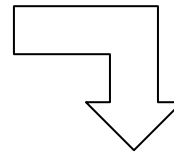


Summary of the Environmental Safety Case 2010 for the New Low-Level Waste Facilities at Dounreay, Scotland

Over the last few decades, nuclear power has met a significant proportion of the UK's electricity needs. The nuclear research site at Dounreay in Caithness, Scotland, was set up by the UK government in 1955 to investigate and demonstrate the feasibility of advanced nuclear reactor designs. The research programme was terminated in 1994, and the buildings are now being emptied and taken down (decommissioned) by Dounreay Site Restoration Limited (DSRL), on behalf of the Nuclear Decommissioning Authority (NDA)¹.



*Current Dounreay
site layout.*



*Most plant and
buildings on site
are to be
dismantled and
demolished within
the next 20 years
or so.*



DSRL is committed to minimising the amount of waste produced by its activities at Dounreay, but these activities inevitably produce radioactive waste. The term “radioactive” indicates that the waste contains some unstable elements (radionuclides), which decay (break down) over time until they are stable, emitting radiation (radioactivity) at a level that has the potential to be harmful to man and the environment. Therefore, the radioactive waste requires safe management.

¹ DSRL was established on 1 April 2008 as part of the restructuring of the United Kingdom Atomic Energy Authority (UKAEA). Work at Dounreay prior to 1 April 2008 was conducted by UKAEA.

Different radionuclides decay at different rates, varying from seconds to thousands or millions of years. Radioactive waste is categorised and managed according to the magnitude and longevity of its hazard. Low-level radioactive waste (LLW) is waste that is at the lower end of the radioactive waste spectrum, being low hazard and containing only a minor amount of long-lived radionuclides. DSRL is planning to dispose of its solid LLW in new, specialised disposal facilities to be constructed at Dounreay.

The New LLW Facilities will be in the form of a series of up to six concrete “vaults” constructed so that the top of the waste is at least four metres below ground level, with the base of the vaults about 12 metres below that. The vaults will have a roof over them while they are being filled with waste to keep rainwater out. After they are filled, the tops of the vaults will be closed off, the roofs removed, and the original ground profile reinstated through the emplacement of an engineered cap. Two of the planned six vaults are for wastes in the form of lightly contaminated soils and building rubble – termed “Demolition LLW”.

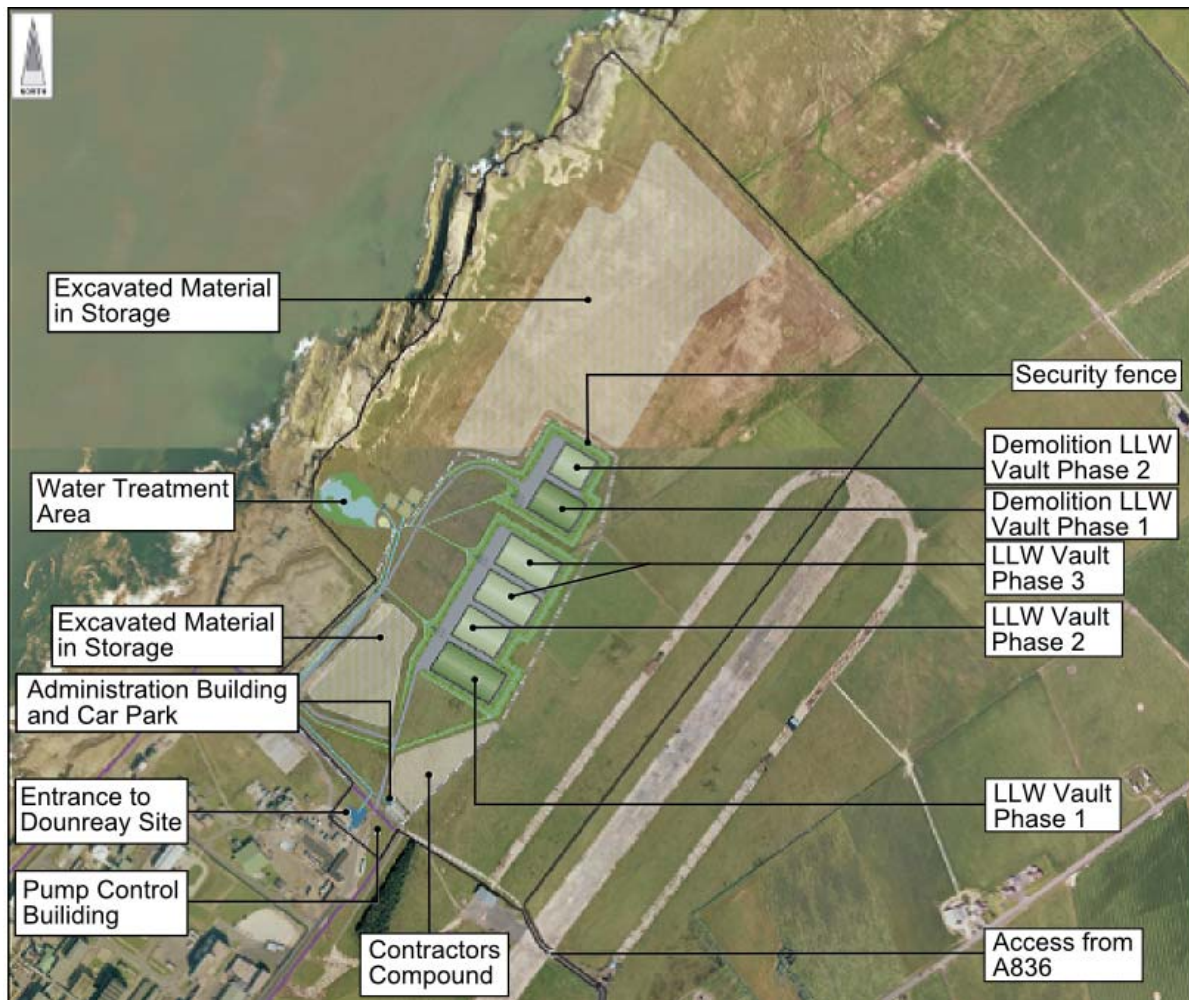
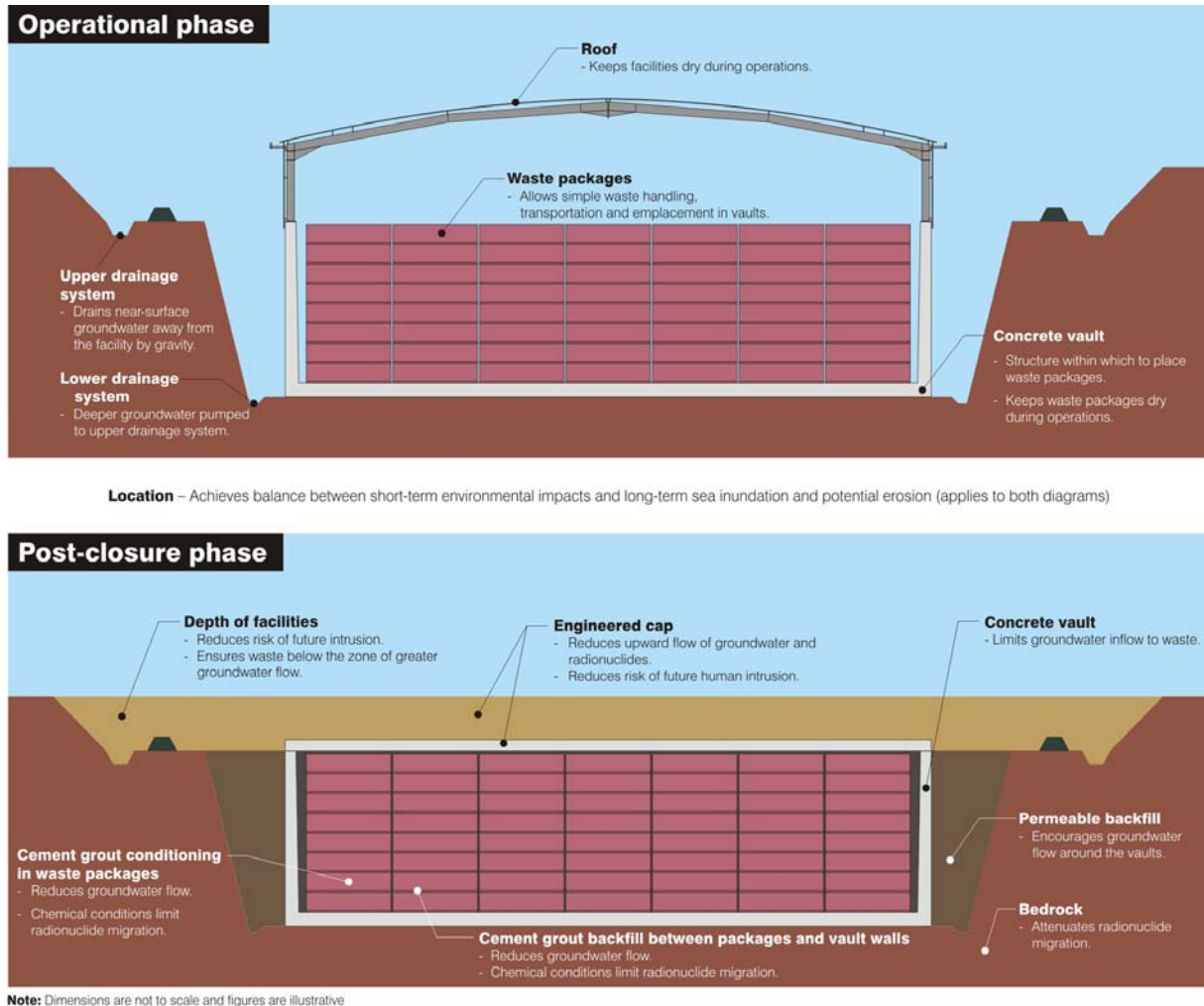


Photo-montage showing location of the planned New LLW Facilities. Black solid line shows site development boundary. The main Dounreay site can be seen in the lower left-hand corner, and the nearest houses and public A836 road are in the lower right-hand corner. The width of the Figure represents about 1,400 metres.



Illustrations of a single LLW disposal vault during operations (top) and after closure and capping (bottom). The red rectangles illustrate individual LLW containers arranged in the vaults in eight-high stacks.

This leaflet focuses on the Environmental Safety Case (ESC), which demonstrates the appropriate protection of people and the environment from the wastes disposed of in the facilities. A sister leaflet² gives background details on the overall project. The ESC is updated over time as the project develops. The project has recently submitted ESC 2010 to the regulators, and ESC 2010 is summarised in this leaflet. ESC 2010 considers how radioactive substances disposed of in the facilities (the source) might migrate over time through the environment (pathways), and the potential effects of this radioactivity on flora and fauna, including humans (receptors), compared to stringent safety and environmental protection criteria. The key arguments making the ESC are summarised below in terms of the source-pathway-receptor linkages used in the environmental safety assessment.

² New LLW Disposal Facilities at Dounreay: 2010 Project Summary. DSRL Report NLLWF/3/ESC/GAL/0xxx/IS/01, February 2011.

Source

Wastes and Waste Emplacement

For waste to be defined as LLW, its radioactivity level must be below set limits. These limits are prescribed by the UK Government, and are consistent with guidance from the International Atomic Energy Agency (IAEA) on waste suitable for disposal in facilities at, or near, the ground surface.

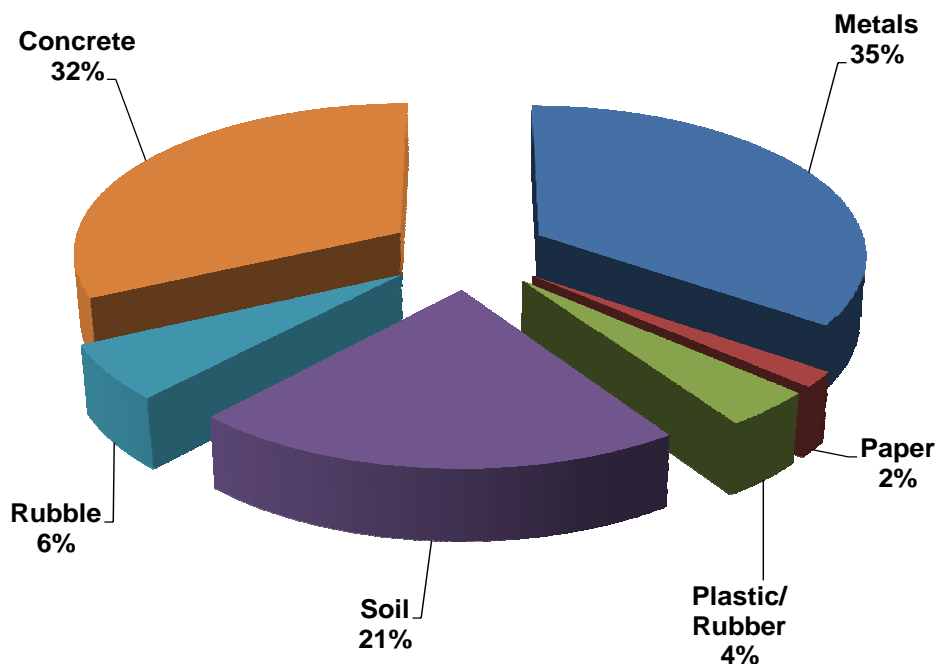
LLW at Dounreay contains less than 0.01% of the radioactivity that is present in all radioactive waste on the Dounreay site, but comprises about 90% of the solid radioactive waste by volume that is expected to result during operation and decommissioning of the site.

The majority of the LLW from operations (i.e., research work) at Dounreay is plastic and metal pipework, laboratory glassware, tools, and items of plant equipment.

The majority of the LLW from current and future decommissioning activities is concrete, building rubble, metals, and contaminated soil. A breakdown of the total LLW inventory from operations and decommissioning for disposal in the planned New LLW Facilities shows a dominance of metals (mostly steel), concrete, soil, and rubble.



Photograph showing the typical contents of a drum of Dounreay LLW.



The percentage of each material type by weight in Dounreay LLW.

DSRL intends to use the New LLW Facilities only for disposal of solid LLW from the Dounreay site and the adjacent Vulcan site. Vulcan is a Ministry of Defence site established in 1957 to test the nuclear propulsion plant used in Britain's submarines.

No higher-activity wastes or non-radioactive wastes, such as putrescible domestic wastes of the type that are typically sent to landfill, will be accepted in the New LLW Facilities.

The LLW to be disposed of contains little in the way of non-radioactive hazards, and DSRL has demonstrated that the design of the New LLW Facilities would anyway meet the standards for disposal of hazardous wastes. The least contaminated LLW (Demolition LLW) will be segregated for disposal in separate vaults to the rest of the LLW because of its lower hazard potential.

DSRL is committed to following best practice for waste management, including minimising the amount of waste produced. Thus, estimates of the waste inventory to be consigned to the New LLW Facilities are continually being driven downwards, both in terms of volume and radioactivity.

Much of the LLW is packaged in steel drums and, where possible, the drums are compacted to reduce volume. The compacted drums, and LLW that it is not possible to compact, are placed into large steel containers similar to the half-height International Standards Organisation (HHISO) containers that are used for transportation on public roads. Before consignment for disposal, any voids in the HHISO-type containers will be filled with a cement-based grout. The containers and grout help ensure that the radioactive waste remains contained for as long as is practicable within the vaults.



Photograph of the interior of the Dounreay Waste Receipt, Assay, Characterisation & Supercompaction facility, showing inspection of LLW drums.

Photographs of the interior of the Dounreay Waste Receipt, Assay, Characterisation & Supercompaction facility, showing compaction of LLW drums into thin “pucks” (below), and filling of a HHISO container with compacted LLW drums (right).



The HHISO-type containers will be transported to the New LLW Facilities and stacked in the vaults, in a similar manner to the process at the national LLW repository (disposal facility) near Drigg. Because the vaults will be below ground, there will be minimal visual impact. Through the use of roofs, ditches, and pumps, the interior of the vaults will be kept dry during operation of the facilities.

Only LLW will be accepted for disposal in the New LLW Facilities, and the majority of the wastes to be disposed of in the facilities will have a radioactivity that is well below the limits for LLW.

Demolition LLW will be handled and disposed of in separate, but similarly constructed, concrete vaults to the rest of the LLW. Demolition LLW is mainly lightly contaminated building rubble with a very low hazard potential. The Demolition LLW will be disposed of in large nylon bags and emplaced in the vaults without the use of any grout, utilising sand or crushed rock to fill the space between packages.



Photograph showing HHISO containers being stored at Dounreay.

Closure of the Vaults

Once all of the LLW has been emplaced, the gaps between adjacent LLW containers and between the containers and the vault walls will be filled with cement-based grout, a lid placed on the vaults, and a cap built over the facilities. The Demolition LLW vaults will also be capped after they are full. The reason for this engineering is to restore the original ground profile, to isolate the wastes from the surface environment, and to provide a deterrent to inadvertent future intrusion of the vaults.

Once the pumps are removed at closure, groundwater will gradually enter the vaults. However, the low permeability of the concrete vaults, and the steel containers and grout (where used) mean that it will take a long time before the groundwater comes into contact with any of the radioactive waste.

The vast majority of the wastes to be disposed of in the New LLW Facilities contains mainly short-lived radionuclides (i.e., radionuclides with half-lives shorter than approximately 30 years). This radioactivity will decay to insignificant levels in less than 300 years. The New LLW Facilities and the restored Dounreay area will remain under care and surveillance until it is agreed with the regulators that it no longer represents a significant hazard. After 300 years, over 95% of the initial radioactivity disposed of will have decayed, and the average radioactivity of the wastes will be similar to that currently found naturally in soils around the Dounreay site (albeit comprised of a different mix of radionuclides).

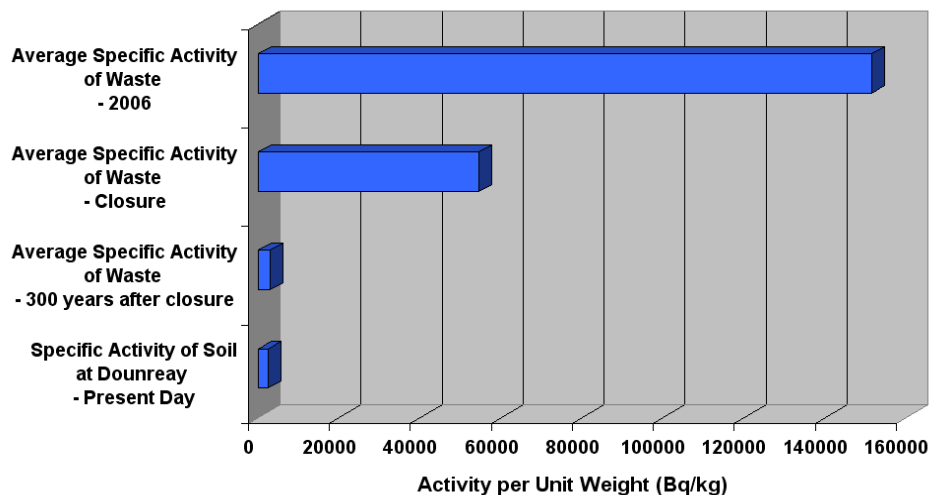


Chart showing the radioactive decay of the Dounreay LLW, compared to the level of naturally occurring present-day radioactivity in Dounreay soils. The specific activity is defined as the disintegrations per second (Bq – Becquerel) (a measure of decay) per kilogramme (kg) of waste or soil.

Pathways

Facility Design and Radionuclide Releases over Time

In terms of safety, the New LLW Facilities have been designed primarily to provide containment and isolation while the vast majority of the radioactivity decays over the next few hundred years. Owing to the long half-life of a small proportion of the radioactivity to be disposed of in the facilities, it is not possible to prevent small releases of radioactivity from the concrete vaults over thousands of years. However, by this time, the remaining radioactivity can no longer pose any hazard greater than that associated with naturally occurring radioactivity in the environment.

A further design aim for the New LLW Facilities is to slow any releases of radionuclides such that concentrations of LLW-derived radioactivity in the environment remain significantly below the levels of naturally occurring radioactivity. The cement used to encapsulate the wastes and construct the vaults in the New LLW Facilities creates an alkaline environment that slows the release of radionuclides. Releases will rise slowly over thousands of years as water penetrates the facilities and the cement and steel barriers degrade. However, the radioactivity in the facilities is very low by this time, and release rates will never exceed the flow of natural radioactivity present in the environment.

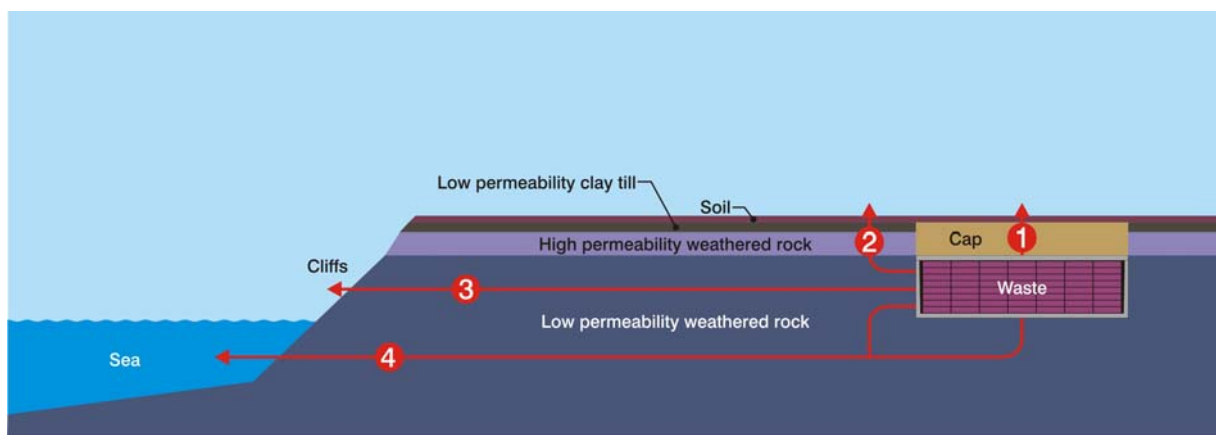
The design of the New LLW Facilities at Dounreay is regarded as best practice and is comparable with the designs for near-surface disposal facilities in other countries, such as those in England, France, and Spain.

The Fate of Releases from the Facilities

The location of the wastes below the ground surface and keeping the vaults dry during operations minimises the possibility of any radiation exposure of the public before the facilities are closed. After closure, providing the facilities remain undisturbed, there are essentially four potential paths for migration of radioactivity from the facilities to the environment over the long term:

1. Directly upwards from the wastes as water or gas, migrating through the cap and into the topsoil. Only certain radionuclides comprising a limited amount of the radioactivity in the facilities could be released as gases.
2. Into the groundwater flowing downstream of the facilities and upwards into the soil between the facilities and the coast.
3. Into the groundwater flowing downstream of the facilities and through the rock or ditches to the cliffs and foreshore and then into the sea.
4. Into the groundwater flowing downstream of the facilities and down into the sea.

Once in the soil or sea water, people might be exposed to the radioactivity directly through external exposure or indirectly as the radionuclides are taken up into plants and animals and enter the food chain. People might also inhale radioactive gases, albeit gas volumes will be vanishingly small.

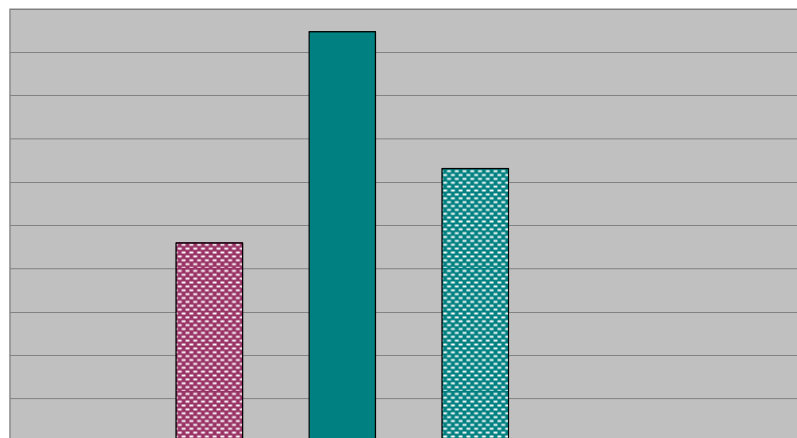


Schematic illustration of the four potential pathways for radionuclides to migrate from the New LLW Facilities through the environment to locations where flora and fauna, including humans, might be exposed to the radiation. Not to scale.

The geology and hydrogeology of the area around the New LLW Facilities have been characterised and monitored by DSRL in some detail and have been shown to help reduce the impact of releases on the environment. The facilities will be several metres underground in the Caithness bedrock, providing long-term stability and low volumes of groundwater flow. The majority of rainwater falling on the area flows downhill to the sea over the surface and in a thin surface zone and does not penetrate to the depth of the wastes. The area is covered by a glacial till, rich in impermeable clay, which acts to separate the surface soils from the deeper groundwater system.

Once the short-lived radioactivity has decayed after a few hundred years, it will take many thousands of years for the residual long-lived radioactivity in the facilities to decay completely. The long-lived radionuclides will be slowly released and will migrate through the rock. Some of the radionuclides will migrate to the topsoil between the facilities and the coast and some will migrate directly to the sea. However, most of the radioactivity will ultimately reach the sea, where the concentration will be minute, owing to the small initial inventory and the inevitable dilution. Radioactivity from the facilities will form only a small fraction of the natural radioactivity flowing into the sea from the terrestrial environment around Dounreay.

Future concentrations of radionuclides in the environment around Dounreay from radioactivity released from the New LLW Facilities are anticipated to be much lower than present-day measured concentrations, which are mainly naturally occurring, but with some related to past discharges from the Dounreay site and elsewhere. For example, the calculated peak concentration in grass of facility-derived strontium, one of the main short-lived radionuclides in Dounreay LLW, will be a thousand times lower than the present-day concentration. The concentration of facility-derived radioactivity in the environment reaches a peak only after thousands of years, and is related to the long-lived radionuclides. Even then, the concentrations of radioactivity are hundreds to thousands of times lower than present-day concentrations (see examples of uranium in the following figure).

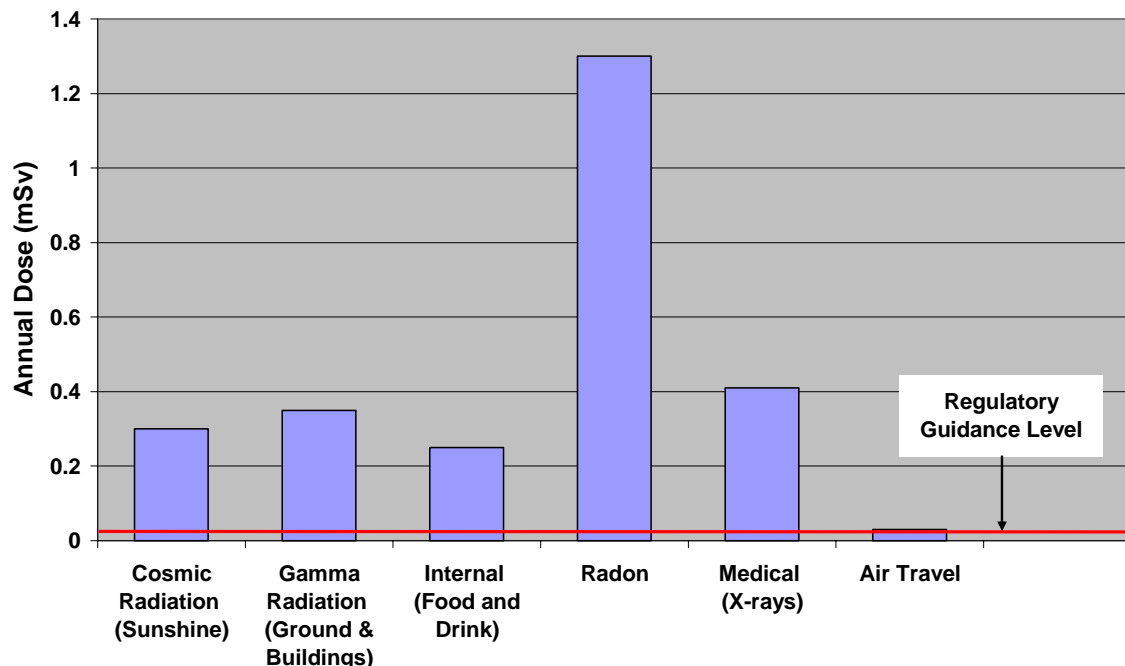


The discussion above focuses on the performance of the facilities while they remain undisturbed. However, there is the potential for the facilities to be disturbed, either by natural events such as sea-level rise and coastal erosion in the very long term, or through human activities, if knowledge of the facilities is lost in the far future.

The radiological consequences of releases from the facilities, either through groundwater or through disruption, are discussed in the next section.

Receptors

The consequences of radioactivity released to the environment are regulated in terms of the potential radiation dose and risk to people and flora and fauna that might be exposed to the radiation. Dose is used for present-day constraints, while risk is used for the far future to take account of uncertainty in the evolution of society and the environment. Risk can be equated to dose by taking account of the probability of exposure; in the following, exposure is assumed to occur, that is the probability is 1. The regulatory guidance level for disposal of solid radioactive wastes after control of the facilities has ceased is expressed as a peak risk equivalent to an annual radiation dose to the most exposed person, measured as a fraction of a milli-Sievert (mSv) per year, that is approximately 100 times smaller than the average dose received every year by a typical member of the UK population from natural sources of radiation. There are no regulatory guidance levels in the UK for doses to non-human organisms, but the potential doses are calculated for a wide range of organisms and compared to international reference levels.



Average annual radiation dose (mSv per year) to a typical member of the UK public from various sources of radiation. The solid red line compares these doses to the regulatory risk guidance level for disposal of radioactive waste to specialised land disposal facilities.

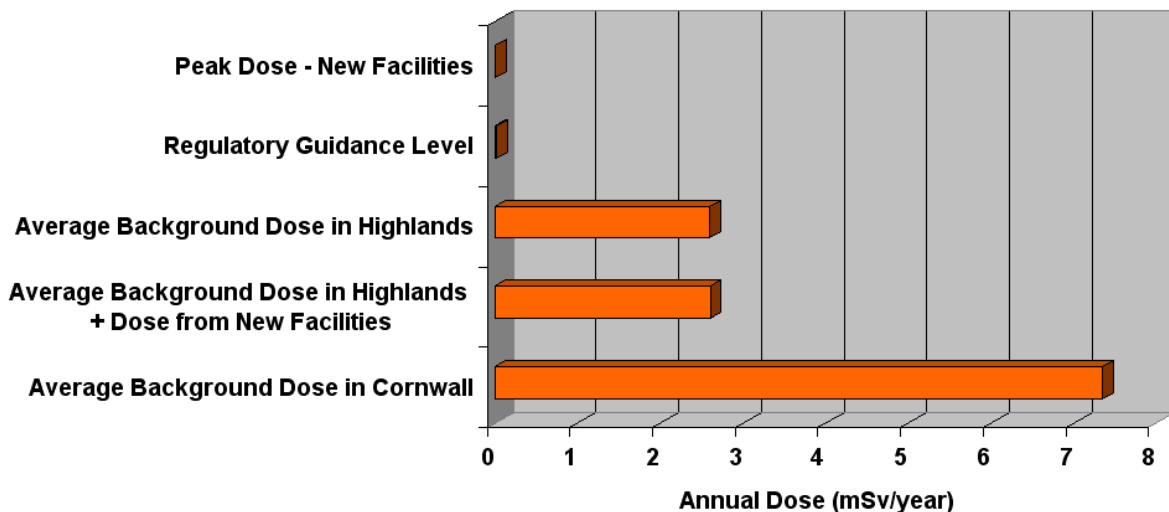
The extremely small concentrations of radionuclides that will reach the sea and their subsequent dilution mean that calculated doses to users of the marine environment (for example, anglers, swimmers, surfers, seafood collectors and eaters) are vanishingly low. This is reinforced by calculations that show radionuclide releases

from the New LLW Facilities will be considerably lower than the present-day authorised discharges from the Dounreay site, which have been shown to have negligible impacts on people and the environment.

Insignificant doses are also calculated for potential users of the land between the facilities and the coast. Doses rise to a peak over thousands of years, related to the slow release and build-up of long-lived radioactivity discussed earlier. The most important potential exposure pathway is consumption of livestock reared on the small strip of grassland between the facilities and the coast - an area of around 12 hectares including the cap over the facilities.

Even with the extremely pessimistic assumption of a complete return to a subsistence economy in the far future, resulting in a crofter family living on and working the land around the facilities for their food (vegetables, meat, poultry, eggs), calculated peak doses would still be below the regulatory guidance level. Such a dose would not be discernible when included in the dose from background radiation in the Dounreay area. Further, the dose from background radiation in the Highlands is quite low when compared to other areas of the UK, such as Cornwall, where higher level of radioactivity in the rocks can occur naturally. This helps to put the possible radiological impacts from the New LLW Facilities into perspective - moving to Cornwall would treble an individual's annual dose, while the dose from the facilities will be indiscernible even with pessimistic assumptions about exposure pathways.

Similarly, the potential radiation doses to non-human organisms have been shown to be insignificant.



Calculated maximum dose from the planned New LLW Facilities, compared to existing background doses in the Highlands and in Cornwall. Even the maximum possible dose from the facilities adds an indiscernible amount to the existing background doses.

Given the location of the facilities a couple of hundred metres from the sea and well above sea level, they could only be disrupted by coastal erosion or sea-level rise after tens of thousands of years. By this time, the radioactivity levels in the facilities will be below background levels. Wave action and strong offshore currents at Dounreay would mean that any eroded waste material would be rapidly washed out to sea. Calculation of possible doses to users of the cliffs and foreshore while the

facilities are eroded at various possible times in the future show very low doses, well below the regulatory guidance level, primarily due to the very low levels of radioactivity remaining by the time erosion could occur.

Were the location or nature of the facilities to be forgotten, the facilities could also be disrupted by development activities undertaken in the far future. Should the facilities be disrupted by such activities and the waste mixed in with topsoil and spread out over the surface, slightly higher exposures could occur compared to a crofter family living on the land above undisturbed facilities. However, even using the worst-case assumptions of a family leading a subsistence lifestyle on the redeveloped land, calculated doses would still be below those from natural background radiation. Other activities, such as use of the area for residential development, a business park, or leisure, would result in much lower doses than received by a subsistence family.

Assurance

In accordance with current legislation and international best practice, the performance of the New LLW Facilities does not rely on actions by future generations to maintain the integrity of the disposal system. Despite this, during the operational period and for a time after closure, the facilities and surrounding environment will be monitored and access will be controlled. This will ensure that the facilities are not disrupted while the short-lived radioactivity decays. It also allows a period to demonstrate that the facilities are functioning as designed.

Approved quality assurance systems and procedures are in place for management activities that are ongoing, such as site characterisation and monitoring, detailed design, waste characterisation, and environmental safety assessment. Further quality assurance procedures and programmes will be developed as needed for future activities, such as facility construction, facility operations, and facility monitoring, and these procedures will be agreed with the regulators.

An authorisation from the Scottish Environment Protection Agency (SEPA) under the Radioactive Substance Act 1993 is required before LLW can be taken to the facilities for disposal. The ESC has been developed to demonstrate that the waste will be disposed of in a manner that protects the health and interests of people and the integrity of the environment, at the time of disposal and in the future, inspires public confidence, and takes account of costs. DSRL has been involved in a process of regulatory dialogue with SEPA on the ESC for approximately five years. This led to DSRL submitting an application for the authorisation for the disposal of waste to SEPA in April 2008. Following further dialogue with SEPA, the application was updated in October 2010.

DSRL will require authorisation from SEPA before the first waste is received at the New LLW Facilities, planned for 2014. Thereafter, the authorisation will be reviewed by SEPA at regular intervals, until such time after closure of the facilities, when they can be considered safe to be released from further regulatory control. Site characterisation, waste characterisation, optimisation, safety assessment, and confidence-building activities will continue as appropriate during detailed design, construction, operation and closure of the facilities. DSRL will develop regular updates to the ESC, and these will be scrutinised by SEPA as part of their periodic review of the authorisation.

Dialogue with stakeholders has been a significant input to decisions on the overall LLW management strategy at Dounreay, and on implementing the preferred option. The results of this stakeholder dialogue have also fed through to the ESC, and

influenced aspects of the design (below-surface as opposed to above-surface vaults) and siting of the facilities (as close as is practicable to the Dounreay site). Stakeholder dialogue will continue throughout the construction, operation and closure periods of the facilities. The views of near-neighbours will continue to be a particularly important input.

Summary

Following an evaluation of environmental, safety, social, technical, and financial issues, DSRL is proposing to deal with its LLW at source by developing specialised disposal facilities at Dounreay. The solid LLW is generally inert and its radioactivity content lies at the lower activity end of the radioactive waste spectrum. The planned disposal facilities are designed using well-established technology, are consistent with national and international guidance, and are similar to established disposal facilities elsewhere in the UK and in other European countries. Compared to disposal facilities for non-radioactive waste, the New LLW Facilities will use a high level of engineering to ensure that the majority of the radioactivity is contained until it decays. Containment levels are close to 100% for hundreds of years and, even over thousands of years, when the engineering will slowly degrade, the quantities of radioactivity that might be released from the facilities are much lower than quantities of radioactivity that are naturally present in the environment. Consequently, radiological impacts on people and the environment from the facilities will be significantly less than impacts from the background radiation that people are exposed to in their everyday lives.

Further Information

Key project references include:

- GNGL(04)TR75 April 2004 - Dounreay LLW Strategy Development - Best Practicable Environmental Option Study - Final Report.
- GNGL(05)P51 March 2005 - Dounreay Solid LLW Overall Strategy.
- LLW(06)S2/61 March 2006 - New LLW Facilities Project - Stage 2 - Environmental Statement.
- LLW(07)S2/261 March 2008 - New LLW Facilities Project - Stage 2 - Environmental Statement Addendum.
- LLW(07)S2/262 March 2008 - LLW Facilities Stage 2 - Environmental Statement Addendum Non-Technical Summary.
- NLLWF/3/ESC/GAL/0425/IS/01 October 2010 - New Low Level Waste Facilities – RSA 93 Environmental Safety Case 2010.

These, and other project documents, are available on the DSRL website: <http://www.dounreay.com/waste/radioactive-waste/low-level-waste/new-low-level-waste-facilities>.

We welcome comments on this summary paper and on the ESC. Contact:

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