice for the near-surface disposal of radioactive waste in Australia* and broadly corresponds to short-lived low and intermediate level waste as defined in the IAEA Safety Guide number 111-G-1.1 1994. According to IAEA classification, short-lived intermediate level radioactive materials have half-lives of about 30 years or less, and typically include gauges and sealed sources used in industry and medical diagnosis and therapy, and small items of contaminated equipment. Disposal options for short-lived intermediate level waste are similar to those for low level waste as the waste decays to very low levels within the institutional control period.
Ionising radiation	Radiation which interacts with matter to add or to remove electrons from (i.e. to ionise) the atoms of the material absorbing it, producing electrically charged (positive or negative) atoms called ions.
Irradiation	Subjection to ionising radiation.
Isotope	One of two or more forms of a chemical element having the same number of protons but a different number of neutrons. All isotopes of the same element have the same chemical properties and therefore cannot be separated by chemical means.
Jurassic	The second period of the Mesozoic Era. It spanned the geological time between 135 and 190 million years ago.
Knapping floors	Dense concentrations of flaked material associated with stone artefact manufacture.
Leach test	A test to determine the leach rate of a waste form.
Liner	A layer of material placed between a waste form and a container to resist corrosion or any other degradation of a waste package.
Long-lived waste	Waste that will not decay to an acceptable level in a period of time during which administrative controls can be expected to last.

Low level waste	Waste containing low levels of beta and gamma emitting radionuclides and normally very low levels of alpha emitting radioactive material. Low level waste is suitable for disposal in the national repository. It includes items such as wrapping materials and discarded protective clothing, and laboratory plant and equipment. Low level waste corresponds to Category A, B, or C waste under the NHMRC *1992 Code of practice for the near-surface disposal of radioactive waste in Australia*, and broadly corresponds to short-lived low and intermediate level waste as defined in the IAEA Safety Guide, number 111-G-1.1, 1994.
Mesozoic	One of the four eras of geologic time, following the Palaeozoic and succeeded by the Cainozoic (q.v.).
Matrix	A non-radioactive material used to immobilise waste.
Mixed waste	Radioactive waste that contains non-radioactive toxic or hazardous materials that could cause undesirable effects in the environment. Such waste has to be handled, processed and disposed of in a manner that takes into account its chemical as well as its radioactive components.
Monitoring	The methodology and practice of measuring levels of radioactivity either in environmental samples or en route to the environment. Examples include groundwater monitoring and personnel monitoring.
National repository	An engineered near-surface underground facility for the disposal of Australia's low level and short-lived intermediate level radioactive waste.
Near-surface disposal	Disposal of waste, with or without engineering barriers, on or below the ground surface, where the final protective covering is of the order of a few metres thick, or in caverns a few tens of metres below the Earth's surface.
Non-conforming waste packages	Waste packages that do not meet the waste acceptance criteria for reasons other than being shipped in approved non-standard containers.
Nuclide	An atom of a particular element distinguished by the number of protons and neutrons in its nucleus.
Overpack	A secondary (or additional) external container for waste.
Perched watertable	Unconfined groundwater separated from an underlying main body of groundwater by an unsaturated zone.
Permeability	The capacity of a porous rock for transmitting a fluid.
Permil ($^{0}/_{00}$)	The amount of heavy isotope in a sample, usually expressed in delta notation, as a permil ($^{0}/_{00}$) difference from a standard, $\delta i = [(R_{unknown} / R_{standard}) - 1)] \times 1000$ where *i* is the isotope of interest, and R the heavy-to-light isotope molar ratio.
Photopoint	A designated point on the ground from which photographic records of progress of vegetation changes are made, usually on a six-monthly or yearly basis.
Playa	A flat area or basin at the lowest part of an undrained desert basin, underlain by clays, silts and sands, and commonly by soluble salts.
Porewater	Water held in the pores of soil or rock in the unsaturated zone, that is between the soil surface and the watertable.
Potentiometric surface	A hypothetical water surface representing the total head of groundwater for a particular locality, and defined by the level to which water will rise in a well.

Precambrian	The geological period of time encompassing the Proterozoic and Archaean eras between 570 and 4600 million years ago, equivalent to some 90% of the Earth's geological history.
Pre-treatment	All of the operations before waste treatment, such as collection, segregation, chemical adjustment and decontamination.
Primary waste	Waste unchanged from the form and quantity in which it was generated, that is waste that has not been processed.
Proterozoic	The geological period of time between 570 and 2500 million years ago. It is the more recent of the two great divisions of the Precambrian.
Province	In geology, part of a region that is isolated and defined by its geological history and development, and where the source, age and distribution of its minerals are unified.
Quadrat	In botany, a designated measured area, usually rectangular, in which individual plants are counted and measured, usually on a six-monthly or yearly basis.
Qualification of a process	The process of demonstrating whether an activity, process or product is capable of fulfilling specified requirements.
Quality factor	A numerical factor used in radiation protection to allow the biological effects of different radiations to be compared.
Radioactive waste	Material that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body, and for which no use is foreseen.
Radionuclide	Any nuclide which is unstable and undergoes natural radioactive decay.
Radon	The heaviest of the 'noble' or inert gases. The predominant isotope, radon-222, is the decay product of radium-226. It has a half-life of 3.82 days and decays to polonium-218 by the emission of an alpha particle (q.v.).
Regolith	Loose surface rock that forms the surface of the land in the absence of true soil and rests on bedrock.
Requirement	A condition defined as necessary to be met by a product, material or process.
Ripping	Breaking, with a tractor-drawn ripper or a long-angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment.
Rip-rap	A layer of coarse rock used to line or protect earthen embankments from erosion.
Sedimentary	Descriptive of rocks formed by deposition by wind, water or ice, by chemical precipitation or by secretion by organisms.
Short-lived waste	Waste that will decay to a level considered to be insignificant, from a radiological point of view, in a time period during which administrative controls can be expected to last.
Sievert (Sv)	The SI unit of measurement of effective dose. One sievert is equal to the product of the absorbed dose by the quality factor (q.v.) and any modifying factor(s). It allows a comparison of the relatively greater biological damage caused by some particles (e.g. alpha particles and fast neutrons). For most beta and gamma radiation, one sievert is equal to an absorbed dose of one joule per kilogram of biological matter.
Silcrete	Surficial sand cemented into a hard mass by silica.

Siliceous	Descriptive of a rock or other substance containing abundant silica, especially as free silica rather than silicates.
Solidified radioactive waste	Liquid waste that has been converted into a solid waste form.
Specifications	Detailed requirements to be satisfied by a product, service, material or process, indicating the procedure by means of which it may be determined whether the specified requirements are satisfied.
Stable waste	Waste which is inherently stable, or has been rendered stable by placement in a high integrity container or by processing with an approved solidification media.
Storage	Storage of radioactive materials such that: isolation, monitoring, environmental protection and human control are provided; and subsequent action involving treatment, transport and disposal is expected.
Swale	The area lying between sand ridges.
Third party wastes	Those wastes that are consigned by an organisation other than the organisation which generates the waste.
Transmissivity	The rate at which groundwater is transmitted through rock of a specific dimension and at a specified hydraulic gradient (q.v.).
Transport package	Container used for transport of waste.
Triassic	The first period of the Mesozoic Era. It spanned the geological time between 190 and 225 million years ago.
Tritium	An isotope of hydrogen, with 1 proton and 2 neutrons in its nucleus; also referred to as ^{3}H, hydrogen-3 or, sometimes, T.
Understorey	The vegetative cover beneath taller trees and shrubs.
Uranium (decay) series	A series of radionuclides produced in the decay of radioactive uranium to stable lead. The most important steps of this series are uranium-238 to uranium-234 to thorium-230 to radium-226 to radon-222 (and its decay products) to lead-210 and finally to lead-206, the stable non-radioactive end-product.
Vadose zone	The unsaturated layer of soil and rock above the watertable.
Volume reduction	One of the treatment methods that decreases the physical volume of a waste.
Waste acceptance criteria	Those criteria relevant to the acceptance of waste packages for handling, storage and disposal.
Waste acceptance requirements	Those requirements relevant to the acceptance of waste packages for handling, storage and disposal.
Waste characterisation	The determination of the physical, chemical and radiological properties of the waste to establish the need for further adjustment, treatment or conditioning; or its suitability for further handling, processing, storage or disposal.
Waste conditioning	The process which converts the waste into an acceptable concentration and stable form for packaging, shipment and disposal. It may involve solidification of the waste and/or encapsulation in a stable matrix such as concrete.
Waste container	The vessel into which the waste form is placed for handling, transportation, storage and/or eventual disposal; also the outer barrier protecting the waste from external intrusions. The waste container is a component of the waste package.

Waste form	The waste in its physical and chemical form after treatment and/or conditioning (resulting in a solid product) prior to packaging. The waste form is a component of the waste package.
Waste generator	The operating organisation for the facility where the waste is generated.
Waste package specifications	The set of quantitative requirements to be satisfied by the waste package for handling, transportation, storage and disposal.
Waste package	The product of conditioning that includes the waste form and any containers and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transportation, storage and/or disposal.
Waste treatment	Operations intended to benefit safety and/or economy by changing the characteristics of the waste. This may involve operations such as solidification, incineration or compaction to minimise waste volume. After treatment the waste may or may not be immobilised to achieve an appropriate waste form. Three basic treatment objectives for radioactive wastes are: ▪ volume reduction ▪ removal of radionuclides ▪ change of composition.
Wastestream	A grouping of wastes from a common source of similar radionuclide composition.

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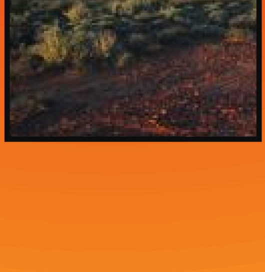

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