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Particles BPEO Complete List of Options			
ABSTRACT			
<p>This document provides a comprehensive list of all the options to be considered in the identification of the Best Practicable Environmental Options (BPEO) for the management of particles in the marine environment.</p>			
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1. INTRODUCTION

To identify the Best Practicable Environmental Option (BPEO) for the management strategy for irradiated nuclear fuel particles in the marine environment, options have been identified for assessment. An initial list of options was identified by a UKAEA team [1]. The initial list was consulted upon as part of the front end stakeholder engagement in December 2005 and January 2006, responses from stakeholders gave rise to three options being revised and three new options [2]. The aim of this document is purely to provide a comprehensive list of all the options as they currently stand to facilitate the screening, combining and scoring of options.

2. ONSHORE AND OFFSHORE OPTIONS

To make clear during the stakeholder engagement process that not all options would be feasible and hence they may not all be taken forward for scoring, an initial feasibility assessment has been completed for each of the options. Options were deemed as not feasible if they are illegal, not technically feasible, or unable to be combined with at least one of the on/offshore options to give an overall strategy. It was made clear during consultation that no options had been ruled out to date. It is up to the scoring panel to identify how they wish to screen the options [3].

The options identified are described and performance against feasibility criteria reviewed in feasibility tables (Table 1) in Sections 2.1 and 2.2 a summary of which is given in Section 2.3.

Table 1 Feasibility Assessment

Feasibility Criteria	Yes/No*	Comments
Legal		
Technically feasible		
Can combine with at least one on/offshore option		

** If there is a No against any criterion then the option may not be feasible.*

2.1 Onshore Options

2.1.1 Onshore Monitoring Without Recovery

The 'Onshore Monitoring Without Recovery' option would provide an ongoing assessment of the particle population distribution and the radioactivity of the particles within the onshore environment. It would involve conducting radiological surveys of beaches and foreshore areas on a regular basis. This would be done using radiation detection systems such as the Groundhog Evolution™ system which is currently used

for beach monitoring. The limits of detection for monitoring systems could result in very small particles or particles buried at depth, not being detected, (typically particles are recovered at depths of up to 20cm). Detected particles would not be recovered.

Monitoring could provide confidence that particles were dispersing. For complete assurance to be provided, monitoring would have to be conducted for a suitable length of time and in the necessary areas. Survey areas would therefore be targeted on the basis of the known extent of the contamination and areas where sediment movement modelling predicted the onshore transfer of contamination. The identification of monitoring locations and frequencies would therefore be constantly reviewed depending on the extent of the particle finds. This review process would ensure that the appropriate level of monitoring would be undertaken and that additional management actions could be undertaken, if the need was identified.

Table 2 presents an initial assessment of the 'Onshore Monitoring Without Recovery' option and indicates that it is likely to be feasible.

Table 2 Feasibility of 'Onshore Monitoring Without Recovery'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	A change from the current regulatory requirements would be required. No prohibitive legislation has been identified.
Technically feasible	Yes	Monitoring to identify particle presence is currently feasible. Would require development to measure activity and depth without particle recovery.
Can combine with at least one offshore option	Yes	Can combine with all offshore options identified.

2.1.2 Onshore Monitoring With Recovery

In 'Onshore Monitoring With Recovery', beaches would be monitored as per 'Onshore Monitoring Without Recovery' option however, particles identified would be retrieved and transported to Dounreay for analysis and storage.

As presented in Table 3, 'Onshore Monitoring with Recovery' is current practice and hence is known to be feasible.

Table 3 Feasibility of 'Onshore Monitoring With Recovery'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	Current regulatory requirement to carry out monitoring with recovery.
Technically feasible	Yes	Monitoring with recovery currently carried out.
Can combine with at least one offshore option	Yes	Can be combined with any offshore option.

2.1.3 Recover All Individual Particles At All Depths Onshore

The 'Recover All Individual Particles At All Depths Onshore' option would involve the identification and removal of all detectable particles in the onshore environment. The objective would be to ensure that the hazard was removed, as far as possible. This option would involve actively over-turning the beach sediment to ensure that all particles including those at depths could be detected and subsequently recovered.

This strategy, if implemented, would represent a focused attempt to reduce the number of particles in the onshore environment and treat the particles *in situ* in such a way as to reduce their potential impact on people and the environment.

This option could be implemented as a one-off project, due to the nature and the scale of the activities required. However, the success of a one-off project would potentially be compromised if there were an ongoing feed of particles from the offshore environment as the beach could be re-contaminated.

Table 4 presents an initial assessment of the 'Recover All Individual Particles' option and indicates that it is likely to be feasible.

Table 4 Feasibility of 'Recover All Individual Particles At All Depths'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Would use standard machinery and current particle monitoring techniques. No technical issues foreseen.
Can combine with at least one offshore options	Yes	Combines with options which prevent/minimise the offshore environment being a continued source of particles to the onshore environment.

2.1.4 Bulk Removal of Beach Sediments

The 'Bulk Removal of Beach Sediments' option would involve excavating and removing all sediment from the beaches and shorelines affected by particles. This could be done fairly readily using mechanical excavators. De-watering or isolation of sub-tidal areas may be required to facilitate excavation.

Following segregation of the detectable particles from the excavated sediments, a number of options for the clean sands have been identified:

1. Return it to the original beach environment.
2. Put it in the sea.
3. Utilise as construction material.

If Table 26 is chosen for implementation a Best Practicable Means assessment may be required to identify which disposal route for the sand is most appropriate.

The ‘Bulk Removal of Beach Sediments’ option could be implemented as a one-off projects. As such the success of a one-off project would potentially be compromised if there were an ongoing feed of particles from the offshore environment.

Two variations of this option have been identified during the consultation process:

1. Target the ‘bulk removal of beach sediments’ to small areas where concentrations of particles have been found in the past.
2. Remove the sand in layers over a period of time, monitoring sand, removing the particles.

Table 5 presents an initial assessment of the 'Bulk Removal of Beach Sediments' option and indicates that it is likely to be feasible.

Table 5 Feasibility of Bulk Removal of Beach Sediments

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Standard construction machinery and monitoring would be employed, dewatering or isolation of sub-tidal areas maybe required, but should be feasible.
Can combine with at least one offshore option	Yes	Combines with options which prevent/minimise the offshore environment being a continued source of particles to the onshore environment.

2.1.5 Onshore Immobilisation/Isolation of Sediments

'Onshore Immobilisation/ Isolation of Sediments' would prevent people, animals or plants from coming into contact with the particles and would prevent further movement for example by wind or wave action. This could be achieved by solidifying the beach sediments, or by covering the beach in a membrane so the particles could not move or be moved. Given the physical nature of the beach environment, the immobilisation/isolation technique would need to be very durable and resistant to wind and wave action. The success of this option would be limited if there was an ongoing feed of particles from the offshore environment.

Table 6 presents an initial assessment of the ‘Onshore Immobilisation/Isolation of Sediments’ option and indicates that it is not likely to be feasible.

Table 6 Feasibility of ‘Onshore Immobilisation/Isolation of Sediments’

Feasibility Criteria	Yes/No	Comments
Legal	No	This option is interpreted as intent to “dispose” of radioactive material within the inter-tidal and marine environment. This would be a contravention of the 1972 London Convention [4], which bans the dumping of all radioactive waste to sea.
Technically Feasible	No	The immobilisation of an entire beach is considered to be technically unfeasible. Long term isolation of the beach is also considered to technically unfeasible owing to the harsh environment.
Can combine with at least one offshore option	Yes	Combines with options which prevent/minimise the offshore environment being a continued source of particles to the onshore environment.

2.1.6 Onshore Bioremediation

Bioremediation is a recognised technique for remediation of chemically contaminated ground and its applications to the nuclear industry are beginning to be realised. It involves using biological processes to physically and/or chemically breakdown contaminants. For example, some bacteria can be used to digest hydrocarbon contamination, and experiments have been conducted to test the ability of willow trees to preferentially extract caesium from contaminated soil. Whatever biota is used would need to be periodically harvested and the radioactive component extracted and treated as waste.

Table 7 presents an initial assessment of ‘Onshore Bioremediation’ and indicates that it is not likely to be feasible.

Table 7 Feasibility of ‘Onshore Bioremediation’

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	No	At present there are no known organisms that can physically degrade, dissolve or selectively uptake radioactive particles, particularly in the harsh environments under consideration.
Can combine with at least one offshore options	Yes	Combines with options which prevents/minimise the offshore being a continued source of particles to the onshore environment.

2.1.7 Onshore Restrict Public Access

Restricting public access to contaminated areas of beach and foreshore would ensure that people could not come into contact with the particles, thereby preventing any harmful effects. This could be achieved by displaying warning signs, and erecting barriers and fences. It could be enforced, if necessary, using other security measures, e.g. wardens. The extent of these restrictions would need to be continually reviewed if there was a possibility of future contamination of other sections of coastline, e.g. if a cache of particles still existed offshore. Limited information on particle distribution would however be available to undertake this review and there would therefore be reliance on existing knowledge and understanding. The restrictions would need to be implemented for as long as the particles were considered to present a risk.

It should be noted that access restrictions would not prevent other environmental receptors, e.g. animals or plants, from coming into contact with a particle. This option therefore makes the implicit assumption that humans are the only significant receptor and there is no other environmental harm.

Table 8 presents an initial assessment of the 'Restrict Public Access' option and indicates that it is likely to be feasible.

Table 8 Feasibility of 'Onshore Restrict Public Access'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Public access is currently restricted at the Dounreay foreshore showing that the option is technically feasible.
Can combine with at least one offshore option	Yes	Could combine with any offshore option, however if there was a continuing cache of offshore particles then onshore monitoring to assess the extent of the contamination may also be required.

2.1.8 Onshore Sever Pathway Option

This strategy would seek to prevent the onshore feed of particles from offshore, thereby preventing further onshore contamination. Although this strategy would only address onshore contamination, it would need to be implemented within the offshore environment. It is based on the evidence that the main flux of particles to the onshore environment is from an offshore cache.

An initial feasibility study of building a barrier across Sandside Bay to prevent a flux of particles onto the beach has identified that a dual-barrier system would be effective. This would consist of an offshore, submerged rubble armour breakwater to absorb wave energy and an impermeable inner barrier to trap sediment and any particles present. Any particles that collected between the two barriers would need to be removed on a regular basis.

Since this initial study was carried out a particle has been found on Dunnet Beach. A feasibility assessment would need to be carried out for this beach also if this option is preferred. Alternatively this could be used just for Sandside Beach and alternative onshore options employed for other onshore areas.

This option would not prevent contamination from the offshore impacting on other areas of the onshore environment, e.g. the Dounreay foreshore. Furthermore, it would not deal with any particles currently residing on Sandside Beach, and may consequently need to be implemented in conjunction with another onshore management strategy.

The construction of a barrier across Sandside Bay or other beaches would create a dramatic alteration to the bay and the beach, with the inevitable formation of a brackish lagoon behind the barrier. As Sandside is currently designated as a Site of Special Scientific Interest (SSSI) considerable effort would be required to obtain the necessary planning permission and approval. In addition, sediment and particles would potentially build up on the offshore side of the outer breakwater.

The initial assessment of the 'Onshore Sever Pathway' option shown in Table 9 identifies that it is likely to be feasible at Sandside Bay but further work on the technical feasibility is required for other areas such as Dunnet Beach, where the scale of works required may prove to make this option unfeasible.

Table 9 Feasibility of 'Onshore Sever Pathway'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Feasibility assessments have only been carried out for Sandside Bay but would be required further work for other areas.
Can combine with at least one offshore option	Yes	Offshore options that leave a cache of particles offshore could be combined with this option. The benefits of this option would not be realised if combined with an offshore remediation option.

2.1.9 Onshore Natural Attenuation

The 'Onshore Natural Attenuation' option is effectively a 'do nothing' option and would rely on the natural dispersion of the particles, by marine process such as waves and tides. Radioactive decay would also occur with time (for example the activity of caesium-137 in a particle will be halved in approximately 30 years). As natural dispersion and radioactive decay will occur anyway, what distinguishes the Natural Attenuation strategy is that it would be unmonitored and its implementation would be accompanied by the termination of all current activities relating to particle monitoring and recovery within the environment.

In the context of the onshore environment, ‘Onshore Natural Attenuation’ would involve allowing the particles to remain on the beaches and foreshore. Long-term natural dispersion could reduce the potential frequency of human contact; however, continued particle feed from the offshore could equally well occur, which would work in opposition to natural dispersion. Radioactive decay, radionuclide release and potential particle break-up would result in a gradual hazard reduction. This attenuation of the contamination would not be monitored and all other associated work, for example scientific investigations, would be terminated. Consequently, there would be no way of knowing if the particles did not disperse as anticipated, or were deposited on other sections of coastline.

Table 10 presents an initial assessment of the 'Onshore Natural Attenuation' option and indicates that it is likely to be feasible.

Table 10 Feasibility of ‘Onshore Natural Attenuation’

Feasibility Criteria	Yes/No	Comments
Legal	Yes	Would require a change in current regulatory requirements. However, no prohibitive legislation has been identified to date.
Technically feasible	Yes	No technical work involved.
Can combine with at least one offshore option	Yes	Could be combined with any offshore options.

2.2 Offshore Options

2.2.1 Offshore Monitoring Without Recovery

'Offshore Monitoring Without Recovery' would provide an ongoing assessment of the particle population distribution and the radioactivity of the particles within the offshore environment. It would involve conducting radiological surveys of the seabed on a regular basis. As with onshore monitoring, the limit of detection for particles is affected by the activity of the particle and the depth of sediment in which the particle is buried. Particles are typically recovered from depths of up to 30cm.

Historically divers would have carried out monitoring. In the future Remotely Operated Vehicles (ROVs) could be used, to avoid the safety risks associated with diving. Consequently, ‘Offshore Monitoring Without Recovery’ will be very susceptible to weather and sea conditions. The interval between successive surveys of a particular offshore area would be greater than for the onshore environment, because of these practical limitations and the larger geographical area that would need to be monitored.

Monitoring could provide evidence to assess whether or not particles were dispersing naturally into deeper water, and whether other areas of the onshore environment were likely to be impacted. For complete assurance to be provided, monitoring would have to be conducted for a suitable length of time and in appropriate areas. Survey areas would therefore be targeted on the basis of the known extent of the contamination and areas where sediment movement modelling predicted migration. The identification of

monitoring locations and frequencies would therefore be constantly reviewed depending on the extent of the particle finds. This review process would ensure that the appropriate level of monitoring would be undertaken and that additional management actions could be undertaken, if a need to do so was identified.

Table 11 presents an initial assessment of the 'Offshore Monitoring Without Recovery' option and indicates that it is likely to be feasible.

Table 11 Feasibility of 'Offshore Monitoring Without Recovery'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	Monitoring is currently carried out. No legal issues identified.
Technically feasible	Yes	ROV technology now proven allows deep water monitoring.
Can combine with at least one onshore option	Yes	Can combine with onshore options which are compatible with a continuing source of offshore particles.

2.2.2 Offshore Monitoring With Recovery

'Offshore Monitoring With Recovery' would be carried out as discussed in Section 2.2.1 but particles would be recovered. As detailed in Table 13 particle recovery to date has been carried out in shallow waters (typically <25m) by divers. The risks associated with diving may make diving unacceptable in the long term. Currently, the ROV which can be deployed to depths of up to 100 metres has particle detection and mapping capability but not particle retrieval capability. Development would be required to allow recovery by an ROV in offshore sediments.

Table 12 presents an initial assessment of the 'Offshore Monitoring With Recovery' option and indicates that it is likely to be feasible.

Table 12 Feasibility of Offshore Monitoring With Recovery

Feasibility Criteria	Yes/No	Comments
Legal	Yes	Monitoring with recovery is currently carried out. No legal reasons foreseen that would make this option unfeasible.
Technically feasible	Yes	Currently carried out by divers so limited to shallow waters. Technology would need to be developed for ROV to recover particles.
Can combine with at least one onshore option	Yes	Can combine with all onshore options identified.

2.2.3 Recover all Individual Particles at all Depths Offshore

The 'Recover all Individual Particles at all Depths Offshore' option would represent a focused attempt to reduce the number of particles in the offshore environment so as to reduce the potential impact of particles on people and the environment. This would also serve to remove the source of the flux of particles to the onshore environment.

This option would involve both the identification and removal of all detectable particles in the offshore environment. The objective would be to ensure that the hazard associated with the particles was removed, as far as possible. The recovery of individual particles offshore would involve actively over-turning the seabed sediments to ensure that all particles could be detected and subsequently recovered.

The practical limitations of working in the marine environment mean that the rate of remediation may be slower than the rate at which particles can migrate. Recontamination of cleared areas could therefore occur and monitoring to validate the success of the remediation would be required. Furthermore, complete clearance of particles on the seafloor, even in the areas nearer the diffuser could therefore not be guaranteed.

Table 13 presents an initial assessment of the 'Recover All Individual Particles At All Depths Offshore' option and indicates that it is not likely to be feasible.

Table 13 Feasibility of Recover All Individual Particles At All Depths Offshore

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	No	Unable to guarantee removal of all particles from the seabed.
Can combine with at least one onshore option	Yes	Combines with onshore options that need the offshore cache of particles removed/reduced.

2.2.4 Targeted Recovery of Individual Particles Offshore

'Targeted Recovery of Individual Particles Offshore' would employ the same technique as described in the 'Recover all Individual Particles at all Depths Offshore'. There are three variations on this option:

1. Recover particles from in areas of high particle population density, or in areas where the most active particles reside. This option would be to remove large numbers of detectable particles.
2. Recover only large particles identified by the ROV. This option would reduce risk by focusing effort on the most active (potentially harmful) particles.

3. Recover particles from areas close to land. This option would mitigate the migration of particles to the onshore environment.

Which of these options would be most effective would be identified in a BPM assessment if this option is identified for implementation.

Table 14 presents an initial assessment of the 'Targeted Recovery of Individual Particles Offshore' option and indicates that it is likely to be feasible.

Table 14 - Feasibility of 'Targeted Recovery of Individual Particles Offshore'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	The technique would require work to optimise but is thought to be feasible. Assessment of burial depth, insitu activity measurement and particle recovery techniques would need further development.
Can combine with at least one onshore option	Yes	Would combine with onshore options that need the offshore cache of particles to be removed/reduced.

2.2.5 Bulk Removal of All Marine Sediments

'Bulk Removal of All Marine Sediments' would involve dredging or 'hoovering' the seabed, to recover and monitor all sediments and ensure that all detectable particles were removed. It is assumed that sediment removed would be returned to the seabed after monitoring.

As with 'Recover all Individual Particles at all Depths Offshore' it would be difficult to ensure that all particles were removed from the seabed. In addition the huge scale of the operation may be problematic.

Table 15 presents an initial assessment of the 'Bulk Removal of all Marine Sediments' option and indicates that it is not likely to be feasible.

Table 15 Feasibility of 'Bulk Removal of all Marine Sediments'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	No	Could not guarantee removal of all particles. The scale of the job would also be problematic.
Compatibility with at least one onshore option	Yes	Would combine with onshore options that need the offshore cache of particles removed/reduced.

2.2.6 Targeted Bulk Removal of Marine Sediments

'Targeted Bulk Removal of Marine Sediments' would involve dredging the seabed, to recover and monitor sediments from targeted areas with the objective of removing large numbers of the detectable particles and to mitigate the migration and feed of particles to the onshore environment. Effort would be concentrated in areas of high particle population density, or in areas where the most active particles reside. Following segregation of the particles from the excavated sediment the sediments would be returned to the seabed.

Table 16 presents an initial assessment of the 'Targeted Bulk Removal of Marine Sediments' option and indicates that it is likely to be feasible.

Table 16 Feasibility of 'Targeted Bulk Removal of Marine Sediments'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Dredging is a proven technique.
Compatibility with at least one On/Offshore Options	Yes	Would combine with onshore options that need the offshore cache of particles removed/reduced.

2.2.7 Immobilising/Isolating Marine Sediments

Options to prevent particle migration and potential contact have been considered. These possibilities include capping the sediments with either geomembrane or concrete and vitrification of the sediments.

Table 17 presents an initial assessment of 'Immobilising/Isolating Marine Sediments' and indicates that it is not likely to be feasible as it contravenes the London Convention.

Table 17 Feasibility of 'Immobilising/Isolating Marine Sediments'

Feasibility Criteria	Yes/No	Comments
Legal	No	This option is interpreted as intent to "dispose" of radioactive material within the inter-tidal and marine environment. This would be a contravention of the 1972 London Convention [9], which bans the dumping of all radioactive waste to sea.
Technically feasible	No	The immobilisation of large areas of offshore sediment is considered to be technically unfeasible. So too is the long-term isolation of the offshore sediments, due to the harsh environment.

Feasibility Criteria	Yes/No	Comments
Can combine with at least one onshore options	Yes	Would combine with onshore options requiring the prevention/minimisation of recontamination from offshore cache of particles.

2.2.8 Offshore Bioremediation

'Offshore Bioremediation' is the removal of particles from the offshore environment using organisms. Bioremediation makes use of some organism's preference to uptake a pollutant and either changes it into a harmless form (e.g. specific bacteria are used for organic materials) or removes it so that it can no longer cause harm (e.g. trees used to remove toxic metals from contaminated land). As radionuclides can not be broken down the bioremediation process would need to include the harvesting of the selected organism. No organisms have been identified that uptake particles and hence it is not technically feasible as detailed in Table 18.

Table 18 Feasibility of 'Offshore Bioremediation'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	No	There are no known organisms that can degrade or selectively uptake particles.
Can combine with at least one onshore option	Yes	Would combine with onshore options that need the offshore cache of particles removed/reduced.

2.2.9 Active Dilution and Dispersion Offshore

'Active Dilution and Dispersion Offshore' has the objective of actively enhancing the processes of natural dispersion. This would involve the jetting or vacuuming of seabed sediments known to contain particles potentially dispersing the particles more widely within the environment. The movement of the marine sediments would therefore have to be sufficiently understood to ensure that no re-accumulation in the offshore or enhanced feed to the onshore occurred.

Table 19 presents an initial assessment of the 'Active Dilution and Dispersion Offshore' option and indicates that it is not likely to be feasible.

Table 19 Feasibility of ‘Active Dilution and Dispersion Offshore’

Feasibility Criteria	Yes/No	Comments
Legal	No	The implementation of this option could be viewed as an attempt to transfer the contamination from one part of the environment to another and would therefore contravene the London Convention [4].
Technically feasible	Yes	Research may be required to ensure that the technique employed would be successful. However there is currently no evidence to suggest that this would not be feasible.
Can combine with at least one onshore option	Yes	Could combine with most onshore options.

2.2.10 Temporary De-watering and Reclamation

'Temporary De-watering and Reclamation' would involve the construction of isolation structures and the de-watering of areas of the seabed where particles resided in order to facilitate several of the other offshore options, particularly those concerned with monitoring and remediation. Large areas would need to be de-watered including areas in deeper water hence as indicated in Table 20, this option is not likely to be feasible.

Table 20 Feasibility of ‘Temporary De-watering and Reclamation’

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	No	Not feasible due to the massive volumes of water involved.
Can combine with at least one onshore option	Yes	Could combine with a number of the onshore options. Would also need to be combined with another offshore option.

2.2.11 Offshore Restrict Access

Restricting access to areas of the offshore where the seabed was contaminated would ensure that people could not come into contact with the particles, thereby preventing any harmful effects. This restriction could be achieved in a variety of ways including continuation and/or extension of the Food and Environment Protection Act (FEPA) exclusion zone and restrictions on recreational groups such as divers and surfers. Unlike the onshore equivalent this option could be less readily enforced, as the controls would cover a much wider area. Given the extent of the offshore contamination, UKAEA recognises that restrictions could not be placed across the entire offshore area where particles may occur. Rather they would be targeted on the

areas where the highest populations and the most radioactive particles resided. As the particles are considered to be dispersing offshore, continual review of the extent of the restriction would therefore be required. The restrictions would, however, need to be implemented for as long as the particles were considered to present a risk.

As with the equivalent onshore option, the identified controls are only protective of humans, the implicit assumption being that there is no environmental harm, which is in agreement with the environmental risk assessment conducted for particles in the environment [5]. Furthermore, given the nature of the marine environment and the habits of marine animals, the arbitrary boundaries of an exclusion zone may not be a robust control measure.

Table 21 presents an initial assessment of the 'Offshore Restrict Access' option and indicates that it is likely to be feasible.

Table 21 Feasibility of 'Offshore Restrict Access'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	Feasibility proven in the FEPA Exclusion Zone.
Can combine with at least one onshore option	Yes	Can combine with onshore options which are compatible with a continuing source of offshore of particles.

2.2.12 Offshore Natural Attenuation

As with the onshore equivalent, the 'Offshore Natural Attenuation' option would mean that the particles remained in the environment. Radioactive decay, physical abrasion, radionuclide release and potential break up and would result in a gradual reduction in the hazard associated with the individual particles. Long-term natural dispersion, by marine processes could reduce the potential frequency of human contact; however, this assumes that particles would not accumulate in a sediment "sink" that was accessible by humans directly or indirectly through the food chain. Natural Attenuation would not be monitored and other activities, such as sediment transport modelling, would be terminated. Consequently, there would be no way of knowing whether the predicted natural attenuation was occurring.

Table 22 presents an initial assessment of the 'Offshore Natural Attenuation' option and indicates that it is likely to be feasible.

Table 22 Feasibility of ‘Offshore Natural Attenuation’

Feasibility Criteria	Yes/No	Comments
Legal	Yes	The appropriate consents and permission would be required but no prohibitive legislation has been identified to date.
Technically feasible	Yes	No technology required.
Can combine with at least one onshore option	Yes	Can combine with onshore options which are compatible with a continuing source of offshore of particles.

2.2.13 Dolphin Retrieval

The ‘Dolphin Retrieval’ option would involve training dolphins to retrieve particles from the seabed.

Particles are very small, radiation monitors are required to detect them and the particle is retrieved with some of the surrounding sand (which is separated off in the lab). It is not thought technically feasible that a dolphin could be trained nor would have the dexterity required to complete retrieval operations. This is reflected in the feasibility assessment shown in Table 23.

Table 23 Feasibility of ‘Dolphin Retrieval’

Feasibility Criteria	Yes/No	Comments
Legal	Yes	No legal reasons have been identified that would prevent this option.
Technically feasible	No	Particles not detectable by dolphins and too small for them to retrieve.
Compatibility with at least one onshore option	Yes	Would combine with onshore options that need the offshore cache of particles removed/reduced.

2.2.14 Breakdown with Lasers

The ‘Breakdown with Lasers’ option would involve the use of ‘marine friendly’ lasers to break down particles found at sea.

The activity associated with particles would not be depleted by lasers, but if enough energy was deployed then the particle could be broken up. It is unlikely that this would be feasible underwater as the water would dissipate the energy.

Particles are very small, hence their location would need to be known very accurately to allow the laser to be aimed directly at them.

The feasibility assessment of option 23 is shown in Table 24 and shows that the option is unlikely to be feasible.

Table 24 Feasibility of 'Breakdown with Lasers'

Feasibility Criteria	Yes/No	Comments
Legal	No	The implementation of this option could be viewed as an attempt to transfer the contamination from one part of the environment to another and would therefore contravene the London Convention [5].
Technically feasible	No	Marine Friendly Lasers not readily available. Particles too small to be able to aim lasers at.
Compatibility with at least one onshore option	Yes	Can combine with all onshore options identified.

2.2.15 Passive Dredging

The 'Passive Dredging' option would involve the use of trenches on the seabed or angled groins, these would use the general eastward longshore drift, either pushes sand and particles further out to sea into deeper water or encourage drift towards the shore where sand could be monitored and particles removed.

Table 25 identifies that this option may be feasible.

Table 25 Feasibility of 'Passive Dredging'

Feasibility Criteria	Yes/No	Comments
Legal	Yes	No legal reasons have been identified that would prevent this option.
Technically feasible	Yes	Technology available to construct trenches or angled groins.
Compatibility with at least one onshore option	Yes	Can combine with all onshore options identified.

2.3 Summary of Onshore and Offshore Options

Table 26 provides a summary of all the onshore and offshore options and the assessment of feasibility.

Table 26 Onshore & Offshore Options Summary

	Option	Description	Likely to be feasible?
	Onshore		
1	Onshore Monitoring Without Recovery	Monitor the beaches to identify where particles are (particles at depth may not be detected).	✓
2	Onshore Monitoring With Recovery	Monitor the beaches to identify where particles are and recover them (particles at depth may not be detected and hence not recovered).	✓
3	Recover All Individual Particles At All Depths Onshore	Identification and recovery of all detectable onshore particles facilitated by overturning the sediments to allow all particles at depth to be found.	✓
4R	Bulk Removal of Beach Sediments	Remove the sand/sediment from the beaches to allow detectable particles to be separated out.	✓
5	Onshore Immobilisation/ Isolation of Sediments	Solidify the beach, or cover it in a membrane to stop the particles present in the sediments from moving.	×
6	Onshore Bioremediation	Use biological processes to break down or take up the particles.	×
7	Onshore Restrict Public Access	Prevent the public from accessing areas affected by particles.	✓
8	Onshore Sever Pathway Option	Build a barrier across affected bays to stop waves from washing particles on to the beaches.	✓
9	Onshore Natural Attenuation	Do nothing and allow marine processes and radiological decay to reduce the risk naturally.	✓
	Offshore		
10	Offshore Monitoring Without Recovery	Monitor the seabed to identify the location of offshore particles (particles at depth may not be detected).	✓
11	Offshore Monitoring With Recovery	Monitor the seabed to identify where particles are and recover them (particles at depth may not be detected and hence not recovered).	✓
12	Recover All Individual Particles At All Depths Offshore	Identification and recovery of all detectable offshore particles facilitated by overturning the sediments to allow all particles at depth to be found.	×
13R	Targeted Recovery of Individual Particles offshore	Identify and recover particles in areas of high particle density, high activity particles or particles close to land to reduce risk from offshore particles.	✓
14R	Bulk Removal of all Marine Sediments	Dredge or Hoover the seabed removing sediments to allow all detectable particles to be separated out and return the sediments once processed.	×
15	Targeted Bulk Removal of Marine Sediments	Dredge areas of the seabed known to have high density of particles present, remove sediments, separate out detectable particles and return sediments.	✓
16	Immobilisation/Isolation Marine Sediments	Stop particles moving from the sediment by covering it in a membrane, capping with cement or vitrifying into a glass.	×
17	Offshore Bioremediation	Use biological processes to break down or take up the particles.	×
18	Active Dilution and Dispersion Offshore	Jetting or vacuuming the seabed to disperse the particles more widely through the marine sediments.	×
19	Temporary De-watering and Reclamation	Build isolation structures and dewater areas to allow monitoring and recovery of particles.	×
20	Offshore Restrict Access	Restrict human access to offshore areas affected by particles.	✓
21	Offshore Natural Attenuation	Do nothing and allow marine processes and radiological decay to reduce the risk naturally.	✓
22N	Dolphin Retrieval	Train dolphins to retrieve particles.	×
23N	Breakdown with Lasers	Use marine friendly lasers to break down particles	×
24N	Passive Dredging	Use trenches/angled groynes to push sand and particles further out to sea or towards shore to allow monitoring and removal of particles.	✓

3. REFERENCES

1. UKAEA, Dounreay Particles BPEO – Options & Attributes Document, EPD(05)P240, Issue 1, December 2005
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3. UKAEA, Screening, Combing and Scoring BPEO Particle Management Options, EPD(06)252, Issue 1, April 2006
4. International Maritime Organisation, *The 25th Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter 1972 – Report on Meeting*, November 2003 (accessed via www.londonconvention.org)
5. Enviros, Environmental Risk Assessment for the Presence of Particles in the Marine Environment in the Vicinity of UKAEA Dounreay, UK0160033, June 2005.