TR534 RADIOLOGICAL ASSESSMENT OF DREDGING APPLICATION FOR HINKLEY POINT C (2020). PART 2 – EVALUATION INCLUDING RADIOANALYSIS OF ALPHA/BETA RADIONUCLIDES
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01	27/01/2021	Alastair Dewar	Senior Radiological Protection Scientist	Franck Dal Molin	Principal Radiological Protection Scientist	Dean Foden	Hinkley Point Programme Lead
02	05/02/2021	Alastair Dewar	Senior Radiological Protection Scientist	Katie Musgrave	Hinkley Point Deputy Programme Lead	Dean Foden	Hinkley Point Programme Lead
03	09/02/2021	Dean Foden	Hinkley Point Programme Lead	Franck Dal Molin	Senior Radiological Protection Scientist	Katie Musgrave	Hinkley Point Deputy Programme Lead

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Radiological Assessment of Dredging Application for Hinkley Point C Power (2020). Part 2 – evaluation including radioanalysis of alpha/beta radionuclides

Radiological Assessment of Dredging Application for Hinkley Point C Power Station, Somerset (2020). Part 2 – evaluation including radioanalysis of alpha/beta radionuclides

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Abbreviation	Text
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DAERA	Department of Agriculture, Environment and Rural Affairs
EDF	Electricité de France
HPC	Hinkley Point C
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ISO17025	International standard for general requirements for the competence of testing and calibration laboratories
keV	Kilo electron Volts (a unit of energy)
MCAA	Marine and Coastal Access Act
MeV	Mega electron Volts (a unit of energy)
MMO	Marine Management Organisation
NNB Gen Co	Nuclear New Build Generation Company (HPC) Limited
NRW	Natural Resources Wales
S. I.	Statutory Instrument (UK legislation)
UKAS	United Kingdom Accreditation Service
Becquerel (Bq)	One radioactive transformation per second
µ Sv/year	Micro Sieverts per year. The unit of effective dose used in this report
manSv/year	Man Sieverts per year. The unit of collective dose used in this report

Executive summary

Nuclear New Build Generation Company (HPC) Limited (NNB Gen Co) (a subsidiary of EDF Energy) plans to commission the second phase of dredging as part of the development of Hinkley Point C nuclear power station in Somerset. NNB Gen Co will seek permission to dispose of dredged material at authorised disposal sites within the Severn Estuary.

In 2020, Fugro Geoservices Limited collected several sediment cores (surface and sub-surface samples) from various locations (Hinkley Point C (HPC) cooling water intakes, outfalls and flotation pocket), at the Hinkley Point C Power Station, currently under development. Cefas carried out radioanalysis of these samples by gamma-ray spectrometry, and for the determination of americium-241 and plutonium radionuclides (by alpha spectrometry), and tritium (total tritium and Organically Bound Tritium).

Two reports have been produced entitled “Radiological Assessment of Dredging Application for Hinkley Point C Power Station, Somerset (2021)”, Part 1 and Part 2. The radiological assessment in Part 1 (BEEMS Technical Report TR533) used doses either measured by or estimated from gamma-ray spectrometry only. This report (Part 2) provides a radiological assessment to supplement Part 1 using doses derived from concentrations measured by the radiochemical analysis of alpha and beta radionuclides in surface and sub-surface sediments. In Part 2, samples from three cores for each depth analysed in Part 1 were further sub-sampled. These sub-samples were analysed specifically for the determination of americium-241 and plutonium radionuclides (by alpha spectrometry), and tritium (total tritium and Organically Bound Tritium). The supplementary assessment presented in this report includes the additional measurements from the radioanalysis of these alpha- and beta-emitting radionuclides, together with those measured concentrations of other gamma-emitting radionuclides (with exception of gamma-emitting americium-241) from Part 1 of this report.

Using the conservative generic radiological assessment procedure developed by the International Atomic Energy Agency (IAEA), to convert radionuclide concentrations in disposed material into radiation doses due to disposal, the derived total doses to individual members of the crew and public were 3.9 µSv/year and 1.2 µSv/year, respectively. The total collective dose was 0.038 manSv/year. The values for individual members of the crew and public, and the collective dose, were within the *de minimis* criteria of 10 µSv/year (individual doses) and 1 manSv/year (collective dose), respectively. The inclusion of measured plutonium, americium and tritium concentrations (alpha- and beta- emitting radionuclides) has insignificant effect on the doses reported in Part 1. The actual concentrations of the plutonium radionuclides measured in Part 2 were lower than those estimated using the IAEA methodology in Part 1. Therefore, the IAEA methodology is robust and perfectly acceptable for assessing the radiological risk in dredging applications.

The initial conservative generic radiological assessment (Part 1 of this report series) and this supplementary assessment indicated that doses received were below recommended limits, and that a subsequent more detailed case specific assessment was not necessary. Therefore, from radiological considerations, there is no objection to this material being dredged and disposed of to sea.

1 Introduction

During 2018, capital dredge works of the cooling water intake and outfall areas were completed and disposed of at Cardiff Grounds disposal site under Natural Resources Wales (NRW) Marine License 12/45/MV v1. Further details of the radiological assessment carried out as part of the licensing application lodged by NNB Gen Co (a subsidiary of EDF Energy) have been previously reported (Leonard *et al.*, 2017). This report concluded, based on undertaking a conservative generic radiological assessment procedure developed by the International Atomic Energy Agency (IAEA), that from radiological considerations, there was no objection to material being dredged and disposed of to sea.

NNB Gen Co plans to commission a second phase of dredging as part of the development of Hinkley Point C (HPC) nuclear power station. Installation of the cooling water intake, outfall structures and flotation pocket requires these locations to be dredged down to bedrock, with the dredged material being taken to a designated disposal site. The proposed locations of these sites are shown in Figure 1. NNB GenCo will seek permission to dispose of this dredged material at authorised disposal sites within the Severn Estuary designated area as per the HPC Development Consent Order (S.I. 2013 No. 648). During 2018, capital dredge works of the cooling water intake and outfall areas were completed under Marine Management Organisation (MMO) Marine Licence L/2013/00178/4 including disposal to LU110 under Natural Resources Wales (NRW) Marine Licence 12/45/MLv1.

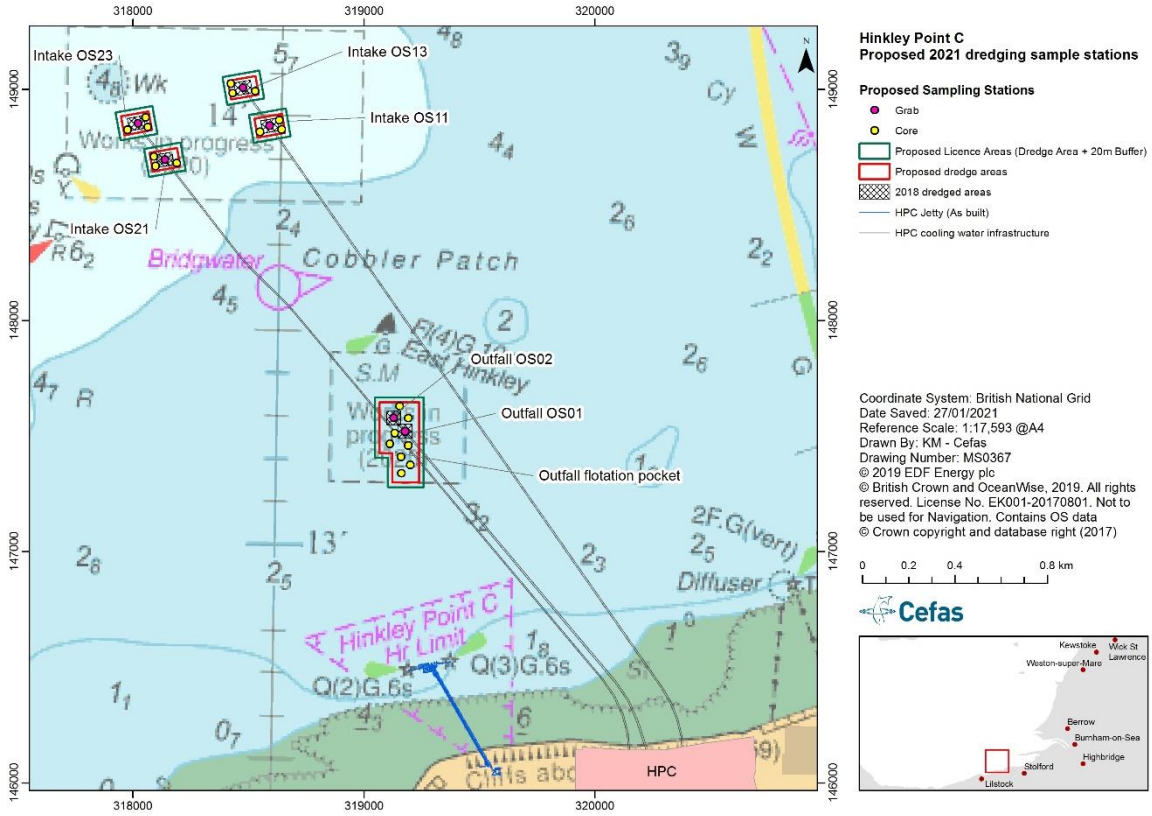

Figure 1 Proposed sampling areas and indicative distribution of proposed sample station locations (BEEMS Technical Report TR502).

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention 1972) prohibits the disposal at sea of radioactive wastes and other radioactive matter. Under the Convention, only materials with *de minimis* levels of radioactivity may be considered for disposal to sea. Guidance on performing specific radiological assessments of candidate materials, to determine whether the materials are *de minimis* in the meaning of the Convention 1972, have been reported by the International Atomic Energy Agency (IAEA) that incorporate a Stepwise Evaluation Procedure for screening candidate material to determine if it can be treated as 'non-radioactive' (i.e., *de minimis*) under the Convention (IAEA, 2003; 2015).

Disposal of dredged material from harbours and other areas is licensed under the Marine and Coastal Access Act (MCAA), 2009 (United Kingdom - Parliament, 2009), and the equivalent for the Devolved Administrations. The Marine Management Organisation (MMO), Natural Resources Wales (NRW), Marine Scotland, Department of Agriculture, Environment and Rural Affairs (DAERA) are the licensing authorities (regulators) for England, Wales, Scotland and Northern Ireland respectively, with regards to the disposal of dredged materials to sea.

The purpose of this report is to support and confirm the robustness and the appropriateness of the conservative generic radiological assessment procedure, as developed by the IAEA. The assessment undertaken in this report includes measurements from the radioanalysis of alpha- and beta-emitting radionuclides in surface and sub-surface sediments for the determination of americium-241 (^{241}Am) and plutonium radionuclides ($^{239+240}$Pu, ^{238}Pu) by alpha spectrometry, and tritium (total tritium and Organically Bound Tritium, by liquid scintillation counting). This supplementary radiological assessment of doses provides an evaluation of the previous assessment in Part 1, that was based on an inherently conservative procedure consistent with the precautionary approach (BEEMS Technical Report TR533). It also investigates whether the models and assumptions used in Part 1, are appropriate and fit for purpose for the disposal to sea in coastal waters under *de minimis* provisions.

2 Methodology and Assessment Details

In 2020, Fugro Geoservices Limited used grabs and sediment cores to collect surface and sub-surface samples from proposed dredging locations (cooling water intakes, outfalls and flotation pocket) at Hinkley Point C marine construction site in accordance with the requirements of the sampling plan (BEEMS Technical Report TR502). The locations, details and depths of sub-samples are provided in Figures 2 - 4 and Appendix A, respectively. Further details of the cores and samples acquired are presented in BEEMS Technical Report TR533.

Sediment samples were sent to the Cefas laboratory for preparation and radioanalysis. Following freeze-drying and homogenisation, radionuclide assay on sediment sub-samples was carried out using gamma-ray spectrometry on a high purity germanium (Ge) detector. These results were reported in Part 1 of the radiological assessment (BEEMS Technical Report TR533). In this report (Part 2 of the radiological assessment), samples from three cores analysed in Part 1 (OS01 (Figure 2), OF-B (Figure 2) and OS-21 (Figure 4)) were further sub-sampled at all depths (Table 3) and analysed for the determination of ^{241}Am, $^{239+240}$Pu, ^{238}Pu by alpha spectrometry, and tritium (total tritium and Organically Bound Tritium). Sediment samples were prepared and analysed for transuranic elements and tritium using long established, and UKAS ISO17025 accredited, Standard Operating Procedures based on Lovett *et al.*, (1990) and the Environment Agency Blue Book (2005), respectively. All analyses passed rigorous internal quality assurance procedures which included, production of appropriate quality control and reagent blank data. This assurance is augmented by regular analysis of Certified Reference Materials and participation in International Intercomparison exercises.

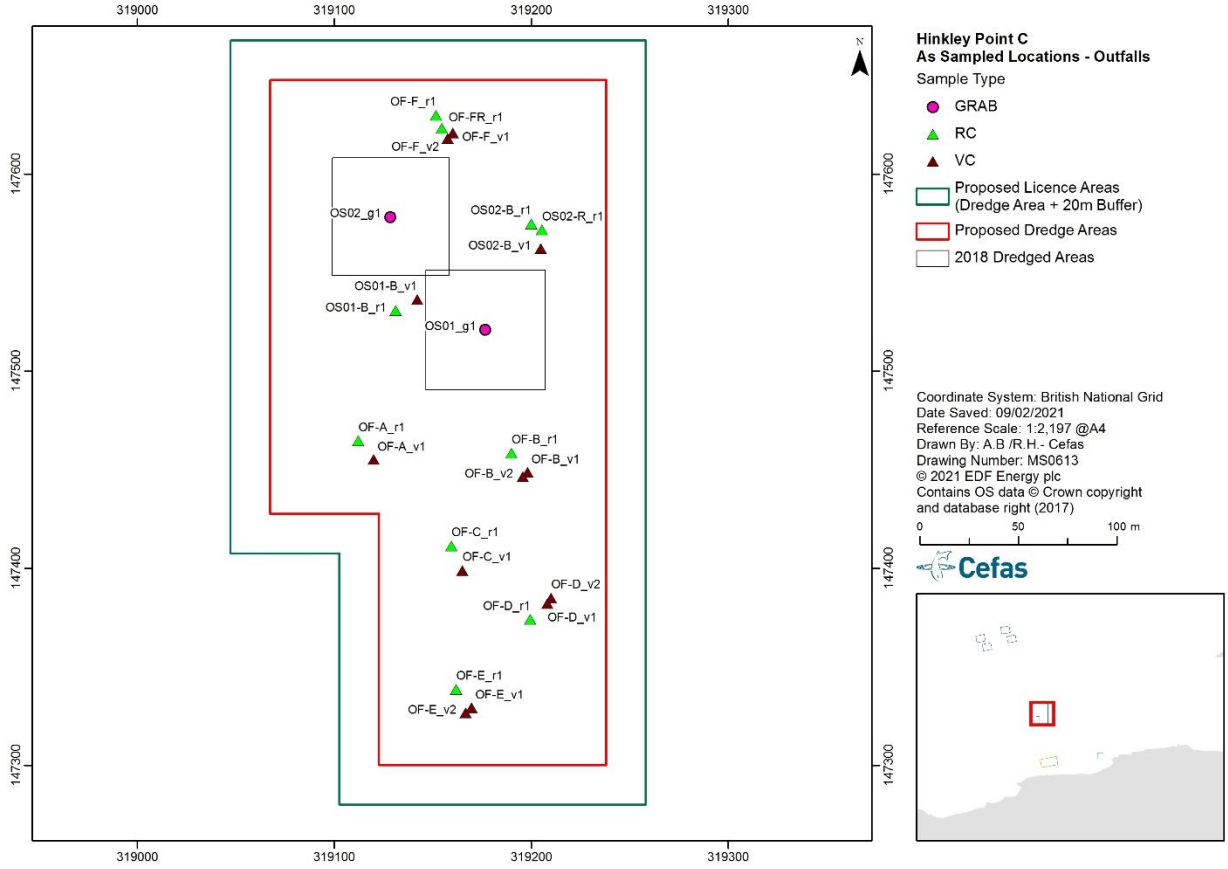

Figure 2 Location site map of samples collected at the outfalls and flotation pocket.

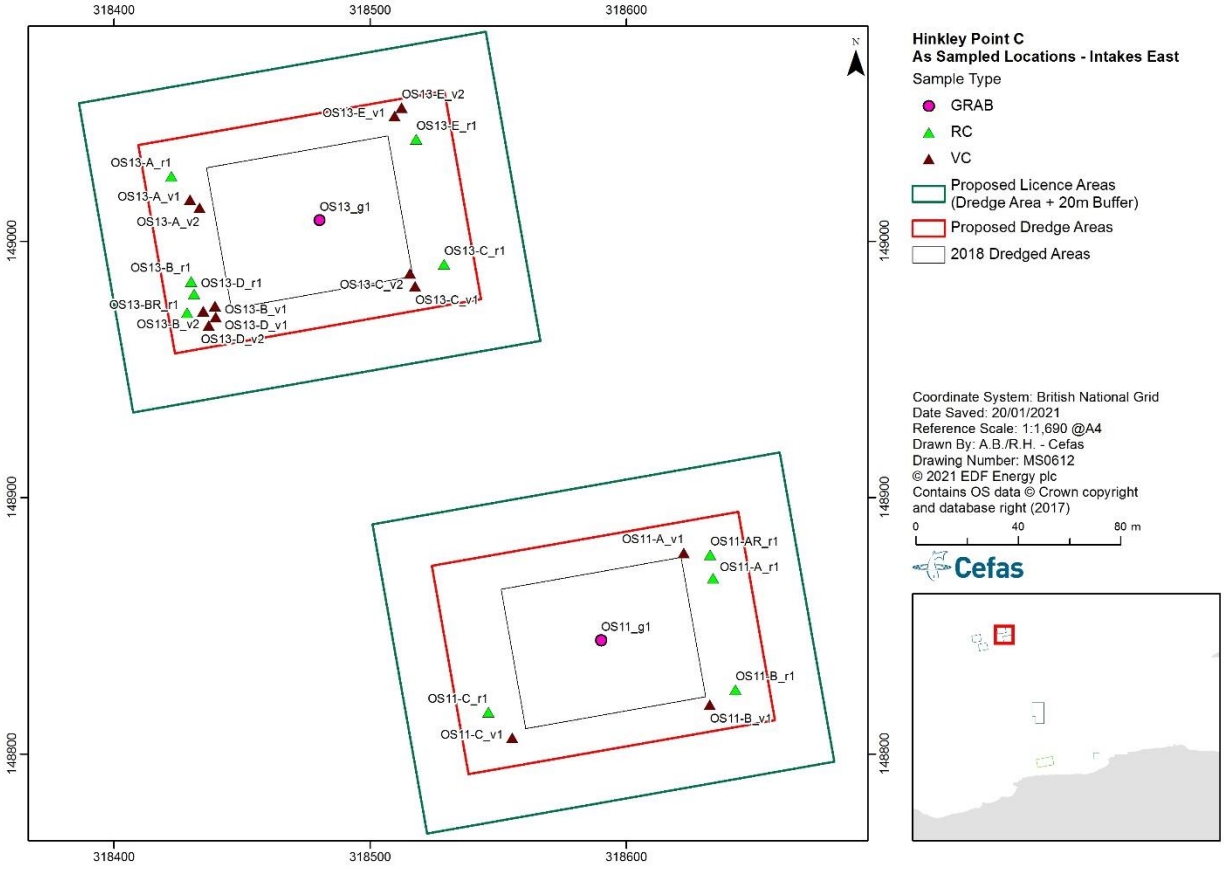

Figure 3 Location site map of samples collected at the eastern intakes.

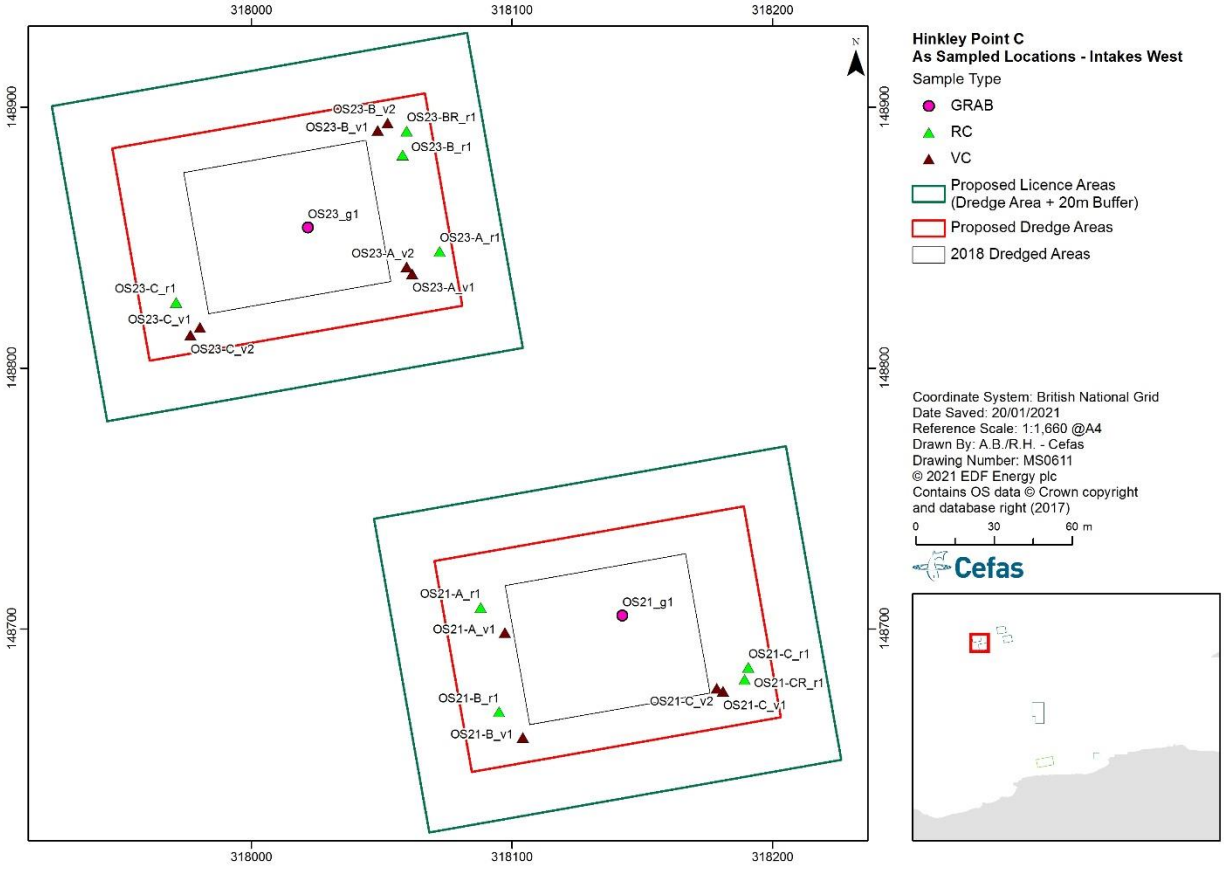

Figure 4 Location site map of samples collected at the western intakes.

Gamma-emitting radionuclides emit characteristic gamma rays in the energy range 60 keV to 2 MeV, corresponding to the typical energy levels in nuclei with reasonably long half-lives. These gamma rays generally accompany alpha and beta radiation. Gamma-ray spectrometry is an analytical technique that allows the direct identification and quantification of gamma-emitting radionuclides (and therefore alpha- and beta-emitting radionuclides indirectly). The measurement gives a spectrum of lines (i.e. many photons emitted at discrete energies) the amplitude of which is proportional to the activity concentration of the radionuclide.

This means that all potential gamma-emitting radionuclides (both naturally occurring and artificial) in a sample, in the energy range 60 keV to 2 MeV, are simultaneously scanned to identify and determine their activity concentrations. The method of radionuclide identification and estimation of activity concentration for gamma-emitters is also UKAS ISO17025 accredited and is based on a key line peak energy approach. This key line is normally derived from the highest abundance energy line which is unique to the radionuclide or has the least interferences. Secondary energy lines are also used for identification purposes however these are not used for calculating activity concentrations (e.g. as in the weighted average method). For the purposes of radiological assessment, under *de minimis* criteria, only selected gamma-emitting radionuclides (both naturally occurring and artificial) are reported. The assessment includes those radionuclides that are positively detected, and also those that are not detected (because they are absent, or present below the detection limit) but could contribute to the dose at the limit of detection (i.e. the dose is assumed to have occurred at the limit of detection, and the limit of detection values are included in the assessment as a

conservative approach). This is consistent with the developed methodology to assess dose in relation to disposal at sea under the London Convention 1972 (McCubbin and Vivian, 2006).

Activity concentrations of gamma-emitting radionuclides radium-226 (^{226}Ra), thorium-232 (^{232}Th) and uranium-238 (^{238}U) were indirectly determined via one of their respective decay products lead-214 (^{214}Pb), actinium-228 (^{228}Ac) and thorium-234 (^{234}Th) and assuming secular equilibrium, where the activity concentrations of the decay products (e.g. ^{214}Pb) are equal to their respective parent radionuclides (e.g. ^{226}Ra).

In addition to the radionuclides detected by gamma-ray spectrometry, sediments are also known to contain activities of plutonium radionuclides. For this supplementary assessment (Part 2), ^{241}Am , $^{239+240}$Pu and ^{238}Pu concentrations measured by alpha spectrometry were used to test the conservative assumptions used for these radionuclides in the initial conservative generic radiological assessment (part 1). The activity concentrations for lead-210 (^{210}Pb) were derived using data for its parent nuclide (^{226}Ra) and assuming secular equilibrium.

Results from the analysis of the additional analyses of alpha- and beta-emitting radionuclides from core sediments collected from HPC cooling water intakes and outfalls locations are summarised in Appendix A (Table 4), together with other supporting information.

Tritium (total tritium and Organically Bound Tritium) is not normally considered within the conservative generic radiological assessment because environmental levels concentrations are very low in many areas, including the Bristol Channel (Environment Agency et al., 2020). Tritium is also one of the least radiologically significant elements (ICRP 2012). Therefore, the screening coefficients (based on conservative assumptions on dose coefficients) for individual and collective doses to humans for tritium were calculated separately using the equations and data presented by IAEA (IAEA, 2015). The estimated individual and collective doses per unit activity concentration were orders of magnitude lower (~10^{-5} µSv) than other artificial radionuclides (~10^{-2} µSv). Therefore, the contribution of dose from tritium was found to be insignificant in terms of determining *de minimis* criteria within the IAEA methodology.

3 Assessment of Doses

Under the London Convention, only materials with *de minimis* levels of radioactivity may be considered for disposal to sea. Using the conservative generic radiological assessment procedure developed by the IAEA (IAEA, 2003) and Cefas (McCubbin and Vivian, 2006), the averaged (over all sample stations and depth ranges in cores) gamma-ray spectrometry results reported in Part 1 (BEEMS Technical Report TR533 and Table 1 below) and the average activity concentration data (averaged over all sampling stations and depth ranges as per the IAEA methodology) for plutonium and americium radionuclides in Appendix A (Table 3) were used to convert radionuclide concentrations in disposed material into radiation doses due to disposal. The derived total doses to individual members of the crew and public were 3.9 µSv/year and 1.2 µSv/year, respectively. The total collective dose was 0.038 manSv/year.

Table 1 Average activity concentrations (over all cores and depth ranges) in sediment samples from Table 1 in part 1 report (BEEMS Technical Report TR533).

Radionuclide	Average specific activity (Bq/kg, dry weight)*
^{60}Co	0.25
^{137}Cs	3.30
^{226}Ra (via ^{214}Pb)	25.16
^{232}Th (via ^{228}Ac)	29.11
^{238}U (via ^{234}Th)	25.96

* Average determinations use < results as positively measured values to produce a conservative estimate.

The dose estimates for individual crew/public (by nuclide), derived using the generic IAEA model, are shown in Figure 5.

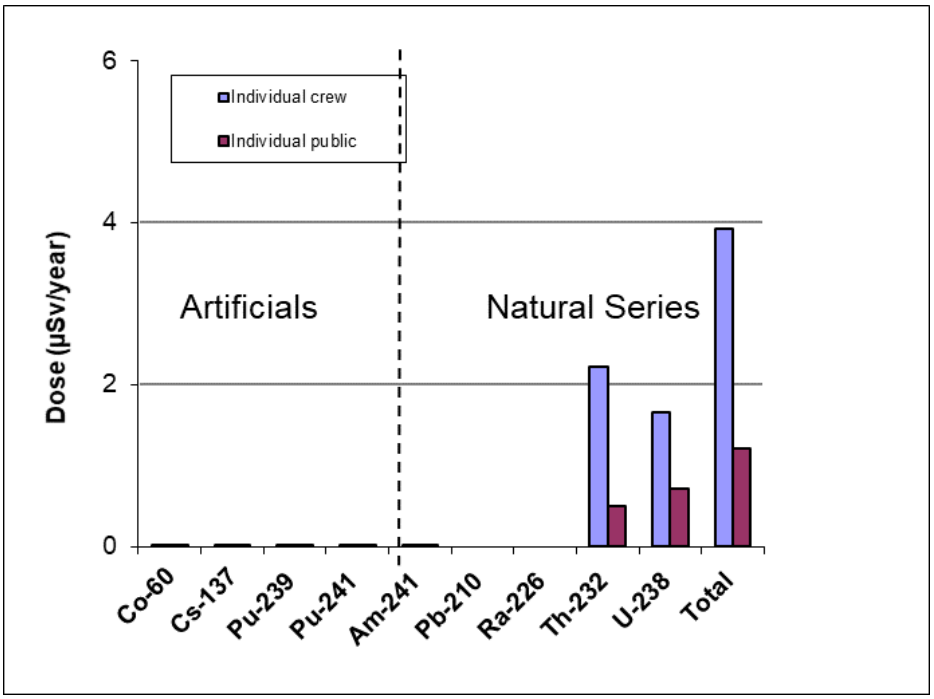

Figure 5 Assessment of dose to individual members of crew and the public arising. (Doses were derived using average activities listed in Appendix A). Note that Tritium is not displayed in the figure because the doses measured were so low, approximately three orders of magnitude lower than the other artificial radionuclides.

In 2020, the values for individual members of the crew and public, and the collective dose, were found to be below the *de minimis* criteria of 10 µSv/year (individual doses) and 1 manSv/year (collective dose), respectively.

The estimated doses (derived from surface sediment samples only) from the previous dredging application for Hinkley Point C nuclear power station in 2017 were reported as 5.8 µSv/year, 1.9 µSv/year (individual doses) and 0.035 manSv/year (collective dose) (BEEMS Technical Report TR444 and Leonard et al. 2017). Corresponding doses estimated in 2020 and 2017 were similar in magnitude.

3.1 Plutonium and Americium radionuclides

In part 1 (BEEMS Technical Report TR533), activity concentrations of the plutonium radionuclides ($^{239+240}$Pu and ^{238}Pu) were derived using ^{241}Am data obtained from gamma spectrometry analysis, assuming that their activity was proportional to the ratio in the time integrated Sellafield discharges (McCubbin and Vivian, 2006). These derived activity concentrations are over-estimates when compared to the analytical results obtained from alpha spectrometry analysis (Table 2). Therefore, the inclusion of analytical results for these particular radionuclides, did not have any impact on the overall dose, which is dominated by naturally occurring radionuclides. This demonstrates that the conservative generic radiological assessment procedure developed by the IAEA, which uses derived plutonium concentration data, is appropriate for estimating the radiological risk for dredging applications.

Table 2 Comparison of estimated and actual activity concentrations for plutonium and americium radionuclides

Radionuclide	Activity concentration estimated in Part 1 assessment (Bq/kg, dry weight)	Average activity concentration* (Bq/kg, dry weight)
^{241}Am	1.66**	0.13
$^{239+240}$Pu	0.95	0.12
^{238}Pu	0.16	0.017

* Average determination, including < results as positively measured values.

** ^{241}Am determined via gamma ray spectrometry.

This supplementary radiological assessment, based on the procedure developed by the IAEA, was used to convert radionuclide concentrations in disposed material into radiation doses due to disposal. The conservative IAEA generic assessment procedure in the Part 1 assessment (BEEMS Technical Report TR533) derived total doses to individual members of the crew and public of 3.9 µSv/year and 1.2 µSv/year, respectively. The total collective dose was 0.038 manSv/year. The values for individual members of the crew and public, and the collective dose, were within the *de minimis* criteria of 10 µSv/year (individual doses) and 1 manSv/year (collective dose), respectively. Because Americium and isotopes of Plutonium contribute so little to the doses (see Figure 5), the calculated doses using the results of the radiochemical analysis were unchanged from those reported in Part 1.

In this assessment, the modelled activity concentrations used in Part 1 were compared with measured activity concentrations. As shown in Table 2, the concentrations modelled in the Part 1 assessment were significantly higher than those actually measured and reported herein, demonstrating that the assessment process used in Part 1 was conservative.

As the initial conservative generic radiological assessment (part 1) and the supplementary radiological assessment (this report), both indicated that doses received were well below recommended limits, a subsequent more detailed case specific assessment was not necessary. All the derived total dose values were less than the *de minimis* criteria of 10 µSv/year and 1 manSv/year for individual and collective dose, respectively.

Therefore, from radiological considerations, there is no objection to this material being dredged and disposed of to sea.

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Appendix A Activity concentration data

Table 3 Representative depth ranges (m) for selected sediment cores for the supplementary assessment

Dredge area	Station	Sample depth [m] (representative range)								
		0 (surface grab)	0.0 – 0.25	0.25 – 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 3.0	3.0 – 4.0	4.0 – 5.0	5.0 – 6.0
Intake OS21	OS21	✓								
	OS21-C		✓	✓	✓	✓	✓	✓		
	OS21-CR							✓	✓	✓
Outfall OS01	OS01-A	✓								
	OS01-B		✓	✓	✓	✓	✓	✓	✓	✓
Outfall Flotation	OF-B		✓	✓	✓	✓	✓	✓	✓	✓

Table 4 Activity concentrations from radiochemical analyses in sediment samples

Core Sample Identifier	Core Sub-sample Identifier and additional information*	Representative depth range, m	Specific activity (Bq/kg, dry weight)				
			Organically Bound Tritium	Total Tritium	^{238}Pu	$^{239+240}$Pu	^{241}Am
OS21-G1	G1 0-0.16m 1rA	0.0 – 0.16	<25.00	<25.00	0.096	0.77	0.80
OS21-C	R1 0-0.25m 1rA	0.0 - 0.25	<25.00	<25.00	0.0025	0.033	0.058
OS21-C	R1 0.25-0.50m 2rA	0.25 – 0.50	<25.00	<25.00	<0.0048	0.00060	0.0025
OS21-C	V1 0.5-1.0m 3rA	0.50 – 1.0	<25.00	<25.00	0.056	0.39	0.43
OS21-C	V1 1-1.65m 4rA	1.0 – 2.0	<25.00	<25.00	0.0053	0.024	0.037
OS21-C	R1 2-2.5m 5rA	2.0 – 3.0	<25.00	<25.00	0.00057	0.0065	0.011
OS21-C	R1 3-3.5m 6rA	3.0 – 4.0	<25.00	<25.00	0.0090	0.069	0.11
OS21-CR	r1 3-3.85m 6rA	3.0 – 4.0	<25.00	<25.00	0.0014	0.00045	0.0015
OS21-CR	r1 4.1-4.55m 7rA	4.0 – 5.0	<25.00	<25.00	<0.0029	<0.0040	0.0027
OS21-CR	r1 5.41-5.87m 8rA	5.0 – 6.0	<25.00	<25.00	0.0013	0.0018	0.00084
OS01-G1	S1 0-0.16m 1rA	0.0 – 0.16	<25.00	<25.00	0.035	0.28	0.31
OS01-B	V1 0-0.25m 1rA	0.0 – 0.25	41.77	<25.00	0.064	0.42	0.46
OS01-B	V1 0.25-0.50m 2rA	0.25 – 0.50	<25.00	<25.00	0.028	0.20	0.20
OS01-B	V1 0.5-1m 3rA	0.50 – 1.0	<25.00	<25.00	<0.0015	0.0016	0.0018
OS01-B	V1 1-1.70m 4rA	1.0 – 2.0	<25.00	<25.00	0.00013	0.0017	0.0033
OS01-B	V1 2-2.70m 5rA	2.0 – 3.0	<25.00	<25.00	<0.0025	0.00079	0.000037
OS01-B	V1 3-3.70m 6rA	3.0 – 4.0	<25.00	<25.00	<0.0021	0.0013	0.0036
OS02-B	V1 4-4.80m 7rA	4.0 – 5.0	<25.00	<25.00	<0.0018	0.00094	0.0032
OS01-B	V1 4.80-5.60m 8rA	5.0 – 6.0	<25.00	<25.00	<0.0019	0.0008	0.0011

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Core Sample Identifier	Core Sub-sample Identifier and additional information*	Representative depth range, m	Specific activity (Bq/kg, dry weight)				
			Organically Bound Tritium	Total Tritium	^{238}Pu	$^{239+240}$Pu	^{241}Am
OF-B	V1 0-0.25m 1rA	0.0 – 0.25	<25.00	<25.00	0.089	0.76	0.77
OF-B	V1 0.25-0.50m 2rA	0.25 – 0.50	<25.00	<25.00	<0.0046	0.00017	<0.0036
OF-B	V1 0.5-1m 3rA	0.50 – 1.0	<25.00	<25.00	<0.0033	0.0011	0.0031
OF-B	R1 1-1.4m 4rA	1.0 – 2.0	<25.00	<25.00	0.018	0.13	0.16
OF-B	V1 2-2.7m 5rA	2.0 – 3.0	<25.00	<25.00	<0.0057	0.0011	0.0024
OF-B	R1 3-3.7m 6rA	3.0 – 4.0	<25.00	<25.00	<0.0042	0.00065	<0.0044
OF-B	R1 4-4.8m 7rA	4.0 – 5.0	<25.00	<25.00	<0.0039	0.00085	0.0011
OF-B	R1 5-5.6m 8rA	5.0 – 6.0	<25.00	<25.00	<0.0020	0.00083	0.00021
	***Average**		**25.62**	**25.00**	**0.017**	**0.12**	**0.13**

* Average determinations use < results as positively measured values to produce a conservative estimate.