Author: Department for Environment, Food and Rural Affairs
Date: May 2007

SUB-SURFACE EXCLUSION CRITERIA FOR GEOLOGICAL DISPOSAL:

JOINT REPORT OF THE CRITERIA PROPOSALS GROUP (CPG) AND THE CRITERIA REVIEW PANEL (CRP)

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Executive Summary

A note by Professor Peter Styles (CPG Chair) and Professor Howard Wheater (CRP Chair)

Our two groups were recruited by Government and convened in February 2007 with terms of reference agreed by Ministers. CPG met first on 6 March and twice subsequently. CRP met on 10 May and jointly with CPG on 11 May. Together with colleagues, we attended a workshop on sub-surface "screening" (exclusion) criteria on 14 May.

Our terms of reference set by the Government were to provide it with advice on the sub-surface scientific criteria that could be used to identify areas of the UK where it would be difficult to develop a geological repository. Our timetable was dictated by the need to include proposals in the Government's Managing Radioactive Waste Safely consultation to be launched in the early summer. This was a challenging timeframe but with the help of our members, we have met it. A summary of our conclusions on the screening criteria that could be used is set out below. In addition, those criteria that we considered but decided not to recommend are set out beside our proposed criteria in tabular form in Annex 1 of the report.

The two key issues behind our recommendations are the need to exclude areas in order to:

- reduce the risk of future intrusion into a geological repository by future generations seeking to extract resources;
- protect the quality of exploitable groundwater.

We recognise that there is a significant element of judgement in deciding the point in the siting process at which intrusion risk is considered, but conclude that where future exploration for natural resources has a high probability, this is an appropriate exclusion criterion.

We also recognise that development of a repository in some areas could mean the loss to the present generation of some mineral resources, but that has been a lesser consideration. There are also a few specific geologies that we believe can be excluded from the siting process straightaway.

Factors such as geological stability, other geohazards (for example, flooding) and geotechnical issues have been considered but rejected as initial screening criteria. They should be considered in the subsequent stages of site assessment.

Explaining our views on the importance of protecting future generations from the consequences of inadvertent intrusion and of protecting the water supply of both present and future generations is complicated by the three-dimensional nature of geology. In the UK, a repository is likely to be excavated several hundred metres below the earth's surface. Hence unsuitable geology at the surface, or at specific depths, is not necessarily a reason for exclusion.

We conclude that in order to protect water supplies, the repository should not be located within an aquifer. However, a repository could be located in the geological column either above or below a permeable rock formation (an "aquifer") provided the repository could be satisfactorily isolated from the water supply by the combined engineered design and containment properties of the intervening strata.

We therefore recommend that criteria should be used to exclude areas where:

- all or part of the potential repository host rock would be provided by aquifers, or other permeable formations that might reasonably be exploited in the future;

- certain mineral resources are located at depths greater than 100 metres – coal, oil and gas, oil shales, and some metalliferous ores (future exploration for minerals at a depth to about 100 metres would not pose a risk of intrusion);

- waste disposal or gas storage is committed or approved;

- deep karstic formations and source rocks for thermal springs are known to exist.

We commend these recommendations to Government.

Membership of CPG and CRP

CPG Chair

Professor Peter Styles	University of Keele; Former President of the Geological Society

CPG Members

Professor Neil Chapman	Geologist, University of Sheffield
Dr Adrian Bath	Hydrogeologist in private consultancy
Professor Rae Mackay	Hydrogeologist, University of Birmingham
Professor Rob Knipe	Structural geologist, University of Leeds
Dr Richard P Shaw	British Geological Survey
Professor Lynda Warren	Former Professor of Environmental Law, University of Wales Aberystwyth; member of CoRWM
Professor John Hudson	Department of Earth Sciences and Engineering, Imperial College
Dr Alan Hooper	Nuclear Decommissioning Authority

Criteria Review Panel (CRP)

CRP Chair

Professor Howard Wheater	Professor of Hydrology, Imperial College London

CRP Members

Professor Steve Sparks	Director of the Centre for Environmental and Geophysical Flows, University of Bristol
Professor John Mather	Lyell Professor of Geology, Royal Holloway College
Dr Johan Andersson	Private consultant in Sweden
Dr Malcolm Wakerley	Research Manager, Radioactive Substances Division, Defra
Dr Andy Baker	Environment Agency

Secretary to CPG/CRP – Steve Mansfield (Defra)

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1. Background

David Miliband, Secretary of State for Environment, Food and Rural Affairs, advised by CoRWM (Committee on Radioactive Waste Management), announced in October 2006 that geological disposal was the preferred method for safely disposing of higher activity radioactive waste[1]. Similar announcements were made by the Devolved Administrations for Scotland, Wales and Northern Ireland. The Government is committed to exploring a voluntarist/partnership approach to selecting a site for development of a geological repository.

In its Final Report (submitted to Government in July 2006) (1), CoRWM suggested that geological disposal should be defined as the burial of radioactive waste in a purpose-built facility excavated 200-1000 metres beneath the surface at a UK site. In forming its recommendation, CoRWM took account of the part that Earth's geology can play in isolating and containing the waste[2].

As suggested by CoRWM in its report, the voluntarist approach to site selection is associated with the development of criteria that allow the screening out of those areas that, because of their sub-surface characteristics, are unlikely to prove suitable for siting a geological repository. A set of high level exclusion criteria reflecting scientific understanding of sub-surface conditions (including geology and hydrogeology) will be required early on in the process to be applied to any area that is proposed by a volunteer community. Any area that is not excluded in this way will be evaluated to test its potential further.

To identify draft exclusion criteria, the UK Government and the Devolved Administrations asked two separate groups of scientists for their advice – a Criteria Proposals Group (CPG) and a Criteria Review Panel (CRP). This document represents the joint advice of the CPG and the CRP. It was developed from a first CPG draft (following a round of comments by CRP members at the end of April 2007) in order to be available for discussion at a workshop of interested parties on 14 May. The two groups met on 11 May to discuss the work and the present advice was developed jointly in light of the outcome of that meeting and of the workshop.

The draft exclusion criteria will be included in the Government's public consultation on the framework for implementing geological disposal due to

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1 Higher activity – a term describing radioactive wastes and materials that might eventually be managed as wastes for which there is currently no permanent management route, i.e., high level wastes, intermediate level waste, low level waste that cannot be consigned to the disposal facility at Drigg, spent nuclear fuel, uranium and plutonium. Together, these are sometimes referred to as "the CoRWM inventory".

2 CoRWM made no specific recommendations about disposal at greater depths, for example that which could be achieved by means of deep boreholes (possibly down to 3000 metres or more) for small volumes of waste. Thus, criteria that might be applied at these greater depths have not been examined and it seems likely that only those relating to hydrocarbon or geothermal exploitation would be relevant.

start in summer 2007 and may be modified as a result. The criteria will not be applied (i.e., unsuitable areas actually identified and eliminated) before the outcome of the consultation is known.

The aim of commissioning this advice was to avoid unnecessary work by volunteer communities and by legislatures on unsuitable areas that would otherwise go forward into the next steps of the site selection process.

1.1 How exclusion criteria fit into the repository implementation process

The use of sub-surface screening criteria is an initial part of the process only and is limited in purpose. Follow on work will then be necessary in relation to the areas that are volunteered (this advice makes no assumptions about the size of areas that may be volunteered). The follow-on may result in the exclusion of some of these areas. The follow on work will also be based on a wider range of criteria that will address the suitability of each proposed area, and will include activities:

- to investigate the geological and hydrogeological characteristics of areas in terms of their influence on repository performance (examples of which are given in the introduction to section 3), initially through desk studies and subsequently by means of in-situ site investigation;

- to assess the relative merits of different areas in terms of their surface characteristics, e.g., environmental impact, transport links, etc.;

- to undertake detailed assessment of potential risks to individuals and the environment as part of a staged process conforming to internationally accepted safety criteria.

It also needs to be made clear that these more detailed investigations of areas will extend over a number of years before any agreed development can begin. Among other things, detailed investigation is a requirement of regulatory consent. The process has the potential to result in the later exclusion of some areas that could not be excluded by application of the criteria recommended here.

The limitations of exclusion criteria are also reflected in international experience which suggests that a safe disposal system can be designed in a wide variety of geological environments and settings by matching engineered design with location and geological characteristics of a repository site. The range of designs of engineered systems is broad, as is the range of geological environments being investigated.

Thus, exclusion factors should aim at providing only a ‘first-cut’ means of readily identifying areas where there would be considerable difficulty in developing an operable disposal system and/or a confident safety case. These first-cut criteria (see Annex 1) would, as suggested above, be used to remove such areas from consideration.

1.2 Major issues raised by CPG and CRP

In evaluating the isolation capacity and safety of a geological repository far into the future, consideration is required of the natural evolution of the repository system after its closure. This involves careful consideration of how the whole system - the engineered components of the repository and the natural geological and surface environments - will change slowly over a period of thousands of years. A central point is to understand how water moves in the deep environment and how it might eventually transport very small quantities of radioactivity to the surface or to sources of drinking water. Protection of water supplies is one of the main discussion points in this document.

In addition to looking at the natural evolution, the regulators will require an evaluation of what might happen if someone inadvertently intrudes into the repository in the future, perhaps after records and surface markers have been lost or destroyed and memory of the repository location has faded. Because the hazard potential of the wastes diminishes with time because of radioactive decay, the possible health impacts of intrusion will decrease the further we go into the future. The first 1000 years sees a major decrease in radioactivity of much of the waste inventory that might be placed in a geological repository, so protection against intrusion in that period is particularly important. Inadvertent intrusion is considered most likely to happen as a result of exploratory drilling for resources. Such intrusion might result in the immediate exposure of the intruders to radioactivity as well as damage to the isolation capacity of part or all of the repository, potentially leading to increased exposure of future populations. The regulatory guidance for the geological disposal of radioactive wastes is currently being reviewed. The approach to the treatment of human intrusion set out in the new guidance may be different from that set out in current guidance, but will still require consideration of radiological impacts to both the intruder and to future populations. In siting and designing a repository, reasonable steps should be taken to reduce the possibility and consequences of future human intrusion.

Thus, the risk of intrusion is another main discussion point of this document. We accept that there is a significant element of judgement in deciding the point in the siting process at which intrusion risk should be considered. On balance, we conclude that where future exploration for natural resources has a high probability of occurring, this could lead to early exclusion during the siting process.

2. Development of exclusion criteria

The experience of overseas countries (such as Sweden, Germany, and Japan) which have carried out work on development of the geological disposal concept, and guidelines issued by the International Atomic Energy Agency (IAEA) are both relevant to the selection and use of sub-surface criteria. It will be necessary to draw on the results of overseas work as the

UK programme develops, and a note on the international background, which provides some key references for the work, is presented in Annex 2. The primary source for the recommendations – applying to the UK, and set out here - is CPG/CRP members' professional experience. Development of the recommendations has, inevitably, involved an element of value judgement. The recommendations are consistent with international practice.

The application of exclusion criteria will depend on existing geological information and interpretations to provide a three-dimensional geological model from the surface to potential repository depths and beyond. While geological knowledge in many areas will be based on significant extrapolation of sparse data coupled with geological interpretation, this will be the best information that is available with which to undertake any initial assessment. The exclusion criteria are developed in the context of this being the type of information that is already available, although some geological advice may be necessary to aid interpretation. The criteria must be applicable within whatever process of site selection is adopted.

It must be appreciated that we are dealing with the physical, chemical and mechanical properties of a three-dimensional volume of rock and the fluids within it and how these vary with time. Geological information is often presented in the form of two-dimensional maps which cannot fully convey the full picture in space and time. Surface rock type, or indeed a limited view at any particular depth, is not a guide to the full geological perspective and an area which may appear to be superficially unsuitable may be eminently suitable when the full vertical geological column is considered.

CPG has adhered to the following principles in formulating this advice:

(a) that all criteria that might be reasonably advanced should be considered for inclusion and applicability; those not recommended should be described and the reasons for their non-inclusion given;

(b) that the subjective elements of each criterion are made clear in advance of any siting process;

(c) that criteria should provide strong, defensible, reasons for excluding any area from consideration.

Thus, the advice includes possible criteria that the group considered but ultimately rejected if they did not meet the requirements given in (c).

The suitability of areas that are proposed and not excluded as an initial step cannot be fully tested until detailed investigations and modelling of site and repository performance have been carried out. These investigations may justify the exclusion of a volunteered area at a subsequent stage.

3. Geological issues affecting suitability

Previous work internationally (see Annex 2) has identified the geological characteristics that are relevant to the characterisation of potential repository sites. These state that (2):

- the geological setting should be amenable to characterisation, should have geometrical, geomechanical, geochemical and hydrogeological characteristics that inhibit radionuclide transport and allow safe repository construction, operation and closure;
- the host rock and repository containment system should not be adversely affected by future dynamic processes, e.g., climate change, tectonics, seismicity, and volcanism;
- the hydrogeological environment should tend to restrict groundwater flow and support waste isolation;
- the physicochemical and geochemical characteristics should limit radionuclide releases to the environment;
- potential future human activities should be considered in siting and the likelihood that such activities could adversely affect the isolation capability should be minimised;
- surface and underground characteristics should allow optimised infrastructure design in accordance with mining rules.

There are various factors such as the hydrogeological, geomechanical and geochemical properties of the host rock and surrounding geological formations that cannot individually be used for assessing site suitability. It is rather the specific combination of these properties that is important. Furthermore, these properties can generally only be realistically assessed at the site scale by dedicated geoscientific investigations, starting with detailed desk top studies of available information.

As a consequence, only the following geological issues will be relevant in various ways to the early exclusion of potential areas. The issues are categorised as follows:

- natural resources (not including groundwater) - coal, oil and gas, oil shales, industrial minerals, evaporite minerals, metalliferous ores, bulk rock, hazardous waste disposal sites, CO_2 disposal sites, gas storage sites, geothermal energy - in terms both of the risk of future intrusion into a repository and of the loss of resource;

- groundwater (exploitable groundwater resources, specific complex or dynamic hydrogeological environments);

- geological stability (earthquakes and faults, uplift and erosion, other geohazards including those linked with future climate and environmental changes);

- geotechnical issues (rock stress, rock engineering);

- ability to investigate and characterise the repository area.

Consideration has been given to whether each of the issues could be the basis for an exclusion criterion at this stage. This has taken into account the availability of existing information, and the extent to which uncertainties inherent in the information may impact on future assessment of suitability.

3.1 Natural resources

The presence of known mineral resource or areas with high mineral potential has been considered as a possible exclusion criterion.

There are two possible reasons why areas with such resources might be excluded:

The loss of a resource: There may be a need to balance the potential loss of a resource against the benefit that might arise from the construction of the repository. In most cases the volume of any repository, and any avoidance zone around it (even taking account of the geological environment and the key pathways and barriers that would be evaluated in the safety case) is still likely to be a small fraction of the volume of any bulk mineral resource[3]. Therefore the loss of that small part of the resource does not, of itself, necessarily support an exclusion criterion.

The risk of intrusion: The risk that inadvertent intrusion by exploratory drilling into a repository during future searches for resources compromises the repository's isolation capability. This risk is related to the economic value of the resources. The criteria developed are based on the assumption that certain resource types are of such value that the risk of intrusion is heightened. Other types of resources are of low value and the risk of intrusion is therefore less. (Future intrusion risks for different resources are not something that is particularly easy to quantify and for this reason, additional explanatory text is included as Annex 3.)

The UK has a long history of exploitation of natural resources and their distribution at depths of interest for a repository is well known. The risk of intrusion in areas where certain mineral resources have been identified is considered to be sufficiently high to justify excluding them from consideration except where the resources occur only at shallow depth. Given that the anticipated repository depth is likely to be significantly greater than 200 metres, resources which have been exploited only at depths of less than 100 metres are less likely to suggest future deep exploration and therefore are not covered by this exclusion criterion.

[3] The dimensions of the excavations will be determined by the properties of the host rock and the geometry of features within it. Indicative repository dimensions are provided in a NDA reference design for the co-located disposal of legacy HLW, spent fuel and ILW in crystalline rock. The plan area for the vaults and tunnels and a buffer zone between the different wastes is 4.3 sq km; the dimension of the major axis being 4km. The maximum height of the larger vaults required is about 15 m. In all, about 4.5 million m^3 of rock would be excavated.

In the following discussion, our recommendations for exclusion are based on the pattern of distribution of known resources and their economic value because there is a higher risk of intrusion in these areas. The justification for this is that areas where resources are already identified are likely to exhibit features and properties to future generations that will make them more likely for investigation than those areas where no resources of any value have presently been found.

Thus the risk of inadvertent intrusion into a future repository is the principal reason for considering whether the distributions of specific natural resources might be a sound basis for exclusion criteria.

In the following sections we suggest excluding areas containing certain resources, which raises the question of what we mean by ‘area’. It is not easy to give a clear answer to this in a generic sense. For some criteria, it may be straightforward to establish whether an area lies within, for example, a coalfield. However, for isolated deep mineral mines the ‘area’ that might be excluded is not definable without considering the local geological environment. Similarly, areas on, or close to, the edges of readily definable resource fields might raise concerns. Consequently, although some criteria will exclude some areas unequivocally, others may be more difficult to interpret and it will be important to take expert geological advice on the application of all the criteria.

(a) Coal

As a result of the economic importance of coal as an energy source, the extent of coalfields in the UK is well known. Given the fact that deep coal mining in the UK has been undertaken to depths of over 1000m and that new exploitation techniques, such as in-situ gasification, can be undertaken at depth, areas known to be underlain by coal at greater than 100 metres depth should be excluded because the risk of later intrusion is high.

(b) Oil and gas

The UK has been thoroughly explored for gas/oil resources, many oilfields have been developed and their distribution is well known. The extent of future exploration and exploitation is difficult to judge and will be dependent on market prices for oil and development of new theories on oil genesis/traps that might lead to novel areas being explored in future.

It is not feasible to predict possible future exploration areas for exclusion but it is appropriate to exclude areas from consideration based on the extent of known oil and gas fields. It is the risk of intrusion into the repository in conjunction with the loss of future oil and gas resource that is addressed by this exclusion.

(c) Oil shales

Oil shales have been mined commercially and retorted for mineral oil since the mid nineteenth century. Smaller scale working took place in earlier centuries with the oil used for lighting. Unconventional hydrocarbon resources such as this may well achieve importance again in the future. Areas in which oil shales are known to occur at greater than 100 metres depth should also be excluded from consideration because of the risk of intrusion.

(d) Industrial minerals (except evaporite minerals)

The UK produces a number of industrial minerals, including calcite, limestone, barite, fluorite, and kaolin (china clay). These materials are of relatively low value, which limits the depths to which they can be economically exploited so their presence at repository depth is not a general exclusion criterion *a priori*.

(e) Evaporite minerals

Evaporite minerals that are extracted in bulk are principally halite (salt), potash, and gypsum/anhydrite. In the UK, evaporite rocks are plentifully distributed, both near surface and at depth. Thus, resource loss and associated intrusion risk for areas with evaporite rocks are not considered sufficient to justify exclusion[4].

(f) Metalliferous ores

Mining for metalliferous ores has occurred in the past in many parts of the UK. Many areas have had small scale mining or mine trials that are shallow (less than 100 metres) and should not be excluded. However, areas underlain by deep (more than 100 metres) known, potentially economic, ore deposits should be excluded.

(g) Bulk rock resources

These include clays, sand and gravel, crushed rock aggregates, limestone and building stone. These materials are of low value and worked depths are shallow. There is no need to apply an exclusion criterion based on the presence of these resources.

(h) Hazardous waste disposal/CO_2 disposal/gas storage

Geological disposal of hazardous waste is presently being carried out. Areas with current or approved future hazardous waste disposal at depths greater than 100 metres should be excluded.

[4] It is well recognised that evaporite formations could be potential hosts for repositories because, amongst other factors, groundwater flow through them is negligible, as shown by the preservation of highly soluble minerals. In some countries, e.g., USA and Germany, repositories have been constructed or are planned in deep halite rocks. In the UK, areas with deep evaporite rocks should not be excluded. At a later stage, the detriments associated with resource loss and intrusion risk would need to be considered against the benefits that might arise from the effective containment properties of such host rocks.

Similarly, geological disposal ('sequestration') of CO_2 is likely to be undertaken and, while current proposals are largely based on disposal into depleted oilfields or related structures (see section 3.2), future disposal into other settings such as un-mined coal seams is possible. Areas with the potential for subsurface CO_2 disposal should not be excluded *a priori* (unless already committed or excluded for another reason, such as the presence of coal), on the basis that their possible use for CO_2 disposal is currently speculative.

Currently, gas is stored in cavities mined by solution of salt, mined cavities in chalk, and in some abandoned oilfields. Areas of actual or approved gas storage should be excluded.

(i) Geothermal energy

The whole of the UK offers potential for the installation of shallow ground source heat pump systems for climatic control of buildings. However, a typical system for a moderate/large building would utilise borehole(s) to a maximum depth of 200 metres which is not within the zone of consideration and thus not considered as a relevant exclusion criterion. Where aquifers may be used to provide energy storage and recovery using open systems that extract heat in groundwater, these systems are covered by the general considerations of groundwater exploitation in section 3.2.

At the moment, there is a single case of deep (1800 metres) low grade geothermal heat extraction from saline groundwater in the UK. There has also been a past project at one site to assess the potential for 'hot dry rock' (HDR) geothermal energy extraction from granite using heat extraction by water circulation in deep boreholes (2-3000 metres deep). That project did not result in any development and there are only limited plans for future investigations in the UK. Areas with potential for geothermal energy should not be excluded *a priori*, on the basis that their possible value for development is speculative.

3.2 Groundwater

All geological formations contain water and in practically all cases this groundwater can flow through the rock, albeit in some cases extremely slowly. Very slow groundwater movement is one of the hydrogeological conditions that will be sought in testing site suitability because the water has little resource value and movement with water is the main mechanism by which radioactive contaminants from a repository would eventually leak into regions where they would be hazardous to future populations. Water movement also affects the dissolution of wastes, the long-term degradation of the engineered components in a repository and the stability of conditions in the rock mass.

Hydrogeological conditions that have been proposed and considered as exclusion criteria are: (a) exploitable groundwater resources, (b) specific complex or dynamic groundwater environments.

(a) Exploitable groundwater resources

A primary consideration in siting a repository and in assessing its safety is that its construction, operation and long-term performance should not prejudice usable sources of water including groundwater. To be usable, groundwater in a geological formation must be extractable technically and economically, and water quality must be acceptable for use. The permeability of a formation determines the ease of extraction. Permeable formations that are exploited for groundwater use are described as aquifers. An aquifer does not necessarily have to include the whole of a single geological formation as permeability can vary substantially between different parts of the same formation. For this reason it can be difficult, for the purposes of the present exercise, to define an aquifer simply and each formation and area will need to be considered on an individual case basis.

Aquifers would not be suitable rock volumes in which to construct a repository. Other permeable formations from which groundwater is not currently exploited but which might reasonably be exploited in future, either as a result of treatment of the water or through the use of these formations as water storage reservoirs using aquifer storage recovery methods, should also be protected. Areas where all or part of the repository host rock would be provided by aquifers, or other permeable formations that might reasonably be exploited in the future, should be excluded.

Areas where a potential host rock volume exists in proximity to an exploitable groundwater resource (laterally or below) could be suitable as long as the thickness and properties of the rock volume provide adequate long-term isolation. Such areas should not be excluded at this stage.

The isolation of a repository from exploitable water resources will be a major issue for proving the eventual suitability of any proposed repository location. There are various geological and hydrogeological factors that determine the degree of isolation offered by a potential repository host formation. All of these will be assessed in detail by both implementer and regulator when judging long-term safety. A site investigation programme would measure properties of the host rock and surrounding geological formations so that these factors are well-understood.

Deep permeable formations (i.e., more than 500 metres in depth) are typically saline and have little or no potential for exploitation as water sources because of their poor quality. These formations should not be excluded.

(b) Specific complex or dynamic hydrogeological environments

Karst formations occur where channels in soluble rocks, primarily limestone but sometimes chalk, have been developed by dissolution by infiltrating water. Enlarged fissures and caves make up discrete pathways for groundwater flow, so that karst has strongly varying groundwater flow properties, directions and flow rates. This unpredictability of groundwater movement and the difficulty of characterisation for reliable modelling make areas with deep karst (extending to hundreds of metres depth) unsuitable and these should be excluded. Karstic aquifer formations should be considered as exploitable groundwater resources as discussed above.

Thermal springs are localised discharges of groundwater at the surface that can indicate deep, typically several hundred metres, groundwater flows to the surface. They can involve relatively large and fast flows in discrete channels usually related to geological faults or karst and are part of a deep groundwater circulation. They may have unusual chemical compositions (reflecting the geochemistry of the rocks through which they flow). Areas in which such deep-seated springs occur, and below which their sources and flow paths are located, should be excluded. This exclusion reflects the dynamism and local complexity (elevated flow rates and volumes; active chemical and thermal processes) of the deep groundwater flow systems in these specific and well known areas. General flow of groundwater to the surface (e.g., at springs, into riverbeds, and generally to the water table) is a normal aspect of groundwater circulation and is not relevant in this respect.

3.3 Geological stability

The UK is currently in a relatively quiescent tectonic setting and the landmass is generally stable. The principal active plate boundary that has any significant tectonic influence on the UK is the Mid-Atlantic ridge where Europe is separating from North America and Greenland at rates of a few centimetres per year. There are additional minor components due to compressional forces associated with Alpine tectonics and minor extension in the North Sea. These influence the general stress regime of the United Kingdom leading to a regional north-west/south-east orientated horizontal principal compressive stress. All rocks in the UK experience this tectonic stress, although there can be variations due to local geological conditions.

(a) Earthquakes and faults

In the geological past, UK rocks have been deformed and faults have been formed in the rock mass along which shear movement has occurred. Some of these faults are still potentially active and could produce some seismic effects, albeit low by global standards. It should be noted that it is the potential for shearing of the rock mass containing the repository and the loss of integrity of containment which is relevant here; the vibrations associated with earthquakes experienced in the UK will not significantly affect a repository at depth, whether before or after closure.

Much of the relatively low-level seismic activity within the UK is located within or close to the mined areas of the UK coalfields due to fracturing of the strata in the vicinity of the extracted seams.

Most faults have little potential for movement. The presence of weak faults with evidence of Quaternary activity (over roughly the last two million years) will be assessed later during site investigation as these may represent structures with a high susceptibility to future movement. Proximity to a mapped geological fault in itself should not be a criterion for initial exclusion.

(b) Uplift and erosion

Uplift and erosion of geological strata are unavoidable geological processes, and generally occur progressively on extremely long timescales. Over hundreds of millions of years, the remains of any repository may become dispersed through erosion. However, well within the first million years after disposal, the radioactivity of the spent fuel will have fallen to a level roughly equivalent to that of the original naturally occurring uranium ore (3).

Periods when more rapid vertical movements can take place are during and following glaciations (on a tens of thousands of years timescale into the future). Glacial processes can lead to erosion by ice-sheet abrasion or deeper down-cutting of rivers due to reduced sea levels. For example, erosion of hard rocks in northeast Scotland during the Quaternary has been estimated to be 34-62 metres in 2.3 million years (4); and the depth of erosion from an extensive glaciation can be up to 200 metres (5), being significantly greater for soft sediments compared to hard rock. The response to ice loading and unloading may also be sufficient to generate seismic activity and influence local stress fields.

The likelihood of significant ice cover for the UK within the timescale that a repository will have to maintain its protective function is dependent on many complex factors, including the levels of atmospheric CO_2, but the likelihood is progressively greater with increasing latitude. Its consequences could impact on a closed repository in relatively shallow strata, which is why geological disposal is planned for the depth range of 200-1000 metres. Assessment of the consequences would be strongly site specific and therefore the likelihood of glaciation across an area is not an exclusion criterion.

Erosion, glacial and periglacial impacts on groundwater flow and the possible impacts of post-glacial seismicity are factors that will be considered in evaluating the post-closure performance of a repository. These factors could affect design, repository depth and layout and make a site unsuitable. The potential effects need to be assessed at this site specific level; therefore factors associated with response to future glaciation are not considered relevant as generic exclusion criteria.

(c) Other geohazards

CPG/CRP’s terms of reference (ToR) refer to the threat from rising sea levels (as the result of climate change) as relevant to decisions on where a repository may be sited. The ToR suggest that coastal erosion and the risk of inundation by seawater are not regarded as a potential sub-surface exclusion criterion. Nevertheless, the issue is one of a range of geomorphological processes that, even if their potential impact relates to pre-closure repository operations, are likely to attract public interest during the site selection process and are considered as part of the CPG advice for completeness. In due course, when the suitability of volunteer sites is being assessed in detail, the potential impact of climate change on the geological environment of the repository, e.g., the hydrogeological regime, will need to be considered.

Sea level rise is one of the issues being considered by the Intergovernmental Panel on Climate Change (IPCC) (6). Its report suggests a global rise in sea levels of between 18 and 59 cm by 2100. A major uncertainty is the rate of ice discharge from the Greenland and Antarctic ice sheets – if this increases in line with projected increases in temperature, a further 10 – 20 cm could be added to the upper estimate. Sea level rise could affect the location of repository access points and surface facilities sited in a coastal area because of the threats of coastal erosion and flooding or storm surges during the construction, operational and any subsequent pre-closure phases which could extend beyond 2100. However, because the protection of surface facilities from coastal flooding, e.g., by engineered protection or, where possible, by relocation to higher ground, requires site specific consideration, it is not recommended as a general exclusion criterion.

The Sumatran earthquake of 2004, and its associated tsunami, which had a severe impact on the Indian Ocean raised awareness of the possibility of the UK being affected by a similar future event elsewhere in the world. A study of the potential impact from tsunamis that could reach the UK (7) has concluded that impacts (above those only detectable on tide gauges) were possible in relation to events originating in the Azores/Gibraltar region, Rockall/North West European continental margin, e.g., where the Storegga slide occurred 8000 years ago, and the Canary Islands. The last of these, a sector collapse such as Cumbre Vieja, would probably be progressive in nature and thus less hazardous. Otherwise, the likelihood of a tsunami reaching the UK from events not exceeding magnitude 8.5 is low. Again, the impact would have no significance on the integrity of a closed geological repository.

Within the UK, both landslides and subsidence can occur depending on local conditions, e.g., over-steepened slopes affected by extreme rainfall and coastal cliff failure in the former case, and above mine workings or soluble rock in the latter. The impact of landslide failure in the UK is restricted, however, to formations at shallow depth.

Subsidence can take several forms and can occur progressively or unpredictably, and be localised or dispersed. Most sudden, localised, collapses (known as sinkholes in limestone areas and crown holes in mining areas) do not exceed depths of more than a few tens of metres. Less localised subsidence sometimes occurring to greater depths (down to about 100 metres) is associated with chalk and salt and especially karst regimes in limestone. Apart from where they are associated with deep karst, however, surface disturbances of this type have no effect on deep geological strata where a repository would be located. Therefore subsidence is not relevant as an exclusion criterion.

Prolonged repository development will require pre-closure safety assessment of the risk posed by geohazards generally. All potential risks, including, for example, dam breaks and fluvial floods, would need to be considered at a later stage of the assessment. Similarly, design of post-closure monitoring would need to take into account geohazards, including risks of inundation.

3.4 Geotechnical issues

(a) Rock stress and rock engineering

The deep geological environment is characterised by rock stresses induced both by the weight of the overlying formations and by the tectonic forces caused by the 'push' from Atlantic sea-floor spreading. This overall UK rock stress field is locally perturbed by lithological boundaries and fractures. Moreover, the rock stress state has different magnitudes in the vertical and different horizontal directions. Consequently, the rock stresses at repository depths vary with the geological formations.

For the design of a repository, the nature of the rock stresses must be taken into account when deciding on the most suitable depth and orientation of tunnels and the design of the rock support systems. Also, stronger rocks allow larger openings to be constructed with less support required. Some rocks with excellent isolation potential are generally classed as 'weak' in engineering terms and, if advantage is to be taken of their containment properties, tunnel and repository engineered barrier designs will have to accommodate their weakness. Another factor is the potential for rock spalling – damage to the rock around excavations due to the concentrated stress reaching the rock strength.

Both rock stresses and the associated factor of rock engineering properties are considered as issues to be dealt with after the first-cut criteria are applied when detailed site investigation data are available. In this context, neither factor is therefore considered appropriate for consideration as an exclusion criterion.

3.5 Ability to investigate and characterise the repository area

Integrated geological and environmental site investigations will be required to gather all the information necessary to carry out the detailed design of a repository and to evaluate its safety performance. Some geological and geographical environments will be easier to characterise than others and the less accessible or more geologically complex a site is, the more effort will be required to collect sufficient information of adequate quality to provide a high level of confidence in its suitability.

There is potentially a wide spectrum of 'investigability' and it is not considered either possible or appropriate to attempt to draw an arbitrary line here between 'simple' and 'complex/difficult' environments so as to exclude the latter.

However, this is an issue that both the implementer and regulator will need to consider carefully when committing resources to a potential site. Clearly, the implementer might be expected to prefer ‘simpler’ environments, as both costs and project risk will be reduced. The regulatory authorities would also have to be convinced that a site can be, and eventually is, well enough understood to support a robust safety case.

References

1. Managing our radioactive waste safely, CoRWM’s recommendations to Government (July 2006), Department of Environment, Food and Rural Affairs, London, final version published in November 2006.

2. International Atomic Energy Agency (1994), Siting of Geological Disposal Facilities, Safety Series 111-G4-1, IAEA Vienna, (currently undergoing revision).

3. Chapman, N. A., and Curtis, C. D., Confidence in the safe geological disposal of radioactive waste, unpublished paper produced for a workshop organised by the Geological Society on the geological disposal of nuclear waste (January 2006), available from the Committee on Radioactive Waste Management (CoRWM).

4. Clayton, K., (1996), Quantification of the impact of glacial erosion on the British Isles, Transactions of the Institute of British Geographers, New Series, Vol. 21, no. 1, 124-140.

5. Glasser, N.F. and Hall, A.M. (1997). Calculating Quaternary glacial erosion rates in North East Scotland. Geomorphology, 20, 29-48.

6. Intergovernmental Panel on Climate Change, Fourth Assessment Report, 2007 (not yet published).

7. The threat posed by tsunami to the UK; BGS, Met Office, et al., commissioned by Defra Flood Management Division, June 2005.

Author: Department for Environment, Food and Rural Affairs
Date: May 2007

Annex 1 - Potential exclusion criteria by type

	Recommended as exclusion criteria?	Reasons/explanations and qualifying comments
Natural resources		
Coal	Yes	Intrusion risk to depth, only when resource at >100m depth
Oil and gas	Yes	Intrusion risk to depth
Oil shales	Yes	Intrusion risk to depth
Industrial minerals (except evaporites)	No	Low resource value - limiting the potential for economic exploitation at depth
Evaporite minerals	No	Wide distribution – insufficient resource loss and intrusion risk to justify exclusion
Metal ores	Some ores	Intrusion risk only where mined at depth, i.e. ,>100m
Bulk rock resources	No	Not exploited at depth
Disposal of wastes/gas storage	Yes	Only where already committed or approved at >100m depth
Geothermal energy – shallow ground source heat	No	Not exploited at depth
Geothermal energy - low grade heat extraction from deep rocks and groundwaters	No	Not an a priori general exclusion – value for development is currently speculative
Groundwater		
Aquifers	Yes	Where all or part of the repository is located within the aquifer
Shallow permeable formations	Yes	Where all or part of the potential repository host rock would be provided by permeable formations that might reasonably be exploited in the future
Deep permeable saline formations	No	No potential as exploitable groundwater resources
Formations neighbouring exploitable groundwater	No	Where the host rock volume provides adequate long-term isolation of the waste
Specific complex hydro-geological environments	Yes	Deep karstic formations and known source rocks for thermal springs
Geological stability		
Earthquakes & faults	No	Later assessment of potential impact on sites
Uplift and erosion	No	Influence on repository depth and design and later site exclusion in extreme cases
Other geohazards	No	Site specific risk assessment will be required later in the process
Geotechnical issues		
Rock stress and engineering issues	No	Later assessment when detailed site data are available
Other sub-surface criteria		
Specific complex geological environments	No	Need not be excluded at this stage
Other geological and hydrogeological characteristics	No	Only required at in-situ geoscientific investigation stage – see paragraph 2 of section 3

Annex 2

Note on international background to the use of exclusion criteria in a geological repository siting

The standard guide to deep geological repository siting was issued by the IAEA in 1994 (1) and has been generally referred to as the key source document by national programmes as they establish their siting projects. A short review of siting approaches in different countries is included in a book on principles and standards for disposal of long-lived wastes by Chapman and McCombie (2).

The IAEA recognises the possibility of using a volunteer approach and defines four stages of siting, which involve the screening of potential sites. However, it does not consider the specific concept of exclusion criteria for use at the outset of a programme, before any survey work has begun. In the first of siting stages (conceptual and planning phase) it only goes so far as to note that:

> *In general it is desirable to determine the potential suitability or acceptability of a site as quickly as possible with use of minimum resources. Thus, those factors or criteria which might result in the rejection of a site should be identified early in the planning stage and investigated early in the survey stage, even if investigations of such factors are not among the most easily conducted.*

The IAEA report also provides a set of general **site selection guidelines** which can be used as one component (along with safety, feasibility, social, economic and environmental considerations) to develop practical national guidelines, should these be considered necessary. It is noted by the IAEA that this is not a complete set, not in order of importance and they should not be applied in isolation. Their use should also take national limitations into account. They are reproduced in précis form below. The report also identifies typical data needs to show that each guideline has been met. These are not reproduced below.

- The geological setting should be amenable to characterisation, should have geometrical, geomechanical, geochemical and hydrogeological characteristics that inhibit radionuclide transport and allow safe repository construction, operation and closure
- The host rock and repository containment system should not be adversely affected by future dynamic processes of climate change, neotectonics, seismicity, volcanism, diapirism, etc.
- The hydrogeological environment should tend to restrict groundwater flow and support waste isolation
- The physicochemical and geochemical characteristics should limit radionuclide releases to the environment

- Potential future human activities should be considered in siting and the likelihood that such activities could adversely affect the isolation capability should be minimised
- Surface and underground characteristics should allow optimised infrastructure design in accordance with mining rules
- The site should be located such that waste transport to it does not give rise to unacceptable radiation or environmental impacts
- Site choice should mean that the local environmental quality will not be adversely affected, or such effects should be mitigated to an acceptable degree
- Land use and ownership in the area of the site should be considered in connection with possible future development and regional planning
- The overall societal impact of developing a repository at the chosen site should be acceptable, with beneficial effects being enhanced and negative effects minimised.

The IAEA guidelines have been adopted to varying extents in national regulations and the level of detail adopted in each country is variable. Chapman and McCombie (2) tabulate examples from several countries. Many of the details of these national regulations concern properties that suitable sites 'should' possess, rather than features that they 'should not' exhibit. In this sense they predominantly comprise 'inclusion factors' rather than 'exclusion factors'. Typically cited 'should not' features are:

- tectonically active structures
- high frequency of large magnitude earthquakes
- high geothermal gradients
- recent volcanic activity
- proximity of exploitable resources
- exceptionally high rock stresses
- large water conducting fractures in the repository
- formation with large heterogeneities
- proximity to aquifers.

However, each national regulatory authority has identified those factors which it considers most relevant to its own situation and not all of the features in this list are found in all regulations.

For example, the Swedish implementing organisation described conditions on a national scale as a general background to the fundamental prospects for siting of a repository (3). Bedrock types and non-geological factors were proposed as criteria, but it was realised that these factors were too general to be of real use and that applying them at a national scale might exclude potentially suitable local areas. Subsequently more specific siting factors were developed but the majority of these are requirements and preferences that have only been applicable at later stages when investigations with deep boreholes provided necessary site-specific information (4). However, some requirements (absence of ore potential or avoidance of regional deformation zone) provided some, although limited, guidance for the selection of areas for site investigations (5).

Similarly in Finland, where geological conditions are much more uniform than in the UK, major geological factors (e.g., related to faulting patterns) were used to identify several hundred areas, but as in Sweden more specific geological characteristics were not useful as criteria before deep borehole drilling was carried out (6). The geoscientific criteria that have been used as suitability requirements, favourable characteristics or preferences in the later stages of site investigations and selection in Sweden and Finland are essentially not analogues for exclusion criteria that could be applied in the pre-investigation process presently being considered in the UK.

A common feature of most siting regulations is that they are couched in rather general, qualitative terms, which leave latitude for interpretation/justification by the implementer. In the UK, the environmental regulators will seek to offer advice and engage with appropriate organisations during the siting process. However, the regulators have no legal powers in relation to the siting process.

In general, the approach in most countries is to evaluate sites as they arise (regardless of how they might first have been identified) with a progressively more detailed level of investigation as confidence in a site increases. This approach tacitly assumes that clearly poor sites would be rejected early on in the process, perhaps even at a desk study stage, with little or no work being carried out on the site.

Only very few countries have opted to establish definitive exclusion criteria to facilitate the start of the site selection process, i.e., before any site work is carried out. Japan, situated in a tectonically highly active part of the world, considers that it is a matter of essential credibility for the national programme (managed by NUMO) to be able to eliminate clearly unsuitable volunteer sites early on – so much so, that a requirement for geological stability is stated in the law governing the NUMO programme.

The siting approach is described in a recent report by NUMO (7), the key thread of which is abstracted below, as it offers perhaps the closest structural analogue to what is being considered in the UK, even though it is in response to the requirement to find a repository site in a highly tectonically active region.

To allow stepwise application, NUMO's Siting Factors fall into two main groups:

- **Evaluation Factors for Qualification (EFQ)**: geological characteristics that the volunteer areas must exhibit in order to be considered as "Preliminary Investigation Areas" (PIAs). Principally, these concern stability with regard to potentially disruptive events, such as volcanic eruptions and fault movements. Their application will lead to some regions of Japan being excluded from further consideration. They are divided into two sets and applied in two steps – nationwide and site-specific (see below).

- **Favourable Factors (FF):** a wide range of geological, environmental, social and economic characteristics of an area that will help to determine the overall practicality of the project and, eventually, to discriminate between potential repository locations. Unlike the EFQ, there are no absolute requirements among these FF. Rather, they express **preferences**, and can be weighed and compared in a flexible manner to highlight the advantages and disadvantages of an area. They will assume progressively greater significance as NUMO moves further into the programme and begin to assess and compare siting options.

NUMO has defined a stepwise evaluation approach that will be used to evaluate volunteer areas and decide whether they will be geologically acceptable for preliminary field evaluation, which could eventually lead on to their detailed investigation as potential repository sites. The first steps in the evaluation process are to apply the EFQ, which are in two groups:

(1) **Nationwide Evaluation Factors (NEF):** designed to identify, at the very start of the evaluation process, only those areas where a repository (of any design) could not be directly disrupted or destroyed by volcanic activity or would not inevitably be transected by known active faults within the next hundred thousand years. Whether an area qualifies against these factors can be readily established using information on the nationwide distribution of volcanoes and active faults. These factors are a decisive means of excluding clearly unstable locations, and will be applied in a simple "first-pass" screening process.

(2) **Site-Specific Evaluation Factors (SSEF):** designed to assess those areas that meet the NEF qualification factors in more detail, with respect to potential volcanism, seismicity, rock deformation and faulting, land uplift and erosion, and the presence of unconsolidated sediments or mineral resources.

An important point to note is that both the NEFs and the SSEFs will be assessed using available literature only, as no site work can legally begin until volunteers have passed the EFQ test.

A further possible analogue can be found in Germany. In 1999 the AkEnd Committee was created by the BMU (Environment Ministry) to develop a siting procedure based on a set of technical selection criteria that are independent of repository host rock characteristics. The AkEnd recommendations were published in 2002 (8) and comprise a procedure in five consecutive steps, starting with a 'white map'. Each step includes a set of criteria that help narrow down the number of potential sites. In the first step, geoscientific criteria are used to exclude areas that are considered to be obviously not eligible for a repository:

- large-area vertical movement (uplift rate) must be < 1 mm/yr over the predictable period;

- there should be no active fault zones in the repository area;
- seismic activity must not be higher than Earthquake Zone 1 (a national category);
- there should be no observed volcanism during the Quaternary, nor any expectation of such in the future;
- groundwaters in the isolating rock zone must not contain measurable tritium or carbon-14.

There are also seven ‘minimum requirements’ during Step 1, the majority of which are so prescriptive that they could equally be interpreted as exclusion criteria:

- the isolating rock zone must be comprised of rock to which a field hydraulic conductivity of < 10^{-10} m/s can be assigned;
- the isolating rock zone thickness must be > 100 m;
- the top of the isolating rock zone must be > 300 m;
- the repository must be constructed above 1500 m deep;
- the isolating rock zone must include an area of 3 km^2 in salt or 10 km^2 in clay/granite;
- neither the isolating rock zone nor host rock can be at risk from rock burst;
- no evidence can be found in approved literature that raises doubts as to whether the minimum requirements with respect to hydraulic conductivity, thickness, and extent of the isolating rock zone can be maintained over the one million year prescribed safety interval.

It should be noted that the AkEnd criteria are contrary to the trend in other countries in being quantitatively prescriptive and in re-introducing what have been termed ‘sub-system criteria’. The latter had been used in early programmes (e.g., in the USA) but abandoned as being inappropriate to the achievement of overall repository safety: the key factor is the performance of the *overall* (total) system, which can be achieved by a balance of a range of properties of the different ‘sub systems’.

In addition, some of the criteria have dubious scientific justification with respect to repository safety (e.g., the requirement for no measurable tritium in groundwaters). Consequently, the AkEnd geotechnical criteria have been heavily criticised, both inside and outside Germany, as inappropriate and unhelpful to the siting process. Nevertheless, it can be seen that the topics addressed in the first four of the first set of (exclusion) criteria broadly parallel the general list identified earlier in Annex 1.

References

(1) International Atomic Energy Agency (1994), Siting of Geological Disposal Facilities, Safety Series 111-G4-1, IAEA Vienna, (currently undergoing revision).

(2) Chapman, N. A., and McCombie, C., (2003), Principles and Standards for the Disposal of Long-Lived Radioactive Wastes, Pergamon (Elsevier), Amsterdam, 277 pps.

(3) Swedish Nuclear Fuel and Waste Management Co. (1995), General Siting Study 95: Siting of a deep repository for spent nuclear fuel. SKB Technical Report 95-34, Stockholm.

(4 Andersson, J., Ström, A., Svemar, C., Almén, K-E. and Ericsson, L.O. (2000), What requirements does the KBS-3 repository make on the host rock? Geoscientific suitability indicators and criteria for siting and site evaluation. SKB Technical Report TR 00-12, Swedish Nuclear Fuel and Waste Management Co., Stockholm.

(5) Swedish Nuclear Fuel and Waste Management Co. (2000), Integrated account of method, site selection and programme prior to the site investigation phase. SKB Technical Report TR-01-03, Stockholm.

(6) McEwen, T, and Äikäs, T. (2000) The site selection process for a spent fuel repository in Finland – Summary report. Report Posiva 2000-15, Posiva Oy, Helsinki.

(7) Nuclear Waste Management Organisation of Japan (2004), Evaluating Site Suitability for a HLW Repository: Scientific Background and Practical Application of NUMO's Siting Factors, NUMO-TR-04-04, Tokyo.

(8) AkEnd (2002) Site Selection Procedure for Repository Sites: Recommendations of the AkEnd Committee on a Site Selection Procedure for Repository Sites. Report of Arbeitskreis Auswahlverfahren Endlagerstandorte, W&S Driuck GmbH, Köln, Germany, December 2002.

Annex 3

Inadvertent intrusion into the repository in the future

The likelihood of intrusion, the most likely cause of which is as a result of exploratory drilling for resources, the extent of the damage it could cause and the consequent level of risk that it might cause to future populations in the vicinity of the repository are generally considered to be uncertain and will depend in part on the geological environment around the repository. The amount of emphasis that should be placed on these future risks is a value judgement for society at large to consider. Overall risk of intrusion can be reduced by removing areas from the siting process where future resource exploration has a higher probability of occurring.

Of course, it is not possible to know fully how people in the future will look for resources, or even which resources will be important to them. Consequently, removing current resource areas from the siting process, which is recommended in the body of this report, is a rather blunt tool. It should thus be recognised that the approach suggested contains a value judgement - that the possibility of intrusion is something that ought to be avoided so far as reasonably possible, even though the actual health risks posed by intrusion might be calculated to be small for any specific site and repository design. The implication of this approach is that some sites with otherwise potentially good geological isolation potential (taking account of the natural evolution of the repository in the absence of human intrusion over time) and for which human intrusion would not be a major safety case issue could be removed. The resource exclusion criteria developed are thus conservative and the implications for losing possibly good volunteer sites needs to be recognised

The alternative less conservative approach would be to ignore intrusion risk during the first stages of the siting process and leave it for later consideration on a site-specific basis for any volunteer area. Eventually, of course, <u>any</u> site that comes forward for consideration will have to be evaluated in great detail on its actual merits and all reasonable scenarios that might lead to radiation exposures in the distant future will have to be considered, so the inclusion of an intrusion assessment at this future stage would be needed. This approach may allow more areas of the UK to be considered and reduce the chances of omitting a possibly acceptable site. The value of adopting this alternative approach could form a topic for consideration in the forthcoming consultation process.

Annex 4

TERMS OF REFERENCE FOR THE WORK

1. The Government is committed to exploring a voluntarist/partnership approach to site selection for a geological repository for the UK's higher activity radioactive waste under the Managing Radioactive Waste Safely (MRWS) programme. A first step is the identification of scientific criteria that – when applied (see below) – will enable those parts of the UK unsuitable for geological disposal to be eliminated (screened out) from further consideration.

2. The overall process of identifying and proving the scientific credentials of a site, to allow a final safety case to be presented to the regulatory bodies, will be a progressive process spanning many years. The purpose of the screening criteria would be to establish that a site would definitely not be suitable, and thereby that it would not be appropriate to pursue any further voluntarist/partnership negotiations with the potential host community concerned.

3. It is foreseen that the criteria will focus primarily on the geological and hydrogeological characteristics of the area or site. However, in considering the issue, it may also be felt to be appropriate to make allowance for the extent to which the natural barriers to radioactive migration could be bolstered by appropriate engineered barriers.

4. There should be no presumption in undertaking this work concerning the point at which the screening criteria would be applied. Whether or not this will be before or after expressions of voluntarist/partnership have been issued will be a matter for downstream political decision.

5. It is not the intent that the CPG or CRP should consider above surface criteria, for example social and environmental impact, transport links, etc. It is believed that these criteria will be covered through the processes by which communities decide whether or not they wish to volunteer, and also in the safety case and environmental impact assessments that will be required. The issue of rising sea levels as a result of global warming is clearly relevant to decisions on where a geological repository may be sited. This will be explicitly considered during the early stages of planning MRWS implementation, but the risk of coastline flooding is not regarded as a potential sub-surface screening criterion.

Approach to be adopted

6. A **Criteria Proposals Group (GPG)** will be established to recommend a suitable set of screening criteria. A **Criteria Review Panel (CRP)** will also be established to peer review the proposed criteria and ensure that they are workable. The CPG's proposals amended in light of the CRP's comments will then be the subject of wider discussion under some form of **workshop** arrangement prior to finalisation of the criteria.

Criteria Proposals Group (CPG) Terms of Reference

7. The CPG will propose scientific criteria for the initial sub-surface screening of areas or sites which are suggested as potential sites for the location of a geological disposal facility for higher activity radioactive waste.

8. CPG will need to devise a clear and easily understood project plan for identifying the criteria at an early stage in its work. This will be assessed by Defra, DTI, and the Devolved Administrations, and the agreed plan published. CoRWM's help in maintaining transparency will be available throughout the course of the work.

9. Initial draft criteria will be developed and, with the project plan, made publicly available. The draft criteria will be reviewed by an expert Criteria Review Panel (CRP) who will make their comments public. The CPG will then develop the criteria further, in light of the CRP's comments, to near-final draft stage.

10. The draft criteria will be taken before a workshop involving interested parties, the proceedings of which will be published. The CPG will be represented at that workshop. The CPG may have a subsequent role in advising Government and the NDA on written material, covering screening issues, for public consultation, following this debate.

11. The CPG will consist of a Chair and up to seven members. It will need to report to Government on its project plan, and provide some initial thoughts on criteria, no later than the second week of March 2007. Its work needs to be completed by the end of April 2007.

12. The CPG will carry out its work mainly through round table discussion, although some limited fact finding may be necessary. Two meetings before the end of February and two more before the end of March are likely to be necessary.

Criteria Review Panel (CRP) Terms of Reference

13. The role of the Review Panel is to undertake independent peer review and assessment of the CPG's proposals to ensure that they are sound and workable, i.e., that they address the key issues at the right level of detail so that the application of the criteria that are eventually agreed delivers a robust and credible result.

14. The Panel should work in a flexible way in order to be able to comment on the CPG's proposals rapidly, perhaps within 10 days of receipt. Most of its work is likely to occur about in late March to early April. It need not necessarily meet formally, but will need to agree its Chair and reporting mechanism in advance. Its report/review will need to be reasonably short and succinct.

Workshop involving interested parties

15. The workshop will be convened at an appropriate date to consider and provide a wider view on the criteria proposed by the CPG in light of CRP comments. The aim will be to test whether the proposals are sensible, robust, and likely to attract public confidence. It is likely that participants will include national and local NGOs, local authorities and their representative groups, radioactive waste practitioners, interested members of the public (including the possibility of some earth science MSc candidates), and sponsor departments/NDA. The CPG and CRP will be represented in some form.

16. The workshop is likely to be held over one-day at an appropriate central location. Its likely format will be presentation of the criteria proposals followed by facilitated discussion of them.

Indicative timescale

Early March	CPG submits project plan and initial thoughts on criteria to Defra/DAs/DTI
March	CPG develops criteria
Late March- Early April	Review by the CRP
April	CPG finalises its proposed criteria
Late April/Early May	Workshop meeting
May	Incorporation of agreed screening criteria into MRWS consultation document (scheduled for release in June)