Australian Government

Department of Industry, Innovation and Science

Preliminary Safety and Waste Acceptance Report of the National Radioactive Waste Management Facility (NRWMF)

July 2018

Executive Summary

This report provides preliminary safety and waste acceptance information for the proposed National Radioactive Waste Management Facility (NRWMF). The NRWMF will dispose of Australia's domestically produced Low Level Waste (LLW) in near-surface engineered disposal vaults, and store Intermediate Level Waste (ILW) in above ground custom-built buildings for a period of time (30 years) sufficient for the Australian Government to establish a permanent ILW disposal facility at a separate site, consistent with international obligations and best practice. The NRWMF will be operated for period of 100 years followed by an institutional control period of up to 300 years.

Three nominated sites in South Australia (Napandee and Lyndhurst near Kimba and Wallerberdina Station near Hawker) are currently undergoing a site selection process managed by the Australian Government Department of Industry, Innovation and Science ('the department'). This process includes extensive public consultation and physical site assessment.

A critical element in the consultative process is the provision of public information on how the NRWMF will be designed and operated to ensure waste is held and managed safely for the workers, the general public and the surrounding environment.

The NRWMF's design and operation will embody internationally accepted principles of radioactive waste management which recommends a multilayer "defence in depth" approach to safety. This approach first begins off-site through the application of strict Waste Acceptance Criteria (WAC) to control the types of wastes accepted, and the forms and packaging in which the waste will arrive. Further layers of defence in depth are provided by the engineered building and disposal vaults and the site characteristics.

For both ILW and LLW the waste packages (the treated waste and the waste container in combination) will require to be physically and chemically stable. All treated wastes (wasteforms) will be solid and non-dispersible, stable, non-reactive, non-flammable, and resistant to degradation over long timeframes. No containers of liquids will be accepted.

Each of the proposed sites has been assessed at a preliminarily level for physical and environmental characteristics, including risks associated with fire, flooding, seismic activity, surface and groundwater. This has found the seismic and flooding risks to be entirely manageable through appropriate engineering, construction and design solutions such as drainage, building materials used, methods that address the risks of ground shaking and deformation and potentially levies or bunds to further reduce flood risk. Further more detailed work on some site characteristics will be carried out as the project progresses and form important input into the safety assessment and design basis for the facility.

Strict radiological controls will be built into the design of the NRWMF to ensure there is no plausible path for radioactive waste or radiation to enter the surrounding environment and to ensure radiation levels immediately around the e vaults and storage buildings are safe for workers and visitors. All plausible risks will be assessed and managed to 'As Low as Reasonably Achievable (ALARA)' principle.

All waste will be kept above ground and multiple barriers used to result in 'defence in depth'. The LLW disposal packages will meet strict waste acceptance criteria. They will be securely sealed and deposited within specially developed concrete vaults, and when sealed inside the vault are fully isolated from rain and other environmental factors. ILW waste will be treated and packaged in well designed and constructed containers that provide containment and shielding. If more shielding is required this will be provided by an outer container (or overpack). The ILW will be stored in specifically designed storage buildings. The engineered structures around and underneath the disposal and storage structures will isolate and trap materials such as rainwater and resist environmental and human intrusion. All conventional waste materials and waste water leaving the NRWMF will first be tested and monitored for the possibility of contamination. The NRWMF will be supported by a comprehensive system of air, ground and water monitoring with results to be publically reported.

By design the radiation levels for NRWMF workers and visitors will be well below regulated levels at all times and there will be no effective additional radiation above background levels for anyone at or beyond the site boundary.

Industrial accidents (not involving radioactivity) are considered to be the most likely risk for worker safety and all equipment and procedures will meet all required workplace health and safety (WHS) standards. A strong safety culture and a comprehensive safety management system will also be implemented in the proposed NRWMF.

Security at the NRWMF will be assessed and maintained in accordance with regulatory requirements and the risks assessed by security agencies. At a minimum it will require full time security presence with secure areas inside the operational zone.

Generic risk evaluation of operational phase activities for LLW disposal and ILW storage was undertaken, following international best practice methodology. The risk evaluations presented in this report are preliminary in nature and based on the site and design related information available at the time of drafting this report. The risks from normal operations are evaluated as low and consistent with ALARA. The risks of fault or accident scenarios were assessed 'low' or 'very low'. Further risk assessment will be performed when the detailed design and further site characterisation information becomes available to update the risk evaluation.

Generic risk evaluation of the LLW post-closure phase (the period following 100 years of LLW operations and 300 years of institutional control) was undertaken, using international best practice scenarios and methodology. It is concluded from the preliminary safety evaluations and calculations of the proposed design that post-closure safety is achievable.

This preliminary safety and waste acceptance report will be refined and developed as further site characterisation data and design detail becomes available and incorporated into a future site specific safety case. The key safety features will be fully documented through a series of specialised technical reports: preliminary and a final safety case, and preliminary and then operating WAC. These documents will be further developed building on the assessments, risks and mitigation strategies in this report once a specific site has been identified, and will be subject to public consultation when licensing approval by the independent regulators is sought.

This report has been released as an initial draft for public information and comment. It is a dynamic document and will evolve as information, design and regulatory requirements become better understood. The department welcomes feedback on all aspects of the report.

Further information on the project can be found at www.radioactivewaste.gov.au and comments on this report can be emailed radioactivewaste@industry.gov.au.

Contents

1 Introduction

Over the past 70 years, Australia has accumulated an inventory of low and intermediate level radioactive waste (LLW and ILW respectively), to which a relatively modest amount will be added each year. This waste results from the production of nuclear medicines as well as from scientific and industrial applications (such as new medical equipment sterilisation, and sources used in industrial drilling). Currently, these wastes are stored in numerous sites across Australia, the most significant of which are nearing capacity. A national inventory of radioactive waste is currently being developed. The National Radioactive Waste Management Facility (NRWMF) project is intended to provide a single, purpose-built facility to safely manage Australia's existing (legacy) and future wastes and minimise the burden of responsibility passed on to future generations.

The NRWMF design process follows the relevant Australian codes and standards and regulatory guides, as well as international best practices, including International Atomic Energy Agency (IAEA) and Organisation for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) guidance that has been implemented in similar facilities in Europe, such as El Cabril in Spain and Centre de l'Aube in France. In most cases these facilities safely manage a waste inventory that is significantly larger and has higher levels of radioactivity than Australia's inventory.

It is intended that the NRWMF will receive and dispose of Australian LLW for up to 100 years. It will also provide consolidated interim storage of Australian ILW. The ILW storage buildings will be operational for 30 years, but will have a design life of 50 years to provide a contingency period for ILW recovery for disposal and for decommissioning the ILW stores. In this timeframe, a separate process for selecting a site and construction of a facility for the permanent disposal of ILW will be undertaken.

The NRWMF will only accept Australian LLW and ILW. It will not accept other countries' wastes, although it will receive the solid vitrified waste formed when ANSTO spent reactor fuel is reprocessed in France. Australia does not produce high level waste (HLW). The NRWMF project is at an early stage, with neither the site chosen nor the NRWMF design finalised. The identification of a preferred site and the development of the NRWMF design will be an iterative process, guided throughout by social, safety, technical, regulatory, environmental and economic considerations and feedback from public consultation.

As the NRWMF will be the permanent LLW disposal site safety needs to be assured. Following the LLW operations when all the vaults are closed and protected by a multi-layer cover system, they will be monitored for a maximum 300 year institutional control period (ICP). Over the ICP time period the radioactivity in the waste will have reduced sufficiently such that residual risk is reduced to below permissible levels for entering into the subsequent post-closure period, in accordance with international best practice.

The development, construction, operation and eventual closure of the NRWMF will be regulated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). Nuclear safeguards aspects will be regulated by ASNO. A staged licensing process will be adopted. At key milestones (siting, construction and operation) the project will require a license from ARPANSA prior to moving to the next stage. It is likely that the NRWMF will require separate licences for LLW disposal and ILW storage. Each licence application will be supported by a safety case submission.

This report precedes and will inform the development of the preliminary safety cases and WAC. It brings together initial thinking on safety, design and waste acceptance along with the results of preliminary site assessments for each site. The full process of WAC, safety and design development is shown in Figure 1 below.

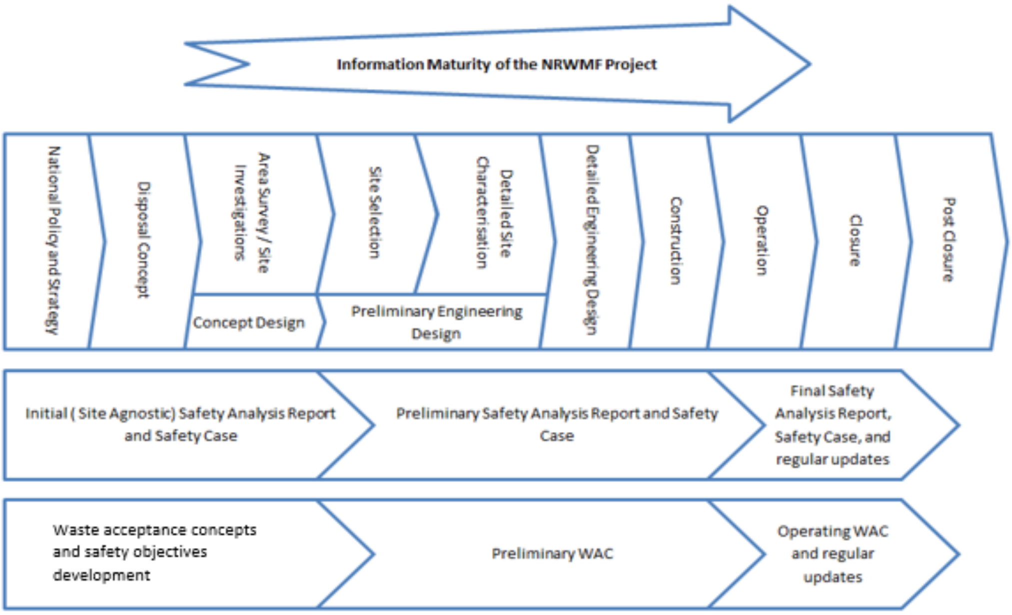


Figure 1: Development of NRWMF WAC, safety and operational design maturity with time

The rationale for this approach to development of the NRWMF is to:

- Take on board community concerns, by adopting a transparent, safety-led design process from the outset.
- Identify and incorporate international best practice.
- Inform the development of waste acceptance criteria for the NRWMF.
- Provide the Commonwealth Government with high confidence that the NRWMF can be safely constructed, operated and ultimately closed.
- Ensure the costings are informed by safety considerations.
- Consider the ARPANSA licensing requirements early in the project.

The Department of Industry Innovation and Science ('the department') has used highly respected experts from AECOM and ANSTO and other specialists to provide technical support in developing the project. The department invites comment on any aspect of the report.

1.1 Document Purpose and Structure

The purpose of this Safety and Waste Acceptance Report is to provide an overview of aspects of waste acceptance, the site investigations by AECOM to date and safety analyses undertaken by ANSTO for the department.

The report follows the following structure;

- Section 2 provides a site description and identifies important safety relevant site characteristics for the three nominated sites.
- Section 3 provides the generic safety principles which will be used in design and operation of the site
- Section 4 provides a description of the waste acceptance criteria, the waste acceptance process, examples of how waste might be treated/conditioned, and waste containers that would be used.
- Section 5 provides the current design thoughts for the site with layout and building diagrams and outlines safety functions of elements of the design.
- Section 6 provides an overview of the safety management systems for an NRWMF. It covers safety practices, considers their extent and implementation, and where in the organisation structure safety management responsibilities lie.
- Section 7 provides a summary of safety analyses for the operational and post closure periods.

- Section 8 provides overall conclusions.
- The Appendices provide the risk assessment tables, seismic categorisation, assessment methodology, and process flow diagrams.

1.1.1 Scope

The scope of this report includes:

- safety relevant aspects of preliminary geohydrology, seismicity, climate, fire and flood related site investigations carried out by AECOM across the three candidate sites
- generic WAC and the process for waste acceptance as developed by the department using an expert task group including Regulators, waste producers and industry experts - this includes physical, chemical and radiological factors for waste acceptance, a process diagram for waste acceptance, examples of treatment/conditioning/packaging processes and the waste container/transport container designs
- proposed safety and design features to manage site specific and generic environmental, radiological and industrial risks, and
- initial safety scenario analyses carried out for the department by ANSTO - this includes normal operating scenarios, fault (accident) events, and covers the operational phase (for LLW disposal and ILW storage) and post-closure phase of the LLW disposal vault system

2 Site Description

2.1 Location

At the start of the siting process landowners were invited to nominate potential sites to host the NRWMF. The department stipulated that an area of 100Ha would be required. Once potential sites were identified a process for initial investigation of site suitability and discussions with the local communities at suitable locations began. Where sufficient community support could not supportive be identified, sites were withdrawn from the siting process.

Currently three sites in South Australia are being considered - one at Wallerberdina Station, near Hawker, and two sites near Kimba, South Australia. A brief description of each site has been provided below. Further information of these sites, including site maps is available in the NRWMF website (http://www.radioactivewaste.gov.au/)

2.1.1 Wallerberdina Station

The Wallerberdina station site is at 377 Wallerberdina Road and located close to the Flinders Ranges, approximately 30km northwest of Hawker and 130km from Port Augusta. It is a 6,300-hectare property with a potential for a viable 100-hectare site development on the property which is close enough to the amenities of Hawker.

2.1.2 Napandee

The Napandee site is located approximately 20km west of Kimba. The site is close to a local township. The site offers sufficient land area for placement of a NRWMF, and no easements or paths of access cross the site. It has a 100 hectare area which is viable for NRWMF development.

2.1.3 Lyndhurst

The Lyndhurst site is located approximately 15km north-east of Kimba. The site is also close to a local township. The site offers sufficient land area for placement of a NRWMF and no easements cross the site. It has also a 100 hectare area which is viable for NRWMF development.

2.2 Site Characteristics

Site characterisation investigating the site geology, hydrogeology, geochemical properties and climatic conditions, has been undertaken for each of the three shortlisted sites.

Among other things, site geology and geohydrology determines how the sites natural characteristics determine the potential for radionuclides to migrate through the environment and provide natural barriers to further safety risks. If radiation were to be released from the NRWMF (a very unlikely scenario) migration could occur via soil to sub-surface aquifers and hence an understanding of the presence and nature of these is required in order to map potential exposure pathways and to assess likelihood.

Site geology and seismicity also informs the likely loads that might be imposed on the disposal vaults from ground movement, such as shaking, subsidence and earthquake events.

Geochemical properties are also important for understanding how the properties of the soils at the site will inhibit the potential for radionuclide migration and how they will ensure the longevity of the disposal system is not compromised in the future.

Over the very long-term, the barriers and isolation provided by the sites natural characteristics, provide the protection that ensures the safety of the surrounding environment.

The preliminary design work for the proposed NRWMF, which is not yet site specific, has taken account of the regional climatic conditions of the sites, such as rainfall, wind speed and direction and temperature variation. Risk-based standards are employed for site design to ensure that an acceptable level of risk is achieved. These standards set out expected design loads, but will be augmented with current site specific data once the preferred site is chosen. The site specific characteristics will be applied to the evaluation of all stages of the NRWMF: the construction, operational, institutional control and post-closure.

2.2.1 Site Characteristics

The following site characteristic information is provided by AECOM, which undertook preliminary analyses on behalf of the department'. If further information on specific site characteristics is required, this will be requested.

Table 1: Candidate Site Characteristics

Characteristics	Napandee	Lyndhurst	Wallerberdina
Background Radiation (in Becquerel per cubic metre – Bq/m^3)	$10Bq/m^3$	$10Bq/m^3$	$12Bq/m^3$
	Well below ARPANSA Action Levels for workplaces (1,000 Bq/m^3) and households (200 Bq/m^3)		
Climate Conditions	Annual rainfall: 348.3mm Average diurnal temperature range: 15°C Annual mean maximum temperature: 23.6°C Mean Minimum temperature: 10.3°C Mean wind Speed: 8.4km/h at 9am and 11.6km/h at 3pm.	Annual rainfall: 348.3mm Average diurnal temperature range: 15°C Annual mean maximum temperature: 23.6°C Mean Minimum: 10.3°C Mean wind Speed - 8.4km/h at 9am and 11.6km/h at 3pm.	Annual rainfall: 308.6mm Average diurnal temperature range - 15°C Annual mean maximum temperature: 25.2°C Mean Minimum: 10.7°C Mean wind Speed - 8.5km/h at 9am and 11.5km/h at 3pm.
Bushfire Risk	Vegetation on and surrounding the site (large patches of grassland and Mallee Mulga vegetation) are sufficiently distant and are unlikely to sustain a fully developed 100m wide fire front particularly if setbacks/areas of cleared vegetation are established around assets commensurate with their vulnerability to bushfire attack. There is no undue bushfire hazard.	The fuel load from vegetation (Mallee woodland directly to the northwest) does not present an undue bushfire hazard if appropriate low threat setbacks are established around assets commensurate with their vulnerability to bushfire attack and there is a provision for firefighting infrastructure.	The bushfire hazard is low and the site would only be exposed to a relatively low intensity grass or scrub fire that would not pose a significant hazard if appropriate bushfire protection measures are provided.
Soil Classification (based at this stage from literature and to be confirmed from field samples)	Soil Classification: Loam over poorly structure red clay or siliceous sand or calcareous loam over clay	Soil Classification: Loam over poorly structure red clay or siliceous sand	Soil Classification: Kandosol, Sandy Loam

Characteristics	Napandee	Lyndhurst	Wallerberdina
Sub-Surface Properties	Due to the depth to groundwater, lack of sub-surface features such as caverns, landform and slope of the site, it is unlikely that potential geohazards (such as soil liquefaction, slope instability, subsidence and long term-settlement) would occur on site. There is the possibility for collapsing soils however these can be mitigated in design (AS2870).	Due to the depth to groundwater, lack of sub-surface features such as caverns, landform and slope of the site, it is unlikely that potential geohazards (such as soil liquefaction, slope instability, subsidence and long term-settlement) would occur on site. There is the possibility for collapsing soils however these can be mitigated in design (AS2870).	Due to the depth to groundwater, lack of sub-surface features such as caverns, landform and slope of the site, it is unlikely that potential geohazards (such as soil liquefaction, slope instability, subsidence and long term-settlement) would occur on site. There is the possibility for expansive or collapsing soils however these can be mitigated in design (AS2870).
Seismic	The seismic hazard level is low based on review and interpretation of seismic data indicating with a high-level of confidence that potentially active faults in the foundation, near-surface faults beneath or near the foundation, and faults in the nearby area are not present (excluding the possibility of one-off faulting). Seismic hazards from ground shaking and deformation can be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods.	The seismic hazard level is low based on review and interpretation of seismic data indicating with a high-level of confidence that potentially active faults in the foundation, near-surface faults beneath or near the foundation, and faults in the nearby area are not present (excluding the possibility of one-off faulting). Seismic hazards from ground shaking and deformation can be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods.	The site seismic data indicates with a high-level confidence (excluding the possibility of one-off faulting) the absence of potentially active faults in the foundation, but the potential for near-surface faults beneath or near the foundation. The Western Range front faults are assumed to exist in the nearby area and further work is required to locate them. Seismic hazards from ground shaking and deformation can be mitigated through design and implementation of structural engineering measures drawn from industry standards and methods.

Characteristics	Napandee	Lyndhurst	Wallerberdina
Hydrology	There are no creek lines in the local area however drainage lines exist in the vicinity of the site and local drainage paths exist through the site. Drainage lines associated with a larger local catchment drains past the south-western corner of the site. There is no anecdotal evidence of waterlogging or runoff from localised or upstream catchments. At this stage of the assessment, any potential risks from the site hydrology are considered to be manageable, subject to flood modelling, through reasonably planned site and civil engineering works.	There are no creek lines in the local area. Drainage lines exist through the site and there is anecdotal evidence of periodic waterlogging. At this stage of the assessment, any potential risks from the site hydrology of are considered to be manageable, subject to flood modelling, through reasonably planned site and civil engineering works.	Drainage lines are present through the site. Hookina Creek passes through and outside the southern edge of Walleberdina Station, from around 3.5 km from the possible site location. A tributary of Hookina Creek is 1.5 km east of the site. Anecdotal evidence is that during the major episodic floods in 1955 and 2005 the floodwaters of Hookina Creek did not reach the site although water logging cannot be excluded. Initial flood modelling has indicated that parts of the site would be affected by certain categories of flood event. However, at this stage of the assessment, any potential risks from the site hydrology can be manageable through the civil engineering and where necessary, bunds and levees.
Groundwater	Groundwater in the water table aquifer was found to be present at depths >20 m below ground surface and as such would not impact on NRWMF buildings or their foundations. Groundwater is of no beneficial use due to its high salinity (up to that of seawater) and low yield.	Groundwater in the water table aquifer was found to be present at depths >10 m below ground surface and as such would not impact on NRWMF buildings or their foundations. Groundwater is of no beneficial use due to its high salinity (up to that of seawater) and low yield.	Groundwater in the water table aquifer was found to be present at depths >20 m below ground surface and as such would not impact on NRWMF buildings or their foundations. Groundwater is of brackish quality and reasonable yield.

2.3 Biosphere Characteristics

An understanding of the surrounding natural habitat will be acquired by studies for the three sites in order to understand potential impact of the NRWMF on flora and fauna and prepare for approvals applications under the environment protection and biodiversity and conservation (EPBC) legislation. The climate and geohydrology/

groundwater conditions have and will inform on-going risk assessments and the development of the NRWMF's safety case and physical design.

2.4 Demographic Characteristics

Demographic characteristics will provide an understanding of social and commercial environments that will surround and interact with the NRWMF. This is an important set of information in undertaking risk assessments and safety in design both in terms of refining operational and post-closure risks and mitigation strategies.

Understanding population density and distribution provides information on how local people may theoretically be impacted by the NRWMF during the operational period, institutional control period and post-closure. All three sites are well separated from sensitive land uses, being located a few kilometres to tens of kilometres away from existing residences, with a low risk of future residential development closer to the site within an area dominated by agricultural land use.

Further assessments will be undertaken once the preferred site is identified.

3 Design Safety Principles

The following safety principles will guide the design of the NRWMF:

- Justification of radiological exposures: A dedicated facility for the safe storage of ILW and disposal of LLW is required that incorporates international good practice, and improves the current ad hoc arrangements.
- Optimisation of Radiation Protection: Identification of radiological hazards will be managed through implementation of engineered controls to mitigate and reduce the risks and hazards and use of dose constraints. The principle of "as low as reasonably achievable" (ALARA) will be applied, with investigations for higher than acceptable doses, individual or collective.
- Dose Limits and Constraints: These are set following IAEA guidelines and the ARPANS Regulations (ARPANSA, Recommendations for Limiting Exposure to Ionizing Radiation, 1995).
- Defence in Depth: A hierarchy of controls achieved through design incorporating a multiple barrier approach, procedures/systems, and emergency arrangements, providing safety through diversity, redundancy in design and multiple layers of safety procedures.

The following key principles will guide nuclear safety at the NRWMF:

- No single process failure could credibly go undetected and result in significant impacts.
- The primary nuclear safety measures are passive.
- Secondary nuclear safety measures (both passive and active) are incorporated as defence in depth to further ensure safety through redundancy and diversity.
- The facility design will allow for inspection of materials subject to international safeguards convention.

3.1 Design Aspects

The safety of the public, employees, and protection of the environment in NRWMF design will be achieved through safety systems and features in the NRWMF design, including: the multi-barrier containment systems; contamination control areas; shielded ILW storage vaults; lifting devices; ventilation systems; personnel and environmental monitoring systems. These will be applied as required to the areas for waste reception, characterisation, treatment, and the waste package storage and disposal areas.

The NRWMF will comprise purpose-built structures. The designs will be built to comply with Australian standards as a minimum, and where required will meet specific nuclear hazard requirements. The designs will cater for site specific environmental conditions - including climate, geology, seismicity, flood and drainage characteristics, and ground conditions. The ILW storage buildings will provide shielding and containment.

Based on the concept design of the NRWMF, structures, systems and components (SSC) with safety critical functions, such as cranes, have been evaluated and radiation doses on failure estimated. In the preliminary assessment for the conceptual design, only the ILW store crane had a failure consequence of concern and further safety scenario analysis for this aspect is presented in Section 7.

Characteristics and quality requirements for construction materials will be specified (to meet their function) including: resistance to radiation damage; corrosion resistance; compatibility with the LLW and ILW container designs and transport container designs; and mechanical durability. The buildings and associated services (e.g. crane, electrical systems) in the NRWMF will be designed for safe decommissioning, minimising the volume and activity of any radioactive waste which requires management at the end of operations. Maintenance areas will be capable of handling significantly contaminated equipment. Out of specification waste packages will be safely stored in a quarantine area, prior to remediation.

Access controls at key locations on the site will contribute to safety and security on site.

Workplace health and safety in design will be addressed using a technique called Construction Hazard Assessment Implication Review (CHAIR) (Commission, 2001) to identify hazards and best practice for the civil works. Operational equipment will be designed to Australian Standards as a minimum, and where required meet additional requirements. Systems and items, such as cranes and lifting devices, will be appropriately designed and signed-off by experts.

The design working life has been set to 100 years for the LLW disposal vaults and 50 years for ILW storage buildings (conservative for a 30 year period for ILW storage) to align with the operational life of the NRWMF. Some operational equipment will have a shorter design life and need to be replaced during the operational period.

Designs for lab and cement grouting facilities will comply with Workplace Health and Safety (WHS) chemical safety standards. At this stage of the generic NRWMF design, the only chemicals used in notable quantities will be used for construction and for grouting, such as cement powders and additives.

The site waste systems will maximise containment, and provide for the testing of any potentially contaminated material. There will be no detectable environmental releases from normal NRWMF operations.

3.2 Codes and Standards

The principal legislation, codes and standards to be used in building the NRWMF are:

Legislation

- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, 1997
- National Radioactive Waste Management Act 2012
- Australian Radiation Protection and Nuclear Safety Act 1998
- Environment Protection and Biodiversity Conservation Act 1999
- Nuclear Non-Proliferation (Safeguards) Act 1987
- Other applicable State and Territory legislation

National regulations, codes and guides

- Environment Protection and Biodiversity Conservation Regulations 2000
- Australian Radiation Protection and Nuclear Safety Regulations, 1999
- ARPANSA, Licensing of Radioactive Waste Storage and Disposal Facilities, 2013
- National Road Transport Commission and Federal Office of Road Safety. Australian Dangerous Goods Code. 6th ed., 1998
- ARPANSA, Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002) (RPS nº 1)
- ARPANSA, Code of Practice for the Safe Transport of Radioactive Material, 2008 (RPS nº 2)
- ARPANSA, Safety Guide for the Safe Transport of Radioactive Material, 2008 (RPS nº 2.1)
- ARPANSA, National Directory for Radiation protection, 2011 (RPS nº 6)
- ARPANSA, Code of Practice for the Security of Radioactive Sources, 2007 (RPS nº 11)
- ARPANSA, Safety Guide for the Predisposal Management of Radioactive Waste, 2008 (RPS nº 16)
- ARPANSA, Safety Guide Classification of Radioactive Waste, 2010 (RPS nº 20)
- IAEA SF1 Fundamental Safety Principles (republished 2002)
- IAEA Safety Standards for Disposal of Radioactive Waste,SSR-5
- IAEA-TECDOC-1347 Consideration of external events in the design of nuclear facilities other than nuclear power plants, with emphasis on earthquakes
- IAEA-TECDOC-1250, ‘Seismic design considerations of nuclear fuel cycle facilities’, October 2001
- ASME AG-1 Code on Nuclear Air and Gas Treatment
- ISO 17873 Nuclear facilities – Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors

International recommendations

- Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. General Safety Requirements No. GSR Part 3 (Interim edition), IAEA 2011
- Classification of Radioactive Waste. General Safety Guide (GSG-1), IAEA 2009

- Predisposal Management of Radioactive Waste for protecting people and the environment. General Safety Requirements No. GSR Part 5, IAEA 2009
- Storage of Radioactive Waste. Safety Guide No. WS-G-6.1. IAEA 2006
- The Management System for Facilities and Activities. Safety Requirements No. GS-R-3. IAEA 2006
- Management of Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education. Safety Guide No. WS-G-2.7. IAEA 2005
- The Safety Case and Safety Assessment for the Disposal of Radioactive Waste for Protecting People and the Environment. Specific Safety Guide No. SSG-23, IAEA 2012
- Safety Standards Series No SSR-5 Disposal of Radioactive Waste Specific Safety Requirements, IAEA 2011
- ICRP Publication 77. Radiological Protection Policy for the Disposal of Radioactive Waste, 1997
- ICRP Publication 81. Radiation Protection Recommendations as Applied to the Disposal of Long-lived Radioactive Waste, 1998
- ICRP Publication 103. The 2007 Recommendations of the International Commission on Radiological Protection, 2007
- ICRP Publication 114. Environmental Protection: Transfer Parameters for Reference Animals and Plants, 2009

Other references

- 10 CFR 61 Licensing Requirements for Land Disposal of Radioactive Waste Nuclear Regulatory Commission (NRC)
- “Safety Assessment Methodologies for Near Surface Disposal Facilities. Results of a coordinated research project (ISAM)”. Volume 1 y 2. IAEA 2004
- Features, Events and Processes (FEP’s) for Geologic Disposal of Radioactive Waste. An International Database, Nuclear Energy Agency. OECD, Paris 2000
- Categorization of Radioactive Sources. Safety guide No. RS-G-1.9, IAEA 2005
- Dangerous Quantities of Radioactive Material (D-Values), EPR-D-Values 2006. Emergency Preparedness and Response, IAEA, August 2006
- Council Directive 99/31/EC of 26 April 1999 on the Landfill of Waste
- United Nations. Sources and Effects of Ionizing Radiation. UNSCEAR 2008 Report to the General Assembly, with Scientific Annexes Volume II: Scientific Annex E (2011)
- 10 CFR 72 "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste" (NRC)
- ANSTO WHS AS2310 ANSTO OHSE Standard - Radiation Safety
- ANSTO.WHS AG2509 ANSTO WHS Guide - Radiation Safety - Radiation and Contamination Control- Classification of Radiation and Contamination Areas, Radiation Protection

Civil Structures

- Building Code of Australia, including the National Construction Code (NCC) 2016
- AS 2243 - Safety in Laboratories
- AS 2982 - Laboratory Design and Construction
- AS 1170.4 - Earthquake Code

Mechanical Engineering

- AS 1668.2 - The Use of Ventilation and Air-conditioning in Buildings - Ventilation Design for Indoor Air Contaminant Control
- ANSTO Engineering and Technical Services - EP-07-05-09 - Active Ventilation Systems
- NVF/DG001 - Nuclear Industry Guidance - An Aid to the Design of Ventilation of Radioactive Areas
- AS 2243.8 - Safety in Laboratories - Fume Cupboards
- AS 1418 - Single failure-proof cranes
- AS1210 - Pressure Vessel Standard

Electrical Systems

- AS 3000 - Electrical Installations - Buildings, Structures and Premises
- AS 3100 - General Requirements for Electrical Equipment

Plumbing and Drainage

- AS 3500.1 - Water Supply Systems
- AS 3500.2 - Plumbing and Drainage Systems
- AS 3500.3 - Rainfall and Runoff

4 Waste Acceptance at the NRWMF

This section sets out the criteria and processes for acceptance of waste into the NRWMF. Illustrative treatment options are presented. Information about the waste container types expected to be used for packaging waste is included.

4.1 Waste Acceptance Criteria

At this early stage, generic Waste Acceptance Criteria (WAC) have been developed for LLW and ILW waste packages to aid facility design. The generic WAC criteria detail requirements with which LLW and ILW waste packages must comply to be accepted for management at the NRWMF. They form an important component of the NRWMF safety system. They are consistent with international best practice.

The WAC will be revised and further developed once a specific site is selected. The WAC will be a live document, revised and updated for the NRWMF site licensing process and throughout the site operations.

4.1.1 Physical Requirements

The waste package is the wasteform and the waste container in combination. There are requirements common to all waste packages:

- Wasteforms (the physical form of the waste following treatment/conditioning) must be physically solid and stable, non-reactive and non-flammable, and resistant to degradation.
- Containers of liquids are not accepted for management at the NRWMF.
- Wasteform volume will be minimised (through waste minimisation, before packaging during waste characterisation, and/or by volume reduction using compaction) and void spaces minimised.
- To confirm the source of waste packages and the contents, a unique waste package identifier/ barcode will be located at two separate locations on the waste container surface (ARPANSA requirements, RPS C-2).
- Waste packages to be stacked will use waste containers designed for that purpose.

There are waste type specific requirements:

- For ILW: including all disused sealed sources and safeguards material - the waste package identifier will be readable for an extended period of around 50 years.
- For ILW: including all disused sealed sources and safeguards material - container shielding can be used to comply with radiation dose requirement.
- For Safeguards material (any uranium, thorium or plutonium held in Australia subject to the Nuclear Non-Proliferation (Safeguards) Act 1987, regulated by ASNO): Australian Safeguards and Non-proliferation Office (ASNO) approval is required for conditioning - Safeguards material shall be available on request for international inspection.

4.1.2 Chemical Requirements

The WAC will require all LLW waste packages will be chemically stable and safe for disposal in the LLW vaults. Similarly, the ILW waste packages to be stored at the NRWMF will be chemically stable and safe. The WAC will require the treatment and/or limitation of chemicals with harmful properties, and will prevent dilution with non-waste material simply to meet the WAC.

The hazard categories which will be controlled are: reactive, explosive, oxidising, corrosive, chelating, chemotoxic and hazardous properties. The requirement is to make such materials passively safe (so the waste packages do not require human actions to be safe).

4.1.3 Radiological Requirements

Radioactivity in a waste is measured in Becquerel (Bq) the number of radioactive breakdowns (disintegrations) of atoms in the waste per second. This is expressed per gram weight of the waste (Bq/g) or, per square centimetre (Bq/cm^2) when the radiation is located on a surface. Radiation dose is measured in Sieverts (Sv), a unit which represents the biological effect of radiation, and is often expressed in thousandths or milli Sieverts (mSv).

The radiological requirements include common requirements for LLW and ILW waste package surface contamination ($\leq$ 4 Bq/cm^2 beta-gamma and $\leq$0.4 Bq/cm^2 alpha) to ensure surface contamination is very low.

Dose rate requirements for ILW and LLW transport packages (packages transported in the public domain may use further packaging to meet requirements) are:

- Non-exclusive use - restricted to ≤2mSv/h on surface, and ≤0.1mSv/h at 1 meter.
- Exclusive use – restricted to ≤10mSv/h on surface, and ≤0.1mSv/h at 1 meter.

Activity and dose limits are waste type specific and are provided in Table 2.

Table 2: Radioactivity limits specific waste package type

Type of waste	Radioactivity limits (based on current UK limits)	Dose limits
LLW	Radioactivity concentration not exceed 4,000 Bq/g alpha and 12,000 Bq/g beta/gamma emitting radionuclides Total package limit 4 GBq alpha or 12 GBq beta/gamma emitting radionuclides	≤2 mSv/hr at package external surface, and ≤0.1 mSv/hr at 1 metres.
ILW	Radioactivity levels greater than that for LLW, and heat generation rate of less than 2 kW/m^3	ILW in dual-purpose storage / transport containers ≤2 mSv/hr at package external surface, and ≤0.1 mSv/hr at 1 metres. ILW in to be stored in shielded vaults can have ≤100 Sv/hr at external surface. These packages are transported in shielded transport containers and unloaded and emplaced at the NRWMF
Short-lived Disused Sealed Sources	Total waste package radioactivity shall not exceed 400 GBq alpha and 1.2 TBq beta/gamma emitting radionuclides, decaying to Exemption Levels* over a 300 year period, which represents the LLW institutional control period, and so allows the safe disposal in LLW vaults. Radioactivity concentration limits do not apply to waste packages containing conditioned sealed sources. Radionuclide based total activity limits will be introduced in the Preliminary WAC.	≤2 mSv/hr at package external surface, and ≤0.1 mSv/hr at 1 metres.
Long-lived Disused Sealed Sources	Radioactivity concentration limits do not apply to packages containing long-lived sealed sources, sealed sources that will not decay to Exemption Levels over a 300 year period and so are stored and managed as ILW. The total activity shall comply with the transport classification given to the package, from the Code for the Safe Transport of Radioactive Material.	≤2 mSv/hr at package external surface, and ≤0.1 mSv/hr at 1 metres.
Safeguards Materials	Packaged Safeguards material shall meet radiological property criteria for ILW	≤2 mSv/hr at package external surface, and ≤0.1 mSv/hr at 1 metres.

*specified in Schedule 4 of the National Directory for Radiation Protection

4.1.4 Package Records

The WAC specifies that records are included for all packages, and that these are linked to a unique identifier on the surface of each waste package. The records will allow individual and collective package inventories to be identified and confirmed and compliance with regulatory requirements and safety aspects to be demonstrated. The information will be used to confirm and validate the safety assumptions used in the safety cases for the operational phase and the post closure phase. They will also allow waste packages to be tracked so that, if needed, a package can be retrieved for operational reasons.

The waste package records required are:

- the consigning organisation/person, the date of transfer from consignor to the NRWMF
- the unique ID of each waste package
- the weight of each waste package
- a description of physical, chemical, structural and biological properties for each waste package – and details of conditioning and packaging
- content of controlled substances (must be WAC compliant), description of the substances, and details of treatment
- the total activity and the reference date, the activity concentration of reportable nuclides and the reference date
- the contact dose rate and measurement date
- contamination clearance certificates showing surface contamination and measurement date
- the number of discrete disused sealed sources in the waste package - drawings and schematics of the sources, shielding and packaging material - source registration certificates / references for the sources in the package, including expired certificates or a declaration from the waste holder with the required information
- decay calculations that demonstrate whether the disused sealed source will decay to Exemption Levels within 300 years
- a nuclear safety assessment, and
- reporting information for Safeguards materials subject to Bi-Lateral Agreements.

4.1.5 Radioactive Waste Inventory

Radioactive waste is defined by the IAEA (IAEA, 1997) as 'material containing radioactivity in gaseous, liquid or solid form for which no further use is foreseen, and which is controlled as radioactive waste by a regulatory body'.

The classification of radioactive waste has been defined in international standards developed by the IAEA (IAEA, 2009). There are four general classes of radioactive waste – exempt waste (where the level of radioactivity is so low that it can be safely disposed in a normal landfill), low level waste (LLW), intermediate level waste (ILW) and high level waste (HLW). Australia does not have any high level waste, as spent reactor fuel is reprocessed abroad (and the resulting vitrified waste is classed as ILW). The inventory comprises best estimates of LLW and ILW and also includes waste/disused sealed sources. Disused sealed sources are classified into: short-lived disused sealed sources (safe for disposal with LLW); and long-lived disused sealed sources (which will be stored with ILW). The inventory also includes Safeguards material which will be stored with ILW.

An Australian Common National Inventory of Radioactive Waste (CNIRW – used to derive Table 3) is being developed as a consolidated database of all radioactive waste that requires management at the NRWMF. The inventory will be updated regularly to incorporate further information about the waste streams, such as the outcome of waste minimisation work and the choice of final waste treatment and waste packaging. The following table provides estimates of LLW for disposal and ILW for storage.

Table 3: Waste Inventory – legacy and future.

Waste types	Legacy (m^3)	Future (m^3)	Total (m^3)
ILW for storage (cubic metres – m^3)	1772	1920	3692
LLW for disposal (cubic metres – m^3)	4976	4886	9862

The waste streams making up the inventory can comprise a range of materials and items including general lab waste (paper and plastic and metal), decommissioning materials (rubble and metallic items), contaminated soils (such as those stored by CSIRO), contaminated ion exchange resins, liquid wastes from nuclear medicine production (planned to be turned into Synroc, a synthetic rock), solid waste from nuclear medicine processes (SUF Cup wastes) and waste radioactive sources (disused sealed sources in shielded containers).

4.2 Waste Treatment

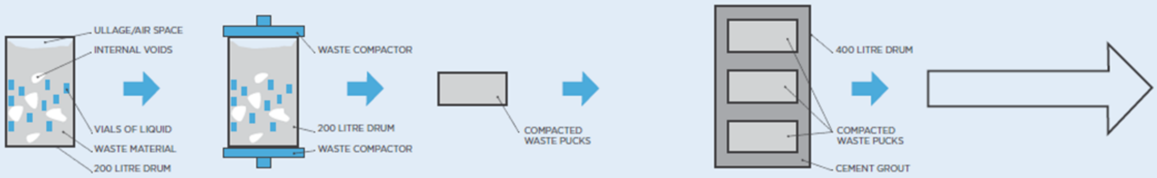
All wastes will be packaged and/or treated (conditioned) to meet the WAC. Potential ways of treating waste material to make it solid and non-dispersible, and meet the WAC, include:

- Thermal treatment of waste: For instance drying liquid or wet wastes to make them solid, then thermally treating them with additives to make them stable and fully WAC compliant. This is how ANSTO will transform the liquid ILW waste from nuclear medicine production to a stable solid Synroc wasteform. The Synroc wasteform is illustrated in Figure 2. Another example is vitrification of waste. When spent Opal reactor fuel is reprocessed the waste, left after the uranium is removed, is mixed with molten glass and poured into a stainless steel container resulting in a stable solid waste package (with the waste packages stored in TN-81's). The TN-81 containing vitrified waste packages currently stored at ANSTO is pictured in Figure 3.
- Immobilisation of waste in cement: Cement technology is well understood and widely used for radioactive waste conditioning. Waste is incorporated into a solid cement wasteform in a container (a steel drum or steel box). Cementing also treats a wide range of unwanted chemical properties (e.g. corrosive, flammable and reactive materials). It locks-in trace liquid and hazardous chemicals, so that the cemented waste packages then meet the WAC. For example ANSTO propose to treat the LLW general and laboratory waste (paper, plastic and metal objects) by crushing/compacting LLW wastes in drums, then cementing the pucks into another drum for disposal in the vaults. This treatment is illustrated in Figure 4.
- Sealing waste into robust sealed containers, often comprising multiple layers of containment, can also be a very effective way of packaging wastes, especially for storage. This method is often used for long-lived sealed sources.

Figure 2: Waste in Synroc can pre-treatment and cutaway showing processed Synroc

Figure 3: TN-81 at ANSTO containing vitrified ILW

Figure 4: Compaction and cementing of LLW general and laboratory waste



Step 1

Low level waste (LLW), in 200 litre metal drum, contains vials of liquid and air pockets.

Drum is scanned to determine the composition, sampled to confirm chemical properties and LLW status confirmed.

Step 2

Waste material and drum compacted in a super-compactor.

Step 3

Compacted waste now has no voids and free liquids have been squeezed out.

Waste is now solid.

Step 4

Waste pucks are cemented into a 400 litre drum.

Step 5

Waste packages are transported to the National Radioactive Waste Management Facility.

4.3 Waste Acceptance Process

Waste will only be accepted at the NRWMF if it meets all the conditions and criteria specified in the WAC.

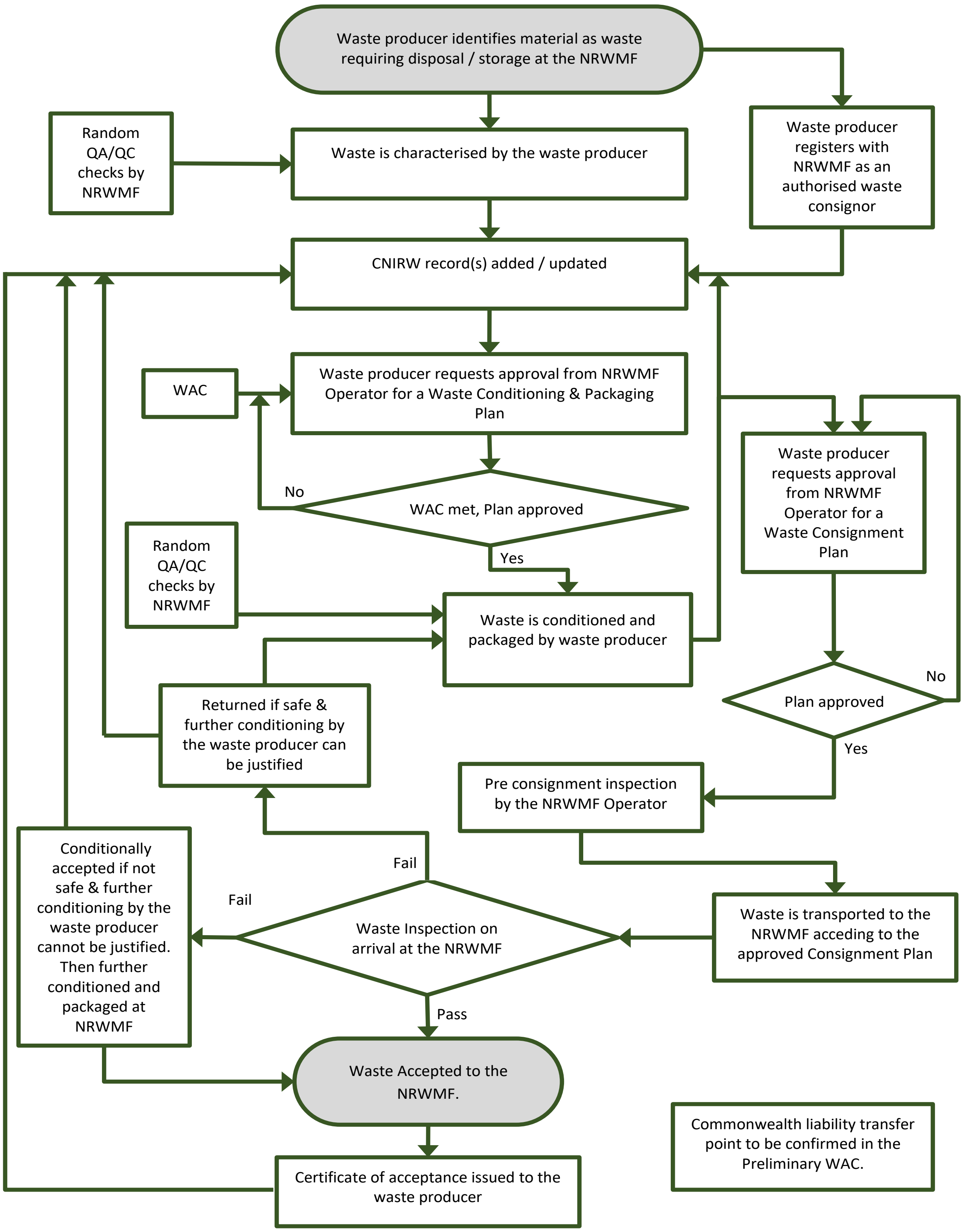
The waste acceptance procedure will ensure that:

- assessment starts at the time the waste producer develops options for waste treatment of a waste or waste stream,

- wastes are fully characterised and the chemical and other properties fully understood to aid the development of treatment options
- treatment and packaging processes are developed for all the CNIRW waste inventory
- the 'green light' is only given if the treatment process produces waste packages of consistent quality that meet the WAC (and so considered suitable for management at the NRWMF) — this will apply to all waste streams whether treated/packaged by the waste producer or at the NRWMF, and
- the waste treatment processes will be audited regularly to ensure the ongoing production of waste packages continues to meet quality criteria and the WAC.

A flow chart of the waste acceptance process is provided in Figure 5, on the following page.

Figure 5: Waste Acceptance Process flow diagram.



4.4 Waste Containers

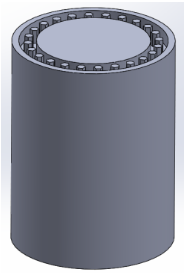
The following tables summarise the range of waste containers to be used for disposal of LLW and storage of ILW at the NRWMF. The information presented here will be updated when the preliminary WAC document is developed.

Table 4: Approved LLW - Containers

Container code	Description	Material of construction	Acceptable waste types (refer to the WAC)	Dimensions (mm)		Internal volume (L)	Package Gross Weight Limit (kg)	Shielding provided by container
				External	Internal			
LL200 	200 L drum – mild steel	Mild steel, min 1.15 mm wall thickness	✓ LLW ✓ Short-lived sealed sources	H: 890±5 D: 615±5	H: 875±5 D: 605±5	205	350	No
LL400 	400 L drum – mild steel	Mild steel, min 1.3 mm wall thickness	✓ LLW ✓ Short-lived sealed sources	H: 1060±5 D: 830±5	H: 950±5 D: 650±5	400	1500	No
LL15000 	Half-height ISO freight container/ rack concept	Mild steel as per ISO standard	✓ LLW ✓ Contaminated soil ✓ Decommissioning LLW	H: 1320±25 L: 6095±25 W: 2440±25	H: 1100±25 L: 5900±25 W: 2350±25	15,250	30,480	No

Table 5: Approved ILW – Containers

Container code	Description	Material of construction	Acceptable waste types (refer to the WAC)	Dimensions (mm) External	Dimensions (mm) Internal	Internal volume (L)	Package Gross Weight Limit (kg)	Shielding provided by container
IL14+.5* 	SUF Cup storage vessel	Stainless steel	✓ Safeguards material ✓ Long-lived Sealed Sources	H: 1160 ±10 D: 135±2	H: 1050±10 D: 130±2	14.5L	35	No Note: This waste container requires further packaging to allow safe transport and storage
IL200 	200 L drum – stainless steel	Stainless steel, min 1.15 mm wall thickness	✓ ILW ✓ Long-lived sealed sources ✓ Safeguards material	H: 890±5 D: 615±5	H: 875±5 D: 605±5	200	350	No

IL400 	400 L drum – stainless steel	Stainless steel, min 1.5 mm wall thickness	✓ ILW ✓ Long-lived sealed sources ✓ Safeguards material	H: 1060±5 D : 830±5	H: 1060±5 D: 790±5	400	1,500	No
IL600 	Cylindrical ILW transport cask	Forged steel or ductile cast iron.	✓ ILW ✓ Long-lived Sealed Sources ✓ Synroc cans	H: 1860±10 D: 1060±10	H: 1400±10 D: 750±10	600	12,000	Yes
IL7000	7m self-shielded ILW box	Ductile cast iron 120mm thickness	✓ ILW ✓ Long-lived Sealed Sources ✓ Decommissioning ILW	H: 2200±25 W: 1970±25 L: 2440±25	H: 1960±25 W: 1730±25 L: 2200±25	7,000	35,000	Yes
TN-81 	TN-81	Forged steel	✓ CSD-U or CSD-V canisters (spent fuel reprocessing waste immobilised in glass)	H: 7215±25 D :2750±25	H: 5180±25 D: 1350±25	20 -28 x CSD-U/V (170L) canisters	114,000	Yes

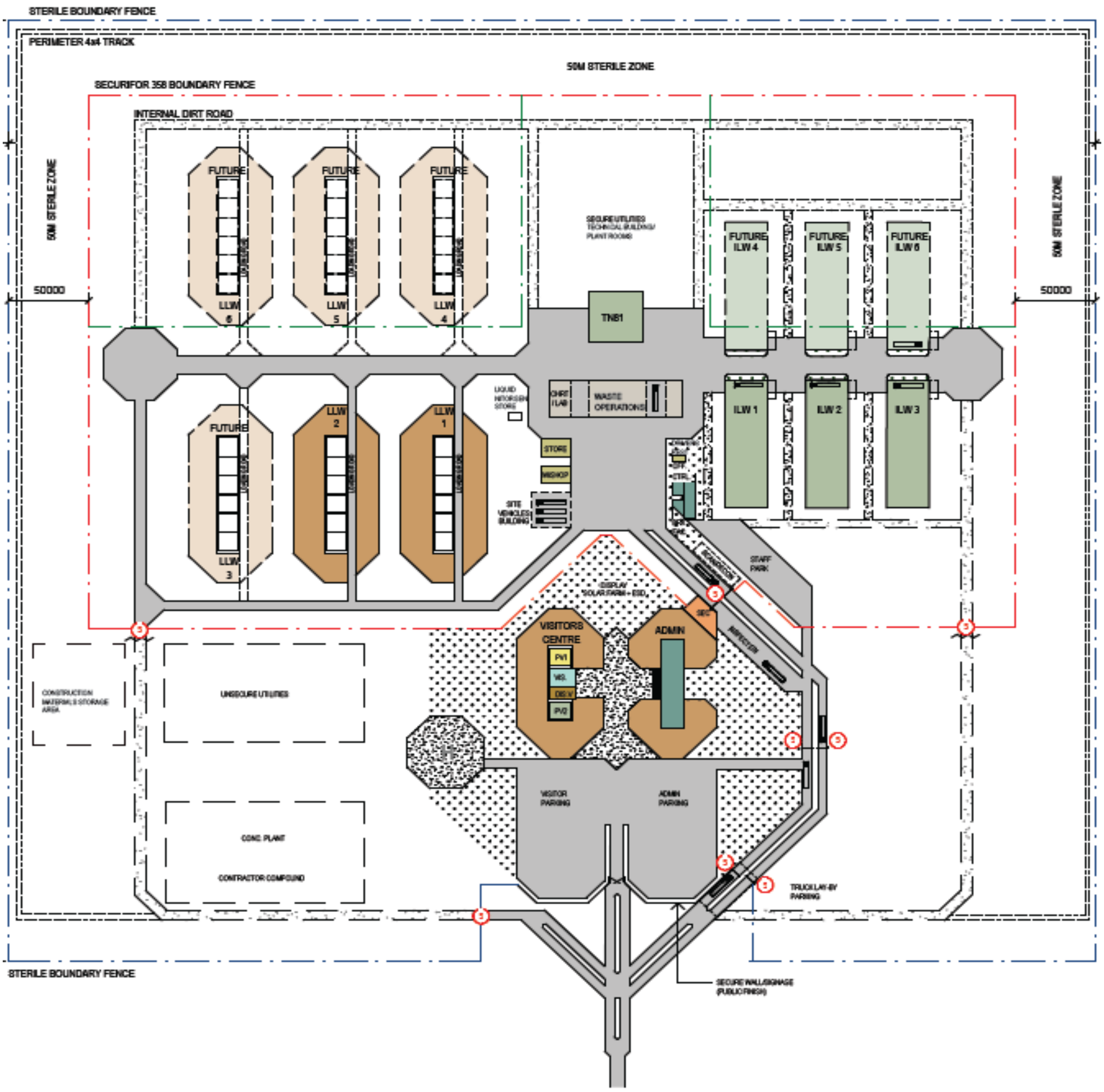
5 NRWMF Description

This section describes NRWMF plant and equipment, safety related systems, and process and maintenance operations.

The site layout for the NRWMF will have the following three specific areas/zones:

1. The Buffer Zone, 100 Ha of land comprising the overall NRWMF footprint.
2. The Sterile Zone, a fenced area of 40 Ha within the Buffer Zone.
3. The Active/Secure Zone within the Sterile Zone, a secured fenced area of 20 Ha where the operational parts of the NRWMF will be located; the preliminary layout is illustrated in Figure 6.

Figure 6: Preliminary Site Layout



The NRWMF will be surrounded by a series of security fences. External personnel, workers and vehicles access the site at a single control point in the sterile boundary fenced area. Further control points within the NRWMF achieve separation of LLW and ILW management. This conceptual layout allows for the separation of radioactive waste package transport from public access, while optimizing NRWMF operation.

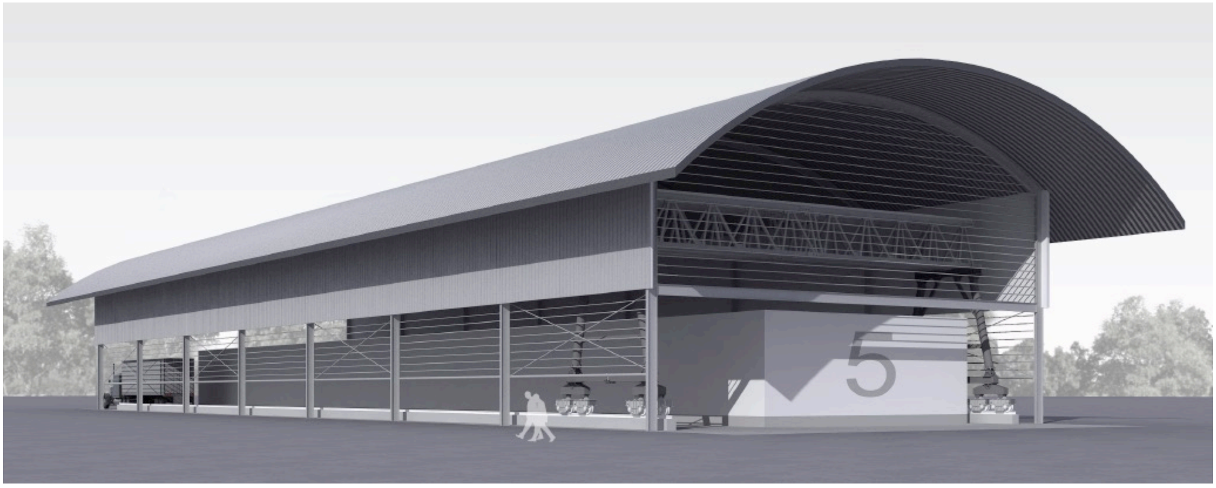
A staged construction plan has been proposed for the NRWMF. Not all the LLW disposal vaults and ILW buildings will be constructed before the NRWMF becomes operational, and further construction of site structures will be flexible to meet demand. The layout allows that different stages of construction will not interfere with operations.

The ILW storage area is located separately from the LLW disposal vaults zone. This will facilitate separation of operations and vehicular movements by waste types, and control the occupational radiation dose.

5.1 LLW Disposal Vaults

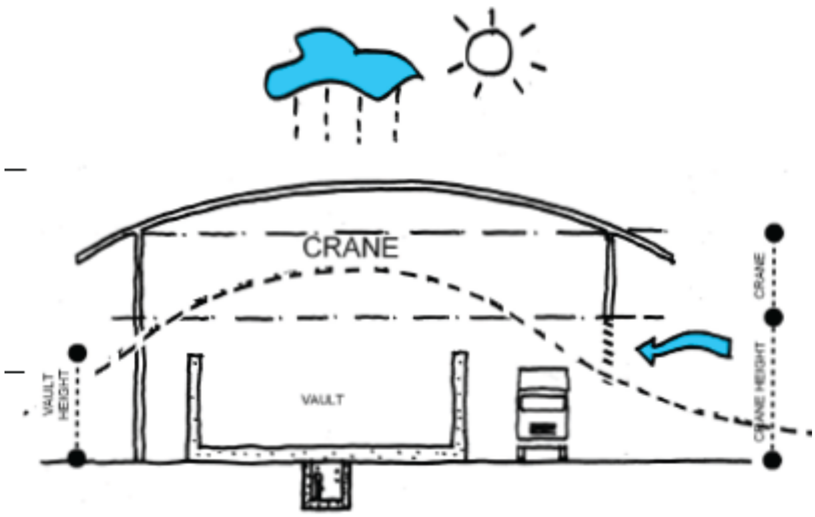
The NRWMF LLW disposal vaults will be built above ground level and aligned in order to optimise operational efficiency and reduce surface footprint. Overall vault capacity will be sufficient to allow contingency to allow for slight changes to the LLW disposal volume and/or future waste inventory. The following figure illustrates the current concept for a LLW disposal vault with weather protective roof.

Figure 7: LLW Vault (and roof)



The LLW vaults will be constructed on a level surface with sufficient space for access roads to each block of vaults for transport/delivery trucks. Vaults are to be filled from one side. The access road will facilitate access for future maintenance and surveillance. This is illustrated in the following figure.

Figure 8: Diagram of cutaway of LLW vault during operations



The following photograph is of similar (but not identical) modular LLW disposal vaults, provided to illustrate operational stages from construction to vault closure.

Figure 9: Modular LLW vaults (Andra in France) showing vault life cycle during operations

The main objective of the disposal vaults is retention and isolation of waste packages and radioactivity from the environment and from people until the radioactivity in the waste reduces/decays to an acceptable level. They comprise part of the multi-barrier system assessed in Section 0.

During the operational phase LLW disposal vaults are filled with waste packages and then gaps are filled using a suitable clean material. An engineered concrete closure slab is then put in place to cover the vault and make it weather proof. At a suitable time (during the operational phase), the vaults will be covered by a multi-layer protective long-term cover or cap (Section 5.1.3) to form a suitable landform. Inspection of the closed vaults and monitoring of the environmental will be undertaken throughout the 300 year institutional control phase.

The design intent of the LLW disposal vault is that at the end of the post-closure phase, the dose rate on top of the final landform will be indistinguishable from that of the background dose rate in the area.

5.1.1 Drainage Network

The vault drainage control network is designed to:

- monitor the behaviour of the vaults
- remove of any rainwater collected before vault operations
- collect, and remove to a waste-water control tank, any water from vaults during operations, and
- allow the sampling of any water collected from the LLW vaults.

There will also be a deep drainage network which will prevent water outside the vault migrating in.

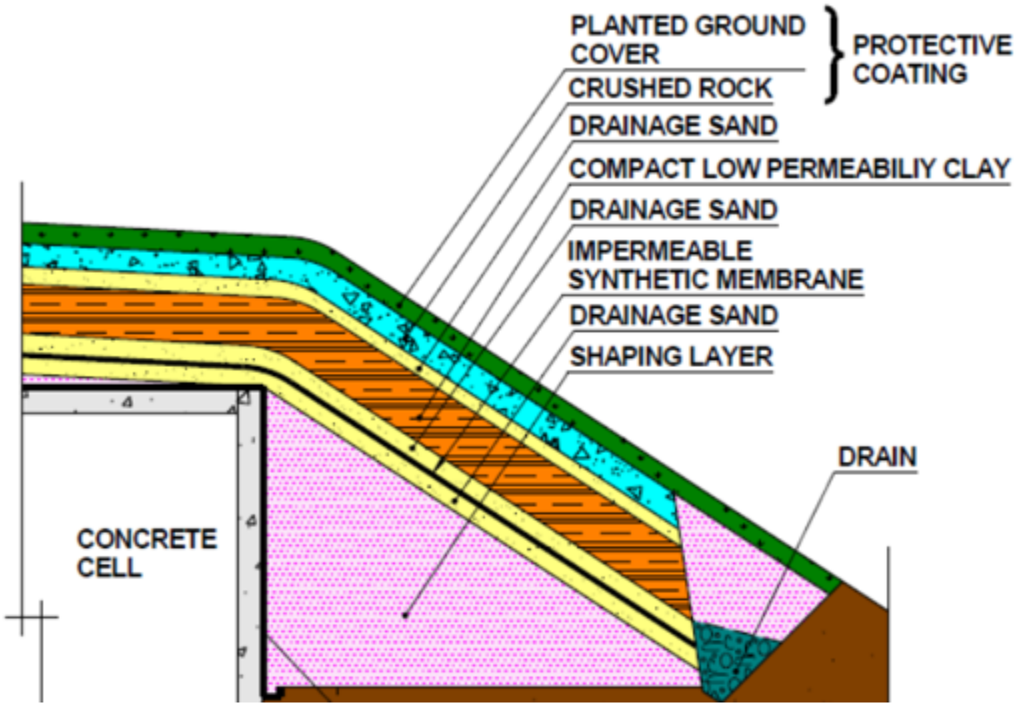
5.1.2 LLW Vault Long-term Cover

The disposal vaults, once filled and closed, will be protected from the environment by a multi-layer engineered earth cover, which will remain stable and provide very low permeability to limit infiltration of water. The cover will be functional at least throughout the ICP of 300 years. A generic design for the long term cover was developed by ENRESA in 2013 and is used as a preliminary working model for the NRWMF. The actual cover design will be informed by the experimental cover used for the pilot vault(s) that form part of the visitor centre. To ensure that closed vaults are properly protected in the interim period while the pilot vault studies are running, temporary protective cover will be used.

Protection from rainfall, wind, temperature changes, erosion and from unplanned intrusion, is provided by through the superimposition of many engineered layers. A typical conceptual multilayer cover (see Figure 10) would include the following components, from the inside to the outside:

- A shaping layer, using excavation material, to provide adequate slopes.
- A layer of drainage sand which also provides to the membrane support.
- A very low permeability synthetic membrane.
- Another layer of drainage sand.
- A layer of compacted low permeability clay.
- A layer of drainage sand.
- A protective layer of crushed rock and planted ground cover.

Figure 10: Typical multi-layer long term cover (ENRESA).



5.2 ILW Storage Area

The reception of ILW and safeguarded nuclear material occurs in the ILW storage buildings. These buildings will be specifically designed to provide the following capacity:

Vitrified Waste Store: for safe storage of vitrified waste from the reprocessing of ANSTO's used research reactor fuel. Space for five (5) TN81 casks placed directly on the floor in vertical orientation. The foundation slab must be made of reinforced concrete, with load strength calculated to support at least the weight of five TN-81 casks at 120 t each. An overhead building crane will be used: dangerous goods rated (DGR), with mechanical and electrical safety systems designed to ensure the safety of the handling operations (including interlocks to avoid dropping the load, overload protection, redundant electro-hydraulic brakes in the lift mechanism, over-speed protection). A fail safe mode will be designed so that the brakes are activated on power loss to result in controlled lowering.

Nuclear Materials Store: for shielded and unshielded nuclear materials. Some will be stored in 200L drums and some stored in specially designed and shielded stacking racks. Safeguarded material requires a secured storage area with security provisions that comply with ASNO requirements. These waste packages must be retrievable during storage to allow for independent safeguards verification by ASNO and IAEA Inspectors.

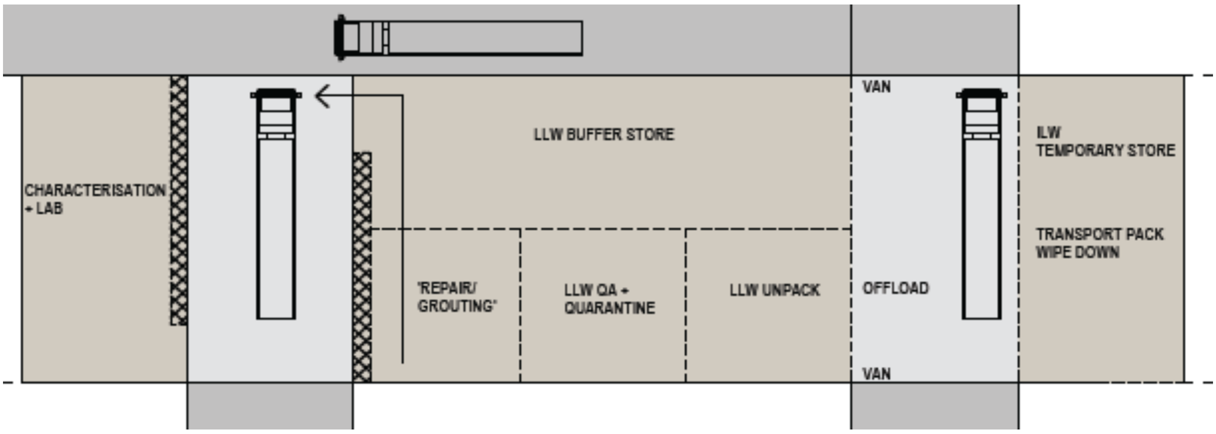
Unshielded ILW Store: for reception and interim storage of ILW waste packages which do not require any extra shielding or are already in suitable overpacks. Waste packages will be stored on the floor, and/or stacked according to container type and waste characteristics. The layout will provide open corridors between stacks to allow visual inspection and safe access.

Shielded store: for reception and interim storage of higher dose/ higher activity packages. Waste packages will be stored in shielded vaults or channels. Packages will be handled using a remotely controlled overhead DGR rated crane to ensure that worker radiation dose is ALARA. The crane has mechanical and electrical safety systems designed to ensure that safe handling operations is achieved (as for the TN81 store crane).

5.3 Waste Reception Building

Layout of a waste reception area is illustrated in the following figure. An operator will verify that all waste packages arriving at the NRWMF comprise the consignment expected and comply with the WAC. This process will include an inspection of the consignment and relevant documentation. A radiological survey of contamination will then be undertaken by a health physics surveyor (HPS) to confirm the packages are clean. LLW packages will then be off loaded from the incoming truck. ILW packages will be sent forward for controlled management by staff in the ILW storage buildings.

Figure 11: Waste reception building layout



The waste reception building has the following areas

- ILW temporary storage area for transport containers.
- LLW buffer storage area.
- QA check area for all types of waste package.
- Quarantine area for LLW (ILW quarantine will occur in a designated ILW building.
- Transport overpack set down area.
- And a specified vehicle entry route to prevent mix-up of waste types.

A DGR overhead crane or a stacker truck, as well as other site vehicles, will be utilised along specified vehicle routes to allow movement of packages within the site.

5.3.1 Characterisation Laboratory

The characterisation laboratory will contain the equipment required for QA sample analysis and selected waste packages received for testing, such as gamma scanners. This will ensure that NRWMF can undertake confirmatory tests and fully control what is stored and disposed of on site. This laboratory will also test effluent samples from the site drainage network to confirm that there is no contamination of waste produced on site.

5.3.2 Conditioning Facility

The conditioning facility will provide a limited capacity to rectify some waste packages that do not meet the WAC (but can do so with minimal remedial treatment), or provide additional grout to finalise packages prior to disposal. Limited conditioning might include:

- Grouting and finishing off (to fill void spaces);
- Over-Packaging;
- Transfer of a waste package to an overpack.

5.4 Other Active-zone Buildings

Maintenance buildings and Stores for operational equipment and materials will be located in the operational area.

5.5 Visitor Centre

A visitor centre designed for up to a busload of visitor will be located near to the Admin building. Two pilot disposal vault will be constructed as part of this design which will allow visitors to look at the disposal design at close hand. The following two figures provide a conceptual illustrations.

Figure 12: General look of pilot vault

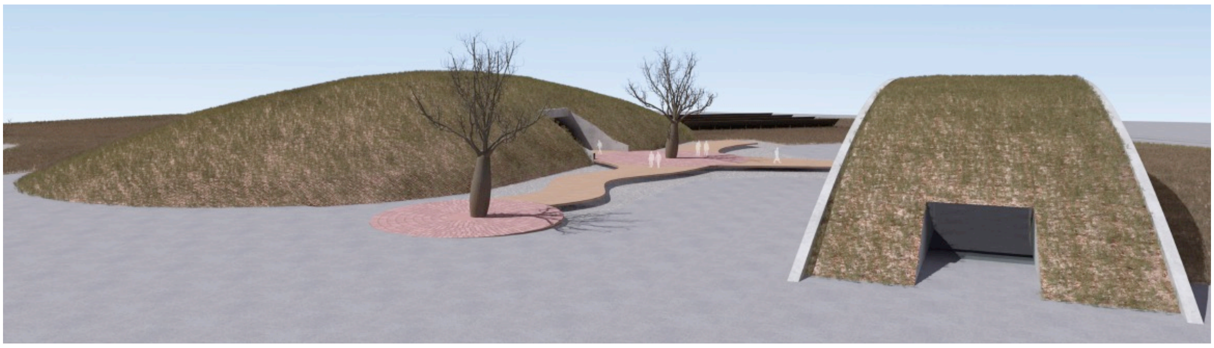
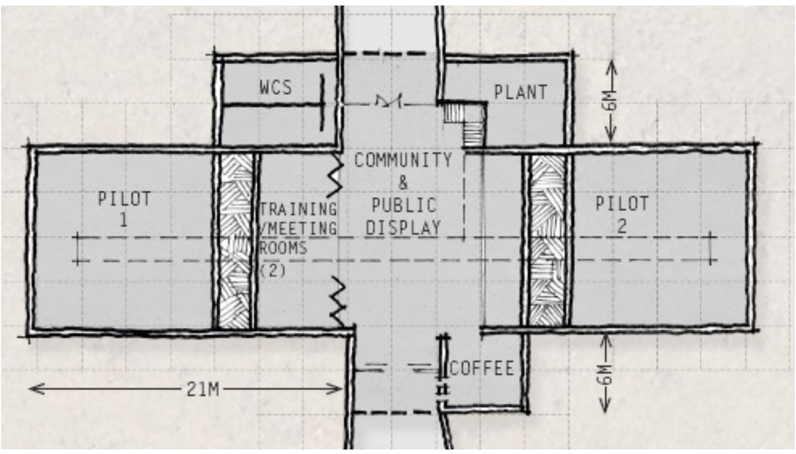


Figure 13: Layout of visitor centre



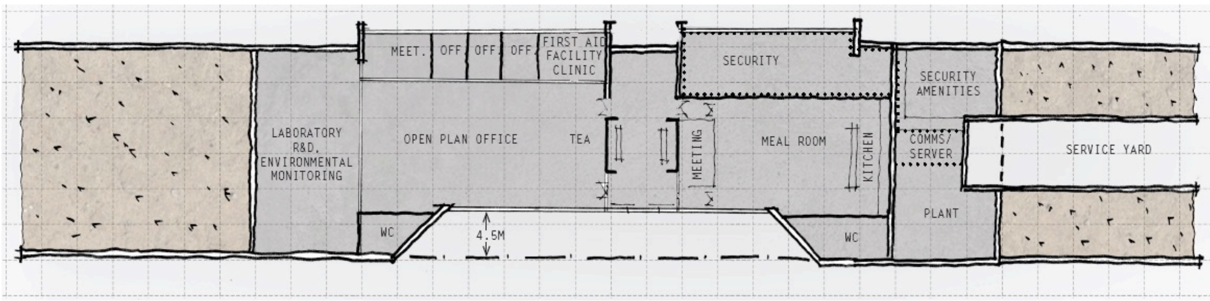
It is envisaged that the two pilot vaults will have the same design features as the LLW disposal vaults but with variant engineered capping options which can be tested for effectiveness. The pilot vaults will not contain radioactive waste. Instead, they will contain packages of inactive material to simulate the presence of waste packages.

The data gathered from the pilot vaults will inform the long-term cover design, which will be implemented prior to commencement of the 300 year institutional control phase.

5.6 Administration Building

The administration building (illustrated in the next figure) will be located in the sterile zone near to the visitors centre. The building houses administrative offices, meeting rooms, first aid, security, environmental monitoring and a laboratory for studying the behaviour of the pilot disposal vaults and environmental samples. Waste package records and monitoring records will be kept here (further copies of waste package records will be kept at a secure off-site location to be determined). The administration building is designed as generally open plan. There will be separate security functional areas and plant rooms.

Figure 14: layout of the Administration Building



There will be a main control area containing centralised monitoring and control functions for major systems, such as alarms from the following systems:

- Water Collection System.
- Radiation Monitoring System.
- Ventilation and Air Conditioning System.
- Fire Protection System.
- On site and off site alarms.

5.7 Support Plant and Services

The LLW disposal vaults and ILW storage building will be naturally ventilated unless otherwise indicated. The conditioning facility within the waste reception/operations area will have its own local ventilation system to prevent emissions when undertaking conditioning work.

The NRWMF will be supplied by commercial power and there will also be standby power supply which will use a diesel generator. When the site power supply fails all identified safety systems will be supported by the standby power system. Where appropriate, uninterruptible power supply (UPS) units will be used for instance for IT systems, radiation monitors, and control panels. The routine inspection and maintenance of the UPS units and diesel generator will be part of the preventative maintenance schedule for the NRWMF.

The objectives of the water supply system are to:

- conserve water through selection of water efficient design and components
- provide water for amenities (showers, toilets, sinks), and
- provide an industrial source of water, if grout/cement manufacture is required.

The trade waste system will collect any water which has come into contact with industrial processes. This will include any drainage from potential contamination areas (including showers and monitoring areas). The system will have capacity to collect, sample, and retain/store while the analysis is taking place. The trade wastes will be captured, retained and tested, and treated or sent off-site for treatment. If clean they may be reused on site to supplement process water as a water conservation measure.

Non-active drainage and toilet wastes will be handled through a 'non-active' drainage system. The majority of liquid wastes (from amenities) will be diverted to the sewage system for on-site treatment and then discharged from the site.

The site public address system will be installed throughout the NRWMF. Telephones will be located throughout and there will also be a local intercom system connecting high-use work areas. There will be closed circuit television cameras (CCTV) for operational use, to allow visual confirmation of operations in other areas of the NRWMF, and for additional security monitoring.

Dangerous goods rated (DGR) cranes may be used across the NRWMF for:

- lifting and storage of ILW within the ILW storage areas
- lifting and disposal of LLW within the LLW disposal vaults
- operations within the Waste Reception Area, including temporary storage in the buffer store for LLW and ILWs, and
- lifting and storage of TN-81 casks.

5.8 Radiation Monitoring

The following will be key features of the radiation monitoring system:

- All radiation workers will wear approved personal dosimetry. They also wear electronic personal dosimeters (EPDs) when they are in classified radiation areas.
- Hand and foot monitors for personal contamination monitoring and walk though monitors.
- Portable hand-held radiation monitors will be available, radiation monitors for alarms preventing accidental radiation exposure to personnel.
- Alpha / beta counters (beta castle) will be installed in selected locations in the NRWMF.
- Fixed area dose rate radiation monitors and air samplers are located in the operating areas at locations agreed with the radiation protection adviser (RPA) to indicate the radiation levels in selected locations in the NRWMF.
- A radiation air sampler monitoring system (RASM) will be used to sample for airborne radioactive contamination in selected locations in the NRWMF. This system will alarm to the main site system.
- Real time monitoring on the supervisory control and data acquisition (SCADA) system will be used for all area radiation monitors, air samplers and process radiation monitors (monitoring pipes, ducts and filters).
- Equipment and facilities for detection and removal of personal contamination will be located at the exit barrier of the controlled area.
- Radiation monitors will form part of a safety interlock system designed to prevent worker exposure.

All alarms and radiation monitors will be displayed on screens located throughout the NRWMF. Final placement and alarm set points will be confirmed by the radiation protection adviser (RPA) during hot commissioning of the NRWMF.

6 Safety Management

This section briefly outlines the safety management system and local specific arrangements that will apply to the NRWMF. It covers the NRWMF safety practices, considers their extent and implementation, and details where safety management responsibilities lie.

NRWMF is subject to the following key Acts:

- National Radioactive Waste Management Act 2012.
- Australian Radiation Protection and Nuclear Safety (ARPANS) Act 1998.
- Environmental Protection and Biodiversity Conservation (EPBC) Act 1999.
- Work Health and Safety Act (WHS) Act 2011 – Commonwealth.
- Nuclear Non-Proliferation (Safeguards) Act 1987.

6.1 Safety Policy

A Work Health, Safety and Environment Policy will be developed, which will commit the NRWMF operator to undertake its work activities in a manner that:

- places the protection of human health and safety and security and the environment as its highest priority
- promotes a positive safety culture and environmental awareness throughout all levels of the organisation
- strives for continual improvement in safe work practices, reducing environmental impact and prevent pollution
- empowers its people regarding ownership of safety, and
- facilitates continual learning from experience, both its own and others.

6.2 Management System

An appropriate Management System, similar to the ANSTO system, will be developed for the NRWMF. This will ensure that an excellent standard of operational performance, required for a facility managing radioactivity, is maintained through a certified management system. This will deliver worker health and safety, protection of the local communities and protection of the environment. The system should be certified to the following standards:

- ISO 9001 Quality management system.
- ISO 14001 Environmental management system.
- OHSAS 18001 Health and safety management system.
- PAS 99 Integrated management system.

Central to the management system will be the Health, Safety, Quality and Environment Policy statement and objectives. These will be documented during operational readiness planning for the NRWMF.

The management system will provide a framework that considers the needs of the business and the impact of business activities on the workforce, neighbours and the environment. Risk assessments will be conducted for all operational activities to ensure adequate operational control procedures have been developed and implemented.

Operational limits and conditions (OLCs) will be developed that form part of the ARPANSA licence comprising; instructions, procedures and managerial limits to ensure compliance. The limits will have a safety margin and define the boundaries of what will be referred to as the “Safe Operating Envelope” for each licensed part of the NRWMF.

Non-radiological workplace health and safety (WHS) will be managed through a NRWMF Safety Management Regime to meet the requirements of the Commonwealth Work, Health and Safety Act 2011 and Regulations. It will help management to establish a framework to protect workers and other persons against harm to their health, safety and welfare through the reduction of risks arising from work. The Commonwealth Regulator (i.e., Comcare) will oversee the implementation of the safety management regime at the site.

Environmental monitoring throughout the operational phase and ICP will include: inspection of the infiltration tunnel and sample collection from underneath the vaults; collection of soil samples, surface water, vegetation samples, and borehole samples.

6.3 LLW Operations

The following arrangements will be incorporated into the operational management system specific to LLW disposal:

- A radiation protection plan and risk assessment, required for a licensed facility, which will be prepared by the site radiation protection advisor.
- Arrangements for implementing the waste acceptance procedure
- Procedures for quarantine of any non-compliant waste packages.
- Procedures for control of employee dose monitoring and for routine and periodic health surveillance monitoring for contamination and exposure.

6.4 Emergency Arrangements

While a radiological emergency is highly unlikely, the site will have an emergency plan which will from time to time be tested. This will including emergency response arrangements to events such as:

- accident (fault) scenarios, e.g. fire, dropped load
- contamination discovery
- non-compliant load
- dose above threshold discovery
- potentially contaminated person
- injury to persons on site, and
- external events requiring emergency actions, such as if consignments are unable to reach the site entrance.

In order to minimise risks from a radiological emergency, arrangements will be put in place to protect staff, the public and the natural environment. These arrangements include:

- emergency sheltering on and off-site
- remedial actions such as investigations/monitoring, and
- decontamination/clean-up on site and similar actions for off-site impacts.

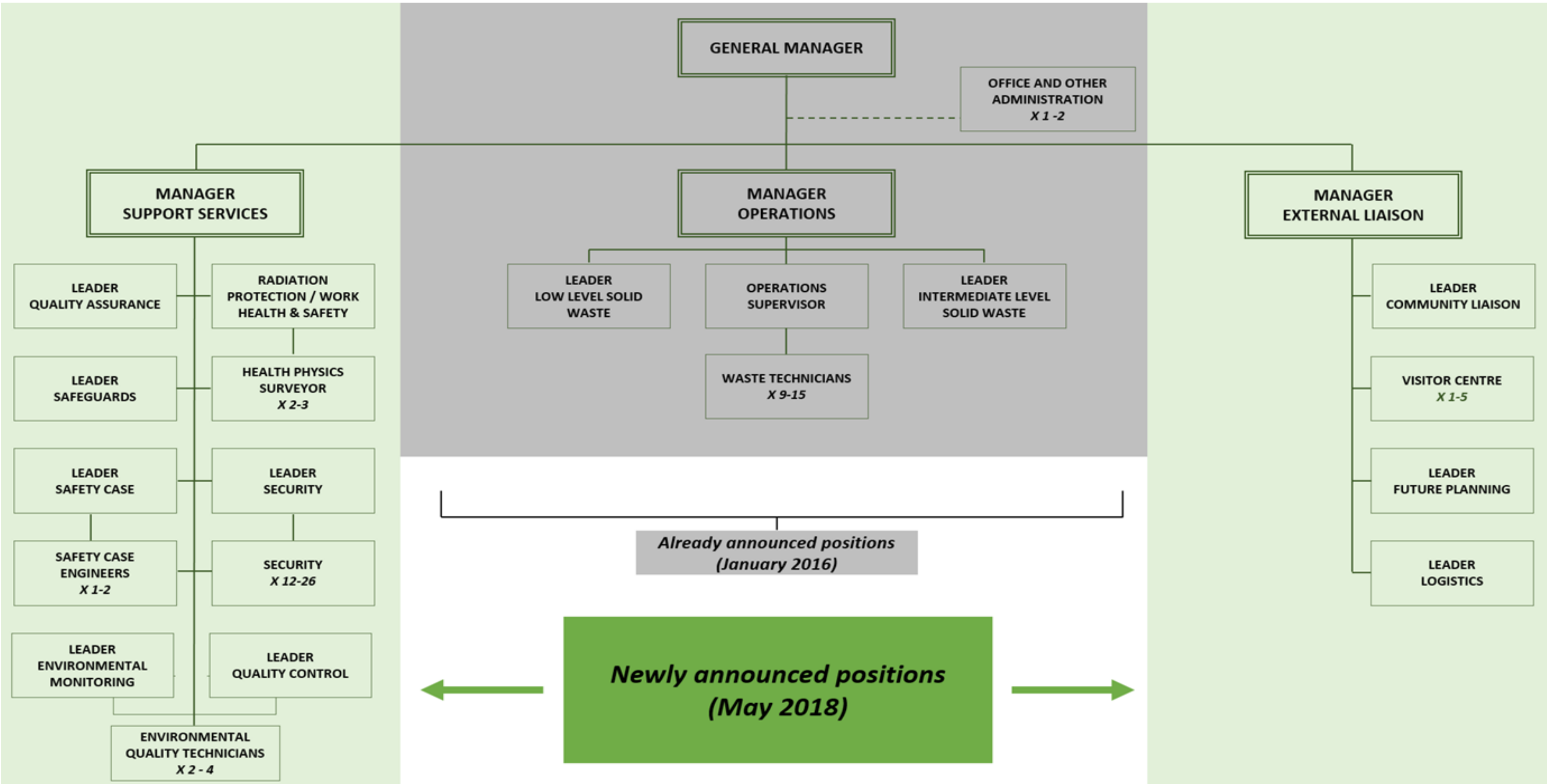
6.5 Management Structure and Responsibilities

6.5.1 Management Structure

The proposed management structure which will be in place to safely manage the operation of the NRWMF is briefly presented below and will be further described during detailed design. All roles will include responsibility for aspects of safety management. A strong safety culture would be established at the NRWMF with full commitment from the senior management.

The proposed organisational chart is outlined in the diagram on the following page.

Figure 15: Proposed NRWMF Organisational Chart (preliminary)



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6.6 Control of Hazards

6.6.1 Radiological Hazards

Staff will be trained and understand the hazards arising from the handling of radioactive materials. There will be protective systems described in the NRWMF WHS Management System on how to operate effectively and safely. Staff will be 'suitable qualified and experienced' (SQEP) and will be provided with regular training and assessment. Experience will be gained by training staff at the existing waste management facility in ANSTO and through practice during the NRWMF commissioning phases.

The control of potential radiological hazards is managed through a range of engineered and administrative controls. Table 6 sets out the hazards and controls planned for the NRWMF.

Table 6: Radiological Hazards and Controls

Radiological Hazard	Controls
Exposure to radiation and potential contamination during transport	▪ Specially designed shielded transport waste containers/ flask for shipping ▪ Use of remotely operated lifting equipment (i.e. Cranes) move waste containers ▪ Electronic Personal Dosimetry ▪ Standard Operating Procedures (including designation of Operating Limits and Conditions) ▪ Routine Health Physics assurance surveys
Radiation and contamination hazard due to waste handling	▪ Shielded waste containers ▪ Waste handling procedures ▪ Electronic Personal Dosimetry ▪ Routine Health Physics assurance surveys ▪ Continuous air monitoring ▪ Area radiation monitoring ▪ Suitably qualified and experienced personnel
General radiation and contamination.	▪ Radiation protection training ▪ Area radiation dose rate monitors ▪ Electronic Personal Dosimeters ▪ PPE ▪ Fixed and portable contamination monitors ▪ Hand and foot exit contamination monitor ▪ Emergency response arrangements
Radiation and contamination hazard during routine maintenance tasks	▪ Maintenance procedures ▪ Electronic Personal Dosimetry ▪ Routine health physics assurance surveys ▪ Continuous air monitoring ▪ Area radiation monitoring
Potential of build-up of gases and release to atmosphere (if applicable)	▪ Area radiation monitoring equipment including air sampling ▪ Continuous recording of gases released to atmosphere via the stack ▪ Filtration

6.6.2 Chemical and Bio- Hazards

There will be no bio-hazards within the NRWMF. Biological, pathogenic or infectious materials shall be treated to eliminate these hazards and comply with the WAC before waste packages are consigned to the NRWMF.

A dangerous goods (DG) review will be performed during the NRWMF detailed design to identify chemical storage requirements (if any) and to ensure conformance with the WHS Chemical Safety Standard. Dependent on the hazard posed from the chemical being used or handled, operators will follow the relevant procedures and will be equipped with appropriate personal protective equipment (PPE).

The general locations, types and protective measures are presented in the following table:

Table 7: Chemical Hazards and Controls

Chemicals	Controls
Hazardous materials include cement powders and chemicals for conditioning, environmental monitoring, decontamination/ cleaning plants and equipment.	▪ Chemicals register ▪ Storage in appropriate ventilated DG cabinets ▪ Storage in appropriately silos (cement powders) ▪ Required spill kits, safety showers, PPE ▪ Training
Liquefied gases and cylinder gases for calibration, workshop operations, gamma scanner, hand/foot monitors.	▪ Purpose built storage facilities for bottled gas ▪ Equipment requires assessment and approval by expert operators ▪ Fume cupboards conform to AS/NZS 2243.8 or AS 2243.9 (as appropriate) ▪ Training ▪ DG assessment

6.6.3 Workplace H&S Hazards

The NRWMF operations will give rise to potential hazards, which are a sub-set of Workplace Health and Safety (WHS) hazards. The hazards and the controls provided are presented in the following table. In addition to these the site will operate a ‘permit to work’ system for operations to ensure staff appreciate workplace hazards and can implement controls. Specific safety management scenarios are discussed in Section 7.

Table 8: General Industrial Hazards and Controls

Hazard	Controls
Pressure and vacuum (for TN-81 casks)	▪ Design and approval of gas stores ▪ Approved design of pressure vessels ▪ Registration of pressure vessels as required ▪ Inspection and maintenance
Electrical	▪ Wiring rules AS 3000 ▪ Licensed electricians ▪ Electrical protection devices to prevent electrocution
Lifting equipment	▪ Lifting equipment requires approval of a specialist ▪ Training, procedures ▪ Certified operators ▪ Restricted access as needed

Hazard	Controls
Moving mechanical equipment and rotating shafts	▪ Guards on machinery ▪ Training, procedures ▪ Restricted access as needed
Working at heights	▪ Training, procedures ▪ Restricted access as needed ▪ Guard rails
Confined spaces	▪ Training, procedures ▪ Restricted access as needed
Traffic – vehicles	▪ One way road systems ▪ Limit number of vehicles ▪ Speed limits ▪ Vehicle/pedestrian segregation (kerbing)
Traffic – helicopter	▪ Dedicated landing/take-off area ▪ Flight path to exclude overflight of NRWMF facilities and buildings

6.6.4 Fire Hazard

Waste packages that meet the WAC will have no credible fire risk.

Generally, the amount of flammable material within the NRWMF buildings is expected to be low, consisting of floor coverings, cabling and small amounts of combustibles. The buildings within the NRWMF will be designed to the requirements of the building code of Australia (BCA) regarding fire hazards.

There will be a limited amount of flammable liquid in the NRWMF, depending on the operational needs. Flammable liquid, if used, will be stored in an approved flammable liquids storage cabinet. Fuels for site vehicles and standby generators will be stored in suitable bunded tanks and containers at specified safe locations in the NRWMF.

A medium fire loading will be present when a delivery truck parks in the loading bay during waste package receipt. No additional fire controls are considered necessary at this stage, but this scenario will be further evaluated by the design team.

Ventilation systems, where applicable, will have a fire detection system. The ILW buildings and other buildings will have fire monitoring and protection systems including smoke detectors, thermal detectors, hose reels and fire extinguishers.

Firefighting arrangements are described later, in the bushfire scenario in Section 7.4, however, site personnel will be trained and provide the primary fire response and a store of firefighting water will be kept on site for this purpose.

6.6.5 Nuclear Hazards

The safety significance of nuclear materials will be incorporated into preliminary stage safety case to reassure the Regulator of all aspects of site safety. Waste package requirements for nuclear hazard safety will be introduced in the preliminary WAC to provide further reassurance. Also ASNO safeguards requirements will apply to all safeguarded nuclear materials.

6.7 Process Operations

Process operations are divided into 5 main process flows (which are illustrated in the Appendix).

1. Gate and Security check Points
2. LLW and ILW waste reception operations
3. Characterisation facility operations
4. LLW disposal operations

5. ILW storage operations

The NRWMF will be surrounded by a series of security fences. Visitors, workers and vehicles will access the main active zone (fenced area) at a single control point.

Trucks will enter the security check point, where security will conduct a check of the truck and confirm the accuracy of the accompanying documentation. If the documents are correct, the truck will be permitted entry to the NRWMF.

Once onsite, the truck will be driven to the waste reception where documents for the waste packages are verified and a visual inspection is undertaken to identify any physical changes to the transport packages. The waste packages will then be surveyed for contamination and dose rate by a health physics surveyor (HPS).

Once cleared by a HPS, LLW packages will either be taken direct to the LLW disposal vault, or placed in buffer storage for a short duration and then transported to the LLW disposal vault, where they will be transferred and emplaced in an assigned vault.

Once cleared by the HPS, ILW packages will either be driven straight to the ILW storage building or placed in the ILW buffer storage for a short time. A decision will be made based on the waste package dose rate records on whether the shielded overpack, if used, can be removed prior to ILW storage. The packages will then be transferred to the required ILW storage building. The ILW storage area will have its own security access and radiological control regime. Waste packages of safeguards material will also follow the ILW process.

7 Safety Assessments

This section of the report provides an initial risk assessment for various operational activities proposed at the NRWMF. It also examines long term safety (post-closure safety) of the LLW disposal system. The information is based on preliminary analyses carried out for the department by ANSTO.

Safety analyses play a major role in demonstrating that radiological dose and risk of harm to persons is acceptably low and controlled (ALARA).

Planned work activities, internal faults and external hazards, each with the potential to cause radiological harm to the public or workers were identified and evaluated. At the detailed design and installation licensing stages a hazard identification study will be used to systematically document hazards to workers and the public. Initiating faults and frequencies will be identified and assessed and appropriate protective safety controls will be developed that reduce risks to acceptable levels. Controls for dose reduction include, in order of hierarchy: eliminate the hazard; passive engineered controls; active engineered controls; warning devices; administrative controls such as systems of work; and PPE.

Legal dose limits will be met and all reasonably achievable dose reduction measures implemented. The legal ionising radiation dose limits are: 1 mSv for the public; and 20 mSv for workers (10 mSv if <18 years of age). For workers, other limits also apply to specific parts of the body. An ALARA assessment will be undertaken for the licencing process to demonstrate show that dose reduction measures are effective. Annual dose constraints (an organisational objective) will also be set, based on ALARA and operational considerations – the dose constraint is always lower than the legal limits. The collective dose to all the workers will also be considered to ensure overall dose from the NRWMF is consistent with ALARA.

The capability of the NRWMF design to withstand credible hazards will be demonstrated at each stage of the licensing process.

7.1 Safety Evaluation

For this conceptual stage of the design process safety and risk evaluations for the NRWMF has comprised:

- identifying hazards, associated fault scenarios and effective safety controls
- making assessments of the potential outcomes for a range of possible hazards, including radiological hazards to staff and to the public and any environmental consequence
- estimating likelihoods associated with each outcome
- assessing radiological exposure to workers and public from routine normal operations
- identifying the potential safety importance of controls, their required reliability and contribution to defence in depth
- assessing operational safety of the NRWMF and
- assessing the post-closure consequence for LLW disposal

At this early stage, engineering judgement and ANSTO experience in managing LLW and ILW have been applied to hazard identification at the NRWMF. This approach is considered adequate at this initial conceptual stage of the design.

Processes included in hazard identification included: movement of radioactive material within the NRWMF site including all buildings, ILW stores and the LLW disposal vaults; loading and unloading of materials; transport within NRWMF; delay and containment processes for any releases and decontamination; receipt and management of waste; and conditioning of LLW wastes on site.

During the detailed design and construction phase of the project, further detailed hazard identification and evaluation processes (HAZOPs) and full Safety Assessments will be completed based on the final detailed designs, and associated supporting systems and processes. This work will provide the safety arguments used to support regulatory licence submissions.

7.1.1 Hazard Assessment

A hazard identification process was used to identify potential fault scenarios. Assessments of the consequence (severity) and likelihood, were carried out utilising the ANSTO risk matrix that applies to worker doses (illustrated in the following table) and through the application of engineering judgement.

Figure 16: Risk Matrix

Medium	High	High	Very High	Very High	Very High	Very High	>1000 mSv	Catastrophic	Impact
Low	Medium	Medium	High	High	Very High	Very High	100 – 1000 mSv	Severe	
Low	Low	Medium	Medium	High	High	Very High	20 – 100 mSv	Major	
Very Low	Very Low	Low	Low	Medium	Medium	High	1-20 mSv	Moderate	
Very Low	Very Low	Very Low	Very Low	Low	Low	Medium	0.1 – 1.0 mSv	Minor	
Very Low	Very Low	Very Low	Very Low	Very Low	Low	Low	<0.1 mSv	Negligible	
Frequency per year 10^{-6} -10^{-5}	Frequency per year 10^{-5} -10^{-4}	Frequency per year 10^{-4} -10^{-3}	Frequency per year 10^{-3} -10^{-2}	Frequency per year 10^{-2} -10^{-1}	Frequency per year 10^{-1}-1	Frequency per year >1			
Extremely Unlikely	Highly Unlikely	Very Unlikely	Unlikely	Likely	Very Likely	Almost Certain			
Likelihood									

In safety assessment:

- the likelihood or frequency is the number of times that something will happen over a period of time. In this section it is expressed on a yearly basis (/yr) — the numbers are presented in scientific notation: where for instance 102 /yr is $10 \times 10 = 100$ times per year; and 10-4 /yr is $\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \frac{1}{10{,}000} = 0.0001$ times per year.
- the consequence is the impact, the thing that happens, as a result of an event or scenario, and
- risk is the combination of the risk and the consequence.

The types of safety risk considered were:

- radiation dose to staff
- radiation dose to the public (following a release to the environment)
- WHS injury, and
- operational/ financial impact.

7.2 Safety Assessment - Normal Operations

Compliance with regulatory radiation limits during normal NRWMF operations will be assured by design. The regulatory dose limit for workers is 20mSv/yr, and it is anticipated that all individual worker exposures will be well below the annual dose limit. It is currently estimated that the average individual dose during normal operations will not exceed the site ALARA assessment trigger level of 2mSv/yr.

During detailed design, the radiation dose data for staff groups from various waste producers and consigners will be further reviewed. The maximum and average annual dose data and estimates of task times will be used to further demonstrate that both collective and individual worker doses are ALARA. The site dose constraint will be determined as part of the dose assessment and ALARA review.

7.3 Safety Assessment - Fault Scenarios

Faults are operations which occur on-site which are not normal and can result in accidents. Fault scenarios (presented in the list following this paragraph) for the operational phase of the site were assessed. These initial hazardous fault scenarios identified are based on ANSTO experience in risk assessments and on the experiences of overseas radioactive waste management facility operators. For each fault scenario, risk of radiological injury, physical injury, and financial impacts were assessed.

The following are some of the fault scenarios that were considered in the risk assessment:

1. Dropped LLW load during cross site transport or disposal within the vaults.
2. Dropped ILW load during cross site transport.
3. Dropped ILW waste container during emplacement in store.
4. Fire within the LLW vaults, ILW storage facilities and/or receipt bay.
5. Spread of contamination.
6. Operator exposure to high dose rate.
7. Truck collision and/ fire during Interstate transport of waste packages.

The risks of radiological consequence of all scenarios were assessed as very low or low. There were no scenarios with potential radiological consequence of major (20 mSv – 100 mSv) or higher. Site responses to such emergency events are provided in Section 6.3.

Each structure, system and component for which credit is taken in the safety assessment of an accident scenario was separately identified as a Category 1 or 2 safety important barrier. Where a system has no safety functional requirement (so the benefit is enhancing defence in depth / ALARA, rather than achieving acceptability), it is a Category 3 SSC. Only one Category 2 SSC was identified, the overhead crane for handling ILW unshielded waste packages in the shielded ILW store.

7.4 Safety Assessment – Major External Fault Analysis

These are scenarios based on types of major events that could happen off-site and in the environment which could have a bearing on site safety.

7.4.1 Seismic Event

All buildings at the NRWMF will be designed to an appropriate earthquake hazard factor for their operational life. Buildings in which radioactive waste will be managed will be designed to withstand worst-case seismic events (ground shaking and/or deformation associated with earthquakes) quantified using conservative return periods, characteristics of fault sources near the site, earthquake source and ground motion models.

It is very unlikely that a seismic event would occur of a magnitude which would result in a major consequence in terms of radiological safety.

The occupancy level for the LLW disposal vaults is moderate to high; however the materials involved in LLW disposal generally are of low radiological hazard. Consequently, following a seismic event leading to vault damage, the operator dose would also be low.

The occupancy rate of the buildings (such as, ILW buildings, waste operations/reception, characterisation facility, etc.) is very low. In the case of seismic event leading to damage to the shielding of the ILW above ground storage block/holes, the operator could receive a higher than normal shine doses which is estimated to be in the range of 1-20 mSv (i.e. moderate).

In terms of off-site radiological consequence following a significant seismic event which results in a breach of ILW building structures, there could be some very limited airborne releases of decay gases. However, since the radioactive waste at NRWMF is treated, stable and solid, and packaged in approved containers the releases will be very limited and only marginally above normal levels. At worst the off-site radiological consequence is estimated minor (0.02-0.05 mSv whole body public dose). The analysis shows on-site worker dose might be higher, but will be limited to a level below the legal dose limit.

Site responses to emergency events are provided in Section 6.3.

The risk associated with the scenario described above has been assessed as follows:

Consequence	Likelihood	Risk
Minor (0.02-0.05 mSv public dose).	Very Unlikely (10^{-4} to 10^{-3} /yr)	Very Low
Moderate (1-20 mSv operator dose)	Very Unlikely (10^{-4} to 10^{-3}/yr)	Low

7.4.2 Ground Liquefaction

Liquefaction is ground failure or loss of strength that causes otherwise solid soil to behave temporarily as a viscous liquid. When in a liquefied state, soil deforms easily and results in a sudden loss of ability to support heavy objects such as structures, which can be damaged or subside. The phenomenon occurs in water-saturated loose soils affected by seismic waves which cause the ground to vibrate during earthquakes. Although earthquakes are the best known cause of liquefaction, certain construction practices can also produce this phenomenon (and can be used intentionally for sinking foundations). Poorly drained fine-grained soils such as sandy, silty, and gravelly soils are the most susceptible to liquefaction.

The site characterisation work indicates that, for any of the three candidate sites, as a result of the depth to groundwater, lack of sub-surface features such as caverns, landform and the slope of the site, it is very unlikely that soil liquefaction would occur.

To ensure this is so, buildings in which radioactive waste will be managed will be designed to withstand worst-case seismic events (ground shaking and/or deformation associated with earthquakes) quantified using conservative return periods, characteristics of fault sources at the site, earthquake source and ground motion models.

7.4.3 High Winds

The NRWMF associated buildings have been designed in accordance to the requirements set out in the Australian Standards AS-1170.2.

In this scenario, the consequence is a worker fatality caused by a flying object, a workplace health and safety consequence rather than radiological safety. The occupancy of vulnerable areas in the NRWMF is low. It is therefore extremely unlikely (frequency in the range of 10^{-6} to 10^{-5} /yr), that a worker fatality would be caused by a flying object in high winds.

The risk associated with the scenario described above has been assessed as low as follows:

Consequence	Likelihood	Risk
Severe (Worker fatality)	Extremely Unlikely (10^{-6} to 10^{-5} /yr)	Low

7.4.4 Flooding – Local Rainfall

The NRWMF will be designed in accordance the requirements set out in the Australian Standards AS-1170.2. Adequate flood mitigation controls will be designed and implemented as are required to reduce the risk of flooding from rainfall to a tolerable level, including site drainage and storage. Analyses of the site characteristics for all three sites indicate annual rainfall is generally low (300mm to 350mm). However there is always a possibility of extreme rainfall and this will be incorporated into the designs for the ILW waste storage buildings and LLW vaults.

The waste packages are conditioned waste in drums/boxes or in overpacks, and in short term floods water is not expected enter into the waste packages. No radiological consequence will ensue and off-site effects are not predicted. A moderate time requirement for inspection and package clean up would be expected, which could delay operations (moderate, < 1month delay).

Site responses to such emergency events are provided in Section 6.3.

The risk associated with the scenario described above has been assessed very low or low as follows:

Consequence	Likelihood	Risk
Minor (<0.1-1mSv — on site only)	Very Unlikely (10^{-4} to 10^{-3} /yr)	Very Low
Moderate (< 1month delay — on site only)	Very Unlikely (10^{-4} to 10^{-3} /yr)	Low

7.4.5 Flooding - Overland Flow

The site investigations will include hydrological modelling of flood events from overland flows. The information derived from the hydrological models will identify the maximum flood levels and return periods. To prevent overland water flow inundating the NRWMF adequate flood mitigation controls will be designed and implemented. These flood control and prevention measures include flood levies, diversions and enhanced site drainage. These would protect the LLW vaults and the ILW storage buildings and the wastes within. It is noted that WAC compliant waste packages will be and water resilient.

In case of a flood event a comprehensive emergency response will be put in place including remedial actions to minimise on-site and off-site consequences (see Section 6.3).

The consequence overland flood will be mitigated significantly by these controls, and therefore it is estimated that the public dose could be in the range of 0.020-0.050 mSv which is minor. The likelihood of such an event leading to minor public dose, has been estimated as very unlikely (10^{-4} to 10^{-3} /yr). This is noted to be a preliminary assessment and further site specific hydrological information will be used to review this conclusion and inform the need for site-specific flood design requirements during the detailed design phase.

The risk associated with the scenario described above has been assessed very low as follows:

Consequence	Likelihood	Risk
Minor (<0.02-0.05mSv public dose)	Very Unlikely (10^{-4} to 10^{-3} /yr)	Very Low

7.4.6 Lightning Strike

The NRWMF design will be in accordance with the requirements of current lightning protection standards.

In the event of a lightning strike to a building it is very unlikely that a person inside the buildings would suffer serious injury or fatality. IT is also very unlikely that there would be any radiological consequence.

However, there is a possibility – although considered very unlikely (frequency in the range of 10^{-4} to 10^{-3} /yr) – that electrical / monitoring equipment maybe damaged as a result of a lightning strike. This will mostly result in a minor operational delay (insignificant damage, or damage to non-safety critical equipment, short interruption to some operations). If damage to more significant equipment occurred this could result in a longer delay before the restart of operations, but no radiological risk.

The risk associated with the scenario described above has been assessed very low as follows:

Consequence	Likelihood	Risk
Minor (Insignificant damage to equipment, short interruption to some operations)	Very Unlikely (10^{-4} to 10^{-3} /yr)	Very Low

7.4.7 Aircraft Crash

All civil and military aircraft are prohibited from entering the restricted airspace above nuclear installations/sites unless a prior air traffic clearance has been obtained. It was estimated that the likelihood of the crash of a commercial jet or a general aviation aircraft on OPAL (ANSTO's Lucas Heights Site) to be 1.1 x 10^{-8} per year using the DOE method (Bastin, DOE-STD-3014-96). This is an extremely low likelihood event (i.e. incredible) and might generally be expected to apply in the candidate sites (recognising that the Lyndhurst site is close to the Kimba Airfield).

The NRWMF design includes a helipad and so 'flying rules' will be put in place to prevent overflying and crashes into LLW vaults or ILW storage buildings.

Nevertheless a full assessment will be carried out during detailed design of the NRWMF, which will also consider deliberate sabotage using an aircraft.

7.4.8 Bushfire

The sites will be located on level ground and vegetation management on site will reduce the intensity of any bushfires reaching the active site boundary. However, for the purpose of the assessment bushfires are considered to occur every 10 years. The fire intensity and duration will be dependent on fuel loads, the approach direction and several meteorological factors—the prevailing wind direction and strength, temperature and humidity.

The site emergency response team will have fire-fighting capability, including a store of firewater on site. This along with advice from the local Fire Service will comprise the site response to a bush fire scenario.

Even assuming a bushfire will be capable of heating the waste packages, the off-site radiological consequences is still considered negligible (<0.02 mSv) since the WAC compliant packages do not provide a credible combustion source.

However following a fire there could be a delay to the restarting of waste operations, estimated as a period of up to a month, while site recovery operations were undertaken.

The risk associated with the scenario described above has been assessed very low and low as follows:

Consequence	Likelihood	Risk
Negligible (<0.02 mSv public dose).	Very Unlikely (10^{-4} to 10^{-3} /yr)	Very Low
Moderate (< 1month delay on site operations)	Very Unlikely (10^{-4} to 10^{-3} /yr)	Low

7.5 Post-closure Safety

The post-closure safety assessment of the LLW disposal system focuses mainly on the development of the reference scenario, which is the projected normal evolution of the LLW disposal system in its surrounding environment. A widely accepted method called 'features, events and processes (FEP) analysis' (referenced in IAEA and Nuclear Energy Agency (NEA) guidance documents) to undertake the post-closure safety assessment of the reference scenario.

At this initial stage of the project, the findings of previous NRWMF studies undertaken by ENRESA are presented (ENRESA, 2013b) . These studies are based on generic post closure scenarios for the LLW vaults. The study will be repeated as the LLW vault design is further developed and further specifications for the vaults are set in place.

The engineered barriers and the waste packages will be expected to contribute to safety throughout the institutional control period (ICP) while the radioactivity in the waste decays to a very low level. Although they might continue to perform for a period of time, no safety credit is taken for these barriers in the post-closure safety assessment. Only the natural barriers comprising the geohydrology and geology of the site will contribute to the post-closure safety assessment.

The safety function of the natural barrier is to minimise the transport of radionuclides away from the LLW disposal vaults over the extremely long-term, that might pose a risk to people living some distance from the NRWMF. The risk to the human population and the environment from radiation exposure reduces to a very low level as the radioactivity decays during the ICP. A specialist contactor (AECOM) has conducted preliminary assessment of the geology and geohydrology of the three sites. Groundwater at all the sites is deep (10-25m sub surface), the soils will provide significant delay to subsoil radioactivity migration, and annual rainfall is low, as a result of which migration of any residual radionuclides into groundwater will take a very long time. Therefore, it is expected that the natural barrier would perform the additional desired safety function in achieving long-term safety. This assessment will be further refined as the NRWMF project.

7.5.6 Post-closure Scenarios

For the purposes of the report, the following three (3) scenarios have been considered for the post-closure phase of the LLW disposal vaults. All of the scenarios are necessarily overcautious so that bounding (in safety terms) dose consequences are calculated:

1. Reference scenario.
2. Accident scenario.
3. Human intrusion scenario.

In 2013, ENRESA performed high-level radiological impact calculations for the scenarios described above and a brief description of the scenarios are provided below.

The reference scenario analysed the radiological consequences to the public as a result of a specific theoretical scenario for the natural evolution of the disposal system and the surrounding environment. The scenario assumes that water eventually enters through the vault cover and infiltrates through the concrete structure into the vaults. Contaminants from the wastes are released as the water eventually comes in contact with the waste packages. The contaminated water flows downward from the waste matrix and through the disposal vault structures to the ground (geosphere). For the theoretical reference scenario it is assumed that an aquifer is present nearby which resulting in environmental (biosphere) contamination. Groundwater is extracted from a water-well that is located at the site boundary (200m from the edge of the disposal area). The theoretical scenario assumes that the well has been drilled after the institutional control period and that water is extracted indefinitely beyond this time. This is clearly a very pessimistic theoretical scenario.

The accident scenarios are variants of the reference scenario which pessimistically assume that a section of vault cover (approximately 100 m^2) has been damaged during the institutional control period that remains unrevealed for a year before it is repaired. Two sub-scenarios have been considered here:

(a) cover failure occurs at the beginning of the institutional control period (t=0 year) and remains in a failed state for a year, and

(b) cover failure occurs at the end of the institutional control period (t=299 years) and remains in a failed state for a year.

The human intrusion scenario is even more pessimistic and assumes that, immediately following the ICP, a person dwells full time on the disposal site and consumes only water and other agricultural produce from the site. It is assumed here that there were no physical barriers to prevent such intrusion, and also the historical knowledge about the site was lost.

The dose consequences for all the post-closure scenarios are shown in Table 9.

Table 9: Post-closure phase dose consequences for LLW disposal

Scenarios		Dose (mSv/yr) at various time periods (years)			
		0-300	300-1,000	1,000-10,000	>10,000
Reference Scenario		0.00013	0.00572	0.00575	0.0081
Accident Scenario – capping failure	T= 0 years	0.00014	0.0058	0.00568	0.00811
	T= 299 years	0.00013	0.0058	0.00568	0.00811
Human Intrusion Scenario (T= 300 years)		0.27			

The public doses from the pessimistic post-closure reference scenario and accident variants range from 0.00013mSv/yr to 0.0081mSv/yr, additional to background radiation. This is indistinguishable from normal variations seen in background radiation (normal background in Australia is about 1.5mSv/yr). The highest public dose arises from the highly pessimistic theoretical human intrusion scenario which is 0.27mSv/yr, additional to background. This would affect only a small number of people on the site. The human intrusion scenario therefore shows that the most extreme post-closure scenario still only results in a small radiation dose increase over background.

The conceptual models used to analyse the scenarios are based on rightly conservative assumptions and values and are deterministic not probabilistic (i.e. they do not evaluate the likelihood of the event, and just look at the outcome). The likelihood of migration of radioactivity in significant quantities to the biosphere, is considered to be very unlikely, but will be informed by further assessments before the site licensing stage.

7.6 Environmental Impact

Prior to the site licensing phase, a comprehensive Environmental Impact Statement (EIS) will be prepared in compliance with the EPBC Act. This will assess the impact of radiation on the local flora and fauna (plants and animals) and provide a baseline data set for comparison with data collected during the lifetime of NRWMF operations and the ICP.

Additionally, a comprehensive environmental protection plan for the NRWMF will be prepared as part of site licence applications. The plan will address wildlife protection issues by comparing the radiological consequence to wildlife in their natural habitats against the screening dose rate specified in the ARPANSA Guide (ARPANSA, 2017).

Due to the robustness of the LLW and ILW operational systems and the ongoing environmental monitoring program until the ICP ends, the impact to flora and fauna is expected to be negligible. The radiological impact from various accident scenarios and the reference scenario is negligible, and so the post-closure environmental impact is also expected to be very low.

7.7 Workplace Health and Safety

The NRWMF will be operated in accordance with the current health and safety requirements (Work Health and Safety Act (WHS)) , (Regulations, 2017). This will provide a framework to secure the health and safety of workers in the workplace through the reduction of risks arising from work.

The WHS issues for routine operations will be comprehensively assessed when the operational procedures/ work instructions of each activity are developed.

At this stage of the NRWMF design process, there are no specific WHS issues identified which could cause higher than tolerable risk to the work force.

7.8 Site Security

Licencing conditions will include a requirement that the operator maintains a best practice radioactivity and nuclear security regime that incorporates a risk-based approach to physical, information and personnel security. For this initial concept design a preliminary security risk assessment was undertaken subject to the following requirements:

- ARPANSA (the IAEA regulatory body responsible for security of radioactive material in Australia) - ARPANSA Requirements RPS 11 (ARPANSA, 2007)
- ASNO (the main IAEA nuclear security regulatory body in Australia) - ASNO requirements including IAEA NSS 13 (IAEA, 2011)
- The Australian Government Protective Security Policy Framework (PSPF).

A draft security risk assessment has been provided by a specialist security consultant. The risk assessment advised on a number of security controls which will be very effective in managing the security threat levels, these are:

- general controls such as bag searches, minimising vehicles on-site
- checking vehicles for explosives prior to entering site
- all vehicles leaving site to drive through a radiation detector system to ensure no radioactive materials are leaving site
- pass and coded operated electronic turnstiles for control of entry (registered staff and visitor entry only)
- security fences
- site surveillance equipment
- access control within site
- security presence at site
- response capability of security personnel and
- staff screening and selection.

Access into the active zone will be subject to strict site security arrangements. The security building will be located inside the entrance to the NRWMF and will provide 24/7 physical surveillance and site access. This security point will also provide administration control, supervision and surveillance. Security personnel will monitor alarms and signals, response to exceptional circumstances, provide inspection and security controls, and coordinate responses with security forces. All security data will be fed back to a control room and stored in central servers. The data will also be fed to external locations to provide defence in depth. Security surveillance will be performed according to regulatory requirements and reflects the risks identified in the detailed security risk assessment (to be produced as site design advances).

The security arrangements of the NRWMF will be detailed in an NRWMF security plan drawn up during detailed site design. A joint ARPANSA and ASNO physical protection and security working group (PPSWG) will be set up to detail and agree the security arrangements.

8 Conclusions

Key aspects of concern raised by the site communities have included whether the NRWMF design would be safe, the suitability of the site geology and environment, and the properties of the waste that would be accepted at the NRWMF. Concerns included that land around the site could be affected and that waste could be in a form that could have serious effects in accidents.

Whilst recognising that the analyses in this report are not final and will be reviewed and updated as the project progresses, the department has released this report to provide information and context for the public.

The general conclusions from this reports are as follows:

- Safety in design is being considered through incorporation of multiple engineered and natural barriers. The high quality waste packages contribute the physical, chemical and radiological safety at the package level. The engineered buildings and vault structure provide the next barrier. The natural site characteristics provide a further barrier. The three barriers provide an effective defence in depth for the control of radionuclide migration throughout the site life-cycle.
- Safety evaluations have examined the safety aspects of the site and design, as understood and defined at this time. The modelled operational and post closure scenarios for normal and for fault conditions indicate that the NRWMF will be low risk to people, workers and the environment. After the ICP the residual radiation from the LLW disposal is so low that it represents a negligible risk. Even the most pessimistic post-closure accident scenario, human intrusion, results in a very small additional risk.
- The preliminary site investigations have been substantial for this early stage of the process, and have not indicated any specific issues which would rule-out the sites from being considered as site selection progresses. This includes consideration of geology, geohydrology, environmental and heritage aspects. This initial work is to be informed by further studies and analysis of the data. Currently, it appears that site issues could be addressed through viable design and engineering solutions.
- Waste acceptance criteria (WAC) and acceptance processes are being developed that will be effective. They will control the physical, chemical and radiological properties of the waste packages delivered for disposal (LLW) and storage (ILW). Only waste that is solid, non-dispersible and meets strict quality standards will be accepted for management. The designs of the waste containers to be used are also specified.

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10 Glossary

The following terms and phrases have been used in this document.

Activity	The average number of spontaneous nuclear transformations of a radionuclide occurring in unit time. The SI unit of radioactivity is the Becquerel (Bq) which is equal to one nuclear transformation per second.
Activity concentration	The concentration of a radioactive substance in any particular material expressed in terms of the activity in Becquerel per unit mass (or volume) of the material.
ALARA	The acronym for as low as reasonably achievable. In terms of waste management the practices that are adopted should be such that the magnitude of doses to individuals, the number of people exposed and the likelihood of incurring exposures where these are not certain to be received should be kept as low as reasonably achievable, economic and social factors being taken into account. This will generally be achieved by the use of the best practicable technology.
Aquifer	An underground zone of rock containing a body water
Best Available Techniques (BAT)	Processes, facilities or methods of operation which are practicable, suitable and appropriate for preventing or minimising waste arisings and/or minimising environmental and possible safety impacts associated with waste disposal
Biosphere	That part of the environment normally inhabited by living organisms. In practice, the biosphere is not usually defined with great precision, but is generally taken to include the atmosphere and the Earth's surface, including the soil, surface water bodies, seas and oceans and their sediments. There is no generally accepted definition of the depth below the surface at which soil or sediment ceases to be part of the biosphere, but this might typically be taken to be the depth affected by basic human actions, particularly farming.
Becquerel (Bq)	Unit of radioactivity in the International System of Units. The Becquerel (Bq) is equal to one nuclear transformation per second.
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 or levee	Wall or earthen flood embankment
Characterisation, Waste	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.
Chelating agents	Chemical compounds, such as amine poly-carboxylic acids, hydroxy-carboxylic acids and poly-carboxylic acids, which are capable of forming soluble complexes with metal cations.

Closure, Disposal facility	The administrative and technical actions required to put a disposal facility in its intended final state on completion of waste disposal.
Conditioning, Waste	See Waste Conditioning.
Contact dose	The radiation rate at the surface of a waste package
Containment	Methods or physical structures designed to prevent the dispersion of radioactive substances.
Contamination	The presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm^2 for better and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm^2 of all other alpha emitters. The contamination can be removable or fixed.
Corrosive materials	Highly reactive substance that causes obvious damage to living tissue and construction materials such as steel.
Decommissioning	Administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for a repository which is closed and not decommissioned). Decommissioning implies that no further use of the facility (or part thereof) for its existing purpose is foreseen.
Defence in depth	The application of more than a single protective measure for a given safety objective such that the objective is achieved even if one or more of the protective measures fails. The layering of protective measures can include multiple engineered barriers plus safety structures plus procedures plus plans for emergency responses
Design life	The period after completion of an engineered disposal structure during which the structure and all its components are expected to perform in accordance with the design objectives.
Disposal	The placement of radioactive waste in a structure and in a manner such that there is no intention of retrieval.
Disposal facility	The land, buildings and equipment which are intended to be used for the disposal of radioactive waste.
Disposal site	The area of land which is used for the disposal of the waste and consists of a disposal facility and a surrounding buffer zone.
Disposal structure	A vault, trench, bore hole or other form of structure which is designed and approved for disposal of radioactive waste.
Dose	A measure of the energy deposited by radiation in a target. A generic term that may mean absorbed dose, equivalent dose or effective dose depending on context. Here, it generally refers to effective dose, measured in Sieverts.

Dose limit	The dose limit represents the upper bound of acceptable additional dose (above natural background and elective doses, such as for medical imaging) for an individual worker or member of the public and is normally the legal limit.
Effective dose	The sum of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor. This is an estimate of the biological effect of the radiation dose.
Engineered barrier	A feature made or altered by humans which delays or prevents radionuclide migration from the waste or the disposal structure into its surroundings. It may be part of the waste package or the disposal structure.
Exempt Level Waste (EW)	Waste that meets the criteria for exemption from regulatory control for radiation protection purposes. Exemption activity concentrations and exempt activities of radionuclides are specified in Schedule 4 of Radiation Protection Series Publication No. 6 - National Directory for Radiation Protection (NDRP), ARPANSA, 2017.
Free liquid	Any liquid which is present as a separate phase. This does not include liquids absorbed or adsorbed on a solid substrates or water present in pore structures of cementitious materials.
Government	The government of the Commonwealth of Australia or of a State or Territory of the Commonwealth.
Groundwater	Water that is located below ground, often in an aquifer.
Human intrusion scenario	A possible series of events or conditions which describe means of human intrusion or other contact with disposed waste after the closure of the site and following the institutional control period.
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 on-going knowledge that the site has been used for the disposal of radioactive waste. This control may be active (monitoring, surveillance, remedial work) or passive (land use control).
Institutional Control Period (ICP)	Period of institutional control.
Intermediate Level Waste (ILW)	Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs little or no provision for heat dissipation during its storage and disposal. Intermediate level waste may contain long lived radionuclides, in particular alpha emitting radionuclides, which will not decay to an activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore waste in this class requires disposal at greater depths, in the order of tens of metres to a few hundred metres.
International Best Practice	Codes, standards, recommendations and guides that are produced by the international organisations listed below. 1. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

	2. International Atomic Energy Agency (IAEA) 3. World Health Organisation (WHO) 4. International Commission on Radiological Protection (ICRP) 5. International Commission on Non-Ionizing Radiation Protection (ICNRP) 6. Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) Note: The Australian Radiation Protection and Nuclear Safety Act 1998 states that the CEO of ARPANSA must take into account international best practice in relation to radiation protection and nuclear safety when making licensing decisions. Although the ARPANS Act does not define the term "international best practice", the CEO has taken it into account by, among other things, the codes, standards, recommendations and guides produced by the above organisations.
Intrusion	The process by which living organisms, including humans, may come in contact with disposed or stored waste. For example, burrowing animals might be able to damage the protective layers and access the radioactive waste.
Ionising radiation	For the purposes of radiation protection, this means radiation capable of producing ion pairs in biological material(s).
Isolation	Containment of radioactive waste to ensure separation from the environment.
Levee or bund	A flood wall or embankment built to stop the overflow of a river.
Long-lived radionuclides	Radionuclides with half-life more than 31 years.
Low Level Waste (LLW)	Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration.
Material subject to Safeguards Act	See Safeguards Material.
Multiple barrier system	A system consisting of a number of barriers to prevent release of radioactivity into the environment, credit for which is taken in a safety case. In the case of LLW disposal there are three barriers: the waste package; the engineered vault and multiple layer cover; and the site characteristics.
Near surface disposal	The disposal of radioactive waste in structures located below and/or above the natural ground surface (within approximately 30 metres of it) and covered by layer(s) of natural and/or manufactured materials.
Nuclear material	See Safeguards Material.

Naturally Occurring Radioactive Material (NORM)	Radioactive material containing no significant amounts of radionuclides other than naturally-occurring radionuclides.
Occupational exposure	All radiation exposure of workers incurred in the course of their work.
Operational Limits and Conditions	The values or ranges of values within which the process parameters normally should be maintained when operating. These values are usually associated with preserving product quality or operating the process efficiently; however, they may also incorporate the safe upper and lower limits of the process, or other important limits.
Optimisation (of radiation protection and safety)	The process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, "as low as reasonably achievable, economic and social factors being taken into account" (ALARA), as required by the International Commission on Radiological Protection System of Radiological Protection.
Oxidizing agent	A substance that tends to gain electrons from another substance, the reducer. The oxidizing agent oxidizes other substances and in turn reduces. The strength of an oxidizing agent is relative and depends on the redox potential of each substance and the reaction conditions.
Overland flow	Water which has fallen as rain a distance away from a place (but which flows over the surface of the land to the location of interest).
Processing, Waste	See Waste Processing.
Putrescible Materials	Materials liable to be readily decomposed by micro-organisms that may give rise to a health hazard and include animal carcasses and sewage sludge but exclude vegetative plant materials (for example moss and algae), wood and paper.
Pyrophoric Materials	Any liquid that ignites spontaneously in dry or moist air at or below 130 F (54.5 C) or any solid material, other than one classed as an explosive, which under normal conditions is liable to cause fires through friction, retained heat from manufacturing or processing, or which can be ignited readily and when ignited burns so vigorously and persistently as to create a serious transportation, handling, or disposal hazard. Included are spontaneously combustible and water-reactive materials
Quality Assurance (QA)	All those planned and systematic actions necessary to provide confidence that a structure, system or component will perform satisfactorily in service.
Quality Control (QC)	Part of quality assurance intended to verify that structures, systems and components correspond to predetermined requirements.
Radiation	See ionising radiation.
Radiation Protection Adviser (RPA)	Person providing radiation protection advice, which can be based on monitoring results.
Radioactive	Exhibiting radioactivity; emitting or relating to the emission of ionising radiation or particles.

Radioactive substance	Substance which spontaneously emits radiation.
Radioactive waste	Waste that contains or is contaminated with radioactive substances and has an activity or activity concentration higher than the level for clearance from regulatory requirements, for which no further use in Australia is envisaged.
Radionuclide	An unstable type of atom that emits ionising radiation
Safeguards	Describes the system of inspection and verification of the peaceful uses of nuclear materials as part of the Nuclear Non-Proliferation Treaty (NPT), supervised by the International Atomic Energy Agency.
Safeguards material	Any uranium, thorium or plutonium held in Australia under ASNO permits, or otherwise subject to the Nuclear Non-Proliferation (Safeguards) Act 1987, with limited exceptions as described in the Nuclear Non-Proliferation (Safeguards) Regulations 1987[*].
Safety Case	The complete "case" for the safety of the facility. The Safety Case includes the Safety Analysis Report together with all the referenced material, all drawings, procedures, instructions, hazard identification studies, facility logs, safety analyses, training records, training programs, training material, and any other records kept that may have a bearing on the safety of the facility.
Seismic	Effects due to shaking of the land (often associated with earthquakes)
Short-lived radionuclides	Radionuclides with half-life less than 31 years.
Sievert (Sv)	Unit of ionizing radiation dose in the International System of Units which has a biological effect. Often expressed in milli or thousandths of Sieverts
Stability	The capability of a waste package or disposal structure to maintain its shape and properties under disposal conditions.
Sterile zone	A zone surrounding the operating facility, within the buffer zone, which has enhanced security designs to prevent unauthorised access to the facility.
Storage	The emplacement of waste in a facility with the intent and in a manner such that it can be retrieved at a later time.
SUF Cup	The filter cups used to collect the solid uranium left after extraction of nuclear medicine. The SUF cups are stored nine to an IL 14.5 waste container.
Synroc	A method using heat and pressure and precursors to turn radioactive waste into an artificial rock.
Treatment, Waste	See Waste Treatment

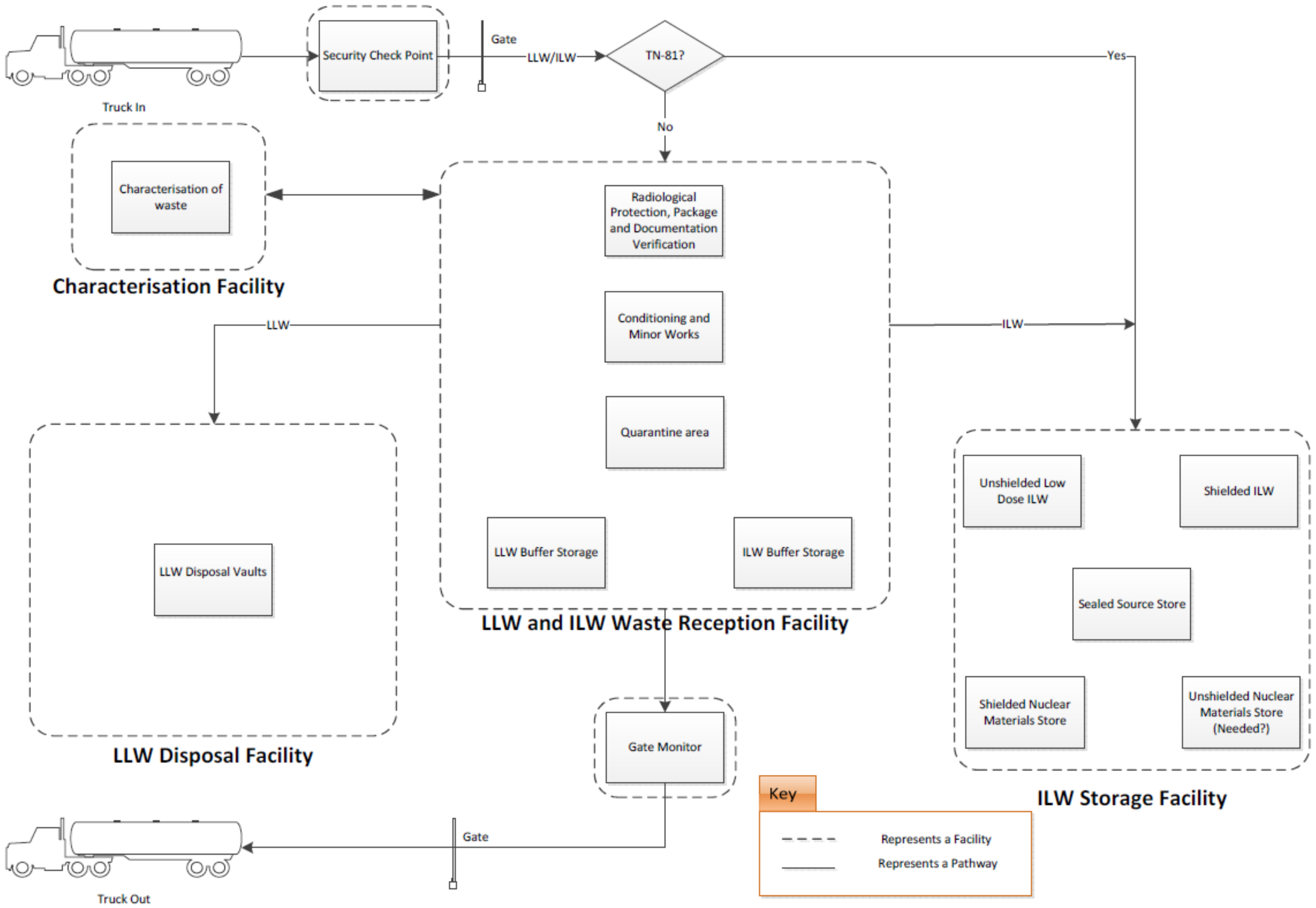
[*] The definition of "nuclear material" for the purposes of IAEA safeguards does not apply to ores and ore residues.

Vault	A large engineered concrete disposal structure into which groups of LLW waste packages are placed for disposal.
Voidage	The relative amount of free space between objects that have been placed in a container, that is unable to be filled.
Waste Acceptance Criteria (WAC)	Quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for radioactive waste to be accepted by the operator of a repository for disposal, or by the operator of a storage facility for storage.
Waste conditioning	Operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of the waste to a solid waste form, enclosure of the waste in containers, and, if necessary, providing an overpack.
Waste container	The vessel into which the waste form is placed for handling, transport, 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 disposal	The placement of radioactive waste in a disposal structure and in a manner such that there is no intention of retrieval.
Waste minimisation	The establishment of practices in all stages of the production, processing and use of radioactive materials to minimise the quantity of waste generated, including its radioactivity.
Waste package	The product of conditioning that includes the waste form, any container(s) and internal barriers (e.g. absorbing materials and liner), as prepared in accordance with requirements for handling, transport, storage and/or disposal.
Waste processing	Any operation that changes the characteristics of waste, including pre-treatment, treatment and conditioning.
Waste producer	Pre-approved agencies of Commonwealth, States and Territories of Australia that generate (current or past activities) or otherwise possess or control radioactive waste.
Waste treatment	The processes that are carried out to change the characteristics of the waste to produce a safe and convenient form for storage or disposal. This may involve operations such as volume reduction, activity removal and change of composition.
Wasteform	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.

Appendix A NRWMF Process Operations flow charts

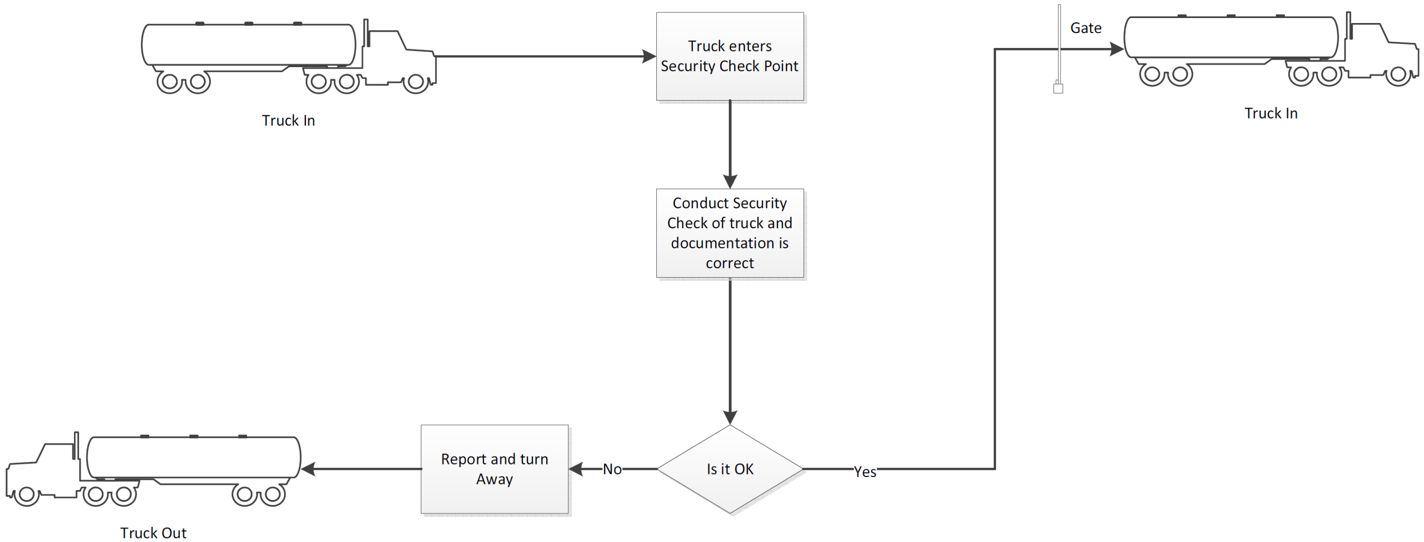
Draft

A.1 High Level NRWMF Process Flow

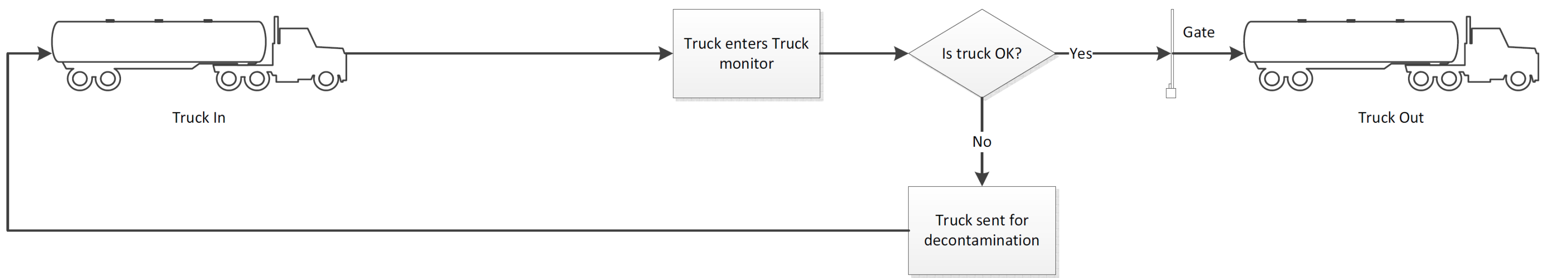


A.2 Gate and Security Check Points Process Flow

In Gate/Security Check Point

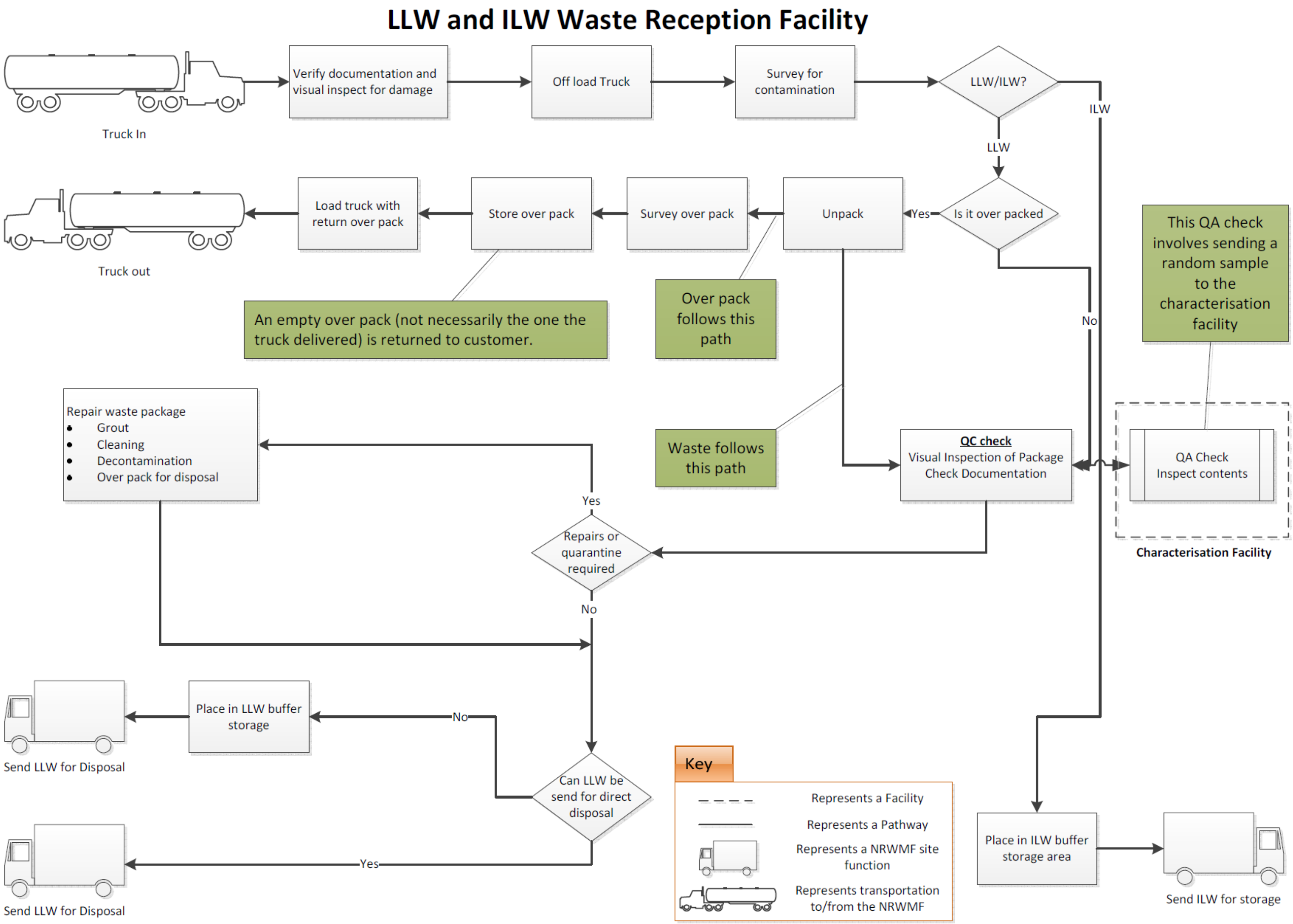


Out Gate/Security Check Point

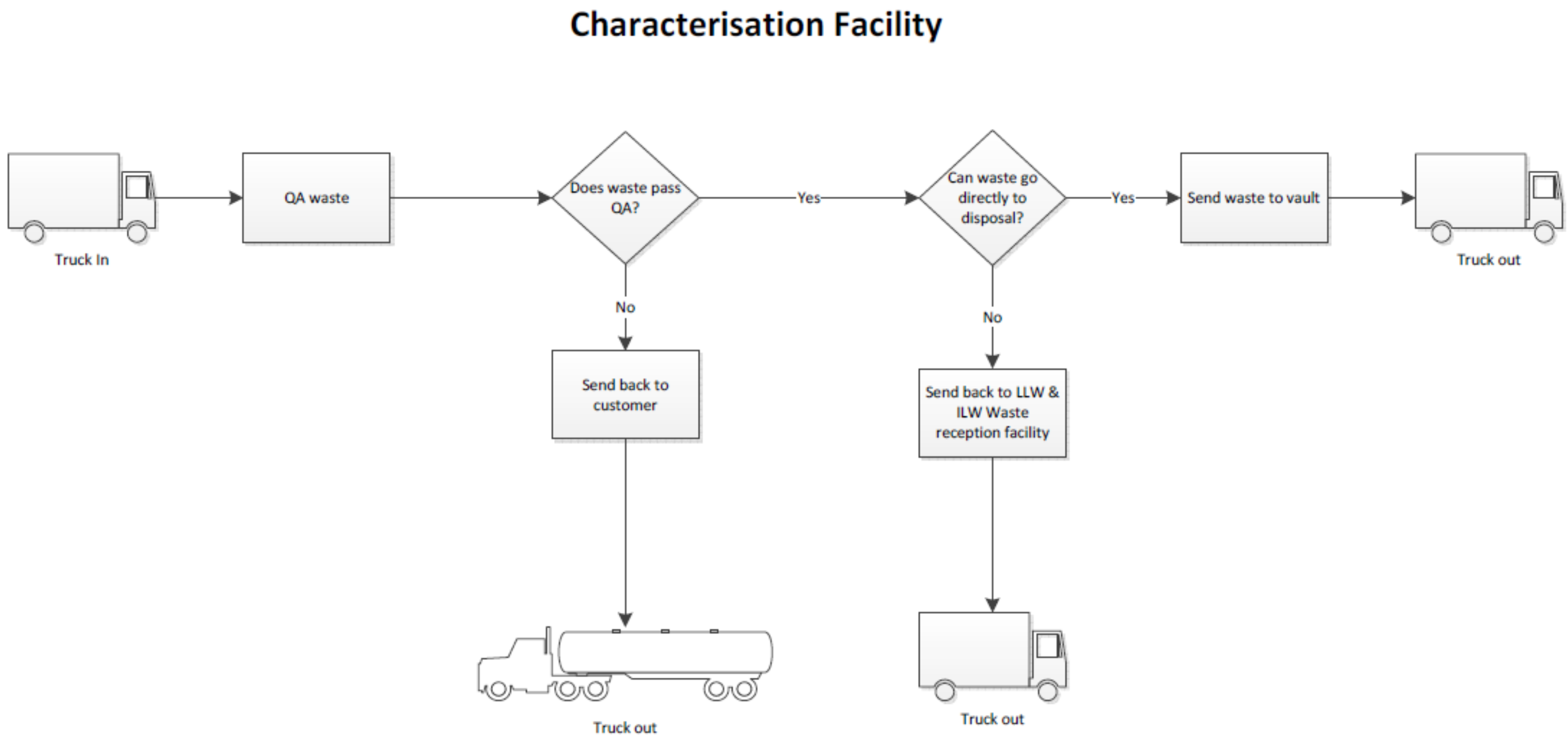


A.3 LLW and ILW Waste Reception Process Flow

Draft

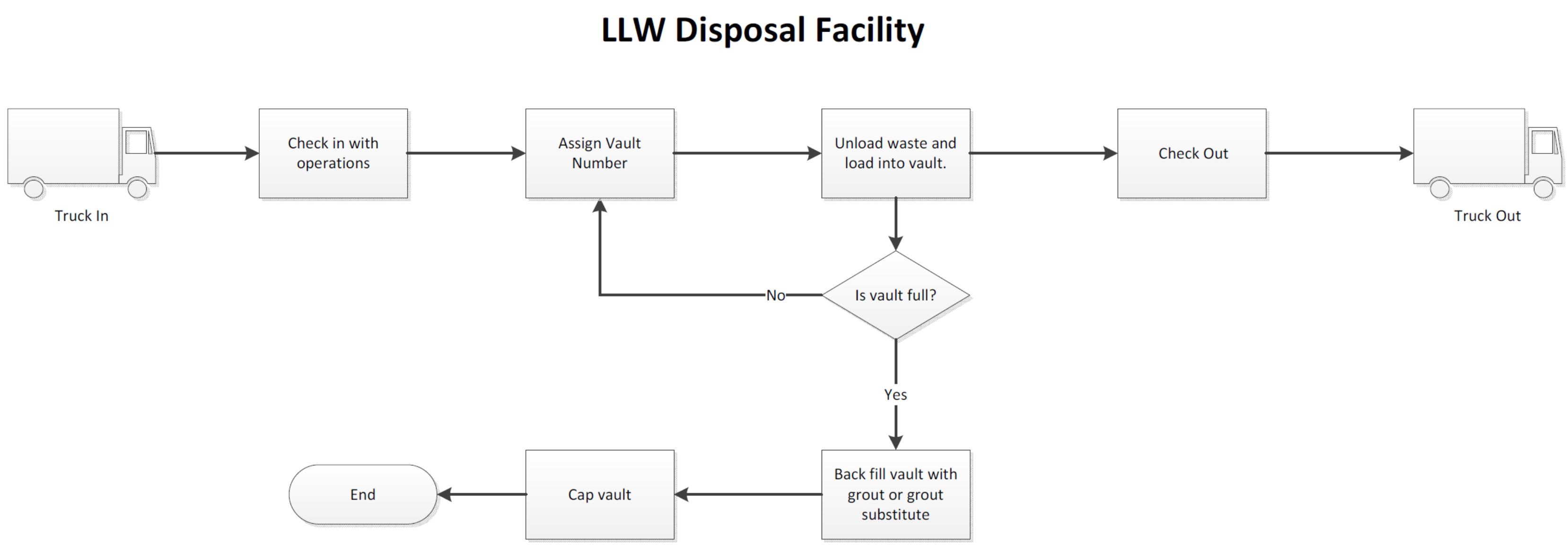


A.4 Characterisation Facility Process Flow



A.5 LLW Disposal Process Flow

Draft



A.6 ILW Storage Process Flow