Development Of Strategy For The Management Of LLW In The United Kingdom - 8112

A.S. Wareing
Nexia Solutions Ltd
Hinton House, Risley, Warrington, Cheshire, WA3 6AS, UK

J. Fisher
Nuclear Decommissioning Authority
Herdus House, Westlakes Science and Technology Park, Moor Row, Cumbria, CA24 3HU, UK

ABSTRACT

The Nuclear Decommissioning Authority (NDA) is a UK non-departmental public body with a remit to clean up the civil public sector nuclear legacy. Much work has been done to date on developing contractor competition for the management of NDA-owned sites, including the UK's principal disposal facility: the Low Level Waste Repository (LLWR) in Cumbria. The competition goals and principles are integrated with the framework for the development of a UK Low Level Waste (LLW) management plan, through which the NDA will deliver its commitments to UK Government and stakeholders.

Nexia Solutions has undertaken work for the NDA in assessing strategic options and scenarios for the management and disposal of current UK LLW. The volumetric, radiological and strategic limitations of existing disposition routes have been assessed against the inventories and characteristics of LLW forecast to arise. A number of potential alternative scenarios and variants for future LLW management have been modelled and assessed.

INTRODUCTION

The total volume of LLW predicted to arise in the UK up to the currently-projected end of operations in around 2129 (not including several millions of cubic metres of potentially-contaminated land *in situ*) is currently estimated to be in the region of 2.6 million cubic metres which, if packaged according to current UK practices, would result in over 3 million cubic metres of packaged waste requiring disposal [1]. This would equate to about four times the potential remaining volumetric capacity within the designated area of the UK's principal disposal facility: the Low Level Waste Repository (LLWR) near to the village of Drigg in Cumbria.

The Nuclear Decommissioning Authority (NDA) is a UK non-departmental public body established on 1st April 2005 under the Energy Act, 2004, with a remit to clean up the civil public sector nuclear legacy. Revised UK Government policy for the management of LLW [2] was published on 26th March 2007, following a consultation period. This paper presents the key points from the revised policy and it is shown how NDA strategy for LLW management [3] is being developed in alignment with this. The potential impact of both UK Government policy and NDA's wider strategic aims on the future management of LLW are discussed.

The work undertaken by Nexia Solutions for the NDA in assessing strategic options and scenarios for the management and disposal of current and future LLW arisings in the UK [4, 5] is presented. The volumetric, radiological and strategic limitations of existing disposition routes are discussed and placed into context with forecast inventories and characteristics of LLW. Potential alternative scenarios for future LLW management have been modelled and assessed, and the results of these are presented and compared. In particular, the opportunity for material segregation and classification that could result in some of the materials being reused, recycled or consigned to alternative management facilities, including ordinary landfill, is discussed.

The NDA is committed to the provision of the most cost-effective solutions for waste management without compromise to safety. Much work has been done to date on developing contractor competition for the management of NDA-owned sites, including the LLWR near Drigg in Cumbria. An overview of the competition goals and principles is given and it is shown how this is integrated with the overall framework for the development of a UK LLW management plan, through which the NDA will deliver its commitments to UK Government and other stakeholders.

THE ROLE OF THE NDA

Sponsored by the Department for Business, Enterprise and Regulatory Reform (DBURR), the NDA has strategic responsibility for the UK's civil nuclear legacy; specifically the decommissioning of 20 former British Nuclear Fuels Limited (BNFL) and United Kingdom Atomic Energy Authority (UKAEA) nuclear sites safely, securely, and cost effectively, whilst protecting the environment. Many of these sites have specific decommissioning problems arising from buildings and facilities that were in use in the 1940s and 1950s.

The NDA's mission is to deliver safe, sustainable and publicly acceptable solutions to the challenge of nuclear clean-up and waste management. In addition, the NDA were tasked with the full integration of the former nuclear waste agency, UK Nirex Ltd, integrating into the NDA's Radioactive Waste Management Directorate (RWMD) in April 2007.

In their approach to cleaning up the nuclear legacy the NDA:

- are responsible for the nuclear licensed sites, ensuring the right arrangements are in place for moving forward with the decommissioning and clean-up programme;
- ensure that the contractors responsible for managing and operating each site are accountable for their individual performance objectives;
- put in place comprehensive long-term plans for the clean-up of each site and ensure that short-term priorities for each site over a 5-10 year period are clearly identified;
- ensure that the knowledge base, skills and resources required for clean-up are available and can be sustained over the medium and long term;
- manage the differing demands of the sites so the available skills and resources are used to best effect by working with site licensees and the nuclear regulators, securing the optimum solutions for each site and the decommissioning programme;

- work with licensees and the regulators to identify best practice across sites and apply relevant lessons across the country; and
- look at best practice used by organisations internationally and in other sectors to improve performance and delivery.

Risks inherent in the programme are managed by the following guiding principles:

- completing the work to the highest environmental, security and safety standards;
- achieving best value for money consistent with those standards;
- operating with openness and transparency; and
- developing competitive markets for decommissioning and clean-up contracts, driving innovation and ensuring the best possible use of available skills.

Each site produces a Lifetime Plan (LTP) that sets out the short, medium and long-term priorities for the decommissioning and clean-up of each site, underpinned by Integrated Waste Strategies (IWS). Individual site LTPs are consolidated into one National LTP for the UK. This consolidated LTP shapes the National strategy for tackling the nuclear legacy. Setting a UK-wide strategy makes the most of existing working relationships between the sites. Best practice is shared between sites and a consistent approach to clean-up is adopted across the UK.

NDA is expected to develop a national strategy in the case of nuclear LLW. Government will assess and approve NDA strategy and plans, which will now include LLW management and disposal strategy to guide national, regional and local planning.

In addition, NDA must develop and publish a plan for the optimum use of the LLWR; assess the extent to which other disposal options might be employed and at what point in the future a replacement or replacements might be required and planned for the LLWR.

NDA will make LLW management and treatment facilities available to other nuclear and non-nuclear managers of radioactive waste on the basis of suitable commercial terms, and will also work in conjunction with Government on the development and maintenance of national strategy in the case of non-nuclear industry LLW to ensure the two strategies are suitably integrated.

UK LLW MANAGEMENT POLICY

Policy Overview

Policy for the long-term management of solid LLW in the UK [2] has been consulted upon and updated during 2006 and was formally published on 26th March 2007. The main aim of the policy is to provide greater flexibility in managing the different types of LLW in the UK.

The new policy statement is non-prescriptive, due to the range of LLW material types and associated radioactivity. It is acknowledged that each LLW management problem will have its own approach and is recognised that the development of solutions on a case-by-case basis is a matter for waste managers; for example, facilities for LLW should be ‘fit-for-purpose’, noting that different engineering solutions may be appropriate for different types of LLW and VLLW.

The policy therefore provides a high level framework where decisions can be taken flexibly to reflect the nature and type of LLW concerned.

The new policy statement provides greater clarity on many aspects of LLW management and expands the remit and responsibility of the NDA. LLW disposal with no intent of retrieval is the Government's desired end point for LLW that remains following application of the waste hierarchy. Postponing final disposal to future generations is considered unjustified.

Alternate waste management routes are made available, with the policy modified for the export and import of LLW to and from other Organisation for Economic Cooperation and Development (OECD) and European Union (EU) countries, for recovery of re-useable materials or where treatment will make its subsequent storage and disposal more manageable.

The revised definitions for high and low volume VLLW relaxes the limits for wastes containing tritium and C-14, which will alleviate pressures on management routes for wastes such as demolition wastes (concrete, rubble and asbestos for example).

Waste management hierarchy principles, diversification of solutions, presumption toward early implementation rather than later are all reinforced, underpinning NDA's Strategy and the direction NDA have been giving their waste producing contractors and the enhanced scope of the LLWR contract.

LLW management plans should take into account current and anticipated future arisings and their radiological and non-radiological properties. Plans should be developed with appropriate regulatory and stakeholder involvement, recognising current best practice and, as a general principle, should be agreed with regulators in advance of production of any new waste streams.

AN OVERVIEW OF UK LLW

Physical and Radiological Properties

LLW in the UK arises mainly from nuclear sites from all stages of the nuclear fuel cycle, enrichment processes, fuel fabrication, power generation, spent fuel reprocessing and waste disposal operations. Other sources of LLW include Research & Development and defence operations, medical and educational establishments (hospitals and universities), various industrial processes and the oil and gas industries [1].

LLW generation can be divided into two categories: operational and decommissioning. The nature of the wastes arising within these categories is highly variable but, typically, operational LLW is "soft and small items" i.e. used gloves, clothing, glassware and paper contaminated during plant operations, whereas items arising from decommissioning are typically less compactable "hard and larger items" i.e. used equipment, demolition waste, pipework and ducting from facilities. Some items are very large and heavy, such as redundant transport flasks. As time progresses, more steelwork and concrete from dismantling and demolition of buildings is expected.

Around 99% of LLW is chemically non-significant and arises from secondary contamination of clothing, plant furniture, etc. LLW covers a broad spectrum of over five orders of magnitude of activity (Fig. 1.) from the boundary with ILW (4 GBq/te alpha, 12 GBq/te betagamma) down through Very LLW (VLLW) to Exempt materials (0.4 MBq/te or below), which are not subject to specific regulatory control. No distinction is made in the UK between short and long-lived radioactivity.

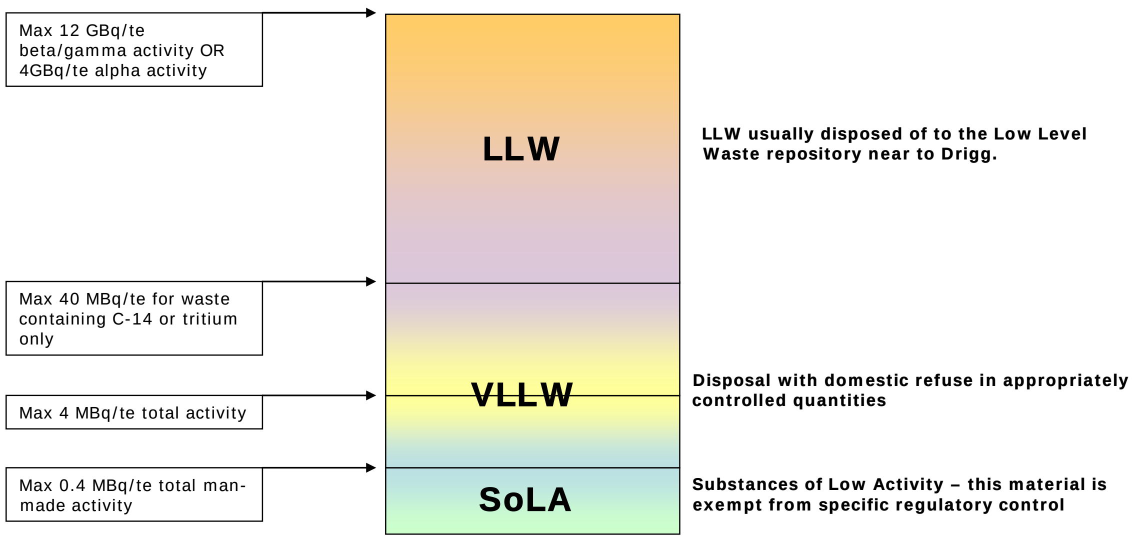

Fig. 1. Schematic showing range of activity of UK LLW

Historically, VLLW has been defined as waste which can safely be disposed of with ordinary refuse (dustbin disposal), each 0.1 cubic metres of material containing less than 400 kBq of betagamma activity or single items containing less than 40 kBq of betagamma activity.

Whilst this definition is suitable for the disposal of small, individual items (e.g. smoke alarms), it is difficult to apply to the much larger volumes of VLLW due to arise within the nuclear industry. The recent new Government policy on LLW Management [2] discussed above has sought to modify this definition, retaining the earlier definition for low volume disposals and providing a separate definition for High-Volume Low-Activity wastes (HVLA) in line with general LLW definitions based on mass as follows:

"Radioactive waste with maximum concentrations of 4 MBq/te of total activity which can be disposed of to ***specified*** landfill sites. *For waste containing solely Hydrogen-3* [tritium], *this value may be relaxed to 40MBq/te."*

Anticipated Volumes

Fig. 2. shows forecast cumulative raw arisings of LLW in the UK by year group, split by order of magnitude activity concentrations. Data are taken from the 2004 UK National Inventory [1] and do not include a significant proportion of lower-end wastes (i.e. HVLA and Exempt materials) which are not routinely recorded in the UK National Inventory.

It can be seen that, as time progresses, the average specific activity of waste arisings increases as more higher-end decommissioning wastes are introduced. The total volume predicted to arise in the UK (not including several tens of millions of cubic metres of potential contaminated land) is in the region of 2.6 million cubic metres which, if packaged according to current practice, would result in over 3 million cubic metres of packaged waste for disposal. This would equate to approximately 150,000 half-height ISO freight containers, or about four times the potential remaining volumetric capacity of the LLWR.

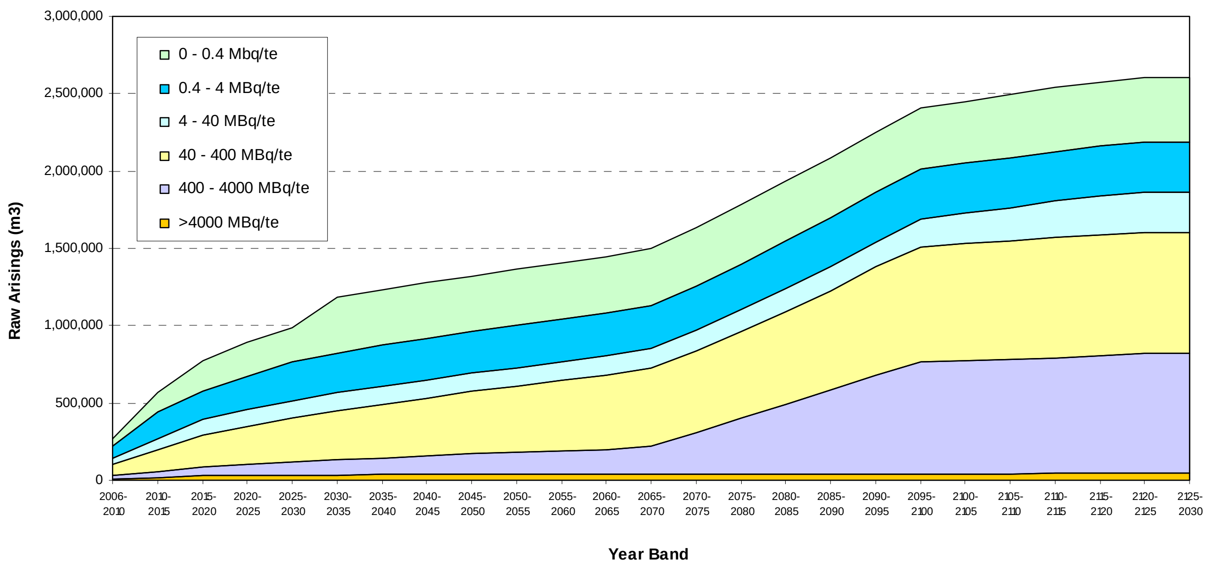

Fig. 2. Quantities of LLW forecast to arise in the UK split by order of magnitude activity concentrations

Current Disposition Routes

There are various options available that may be considered for the disposal of the wide spectrum of waste types and activity concentrations within LLW in the UK. The principal site for LLW disposal in the UK is the LLWR in Cumbria. Wastes are high-force compacted where appropriate and the resulting pucks grouted into half-height ISO freight containers prior to disposal. Other current disposal routes are summarised as follows:

- Disposal to specific areas of, or adjacent to, nuclear licensed sites (e.g. the current landfill-type disposal at Sellafield);
- In situ disposal; that is burial at the point of arising;
- Disposal at specified landfill sites, including the practice of controlled burial;
- General disposal to unspecified landfills; and
- Incineration

Commercial disposal for VLLW arising at the Springfields and Capenhurst sites is currently to the landfill site at Clifton Marsh. However, this route may not remain available; the recent reauthorisation of the Clifton Marsh site covers just the next five years, accounting for just 35% of the total forecast arisings for these waste streams.

LLW arising at Dounreay is stored on site pending the development of an on-site disposal repository.

Whilst the LLWR is the principal site for disposal of UK LLW, there is limited remaining capacity in the currently operational disposal vault; Vault 8, which is predicted to be full by mid-2009. Seven future disposal vaults (Vaults 9 to 15) are planned with a total capacity for around 700,000 cubic metres of containerised waste. As discussed, these future disposal vaults will be able to accommodate only around one quarter of forecast UK LLW arisings.

DEVELOPMENT OF UK LLW MANAGEMENT STRATEGY

Assessment Model and Parameters

In order to provide a complete assessment of the impact of LLW arisings on available disposition routes, it was first necessary to determine the quantities and nature of all future UK LLW arisings. The starting point for this work was the 2004 UK National Inventory [1], at the time the most up-to-date publicly–available data. However, the UK National Inventory does not contain information for all low-active wastes, and therefore data for additional waste streams had to be obtained from non-public domain sources within the nuclear industry. The separate provision of this lower-end LLW data also allowed for more up-to-date and more detailed information to be incorporated into the study.

Nexia Solutions has developed a software tool; the Waste Inventory Disposition Route Assessment Model [4, 5], which is a Microsoft Access® database model that serves as both a repository for the LLW inventory information and a tool to calculate packaged waste arising volumes, their associated radioactive inventories and the impact of these on potential disposition routes across different scenarios.

Packaging factors based on current disposal methodologies at the LLWR were available within the 2004 UK National Inventory and were used to calculate packaged stock and arising volumes for each waste stream. Radionuclide fingerprint data were used to calculate corresponding total activities for each radionuclide.

WIDRAM was set up such that the calculated LLW packaged volumes and activities could be assessed against a number of different disposition route scenarios, principally calculating the impact on the LLWR, for which limits are known, but also for other potential disposal routes such as the landfill site at Clifton Marsh, Dounreay, *in situ* disposal and potential new LLW repositories.

In addition to the volumetric capacity limitations for future disposals to the LLWR discussed above, there are restrictions on the amount of radioactivity that can be disposed of at the site, on both an annual and a total basis. Remaining volumetric and radiological capacities for the LLWR were calculated independently from WIDRAM and the results of these calculations incorporated into the model. It was assumed for the purposes of the assessment that the LLWR will continue to operate under current Authorisation limits, which were set in 1988. The radiological capacity values used are based on the current Disposal Authorisation. Remaining radiological capacities are calculated by subtracting actual arising activity values between 1988 and 2006 from the Authorisation limits.

Table I shows a comparison of the remaining radiological capacities with the forecast future inventories by each radionuclide group as restricted in the current Disposal Authorisation. The future inventory shown is for all LLW forecast to arise in the UK up to 2129, as taken from WIDRAM. The large majority of these wastes are suitable for disposal at the LLWR. Dates at which each capacity would be reached have been calculated based on the assumption that wastes would be disposed of in the year of their arising, which is common practice for the majority of LLW streams.

In order to achieve the level of detail required in the analysis of LLW disposition routes it was first necessary for the LLW streams to be divided into three categories in WIDRAM according to their levels of activity concentration, as follows:

LLW1	α <= 4 $GBq.t^{-1}$ and/or $\beta\gamma$ <= 12 $GBq.t^{-1}$ and α >= 1 $Bq.g^{-1}$ and or $\beta\gamma$ >= 40 $Bg.g^{-1}$
LLW2	α < 1 $Bq.g^{-1}$ and or $\beta\gamma$ < 40 $Bg.g^{-1}$ and $\alpha + \beta\gamma$ >= 0.4 $Bq.g^{-1}$
Exempt Waste	$\alpha + \beta\gamma$ <0.4 $Bq.g^{-1}$

These categories correspond approximately to the three subdivisions of LLW demonstrated in Fig. 1. and generally have differing disposition routes.
As has been demonstrated, the volumetric and radiological limits of the LLWR are exceeded by future LLW arisings. Taking this into account, potential alternative disposition routes were identified for analysis. These alternatives were:

1. to open a new generic LLW facility at a fixed point in the future to incorporate LLW1 type wastes or both LLW1 and LLW2 type wastes;
2. *in situ* or local disposal of waste at appropriate sites (e.g. Magnox reactor sites);
3. continued use of the Clifton Marsh landfill site for suitable wastes from Capenhurst and Springfields; and
4. Dounreay to dispose of its own LLW on site.

Four scenarios for future UK LLW management were assessed within WIDRAM. The two most distinct scenarios, Scenario 1 and Scenario 3, are presented here. Scenario 1 (Table I) is intended to represent current UK LLW disposal strategy. All LLW is routed for disposal to the LLWR except Sellafield LLW2 (which is disposed at dedicated landfill facilities on the Sellafield site), Capenhurst and Springfields LLW2 (which is disposed at the Clifton Marsh landfill), Dounreay LLW1 and LLW2 (which is expected to be disposed at a purpose-built facility at Dounreay) and all exempt wastes.

Volumetric rates of arising are as given in WIDRAM. Exempt waste is considered to have an identified disposal route and is not included in the scenario analysis.

Table I. Scenario 1: Current disposal strategy

Site Groupings	Activity Level	LLWR at Drigg	Dounreay	Clifton Marsh	On Site/Local LLW facility
Sellafield	LLW1	2006 – end	X	X	X
	LLW2	X	X	X	2006 – end
Capenhurst & Springfields	LLW1	2006 – end	X	X	X
	LLW2	X	X	2006 - end	X
Magnox Reactor Sites	LLW1	2006 – end	X	X	X
	LLW2	2006 – end	X	X	X
UKAEA (excl. Dounreay)	LLW1	2006 – end	X	X	X
	LLW2	2006 – end	X	X	X
UKAEA Dounreay	LLW1	X	2006 – end	X	X
	LLW2	X	2006 - end	X	X
British Energy	LLW1	2006 – end	X	X	X
	LLW2	2006 – end	X	X	X
Ministry of Defence	LLW1	2006 – end	X	X	X
	LLW2	2006 – end	X	X	X
Others	LLW1	2006 – end	X	X	X
	LLW2	2006 – end	X	X	X

Scenario 3 represents a possible interpretation of the decommissioning strategy set out by the NDA. In this scenario, the accelerated timescales for decommissioning of NDA-owned facilities are taken into account, together with the availability of a new LLW repository. All LLW is routed for disposal to the LLWR except Sellafield LLW2 (which is disposed at dedicated landfill facilities on the Sellafield site), Capenhurst and Springfields LLW2 (which is disposed at the Clifton Marsh landfill), Dounreay LLW1 and LLW2 (which is expected to be disposed at a purpose-built facility at Dounreay) and all exempt wastes. In addition, LLW2 from Magnox reactors is assumed to be disposed of to localised/on-site facilities from a range of dates dependent on the site of origin. Furthermore LLW2 from all other facilities except Sellafield, Capenhurst, Springfields and Dounreay is assumed to be disposed of to localised/on-site facilities from around 2015. This scenario also considers the possibility that the LLWR will not be available for disposals beyond 2020 (requiring a limited number of future vaults) but that its closure will coincide with the availability of a new UK LLW facility.

Table II. Scenario 3: New LLW1 facility at 2020 with programme acceleration

Groupings	Activity Level	LLWR at Drigg	New UK LLW Repository	Dounreay	Clifton Marsh	On Site/Local LLW facility
Sellafield	LLW1	2006 - 2020	2020 – end	X	X	X
	LLW2	X	X	X	X	2006 – end
Capenhurst & Springfields	LLW1	2006 – 2020	2020 – end	X	X	X
	LLW2	X	X	X	2006 - end	X
Magnox Reactor Sites	LLW1	2006 – 2020	2020 – end	X	X	X
	LLW2	2006 – *	X	X	X	* - end
UKAEA (excl. Dounreay)	LLW1	2006 – 2020	2020 – end	X	X	X
	LLW2	2006 – 2015	X	X	X	2015 - end
UKAEA	LLW1	X	X	2006 - end	X	X

Groupings	Activity Level	LLWR at Drigg	New UK LLW Repository	Dounreay	Clifton Marsh	On Site/Local LLW facility
Dounreay	LLW2	X	X	2006 - end	X	X
British Energy	LLW1	2006 – 2020	2020 – end	X	X	X
	LLW2	2006 – 2015	X	X	X	2015 - end
Ministry of Defence	LLW1	2006 – 2020	2020 – end	X	X	X
	LLW2	2006 – 2015	X	X	X	2015 - end
Others	LLW1	2006 - 2020	2020 – end	X	X	X
	LLW2	2006 – 2015	X	X	X	2015 - end

* Date variable, dependent on reactor site.

Assessment Results

WIDRAM calculates the potential future volumetric capacity of the LLWR to be filled by around 2051 for Scenario 1. Approximately 1.5 million cubic metres of packaged waste are forecast to arise beyond this date which may require disposal at a future LLW repository.

Table III shows the dates by which each of the LLWR calculated remaining radiological capacities for authorised radionuclide groupings are filled, according to the results from WIDRAM for Scenario 1. It can be seen that the most significantly challenged radionuclide group is C-14, with forecast arisings sufficient to achieve the capacity limit for C-14 by 2011. However, the Uranium, Other Betagamma and Other Alpha authorised radionuclide groups also achieve capacity prior to volumetric filling of the LLWR. Assessment of individual waste streams shows that a relatively small number of waste streams are commonly identified as major contributors to more than one radionuclide group; thus the removal of just one waste stream from LLWR disposal could, potentially alleviate the impact over several radionuclide limits

Table III. Use of the LLWR's Remaining Radiological Capacity (Scenario 1)

Nuclide Group	Limit (TBq)	Arising (TBq)	Date Filled	% Capacity Used	% Arising Uptaken
Uranium	7.37	10.59	2029	100	69.6
Ra-226/Th-232	0.76	3.04	2060	100	25
Carbon-14	1.35	112.29	2011	100	1.2
Iodine-129	1.49	0.00	Not Filled	0.2	100
Tritium	284.58	129.73	Not Filled	45.6	100
Cobalt-60	54.92	59.81	2059	100	91.8
Other Betagamma	383.53	636.17	2019	100	60.3
Other Alpha	7.07	19.80	2028	100	35.7

Table IV shows the volumes of packaged waste by disposition route for LLW not planned for disposal at the LLWR in Scenario 1. Dounreay wastes, with a volume of approximately 360,000 cubic metres are a significant component and a large part of this volume is in the category LLW1. Capenhurst and Springfields wastes for disposal at Clifton Marsh total around 250,000 cubic metres over a 25-year period. This is significant, since the recent reauthorisation of the Clifton Marsh site covers just the next five years, in which approximately 87,500 cubic metres of packaged waste will arise – around 35% of the total forecast arisings for these waste streams.

Over 120,000 cubic metres of Sellafield LLW2 category wastes are predicted to arise in Scenario 1, assumed to be routed to a local or on-site facility at Sellafield.

Table IV. Other Disposal Routes Required: By Category (Scenario 1)

Consignor Group	Category	Disposition Route	Volume (m^3)
Sellafield	LLW2	Local/On-Site Facility	121,600
Capenhurst & Springfields	LLW2	Clifton Marsh	252,700
UKAEA Dounreay	LLW1	Dounreay	146,000
UKAEA Dounreay	LLW2	Dounreay	11,500

WIDRAM calculates that less than two-thirds of the potential future volumetric capacity of the LLWR will be utilised by 2020 for Scenario 3, when the LLWR is assumed to be no longer available. Approximately 1.6 million cubic metres of packaged waste are forecast to arise beyond this date which will require disposal at a future LLW repository.

Table V shows the dates by which each of the LLWR calculated remaining radiological capacities for authorised radionuclide groupings are filled, according to the results from WIDRAM for Scenario 3. With the exception of C-14 and Other Betagamma, all radionuclide group limits are not achieved by the assumed date of site closure in 2020. Less than half of the C-14 activity routed to the LLWR up to 2020 can be accepted, whilst the Other Betagamma activity limit falls short by one year, with just 6% of the forecast activity not uptaken.

Table V. Use of the LLWR's Remaining Radiological Capacity (Scenario 3)

Nuclide Group	Limit (TBq)	Arising (TBq)	Date Filled	% Capacity Used	% Arising Uptaken
Uranium	7.37	4.48	Not Filled	60.8	100
Ra-226/Th-232	0.76	0.21	Not Filled	27.6	100
Carbon-14	1.35	2.93	2011	100	46
Iodine-129	1.49	0.00	Not Filled	0.1	100
Tritium	284.58	44.77	Not Filled	15.7	100
Cobalt-60	54.92	50.56	Not Filled	92.1	100
Other Betagamma	383.53	408.22	2019	100	94
Other Alpha	7.07	3.88	Not Filled	54.9	100

The volumes of waste forecast for disposition routes other than the LLWR at Drigg in Scenario 3 are shown in Table VI. The new LLW repository will be required to receive approximately 1.6 million cubic metres of packaged waste in this scenario; around half of which is Sellafield LLW1 arisings.

Table VI. Other Disposal Routes Required: By Category (Scenario 3)

Consignor Group	Category	Disposition Route	Volume (m^3)
Sellafield	LLW1	New LLW Repository	797,700
	LLW2	Local/On-Site Facility	145,800
Capenhurst & Springfields	LLW1	New LLW Repository	2,700
	LLW2	Clifton Marsh	251,700
Magnox Reactor Sites	LLW1	New LLW Repository	267,200

Consignor Group	Category	Disposition Route	Volume (m^3)
	LLW2	Local/On-Site Facility	152,900
UKAEA (excl. Dounreay)	LLW1	New LLW Repository	26,600
	LLW2	Local/On-Site Facility	3,800
UKAEA Dounreay	LLW1	Dounreay	1465,000
	LLW2	Dounreay	11,500
British Energy	LLW1	New LLW Repository	54,900
	LLW2	Local/On-Site Facility	12,400
Ministry of Defence	LLW1	New LLW Repository	461,200
	LLW2	Local/On-Site Facility	695
Others	LLW1	New LLW Repository	15,700
	LLW2	Local/On-Site Facility	6,400

Total activities forecast for the new LLW repository disposition route in Scenario 3 for each of the eight Drigg LLWR authorisation groupings were calculated in WIDRAM as follows:

Carbon-14: 1.11E+02 TBq
Cobalt-60: 7.66E+00 TBq
Iodine-129: 1.32E-03 TBq
Other Alpha: 1.58E+01 TBq
Other Betagamma: 2.20E+02 TBq
Ra-226/Th-232: 7.45E-01 TBq
Tritium: 8.31E+01 TBq
Uranium: 5.73E+00 TBq

If these are compared to the remaining radiological capacities at the LLWR (Table III), it can be seen that, with the exception of C-14 and Other Alpha, the forecast activity arisings for all radionuclide groups are lower than the remaining capacities at the LLWR. Forecast arisings of Other Alpha for the new repository are around twice the LLWR's remaining capacity, whilst C-14 forecast arisings for the new repository are approximately two orders of magnitude greater than the LLWR's remaining capacity. The waste streams making up the largest portion of this C-14 activity are predominantly reactor activated graphite, with lesser, but nevertheless considerable, contributions from reactor activated stainless steel and concrete. There is, however, some uncertainty over what the final classification of graphite wastes from Magnox reactors will be: it is possible that these waste streams may be designated as ILW, dependent on the level of irradiation of the graphite within the reactor and the activity content of C-14 as an activation product.

The analysis results suggest that, in general (and with the exception of C-14), the radiological requirements of the new LLW disposal facility will be broadly similar to those of the current LLWR and, with forecast arisings of around 1.6 million cubic metres, not dissimilar in volumetric capacity.

Further Development of the WIDRAM Tool

The results from the WIDRAM assessment presented above have shown that the LLWR does not have enough volumetric or radiological capacity to accommodate anticipated future arisings of

UK LLW. Whilst the additional capacity required could be provided by one or more new engineered disposal facilities, the recently revised UK LLW management policy requires that more cost-effective, fit-for-purpose disposition routes should be developed through application of the waste hierarchy, with disposal to engineered facilities or landfill being seen as a last resort.

The need to develop disposal routes alternative to engineered facilities such as the LLWR is further highlighted by examination of the physical make-up of forecast future LLW arisings. It is shown in Fig. 3. that compactable and non-compactable proportions change in favour of non-compactable as time progresses. There is approximately 1.7 million cubic metres (2.5 million tonnes) of raw non-compactable wastes against around 850,000 cubic metres (100,000 tonnes) of raw compactable wastes. The importance of applying the waste hierarchy becomes clear; as decommissioning operations increase the current compacted, containerised waste form utilised at the LLWR will be decreasingly efficient as more non-compactable wastes arise. There is therefore a need to identify appropriate treatment routes higher up the hierarchy, such as recycling and reuse. It is important to note that the majority of the 2.6 million cubic metres of raw LLW forecast to arise in the UK is already present as contaminated plant, equipment and ground, and therefore cannot be prevented.

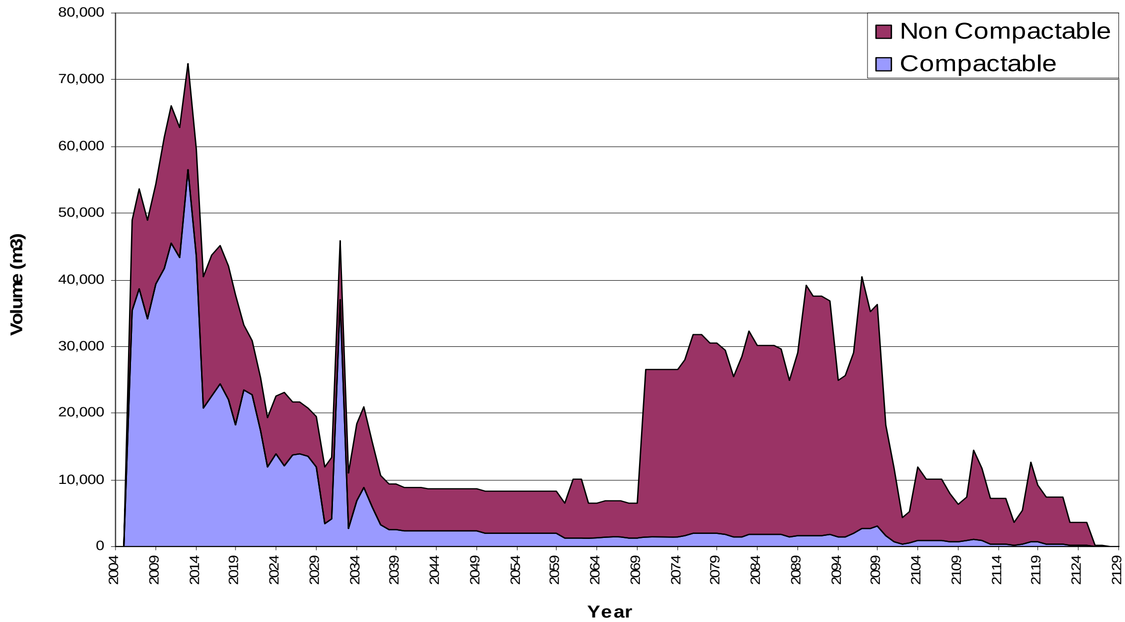

Fig. 3. Compactable and non-compactable components of future forecast UK LLW

Application of the waste hierarchy, which is central to NDA strategy, is likely to focus on the treatment of wastes by location, physical makeup, levels of contamination and overall quantity; for example, a large volume of lightly-contaminated metallic waste at a single site, or several smaller volumes of such waste located at a number of sites in close proximity might be an ideal stream to consider metal-melting rather than disposal to the LLWR. With such a route in place, a waste stream recorded in WIDRAM as comprising 50% cellulosics and 50% metal might then be shown to be suitable for splitting into two sub-streams, with the metallic component being routed for metal melting and the cellulosic component incinerated or disposed of to a suitable repository. Of course appropriate regard would have to be given to the extent of the streams volume, the ability to segregate the waste and the radionuclide fingerprint and activity concentration.

To achieve this versatility in the modelling of LLW management scenarios, WIDRAM has been further developed with improved modelling capability to facilitate the creation of sub-streams based on material contents and the assigning of individual disposition routes to such sub-streams. Additionally, recognising that changes in disposal strategy take time to implement and therefore new treatment routes may not come on line for some years, the ability to assign different disposition routes to individual streams or sub-streams by time has been a valuable inclusion to the model (Fig. 4.).

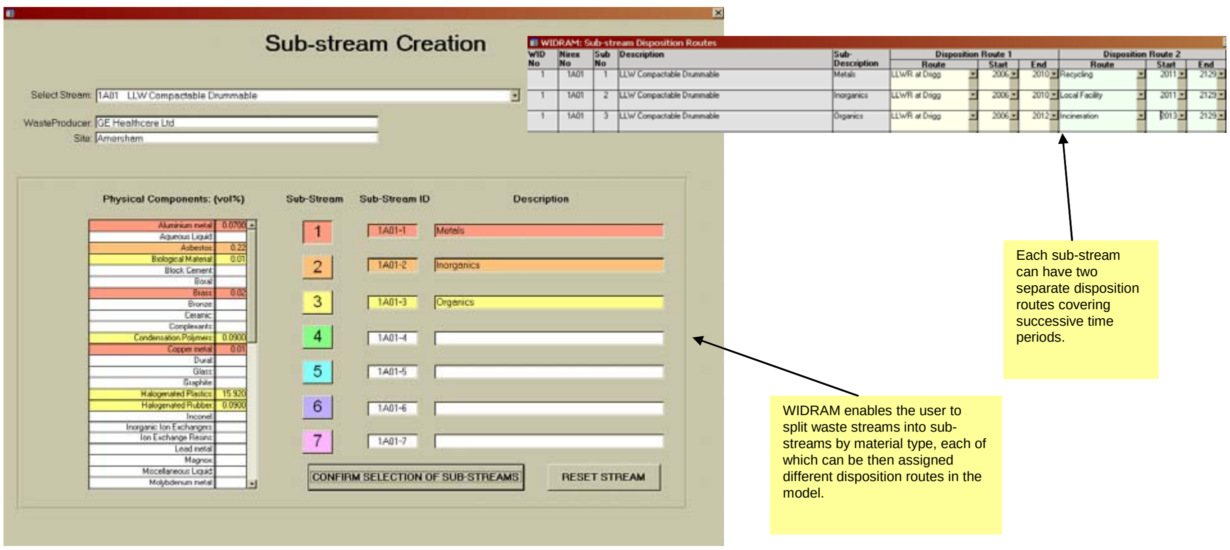

Fig. 4. Example Input Screens from the 2nd Generation WIDRAM Tool

The 2nd generation WIDRAM tool, which has undergone peer review within the UK nuclear industry, is one of several components put in place by the NDA to achieve its LLW management strategy. It is recognised that the analysis of waste stream data required to identify and model appropriate disposition routes can only by successfully achieved if the input data is of sufficient quality and currency. To this end, Nexia Solutions has sought to assist the NDA in developing processes for waste tracking and reporting and in identifying and sharing best practice amongst the sites in the production of IWS and LTP documentation.

Nexia Solutions has, since the middle of the 2006/07 financial year, taken on the development of a formal system for the forecasting and accountancy of waste arising at NDA sites, known as the Waste Accountancy Template (WAT). The WAT is being used by the sites to record the waste inventory data underpinning the annual IWS and LTP submissions, which will be input to the WIDRAM tool. In addition, it provides detailed waste accountancy data such that the NDA is able to track progress against clean-up plans and produce stakeholder reports.

It is anticipated that the improved inventory data quality will reduce uncertainty in modelling results and hence build confidence in the identified strategy for UK LLW management and disposal and in the estimated financial provision required to deal with these liabilities.

CONCLUSIONS

An assessment of future arisings of UK LLW has shown there to be a significant shortfall in the volumetric and radiological capacities of the LLWR, with future arisings anticipated to be around four times the potential volumetric capacity. In particular it has been shown that, with no alternative measures in place, the LLWR could be full volumetrically by around 2051 and radiologically, for C-14, by as early as 2011.

The introduction of alternative disposal facilities in Scenario 3 has been shown to reduce the impact on the LLWR such that, with the exception of some provision needing to be made for the significantly challenging waste streams contributing to the C-14 and Other Betagamma radionuclide groups, uninterrupted disposal capacity for UK LLW could be achieved. This is based on the assumption that an alternative engineered disposal facility to the LLWR will be available by 2020; however, there is potentially some room for manoeuvre, as it is shown that less than two thirds of the potential future volumetric capacity of the LLWR is utilised by this date.

Application of the UK Government's recently revised LLW management policy will require the NDA and Site Licence Companies (SLCs) to seek more environmentally sound and cost-effective disposition routes higher up the waste hierarchy, in line with NDA strategy. Tools and mechanisms have been put in place to assist the NDA in developing appropriate solutions for the management and disposal of UK LLW through the gathering of up-to-date and high-quality inventory data using the Waste Accountancy Template and the assessment of the impact of LLW arisings on disposal routes via WIDRAM.

ACKNOWLEDGEMENTS

The work described in this paper was carried out under the sponsorship and funding of the NDA and the authors are grateful for their support and encouragement throughout.

REFERENCES

1. "The 2004 United Kingdom Radioactive Waste Inventory – Main Report", Electrowatt-Ekono (2005).
2. "Policy for the Long-Term Management of Solid Low Level Radioactive Waste in the United Kingdom", PB 12522, Defra, DTI and the Devolved Administrations (2007).
3. "Nuclear Decommissioning Authority Strategy", NDA (2006).