

| WASTE STREAM | 9A316 | Graphite LLW |
|--------------|-------|--------------|
|--------------|-------|--------------|

**SITE** Berkeley

**SITE OWNER** Nuclear Decommissioning Authority

**WASTE CUSTODIAN** Nuclear Restoration Services Ltd (NRS)

**WASTE TYPE** LLW

#### WASTE VOLUMES

|                        | Reported (m <sup>3</sup> ) | OR   | Conditioned (m <sup>3</sup> ) | Packaged (m <sup>3</sup> ) |
|------------------------|----------------------------|------|-------------------------------|----------------------------|
| Stocks:                | At 1.4.2025                | = 0  |                               |                            |
| Future arisings:       | 1.4.2060 - 31.3.2079       | 33.0 |                               |                            |
| Total future arisings: |                            | 33.0 |                               |                            |
| Total waste volume:    |                            | 33.0 |                               |                            |

Number of waste packages in stock: At 1.4.2025..... - packages

Comment on arising rates: For inventory purposes waste arisings are assumed to occur at a uniform rate over 20 years.

Additional information on quantities: Reactor Dismantling and Site Clearance is assumed to commence in 2060 and last for 20 years.

Uncertainty factors on volumes: Stock (upper): x - Arisings (upper): x 1.20  
Stock (lower): x - Arisings (lower): x 0.80

**WASTE SOURCE** Gas deflector and thermal column graphite from reactor dismantling.

#### PHYSICAL CHARACTERISTICS

General description: Graphite blocks and other graphite components. Waste can be packaged in standard LLW packages.

Changes since waste generated: -

Bulk density (t/m<sup>3</sup>): ~ 1.3

Comment on density: The density is of the waste as cut for packaging. Density estimate based upon assumed packing efficiency of the waste with 90% of the graphite in blocks and 10% as rubble.

#### CHEMICAL COMPOSITION

General description and components (%wt): Graphite and possibly traces of ferrous metals.

Chemical state: Neutral

Sheet metal proportion / thickness: There are no metallic items present.

Metals and alloys (%wt):

|                           | (%wt) | Type(s) / Grades(s) with proportions                | % of total C14 activity |
|---------------------------|-------|-----------------------------------------------------|-------------------------|
| Stainless steel.....      | TR    | There may be trace contamination by ferrous metals. |                         |
| Other ferrous metals..... | TR    | There may be trace contamination by ferrous metals. |                         |
| Iron.....                 | -     | -                                                   |                         |
| Aluminium.....            | = 0   | -                                                   |                         |
| Beryllium.....            | TR    | -                                                   |                         |
| Cobalt.....               | -     | -                                                   |                         |
| Copper.....               | = 0   | -                                                   |                         |
| Lead.....                 | = 0   | -                                                   |                         |
| Magnox/Magnesium.....     | = 0   | -                                                   |                         |
| Nickel.....               | -     | -                                                   |                         |
| Titanium.....             | -     | -                                                   |                         |
| Uranium.....              | -     | -                                                   |                         |
| Zinc.....                 | = 0   | -                                                   |                         |
| Zircaloy/Zirconium.....   | = 0   | -                                                   |                         |
| Other metals.....         | = 0   | There are no "other" metals present.                |                         |

Organics (%wt):

|                                     | (%wt) | Type(s) and comment | % of total C14 activity |
|-------------------------------------|-------|---------------------|-------------------------|
| Total cellulose.....                | = 0   | -                   |                         |
| Paper, cotton.....                  | = 0   | -                   |                         |
| Wood.....                           | = 0   | -                   |                         |
| Halogenated plastics.....           | = 0   | -                   |                         |
| Total non-halogenated plastics..... | = 0   | -                   |                         |
| Condensation polymers.....          | = 0   | -                   |                         |
| Others.....                         | = 0   | -                   |                         |
| Organic ion exchange materials..... | = 0   | -                   |                         |
| Total rubber.....                   | = 0   | -                   |                         |
| Halogenated rubber.....             | = 0   | -                   |                         |
| Non-halogenated rubber.....         | = 0   | -                   |                         |
| Hydrocarbons.....                   |       | -                   |                         |
| Oil or grease.....                  |       | -                   |                         |
| Fuel.....                           |       | -                   |                         |
| Asphalt/Tarmac (cont.coal tar)..... |       | -                   |                         |
| Asphalt/Tarmac (no coal tar).....   |       | -                   |                         |
| Bitumen.....                        |       | -                   |                         |
| Others.....                         |       | -                   |                         |
| Other organics.....                 | = 0   | -                   |                         |

Other materials (%wt):

|                                       | (%wt)   | Type(s) and comment | % of total C14 activity |
|---------------------------------------|---------|---------------------|-------------------------|
| Inorganic ion exchange materials..... | = 0     | -                   | 100.0                   |
| Inorganic sludges and flocs.....      | = 0     | -                   |                         |
| Soil.....                             | = 0     | -                   |                         |
| Brick/Stone/Rubble.....               | = 0     | -                   |                         |
| Cementitious material.....            | = 0     | -                   |                         |
| Sand.....                             |         | -                   |                         |
| Glass/Ceramics.....                   | = 0     | -                   |                         |
| Graphite.....                         | = 100.0 | -                   |                         |
| Desiccants/Catalysts.....             |         | -                   |                         |
| Asbestos.....                         | = 0     | -                   |                         |
| Non/low friable.....                  |         | -                   |                         |
| Moderately friable.....               |         | -                   |                         |
| Highly friable.....                   |         | -                   |                         |
| Free aqueous liquids.....             | = 0     | -                   |                         |
| Free non-aqueous liquids.....         | = 0     | -                   |                         |
| Powder/Ash.....                       | = 0     | -                   |                         |

#### COMPONENTS OF MATERIALS, WASTE PROPERTIES, MATERIALS NOT CONTRIBUTING TO MASS

Inorganic anions (%wt):

|                | (%wt) | Type(s) and comment                                     |
|----------------|-------|---------------------------------------------------------|
| Fluoride.....  | TR    | Detected at trace levels in inactive graphite material. |
| Chloride.....  | TR    | -                                                       |
| Iodide.....    | = 0   | -                                                       |
| Cyanide.....   | = 0   | -                                                       |
| Carbonate..... | TR    | -                                                       |
| Nitrate.....   | TR    | -                                                       |
| Nitrite.....   | = 0   | -                                                       |
| Phosphate..... | TR    | Detected at trace levels in inactive graphite material. |
| Sulphate.....  | TR    | Detected at trace levels in inactive graphite material. |
| Sulphide.....  | = 0   | -                                                       |

Materials of interest for waste acceptance criteria:

|                                                | (%wt) | Type(s) and comment                                     |
|------------------------------------------------|-------|---------------------------------------------------------|
| Combustible metals.....                        | = 0   | -                                                       |
| Low flash point liquids.....                   | = 0   | -                                                       |
| Explosive materials.....                       | = 0   | -                                                       |
| Phosphorus.....                                | TR    | Detected at trace levels in inactive graphite material. |
| Hydrides.....                                  | = 0   | -                                                       |
| Biological etc. materials.....                 | = 0   | -                                                       |
| Biodegradable materials.....                   | 0     | -                                                       |
| Putrescible wastes.....                        | = 0   | -                                                       |
| Non-putrescible wastes.....                    |       | -                                                       |
| Corrosive materials.....                       | = 0   | -                                                       |
| Pyrophoric materials.....                      | = 0   | -                                                       |
| Generating toxic gases.....                    | = 0   | -                                                       |
| Reacting with water.....                       | = 0   | -                                                       |
| Higher activity particles.....                 |       | -                                                       |
| Soluble solids as bulk chemical compounds..... |       | -                                                       |

Hazardous substances / non hazardous pollutants:

|                             | (%wt) | Type(s) and comment                                                                     |
|-----------------------------|-------|-----------------------------------------------------------------------------------------|
| Acrylamide.....             | -     | -                                                                                       |
| Benzene.....                | -     | -                                                                                       |
| Chlorinated solvents.....   | -     | -                                                                                       |
| Formaldehyde.....           | -     | -                                                                                       |
| Organometallics.....        | -     | -                                                                                       |
| Phenol.....                 | -     | -                                                                                       |
| Styrene.....                | -     | -                                                                                       |
| Tri-butyl phosphate.....    | -     | -                                                                                       |
| Other organophosphates..... | -     | -                                                                                       |
| Vinyl chloride.....         | -     | -                                                                                       |
| Arsenic.....                | TR    | Detected at trace levels in inactive graphite material.                                 |
| Barium.....                 | -     | -                                                                                       |
| Boron.....                  | 0     | -                                                                                       |
| Boron (in Boral).....       | -     | -                                                                                       |
| Boron (non-Boral).....      | -     | -                                                                                       |
| Cadmium.....                | -     | -                                                                                       |
| Caesium.....                | -     | -                                                                                       |
| Selenium.....               | -     | -                                                                                       |
| Chromium.....               | -     | -                                                                                       |
| Molybdenum.....             | -     | -                                                                                       |
| Thallium.....               | TR    | Detected at trace levels in inactive graphite material.                                 |
| Tin.....                    | -     | -                                                                                       |
| Vanadium.....               | -     | -                                                                                       |
| Mercury compounds.....      | -     | -                                                                                       |
| Others.....                 | TR    | Gallium, germanium and rubidium detected at trace levels in inactive graphite material. |

Complexing agents (%wt):

| Yes                            |       |                     |
|--------------------------------|-------|---------------------|
|                                | (%wt) | Type(s) and comment |
| EDTA.....                      | -     | -                   |
| DPTA.....                      | -     | -                   |
| NTA.....                       | -     | -                   |
| Polycarboxylic acids.....      | -     | -                   |
| Other organic complexants..... | -     | -                   |
| Total complexing agents.....   | TR    | -                   |

Physical components:

|                                         | Number | Type(s) and comment |
|-----------------------------------------|--------|---------------------|
| Sources.....                            | -      | -                   |
| Electronic & Electrical Equipment (EEE) | -      | -                   |
| EEE Type 1.....                         | -      | -                   |
| EEE Type 2.....                         | -      | -                   |
| EEE Type 3.....                         | -      | -                   |
| EEE Type 4.....                         | -      | -                   |
| EEE Type 5.....                         | -      | -                   |

## TREATMENT, PACKAGING AND DISPOSAL

Planned on-site / off-site treatment(s):

| Treatment                                                  | On-site / Off-site | Stream volume % |
|------------------------------------------------------------|--------------------|-----------------|
| Size reduction                                             |                    |                 |
| Decay storage                                              |                    |                 |
| Low force compaction                                       |                    |                 |
| Supercompaction (HFC)                                      |                    |                 |
| Incineration                                               |                    |                 |
| Drying/dewatering/liquid separation                        |                    |                 |
| Tie down/fixatives/strippable coating/painting application |                    |                 |
| Decontamination                                            |                    |                 |
| Metal treatment                                            |                    |                 |
| Recycling / reuse                                          |                    |                 |
| Thermal treatment, including vitrification                 |                    |                 |
| Encapsulation                                              |                    |                 |
| Polymer encapsulation                                      |                    |                 |
| Other physical treatment                                   |                    |                 |
| Other chemical treatment                                   |                    |                 |
| Containerisation                                           |                    |                 |
| Treatment not yet determined                               |                    |                 |
| None                                                       |                    |                 |

Comments on planned treatments:

It is envisaged that the waste will be put into baskets, placed in the container and grouted. Different reactor dismantling and site clearance LLW may be placed in the same package. The occupied volume in the package is greater than the original waste volume. A conditioning factor of 1.167 has been assumed to allow for the waste being placed in baskets before loading into standard 4m boxes.

Conditioning method:

-

|                      |            |          |
|----------------------|------------|----------|
| Conditioning plants: | Plant Name | Location |
|                      |            |          |

Likely conditioning matrix: -

Further information on the conditioning matrix: -

#### Waste Packaging:

|                        |               |                       |                    |              |                    |                                    |
|------------------------|---------------|-----------------------|--------------------|--------------|--------------------|------------------------------------|
| Likely container type: | Container     | Waste packaged (vol%) | Waste loading (m³) | Payload (m³) | Number of packages | Estimated start date for packaging |
|                        | 4 m box (LLW) | 100.0                 | 16.2               | 16.2         | 3                  | -                                  |

Range in container waste loading: -

Other information on packaging and conditioning: -

Conditioned density (t/m³): -

Conditioned density comment: -

#### Management Routes:

| Disposal Route                                                                     | Stream volume % | Raw density t/m³ | Start date |
|------------------------------------------------------------------------------------|-----------------|------------------|------------|
| Expected to be consigned to a Near Site, Near Surface Disposal Facility (Scotland) | = 100.0         | 1.3              | 2060       |
| Expected to be Non-NSD HAW managed under Scottish Government's policy              |                 |                  |            |
| Expected to be disposed to LLW Vaults NRS Dounreay                                 |                 |                  |            |
| Expected to be consigned to the Geological Disposal Facility                       |                 |                  |            |
| Expected to be consigned to a Near Surface Disposal Facility                       |                 |                  |            |
| Expected to be consigned to the LLW Repository                                     |                 |                  |            |
| Expected to be consigned to a Landfill Facility                                    |                 |                  |            |
| Expected to be disposed On-Site                                                    |                 |                  |            |
| Expected to be managed by In-Situ Disposal                                         |                 |                  |            |
| Expected to be consigned to an Incineration Facility                               |                 |                  |            |
| Expected to be consigned to a Metal Treatment Facility                             |                 |                  |            |
| Expected to be Out of Scope                                                        |                 |                  |            |
| Expected to be recycled / reused                                                   |                 |                  |            |
| Disposal route not known                                                           |                 |                  |            |

Classification codes for waste expected to be consigned to a landfill facility:

Opportunities for alternative disposal routing: No

| Baseline Management Route | Opportunity Management Route | Stream volume (%) | Opportunity Confidence | Comment |
|---------------------------|------------------------------|-------------------|------------------------|---------|
| -                         | -                            | -                 | -                      | -       |

#### RADIOACTIVITY

Source: Activation of the graphite and impurities.

Uncertainty: The values quoted were derived by calculation from available material specification and are indicative of the activities that are expected. The major source of uncertainty is the impurity levels.

Measurement of radioactivities: The specific activities have been estimated using a neutron activation calculation. The activities quoted are those at 72 years after reactor shutdown, i.e. in 2060. There may be some contamination by Cs137. Fission of trace uranium impurity in the graphite may result in some fission product and actinide activity.

Chemical form of radionuclides: H-3: Tritium may be chemically bound with the graphite.  
C-14: The carbon 14 will be present as graphite.  
Cl-36: The chlorine 36 will probably be chemically bound to the graphite. Some may be linked chemically with impurities in the graphite.  
Se-79: -  
Tc-99: -  
I-129: -  
Ra: -  
Th: -  
U: There may be traces of uranium as metal or oxide.  
Np: -  
Pu: There may be traces of plutonium as metal or oxide.

| WASTE STREAM 9A316 Graphite LLW |                            |                |                 |                |                  |                            |                |                 |                |
|---------------------------------|----------------------------|----------------|-----------------|----------------|------------------|----------------------------|----------------|-----------------|----------------|
| Nuclide                         | Mean radioactivity, TBq/m³ |                |                 |                | Nuclide          | Mean radioactivity, TBq/m³ |                |                 |                |
|                                 | Waste at 1.4.2025          | Bands and Code | Future Arisings | Bands and Code |                  | Waste at 1.4.2025          | Bands and Code | Future Arisings | Bands and Code |
| H 3                             |                            |                | 1.66E-03        | C C 2          | Gd 153           |                            |                |                 | 8              |
| Be 10                           |                            |                |                 | 8              | Ho 163           |                            |                |                 | 8              |
| C 14                            |                            |                | 1.04E-03        | C C 2          | Ho 166m          |                            |                | 5.24E-09        | C C 2          |
| Na 22                           |                            |                |                 | 8              | Tm 170           |                            |                |                 | 8              |
| Al 26                           |                            |                |                 | 8              | Tm 171           |                            |                |                 | 8              |
| Cl 36                           |                            |                | 3.61E-06        | C C 2          | Lu 174           |                            |                |                 | 8              |
| Ar 39                           |                            |                |                 | 8              | Lu 176           |                            |                |                 | 8              |
| Ar 42                           |                            |                |                 | 8              | Hf 178n          |                            |                |                 | 8              |
| K 40                            |                            |                |                 | 8              | Hf 182           |                            |                |                 | 8              |
| Ca 41                           |                            |                | 3.03E-06        | C C 2          | Pt 193           |                            |                |                 | 8              |
| Mn 53                           |                            |                |                 | 8              | Ti 204           |                            |                |                 | 8              |
| Mn 54                           |                            |                |                 | 8              | Pb 205           |                            |                |                 | 8              |
| Fe 55                           |                            |                |                 | 8              | Pb 210           |                            |                |                 | 8              |
| Co 60                           |                            |                | 6.29E-08        | C C 2          | Bi 208           |                            |                |                 | 8              |
| Ni 59                           |                            |                | 5.19E-07        | C C 2          | Bi 210m          |                            |                |                 | 8              |
| Ni 63                           |                            |                | 3.44E-05        | C C 2          | Po 210           |                            |                |                 | 8              |
| Zn 65                           |                            |                |                 | 8              | Ra 223           |                            |                |                 | 8              |
| Se 79                           |                            |                |                 | 8              | Ra 225           |                            |                |                 | 8              |
| Kr 81                           |                            |                |                 | 8              | Ra 226           |                            |                |                 | 8              |
| Kr 85                           |                            |                |                 | 8              | Ra 228           |                            |                |                 | 8              |
| Rb 87                           |                            |                |                 | 8              | Ac 227           |                            |                |                 | 8              |
| Sr 90                           |                            |                |                 | 8              | Th 227           |                            |                |                 | 8              |
| Zr 93                           |                            |                |                 | 8              | Th 228           |                            |                |                 | 8              |
| Nb 91                           |                            |                |                 | 8              | Th 229           |                            |                |                 | 8              |
| Nb 92                           |                            |                |                 | 8              | Th 230           |                            |                |                 | 8              |
| Nb 93m                          |                            |                |                 | 8              | Th 232           |                            |                |                 | 8              |
| Nb 94                           |                            |                | 2.02E-09        | C C 2          | Th 234           |                            |                |                 | 8              |
| Mo 93                           |                            |                |                 | 8              | Pa 231           |                            |                |                 | 8              |
| Tc 97                           |                            |                |                 | 8              | Pa 233           |                            |                |                 | 8              |
| Tc 99                           |                            |                |                 | 8              | U 232            |                            |                |                 | 8              |
| Ru 106                          |                            |                |                 | 8              | U 233            |                            |                |                 | 8              |
| Pd 107                          |                            |                |                 | 8              | U 234            |                            |                |                 | 8              |
| Ag 108m                         |                            |                | 4.53E-09        | C C 2          | U 235            |                            |                |                 | 8              |
| Ag 110m                         |                            |                |                 | 8              | U 236            |                            |                |                 | 8              |
| Cd 109                          |                            |                |                 | 8              | U 238            |                            |                |                 | 8              |
| Cd 113m                         |                            |                |                 | 8              | Np 237           |                            |                |                 | 8              |
| Sn 119m                         |                            |                |                 | 8              | Pu 236           |                            |                |                 | 8              |
| Sn 121m                         |                            |                | 2.08E-07        | C C 2          | Pu 238           |                            |                |                 | 8              |
| Sn 123                          |                            |                |                 | 8              | Pu 239           |                            |                |                 | 8              |
| Sn 126                          |                            |                |                 | 8              | Pu 240           |                            |                |                 | 8              |
| Sb 125                          |                            |                |                 | 8              | Pu 241           |                            |                |                 | 8              |
| Sb 126                          |                            |                |                 | 8              | Pu 242           |                            |                |                 | 8              |
| Te 125m                         |                            |                |                 | 8              | Am 241           |                            |                |                 | 8              |
| Te 127m                         |                            |                |                 | 8              | Am 242m          |                            |                |                 | 8              |
| I 129                           |                            |                |                 | 8              | Am 243           |                            |                |                 | 8              |
| Cs 134                          |                            |                |                 | 8              | Cm 242           |                            |                |                 | 8              |
| Cs 135                          |                            |                |                 | 8              | Cm 243           |                            |                |                 | 8              |
| Cs 137                          |                            |                |                 | 8              | Cm 244           |                            |                |                 | 8              |
| Ba 133                          |                            |                | 2.11E-08        | C C 2          | Cm 245           |                            |                |                 | 8              |
| La 137                          |                            |                |                 | 8              | Cm 246           |                            |                |                 | 8              |
| La 138                          |                            |                |                 | 8              | Cm 248           |                            |                |                 | 8              |
| Ce 144                          |                            |                |                 | 8              | Cf 249           |                            |                |                 | 8              |
| Pm 145                          |                            |                | 1.37E-09        | C C 2          | Cf 250           |                            |                |                 | 8              |
| Pm 147                          |                            |                |                 | 8              | Cf 251           |                            |                |                 | 8              |
| Sm 147                          |                            |                |                 | 8              | Cf 252           |                            |                |                 | 8              |
| Sm 151                          |                            |                | 3.49E-07        | C C 2          | Unsp a           |                            |                |                 |                |
| Eu 152                          |                            |                | 8.45E-06        | C C 2          | Unsp b/g         |                            |                |                 |                |
| Eu 154                          |                            |                | 2.02E-07        | C C 2          | <b>Total a</b>   | <b>0</b>                   | <b>*</b>       | <b>3.84E-18</b> | <b>*</b>       |
| Eu 155                          |                            |                | 2.61E-09        | C C 2          | <b>Total b/g</b> | <b>0</b>                   | <b>*</b>       | <b>2.75E-03</b> | <b>*</b>       |

#### Bands (Upper and Lower)

A a factor of 1.5  
B a factor of 3  
C a factor of 10  
D a factor of 100  
E a factor of 1000

Note: Bands quantify uncertainty in the mean radioactivity.

#### Code

1 Measured activity  
2 Derived activity (best estimate)  
3 Derived activity (upper limit)  
4 Not present  
5 Present but not significant  
6 Likely to be present but not assessed  
7 Present in significant quantities but not determined  
8 Not expected to be present in significant quantity  
\* Total calculated from the 114 declared radionuclides