Office for Nuclear Regulation
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DELICENSING OF A PART OF THE OLDBURY POWER STATION NUCLEAR LICENSED SITE

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David Simister, Office for Nuclear Regulation, Redgrave Court, Bootle, Merseyside. L20 7HS.

Jan McClure, Health Protection Agency, Chilton, Didcot, Oxon, OX11 0RQ

Matt Thames, Magnox Limited, Oldbury Nuclear Power Station, Oldbury Naite, Thornbury, South Gloucestershire BS35 1RQ

Paul Mountford-Lister, Environment Agency, Red Kite house, Howbery Park, Wallingford, Oxford OX10 8BD

Abstract - This paper reports recent work undertaken by the licensee, Magnox Limited and the regulatory oversight work undertaken by the Office for Nuclear Regulation to delicense, and the Environment Agency to partially surrender the permit for part of the nuclear licensed site at the twin Magnox Reactor Power Station at Oldbury in Gloucestershire. The paper sets out in straight-forward terms, the safety justification for releasing part of the site from regulatory control and identifies other factors important to decision-making by the operators and by the regulators.

1. Introduction

The purpose of this paper is to consider the main factors underpinning the operational and regulatory decisions to enable part of the nuclear licensed site at Oldbury nuclear power station to be delicensed. Delicensing requires a demonstration by the licensee that there is no danger from ionising radiations arising from licensable activities within the area concerned.

The Oldbury site is owned by the Nuclear Decommissioning Authority (NDA) which is a non-departmental Public Body, part of the Department of Energy and Climate Change (DECC). The nuclear licensed site is managed under contract by Energy *Solutions*, the Parent Body Organisation, and is operated by Magnox Limited, the nuclear licensee.

2. Background / Historical perspective

Several sites in the UK have already undertaken full or partial delicensing of their sites [Refs 1, 2 and 3] and delicensing activities are currently underway on other sites, so the current initiative at Oldbury is not novel. During 2006, Magnox Electric Limited successfully delicensed land occupied by the Berkeley Centre which comprised a total of 32 buildings. Similarly, in October 1993, the area of land known as Silt Lagoon 1 was successfully delicensed at Oldbury.

The Oldbury nuclear licensed site consists of the twin Magnox reactor power station and adjacent land (total 71 ha) located on the southern bank of the River Severn estuary, eleven miles north of Bristol. The owners, the NDA, have asked the licensee to prepare a safety case to delicense part of the existing nuclear licensed site. The area to be delicensed, referred to as "the Application Area", presented a number of unique challenges. It is relatively large, around 32 ha, and situated outside of the site security fence. Much of the area is relatively inaccessible due to either being marsh land or densely wooded. In addition, Silt Lagoon 2 is designated by South Gloucestershire Council as a site of Nature Conservation Interest imposing constraints on work in this area. The public currently have access to parts of the Application Area which is used for a number of activities such as dog walking, horse riding and bird watching.

3. Details of Oldbury site, construction areas

The power station was constructed in the 1960s and first generated electricity in 1967. It remained operational at the time of the partial delicensing; however no part of the power station site including the Reactor Controlled Area [RCA]) fell within the Application Area. The position of the outer security barrier has remained unchanged since the power station was originally constructed. The Application Area was sub-divided into a number of smaller zones for the purposes of the safety case and these are shown in Figure 1. These were:

- Silt lagoon 2 and its associated raised bund
- Open undisturbed grass and woodland, including
    - Pear shaped meadow
    - Helipad
    - Orchard
    - Overflow car park
- Roads and car parks
- Oldbury technical centre and Oldbury Conference centre

Silt lagoon 2

To provide a continuous supply of cooling water at low tide, a tidal reservoir was constructed and used to manage the high tidal range of the River Severn. The reservoir was constructed on the rock shelf in the Severn adjacent to the station to provide a continuous supply of cooling water at low tide. From the late 1970s, the dredged sediment from the reservoir has been placed in three on-shore silt lagoons with Silt Lagoon 2 being used between 1983 and 1994. This area has not been used for operational purposes since its closure. It has been colonised by a diverse range of vegetation which attracts significant

wildlife and as such, it was designated by South Gloucestershire Council as a Site of Nature Conservation Interest.

Open undisturbed grass and woodlands

Historically, the majority of land within the Application Area was used as a construction camp and contractors' compound during the 1960s when the power station was built. At the time of application, the land was a mixture of cultivation and informal nature conservation.

Roads and car parks

The site is served by an access road system and car parks which are laid with tarmac. During the lifetime of the site, radioactive materials have been transported over these roads, but rigorous site procedures and transport requirements are such that likelihood of radiological contamination of road surfaces and associated drains is extremely remote.

Drainage

The site is served by three separate drainage systems; Active drains, Foul drains and Storm drains. There were no Active drains within the Application Area, nor were they connected to either of the other drain systems. There was one leg of the foul drainage system within the Application Area which leads to the site sewage treatment plant. Similarly, there were Storm drains within the Application Area and these discharge into an adjacent water course known as Drough Rhyne.

The Oldbury Technical Centre (OTC) and Oldbury Conference Centre

The OTC was constructed in 1972 and included two full scale reactor control room simulators. Some radioactive sources were held within the centre for training purposes, but these were transferred to the main power station site in 2007. The facility is now used as office accommodation for the company's central technical staff.

The Oldbury Conference Centre was constructed in 1989 as a visitor centre for the public. One of the exhibits contained a small sealed display cabinet containing naturally occurring radioactive materials. However this facility was closed to the public in 2006 and the display was transferred to the main power station site. A Magnox Fuel Flask was stored on the area adjacent to the Oldbury Conference Centre, but this was used solely for demonstration and training purposes and has been removed.

Silt lagoon 1

The Application Area was not the first area of site to be subject to a request for variation of the site licence boundary. Measurements were performed in 1990 on an area known as Silt Lagoon 1. Levels of man-made radioactivity contained within samples analysed and

the levels of radiation measured during the district surveys were very low. After reviewing the measurement results, a variation was granted in October 1993.

4. Ground contamination event

In 1976, there was a leakage of radioactivity into the soil near reactor 2 which resulted from a cracked pond cooling water pipe. The nearby contaminated ground (extending across a relatively small area) and groundwater have been monitored for radioactivity including the isotopes of Strontium and Caesium. However contamination of the ground has only been detected within the Reactor Controlled Area and not within the Application Area.

Figure 1 - Plan showing the Area to be Delicensed

5. Delicensing Criteria

In the UK, the main legislation governing health and safety at work is the Health and Safety at Work etc. Act.1974. In addition the Nuclear Installation Act 1965 (as amended) provides the framework for the regulation of the safety of nuclear installations. The Office for Nuclear Regulation (ONR) is an Agency of the HSE that regulates safety at nuclear installations within the UK. Once a nuclear site licence has been issued, the licensee's period of responsibility can only be ended, when, in the opinion of the HSE, there has ceased to be any danger from ionising radiation from anything on the site to be delicensed.

This principle of 'no danger' has been expanded on by the issue of further guidance from the HSE. This states:

"On the basis of existing, published guidance, HSE considers that an additional risk of death to an individual of one in a million per year is 'broadly acceptable' to society. Applying this to nuclear licensed sites, any residual radioactivity, above average natural background, which can be satisfactorily demonstrated to pose a risk less than one in a million per year, would be 'broadly acceptable'.

Further HSE criterion states:

"Annex 1 of the Basic Safety Standards Directorate (Euratom 96/29) allows member states to exempt a practice where appropriate and without further consideration if doses to members of the public are of the order of 10 microsieverts per year. HSE is of the view that this dose limit broadly equates to the 1 in a million per year 'no danger' criterion as well as being consistent with other legislation and international advice relating to regulatory protection of the public".

HSE have further stated in their guidance document, (Ref 4), that their preferred position was that land should be cleared to the values given in RS-G-1.7 to demonstrate achievement of the policy criterion of the residual risk of death being one in a million per year, which broadly equates to the no danger criterion.

RS-G-1.7 is contained within a series of International Atomic Energy Agency safety standards. RS-G-1.7 relates to the application of the concepts of exclusion, exemption and clearance. Section 3.4 of this Safety Guide states that 'The primary radiological basis for establishing values of activity concentration for the exemption of bulk amounts of material and for clearance is that the effective doses to individuals should be of the order of 10 μSv or less in a year.' The licensee also has a duty to demonstrate that radiological risks have been reduced to as low as reasonably practicable.

It is useful to put the 1 in a million risk of death in context by comparison to the average annual risk of death in the UK from some common causes.

Smoking 10 cigarettes a day	1 in 200
Heart disease	1 in 300
Accident in the home	1 in 15,000
Accident on the road	1 in 17,000
Homicide	1 in 100,000

6. Licensee's safety case

Magnox Limited's justification for their application was based upon a safety case which included the following principles:

A demonstration that no installations as given in Schedule 1 of the Nuclear Site Licence were currently operating or plan to be operated by Magnox Limited in the foreseeable future.

Implementation of an adequate survey strategy to demonstrate that appropriate radiological criterion, i.e. radiation and contamination levels, had been achieved.

Cessation of any danger from ionising radiations from anything on the site, or the part of the site, under consideration for delicensing according to radiological criteria set by Magnox Limited.

In addition to demonstration of meeting the 'no danger' criteria, the delicensing results were compared to limits specified in other relevant legislation and guidance including:

Schedule 1 of the Radioactive Substances act (93) (RSA93) and the associated Substances of Low Activity (SoLA) exemption order.

Health and Safety at Work etc Act 1974 (HSWA) and Ionising Radiations Regulations 1999 (IRR99) requirement that operators reduce risk to levels that are "As Low As Reasonably Practicable" (ALARP)

International Atomic Energy Authority (IAEA) RS-G-1.7 safety Guide.

7. Monitoring and Sample Planning

In order to ensure a robust demonstration of meeting the requirements specified in the Licensee's safety case, a detailed monitoring programme was planned and executed. This consisted of desktop studies, determination of a site fingerprint and followed Data Quality Objectives (DQO) methodology.

DQO methodology

In order to develop a successful application for delicensing, the licensee recognised at an early stage that the ONR and EA must be content with the approach to demonstrating compliance with the “no danger” criterion. The DQO approach [Ref 5] has international recognition and acceptance and is the approach adopted by a number of other sites across the UK.

The survey of any area depends on statistics; no matter how many samples are taken, a finite number of samples are being used to represent an entire site. Whenever a sample of a population is used to draw a conclusion about the entire population, statistics are used to determine how many samples are needed, how accurate the results are and what margin of error or uncertainty exists. The more samples taken the greater the confidence level of the final result. However it can be seen that the only way to have a 100% confidence level is to sample every gram of every object within the area to be delicensed.

The DQO Process is a strategic planning approach based on a scientific method to prepare for a data collection activity. It provides a systematic procedure for defining the criteria that a data collection design should satisfy, including when to collect samples, where to collect samples, the tolerable level of decision error for the study, and how many samples to collect, balancing risk and cost in an acceptable manner.

Use of the DQO Process has assured that the type, quantity, and quality of environmental data used in decision making was appropriate for the intended application, resulting in environmental decisions that are technically and scientifically sound and legally defensible.

DQOs are qualitative and quantitative statements derived from the outputs of the first six steps of the DQO Process that clarify the study objective, define the most appropriate type of data to collect; determine the most appropriate conditions from which to collect the data; specify tolerable limits on decision errors which will be used as the basis for establishing the quantity and quality of data needed to support the decision and are then used to develop a scientific and resource-effective data collection design.

The DQO process implemented by Magnox Limited was developed by the United States Department of Energy. It has been incorporated in the MARSSIM [ref 6] guidance document written and issued by the U.S. Environmental Protection Agency, the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy and the U.S. Department of Defence. It has been extensively reviewed by the Radiation Advisory Committee of the Science Advisory Board [ref 7] and was therefore judged to be an approved and validated approach to employ. A Visual Sample Plan has been used to define the required number of samples to be collected and analysed.

In this instance, the Application Area was sub-divided into a number of discrete regions, because construction materials (buildings, drains, and car-parks), and the terrain type (silt lagoon, and grass lands) can significantly affect contaminant levels and sampling /

monitoring techniques. Therefore, the land was divided into regions according to terrain and each region was treated as a separate population, as were the buildings, drains and tarmac areas. The sub-divisions were selected to allow the assumption that contamination was distributed relatively homogeneously within each region.

This information was used to determine the area classification for a number of zones within Oldbury site as part of the DQO. In the MARSSIM process, zones are classified based on the likelihood of contamination being present. Type A zones are areas where there is potential for contamination above the limit for delicensing or where areas have been remediated. Type B zones are areas that have the potential for contamination but this is unlikely to be above the delicensing limit. Type C zones are classified as areas that are not expected to contain residual contamination. Magnox Limited classified all areas as having the potential for contamination but at levels unlikely to be above the delicensing limit (Type B).

The area of interest was defined. This consisted of: the pear shaped meadow, the helipad, the meadow north of the orchard, the orchard, woodland areas to the South East area of the site, silt lagoon 2, and the main corridor from the edge of the site to the outer security fence, the visitors car park, Oldbury Conference Centre and the Oldbury Technical Centre. The Application Area was sub-divided into zones in accordance with previously decided criteria according to likely risk of contamination as derived from the site history, and taking into account the mechanisms for potential contamination to occur.

One of these zones was considered to be potentially contamination by authorised gaseous and particulate aerial discharges which were expected to be limited to the top few cm's only and uniformly distributed. The methodology was applied to zones that consisted of soils that were undisturbed since the site became operational. This zone was called the grasslands and includes the pear shaped meadow, the helipad, the meadow north of the orchard, the orchard and the woodland areas to the South East area of the site.

Another authorised discharge route was considered, this being liquid discharges to the river Severn. This gave rise to a separate zone for the Silt Lagoon 2 since this contains material dredged from the Severn estuary. Silt Lagoon 2 was further subdivided into two zones due to there being a mechanism for the transport of fine sediment in surface water following heavy rainfall. This could lead to the deposition of fine sediments containing elevated radionuclide concentrations nearer the outfall structure. These zones were Silt Lagoon 2a located nearer the outfall and Silt Lagoon 2b being the eastern half of the lagoon.

Transport of radioactive materials across the area to be delicensed was considered to be another possible route for contamination. This gave rise to a zone which consisted of the main corridor from the edge of the reactor site to the outer boundary and the visitors' car park.

One zone was considered to be potentially contaminated by authorised gaseous and particulate aerial discharges but where the ground had been disturbed since the Power station became operational. Although the top few centimetres were considered to be the most likely to be contaminated, there did exist a possible pathway for there to be contamination at depths below this. The methodology was applied to zones that consisted of disturbed soil bunds and made up areas, such as the bund around the silt lagoon and the grassed areas around the Oldbury Technical Centre. (OTC)

A final zone was formed that consisted of the Oldbury Conference Centre and the Oldbury Technical Centre with the most likely route for contamination being the transport of radioactive contamination by persons entering the buildings from the reactor site or the non - removal of sources that were brought into the building for training or information purposes.

Within each zone the contaminants were believed to be relatively homogeneous and this has been demonstrated by the homogeneity of both low and high resolution gamma spectrometry survey of the site.

8. Desk top studies

The licensee undertook Desk Top Studies to investigate the history of the Application Area and identify any factors that might guide the monitoring and sampling programmes. Two studies were undertaken, one addressed Silt Lagoon 2 and the other the remainder of the Application Area.

Silt lagoon 2

The objectives of the desk top study for Silt Lagoon 2 were as follows:

- to describe the development and use of the area of Silt Lagoons 1 and 2 from the time before construction up to the present day, sufficient to provide confidence that apart from the settling of silt, no activities involving nuclear matter or other radioactive material have taken place within Silt Lagoon 2,

- to use relevant existing information (including information from the delicensing of Silt Lagoon 1) to infer the mean levels of radioactive contamination throughout the silt and other materials deposited in Silt Lagoon 2. This included qualitative consideration of the theoretical possibility of re-concentration of radionuclides to levels higher than those initially present,

- to compare the inferred mean radioactive concentrations with screening levels cited in current HSE guidance on delicensing, in order to inform recommendations for additional survey / sampling work,

- to identify any gaps in radiological characterisation information that may prevent a robust demonstration of “no danger” using existing information.

Following detailed analysis of the information gathered during the desktop study the following conclusions were drawn regarding the silt lagoon 2.

- radionuclides other than ^{137}Cs were identified as having negligible significance in relation to delicensing of Silt Lagoon 2.
- there was no evidence to suggest a significant difference in ^{137}Cs activity with depth in Silt Lagoon 1 and therefore by association, in Silt Lagoon 2.
- silt contained within the Silt Lagoons was found to have the same, or slightly lower mean activity than silt in the Severn Estuary.
- the postulated true mean ^{137}Cs activity of silt in Silt Lagoon 2 was 18 ± 3 Bq/kg.
- there was good evidence to suggest that the postulated Silt Lagoon 2 ^{137}Cs activities were less than the IAEA screening value for ^{137}Cs of 100 Bq/kg. Nevertheless, sampling of Silt Lagoon 2 was considered to be warranted to test the validity of the conceptual model.

On this basis, it was recommended that:

- approximately 30 confirmatory silt samples be taken from Silt Lagoon 2 to test the conceptual model of contaminant distribution and to confirm that the mean concentrations of ^{137}Cs and other radionuclides (taken together) were below the IAEA screening values.
- the majority of the samples be taken from the surface of Silt Lagoon 2 with a small number taken at depth.
- silt samples should, in general, be non-targeted (unbiased), but that surface sampling should include the area near the outfall.
- a small number of water samples be taken from standing water in the area of Silt Lagoon 2 and from the adjoining ditch and pond.

Remainder of the Application Area

Objectives of the desk top study for the remainder of the Application Area (excluding Silt Lagoon 2) were as follows:

- to describe the development and use of the area to be delicensed from the time before construction up to the present day.
- to identify the potential for radioactive contamination on all land and facilities within the area to be delicensed.

- to address the potential for undetected subsurface pathways (including groundwater).

- to assess the potential for radioactive contamination, originating on the Licensed Site, to migrate onto the Application Area.

- to identify any gaps in information that may prevent a complete and robust demonstration of “no danger” using existing information, and where necessary, to make recommendations for additional survey / sampling.

An overview of potential contamination sources that could affect the Application Area was compiled by the licensee. These included active effluent discharges (both gaseous and liquid), movement of contaminated vehicles or radioactive materials along the roads, unauthorised deposition of waste, use of radiological materials within buildings and migration of contamination through groundwater. It was concluded that the main contamination mechanism with the potential to contaminate the Application Area was fallout from active aerial discharges. A survey of “known events” that had the potential for contaminating the Application Area was also carried out. The only significant event identified was a leak of pond cooling water.

All available historical radiological data was assessed. This included data from borehole sampling, data from tarmac sampling during remedial work in the staff car park and on the access road and the District Survey data.

In summary, the key findings of the Application Area desk top study were as follows:

- Oldbury has a pre-power station land-use history that was considered to be of low significance in relation to potential radiological ground contamination.

- the level of control of radiological material has remained constant since operations began. Location of the outer security barrier and reactor controlled area (RCA) have remained unchanged.

- active aerial discharges were considered to be the main mechanism of contaminating the area to be delicensed.

- the main area of known ground contamination resulted from a leak of cooling pond water from a pond chiller pipe in 1976. This contamination was routinely monitored utilising groundwater samples from boreholes and there was currently no evidence of contaminant migration outside the RCA boundary.

- Buildings - these were mainly used for training, visitors and security. The OTC previously contained a source store and the Oldbury Conference Centre had sealed displays containing naturally occurring radioactive material.

- Roads and car parks – radiological materials were transported along site access roads and there was a very remote possibility of localised contamination of the tarmac and associated road drains.

- Other Open Land - this area was used as a construction camp during the time at which the reactor was built and it was considered possible that landfilling of construction waste may have occurred at that time. However, no nuclear operations have been undertaken within this area and the land has since been developed into nature areas.

- Drains - Active drains are situated within the RCA. Drains in the Application Area were limited to Storm drains and soakaways only.

The Licensee's internal review recommended that:

- due to potential contamination from active aerial discharges, soil samples be taken from areas around the OTC and Oldbury Conference Centre plus silt samples from the associated ornamental ponds.

- reassurance surveys be carried out within both buildings. These included targeted surveys within the OTC source storeroom and the area of the Conference Centre where the active displays were previously housed.

In summary there was found to be a large amount of existing data that was studied in developing a monitoring and sampling strategy was planned for the purpose of demonstrating compliance with the no danger criterion.

Existing Knowledge	Documents
Documents of the site's history.	Desk Top Study of Oldbury Site and Desk Study of Silt Lagoon 2. No evidence of contamination spills/leaks on area of interest. Desk study research included examination of event records, interviews with staff and retired operators, examination of radiological survey records.
Previous land surveys for activity and all previous studies relating to de-licensing the area.	Survey information is summarised in the Compilation of District Survey Data and other reports .No records of radioactive contamination events on this area. Source records show no records of lost sources In Situ Gamma Survey by contractors
Maps and aerial photos.	Maps and plans associated with the Oldbury site are available from archive and the project e-room.
IAEA nuclear materials accountancy data sheets. Evidence of the movement of nuclear materials on the land.	Control of nuclear fuel records – refs and date range (No records of fuel being lost).

Existing Knowledge	Documents
Evidence of radiological contamination from authorised discharges	Summary of District Survey Data

9. Radiological Fingerprint

Most sites have more than one radionuclide present and to monitor for every nuclide would be impossible since some may decay via a process that does not result in the emission of a easily detected particle or photon. e.g. ^{241}Pu which emits a 21 keV_{Emax} beta particle. In order to overcome this, a number of samples are taken from representative locations across the site and analysed using appropriate radiochemical methods. From these results the relative activities of a number of radionuclides can be determined. This ratio of radionuclides was known as the site fingerprint. Use of a radiological site fingerprint was standard practice throughout the nuclear industry. Using this ratio, monitoring can be performed for the radionuclide which can be measured most efficiently and the total activity present was then calculated from the known ratio. The range of radionuclides determined was informed by the 'CEAR' list.

H-3	C-14	S-35	Ca-45
Mn-54	Fe-55	Fe-59	Co-58
Co-60	Zn-65	Sr-90/Y-90	Zr-95
Nb-95	Ru-106/Rh-106	Ag-110m	Sb-124
Sb-125	I-131	Cs-134	Cs-137/Ba-137m
Ce-144	Pm-147	Eu-154	Eu-155
Pu-238	Pu-239+240	Pu-241	Am-241
Cm-242	Cm-243+244		

Nineteen samples were analysed for a suite of contaminants of concern derived from the compilation of the Environment Agency's requirements (CEAR) document which supports the site's discharge authorisation. This enabled the derivation of a fingerprint for the different zones, which in turn enabled a decision to be made as to which was the dominant nuclide. This was determined to be ^{137}Cs. Magnox Limited then analysed the remaining 179 samples for ^{137}Cs in terms of Bq g^{-1}. This was performed by the AMEC NIRAS laboratories using high resolution gamma spectrometry, in addition gross alpha and beta analysis was also performed.

Portable Gamma spectrometry survey

The plant history indicated that a widespread, homogeneous model for contamination distribution was appropriate. This was substantiated by gamma surveys.

Measurements for environmental areas

Gamma spectrometry was used in areas of open ground, including transects across Silt Lagoon 2, to provide confirmation that there were no unexpected heterogeneities in concentrations of artificial radionuclides. Actual concentrations of radionuclides were determined using accredited analyses of samples taken from a selection of locations surveyed by portable gamma spectrometry. The coverage of areas surveyed varied depended on the expected concentrations and scale of heterogeneity of any surface contamination by gamma emitting radionuclides.

Non-nuclide-specific radiological (e.g. gamma dose) measurements were not considered suitable for de-licensing survey measurements of environmental media as the response from natural background would introduce more variation in the measurements than the expected very low level contribution from artificial radionuclides.

10. Measurements for the Built Environment

This involved measuring one high-resolution gamma spectrum at the centre of each room or in a few of the larger rooms and every 10m along corridors. An uncollimated detector was used with results interpreted as dose at the detector. This measurement was then compared to the criterion for ‘no danger’ dose of 10 µSv/yr. Targeted beta/gamma Health Physics probe surveys and swab samples were taken around the locations of the ex source cupboard and information centre display. Results could only be compared with adjacent areas which were unlikely to have been contaminated and were only capable of determining gross contamination which was unlikely to be present. The main reassurance monitoring technique was the high resolution in-situ gamma spectrometry measurement.

Portable gamma spectrometry was also used to survey roadways and tarmac car parks. Unlike the envisaged portable gamma spectrometry surveys of areas of ‘environmental media’ (grassed areas), the roadway/car park surveys were not envisaged as being accompanied by physical sampling/analysis of roadway materials, unless unexpectedly high levels of contamination were found. Where there was a theoretical potential for heterogeneous surface contamination identified from the desk study information, these surveys had a higher degree of coverage. Any superficial contamination of the road or car park surfaces could reasonably be expected to have washed into the drainage system therefore sampling silt from adjacent drains was deemed to be a useful indicator of contamination.

For the drainage infrastructure, samples of sediment were taken from manhole sumps for accredited analysis to confirm the absence of artificial radionuclides.

Sampling Survey

The intention was to monitor a statistically significant number of samples for evidence of levels of man-made radioactivity resulting from the operation of Oldbury Power Station. The sampling plan had been developed assuming that the levels of man-made radioactivity were essentially uniform so that the samples need only be analysed for a few key radionuclides and screened for unexpected high activity concentrations.

Grassland, Meadows, Orchard and Woodland

An in-situ gamma spectrometry survey was carried out. No indication of man-made contamination from discharges approaching guidance levels (<<0.1Bq/g Cs-137 detected). Cs-137 was assumed the dominant gamma emitting radionuclide.

Silt lagoon 2

The Silt Lagoon 2 area was divided into three separate sampling areas:

- SL2a : west of Silt Lagoon 2 (silt);
- SL2b: east of Silt Lagoon 2 (silt); and
- Bund: engineered bund around the outside of Silt Lagoon 2 (clay/soil).

An in-situ gamma spectrometry survey was carried out. No indication of man-made contamination from discharges approaching guidance levels (<<0.1Bq/g Cs-137 detected). Cs-137 was assumed the dominant gamma emitting radionuclide.

Systematic grid sampling was chosen to determine the sample points; there were 32 locations in each of the three sampling areas. In addition three boreholes were sunk to 6.5m depth from areas where silt had been accumulated at different times. There was some evidence of stratification of the deposition but whether this has resulted in stratification of the radioactivity concentration was unknown. Therefore samples were taken to confirm a relatively homogeneous distribution of activity with depth. Samples were taken from the top (as part of the surface sampling survey), and every 2 m resulting in one surface and three samples at depth.

Drainage

The site was served by three separate drainage systems; Active drains, Foul drains and Storm drains. There were no Active drains within the Application Area, nor were they connected to either of the other drain systems. There was one leg of the foul drainage system within the Application Area which leads to the site sewage treatment plant. Similarly, there were Storm drains within the Application Area and these discharge into an adjacent water course known as Drough Rhyne. These drains were routinely monitored for radioactive contamination, but no contamination has been detected in the drains within the Application Area.

Buildings

Systematic grid sampling was chosen to determine the rooms to be measured; there were 32 locations in all. Locating the survey points over a systematic grid with a random start ensured spatial coverage of the floor area. Additional directed measurements were carried out in the training props store room which contained the source cupboard. These were one in-situ gamma spectrometry measurement of the same specification as the unbiased measurements and standard contamination monitoring of the source cupboard to demonstrate the area was free from gross contamination above background levels.

11. Chernobyl

In interpreting the definition of no danger the ONR and EA take account of artificial radioactivity associated with licensed activities. This is interpreted to mean that land is considered to radioactively contaminated if activity levels are above the ubiquitous natural and artificial background that is typical of the area in which the land is located. The ubiquitous artificial background is taken to include radioactivity from atmospheric testing of nuclear weapons in the 1950s and 1960s, fallout from the Chernobyl accident, and radioactivity resulting from effluent discharges from distant nuclear facilities. The aim of the licensee's surveys has been to demonstrate that there is no danger from man made radionuclides, additional to background. This background includes contributions from naturally occurring radioactive materials, previous weapons testing, the Chernobyl accident of 1986 and authorised discharges, resulting from operations at other sites.

Although trace amounts of Cs-137 were identified in some of the samples analysed a quantity of Cs-137 was deposited in the area from the Chernobyl accident and it is believed to be this Caesium that is being detected. The maximum 95% upper confidence level of Cs-137 found to be present was 0.065 Bqg^{-1} which lies within the range 0.01 - 0.34 Bqg^{-1} which is typical of Cs-137 contamination levels deposited in the area due to the Chernobyl accident.

12. Review of incidents

A review of site records at Oldbury has been undertaken and the only event of significance to the application for a licence variation was considered to the 1976 pond cooling water pipe leak. A number of boreholes were established following the event and these have been routinely monitored since 1977. Monitoring has shown no evidence of contaminant migration outside the RCA to date (but the licensee has committed to maintain this monitoring into the future, so as to provide early warning of any such migration). In order to provide additional confidence in this regard, additional boreholes were installed in 2007/08 and detailed hydro-geological assessments have been undertaken to strengthen understanding in relation to the potential migration of active nuclides within soils and water courses. The revised scope and frequency of borehole monitoring was detailed in the Hydro-geological Risk Assessment.

13. Regulatory Perspective

Assessment of adequacy of licensee's safety case

Magnox Limited has prepared a robust delicensing safety case from which the regulators ONR and EA have gained confidence in the licensee's arrangements. As part of this work the licensee has undertaken a significant programme of monitoring to substantiate delicensing of the Application Area. Details have been shared with regulators at regular technical meetings held throughout the project. The scale of the monitoring was considerable, particularly when the results of the walk-over gamma survey was taken into account (327,000 Groundhog™ readings), but in addition to the scale, there has been diversity of sampling and monitoring. The monitoring programme has included an extensive walk-over survey, High Resolution Gamma Spectrometry, investigation of

roadways and in-building assessments. Similarly, the sampling has been extensive and in addition to sampling of the silt, the sampling programme has included soil and surface drain samples with sample analysis being undertaken by accredited laboratories. Assessments have also been made of several “less obvious” contamination mechanisms, in particular, the ground water pathways.

Magnox Limited contracted an independent specialist to perform a large area land survey using both Low and High Resolution Gamma Spectrometry (L/HRGS). This was performed mainly between November 2009 and January 2010, with a small additional area being surveyed in August 2010.

The High Resolution Gamma Survey equipment was based on an uncollimated ‘ISOCS’ high purity germanium detector situated approximately one metre above the ground. A total of 1564 HRGS spectra were reported with 168 of these being on tracks over a small area of the silt lagoon. A target Minimum Detectable Activity (MDA) of 0.02 $Bqg^{-1}$was set for ^{137}Cs and ^{60}Co, this lead to a counting time at each position of 150 seconds. Where unusual features were observed this counting time was increased in order to improve the identification of radionuclides associated with the feature. The averaging area of each measurement was assumed to be a circle of radius 7 m with measurements being taken every 10 m where possible.

The Low Resolution Gamma Survey equipment was based on a 3” x 3” Sodium Iodide detectors. A total of over 329,000 measurements were taken with around 95% of the results being below 450 counts per second. The total area covered was considered to be around 12.7 hectares and apart from the alarms being activated due to the routine release of the inert gas, ^{41}Ag from the reactor, the only area identified as being significantly above background was ‘feature 1’ which forms part of the track around the silt lagoon.

This elevated feature on the track surrounding the silt lagoon was investigated further, both by the collection of samples for radiochemical analysis and by the collection of HRGS spectra. The HRGS spectra indicated the presence of elevated levels of ^{214}Bi and the levels predicted by the HRSG system show good correlation with the counts observed by the LRGS. However it was noted that no elevated levels of 214 Bi were identified in the samples taken for analysis. The presence of ^{137}Cs was identified within these samples with a 95% upper confidence of the mean being 35% of the IAEA exemption limit.

Most incidences of ^{137}Cs contamination were found to occur on the silt lagoon and for this reason it was appropriate to zone the silt lagoon separate from the other areas. Also it was noted that the results associated with the contractor’s car park and some roads were different to the majority of wooded and grassed areas. The wooded and grassed areas appeared to have a mean background around 320 cps with the car park and road area having a mean in the order of 250 cps. This supports the separate zoning of the road and car park areas. In general the uniformity of the remaining areas supports the decision that the remainder of the grassed and wooded areas have a homogenous distribution and can be regarded as a separate zone.

Refs 8 and 9 provide further details of the regulatory approach to site decommissioning and clearance. It can be concluded that the licensee has designed and implemented a safe and successful sampling programme which has in turn enabled the development of an effective safety case. The conclusions of the delicensing exercise were based on over 330,000 monitoring results and these have been used to demonstrate that conditions within the Application Area adequately meet the “no danger” criterion.

Independent advice on hydrogeology

The existing arrangements to monitor any potential spread of radioactivity from the site of the 1976 pond water cooler pipework leak mentioned previously were based on a ring of boreholes, all varying depths and distances from the source. The principal radionuclides of interest on grounds of impact or quantity were Caesuim-137, Sr-90 and tritium This situation required the licensee to have a good understanding of the sub-surface hydrogeological ground conditions (including direction and speed of groundwater movement), the nature of the radioactivity which was contained within the soil, and an ability to demonstrate with confidence, that any activity that could have reached the Application Area (either now or in the future) was of no significance.

The licensee’s assessments of any potential migration towards the Application Area were based on those boreholes monitoring the relatively permeable siltstone `aquifer ‘ layers in the bedrock underlying the site, since the overlying made ground is relatively impermeable.

The licensee’s safety case demonstrates that extensive monitoring and measurements of water samples taken from these boreholes has provided confidence that there has been no significant activity flowing from the site which would challenge the `no danger‘ delicensing criterion. ONR supports the view of the licensee that the ground conditions were well understood with groundwater flow in the `aquifer’ horizons broadly towards the River Severn. Although the potential for migration of contamination towards the Application Area was discounted in the licensee’s Desk Study, ONR thought it prudent to undertake a quantitative hydro-geological assessment of this possibility. ONR sought independent expert advice from external contractors on specific geoscientific aspects of this assessment.

Using a conceptual site model of the hydrogeology based on previous investigations, two contaminant transport models were established using the ConSim methodology endorsed by the Environment Agency.

Although the potential for radionuclides to cross the site boundary in future cannot be completely discounted, the levels are expected to be low compared to drinking water standards adjusted to the 10 uSv per year criterion, noting that the ground water is not suitable for use as drinking water due to its brackish nature. The conclusion of these studies has been that introduction of a new licensed site boundary will have a negligible effect on risk to members of the public.

Although the regulatory decision on delicensing was based upon the safety case and conditions at the time of the application to delicense, the future condition of the land and potential for migration of contaminants has been considered. Local arrangements for monitoring ground water flow from the affected area have been reviewed and strengthened and will be subject to on-going regulatory oversight.

Independent sampling and analysis by HPA

The results and their interpretation were discussed with the licensee and ONR commissioned an independent radiological survey from the Health Protection Agency. Independent monitoring activities performed by HPA, provide confidence that the survey work undertaken by the licensee was robust and that the radiological conditions within the Application Area were as expected. Similarly, concentrations of artificial and naturally occurring radionuclide were determined by independent sampling. This was followed by a comparison of the concentration levels of radioactivity determined by the HPA with those reported by the licensee. The HPA has also assessed monitoring data provided by the licensee and performed an independent analysis of the results to ensure that the licensees' conclusions are valid.

Engagement with other stakeholders

When considering the this application for a variation of the nuclear site license, the Office for Nuclear Regulation engaged with a number of other stakeholders including specialist contractors for independent advice, other regulatory bodies and external organisations as appropriate.

EA perspective

The Environment Agency is responsible, under the Environmental Permitting Regulations 2010 (EPR), for the disposal of radioactive waste from nuclear licensed sites and is a statutory consultee to all delicensing applications. Aligned to the ONR delicensing process, the Environment Agency determines the adequacy of the licensee's case for surrender of part of the permit under EPR. The Environment Agency has been consulted by ONR when assessing the adequacy of the licensee's proposals to delicense part of the Oldbury nuclear licensed site.

The Environment Agency takes a formal interest in the disposal of any radioactive waste arising from the remediation of land in preparation for delicensing and also needs to have confidence that any residual activity in the delicensed area was below levels specified in the relevant legislation, primarily the remaining extant parts of the Radioactive Substances Act, Schedule 1 and associated Exemption Orders.

In this case no material has been removed from site (other than for purposes of sampling and analysis) and no residual radioactivity of any significance has arisen from authorised

discharges from Oldbury and other nuclear licensed sites or from atmospheric deposition not associated with the Oldbury site.

The Environment Agency has reviewed the monitoring data provided by the licensee and was content that residual levels were compliant with the legal requirements.

Separately, Silt Lagoon 2 within the area to be delicensed was previously subject to a waste management licence. Waste (silt) disposal to Silt Lagoon 2 finished in 1994 and the lagoon has subsequently been extensively colonized by plants and animals. As part of the current regulatory activity the site applied to the Environment Agency and the waste management license has been surrendered, subject to a number of conditions relating to the condition of the site.

The Environment Agency has indicated its support for application to delicense part of the nuclear licensed site shown in Figure 1 and will follow due process to amend the site permit under the Environmental Protection Regulations to reflect the new boundary.

Security considerations

The Office for Civil Nuclear Security (OCNS) is now part of the Office for Nuclear Regulation and as such, consideration has been given to the proposals for delicensing within the context of the Nuclear Industries Security Regulations 2003. The civil nuclear security regulator has not raised any concerns that would preclude the issue of a licence variation.

13. Conclusions

The purpose of this programme was to ensure that the licensee satisfactorily met all the criteria required to enable a variation to be made to the Oldbury Nuclear site license. The main requirement being a demonstration that there is no danger from ionising radiations on the site or radioactivity being present above statutory limits.

The historical investigation was detailed and analysis of the site fingerprint for dominant nuclides of concern was of sufficient depth to determine radionuclides of interest during the survey and sampling phase of the project.

Despite the site being large; the investigation and both gamma and sampling surveys has been thorough and complete. Robust and defensible sampling procedures have been well executed following strict quality procedures to demonstrate any areas where the mean level of contamination would give rise to a dose that exceeds the 10µSv y^{-1} ‘no danger’ criteria.

The process implemented by Magnox Limited assumed homogeneity within each zone. Detailed gamma surveys were conducted and found to support this assumption. A number of zones were defined using past history and likely contamination pathways to classify each area. This process assumes a mean value of the level of contamination in the

determination of whether the no danger criteria are met. This in turn assumes that mean doses across each zone to members of the public will be in the order of 10 µSv per year or less.

The maximum level of Cs-137 determined at the 95% upper confidence level within the application area was 0.065 Bq/g. This is well below the appropriate Exemption Order value and even well below the indicative value for regulatory concern of 0.1 Bq/g.

Overall, the measurements performed by Magnox Limited and the Health Protection Agency indicate there is no residual contamination with activity above radiological criteria set by Magnox Limited and accepted by regulators. All the criteria required to enable a variation to be made to the Oldbury Nuclear site licence have thus been met.

The content of this paper represents the views of the authors and does not necessarily reflect the views of the Office for Nuclear Regulation, the Health Protection Agency, the Environment Agency, the Nuclear Decommissioning Authority, or Magnox Limited. The authors wish to acknowledge assistance from colleagues in Office for Nuclear Regulation, Oldbury Nuclear Power Station, the Environment Agency, the Health Protection Agency, the Nuclear Decommissioning Authority and Serco Technical Consulting Services in the preparation of this paper.

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