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UNITED KINGDOM NIREX LIMITED

Rock Characterisation Facility

Longlands Farm, Gosforth, Cumbria

PROOF OF EVIDENCE

OF

PROFESSOR R K O'NIONS

FRS

SCIENTIFIC CASE FOR THE RCF

CONTENTS

PROFESSOR KEITH O'NIONS will say:

1. PERSONAL DETAILS

1.1 I have held a Royal Society Research Professorship in Earth Sciences at theUniversity of Cambridge since 1979. From 1 October 1995 I will become the Professor of the Physics and Chemistry of Minerals in the University of Oxford.

1.2 I hold a B.Sc. (Hons.) from Nottingham University (1966), a Ph.D. from the University of Alberta (1969), and I am a Member of the Norwegian Academy of Sciences, a Fellow of the Royal Society (1983), and the author of more than 150 papers in the refereed international scientific literature.

1.3 I held a postdoctoral research appointment in Oslo (1970) and prior to my present position, academic appointments in the University of Oxford (1971 -1975), and Columbia University, New York (1975-1979).

1.4 Since 1993 I have been one of four Professorial Advisers to United Kingdom Nirex Limited ('Nirex'), constituted as the Nirex Review Panel. In this capacity

I have had access to scientific results obtained by Nirex in advance of their publication, and provided comments to Nirex on both their interpretation and the overall balance of the geological and hydrogeological investigation. I am a co-author of the 1994 Annual Report of the Nirex Review Panel.

2. BACKGROUND AND SCOPE

2.1 The purpose of this evidence is threefold. Firstly, to provide a view on the scientific approach that Nirex have taken to site evaluation at Sellafleld, particularly in regard to the geology and hydrogeology (Section 3). Secondly, to provide a view on the scientific need for a Rock Characterisation Facility ('RCF') as part of the site characterisation programme and on the expectations that should be held at present for the site (Section 4). Thirdly, given the nature of the scientific process, to express an opinion on the likelihood that sufficient scientific understanding of the site will be forthcoming to assess confidently the post-closure safety performance of a repository at Sellafield (Section 5).

2.2 The Nirex repository concept for the Sellafield site and the current regulatory requirements are not reproduced here. These are described in Proofs of Evidence submitted by Nirex personnel.

3. SCIENTIFIC APPROACH TO SITE CHARACTERISATION

3.1 This Section provides an opinion on the appropriateness of the scientific methodology and approach adopted by Nirex to the characterisation of the Sellafield site.

The Sellafield site

3.2 When Sellafield was nominated in 1989 as one of the two locations at which Nirex would commence physical investigations, the geology of the Lake District region in which Sellafield is located was known as well as many areas in the UK, having been mapped by the British Geological Survey. In part, because of earlier mining activities, it was known a little better than some others, but probably not as well as some coalfield areas subject to intensive mining activity. The geological information was for the most part two-dimensional from surface observation with some borehole data. The hydrogeology at depth was essentially unknown from observation, but there was a reasonable expectation that the Borrowdale Volcanic Group ('BVG') would have a low permeability and that flow rates of water would be much lower there than in the more permeable overlying rocks.

3.3 The challenge for Nirex has been to construct a programme of site characterisation focused on the need to assess the post-closure safety performance of a repository at Sellafield.

The Scientific Approach

3.4 The essential aim of the scientific programme must be to understand the potential pathways and timescales for the return of radionuclides from a repository to the near-surface and assess the risk they pose in the human environment. This requires that the transport of radionuclides from the repository in groundwaters and/or gases to the surface can be modelled with an appropriate level of confidence, taking account of possible environmental and geological change that may occur on the relevant timescales.

3.5 The approach taken by Nirex has been to identify the principal scientific observations that are required. These include, for example, the characterisation of the rock formations and

an assessment of their response to past geological events, such as climate change and earthquakes. It has involved characterisation of the hydrogeology of the area, and in particular the rates and mechanisms of transport of groundwater. These and other detailed aspects of the programme are described in Proofs of Evidence presented by Nirex personnel. The programme has involved one of the most comprehensive and technically sophisticated pieces of geological characterisation ever carried out in the UK.

3.6 In identifying features to be characterised (such as hydraulic conductivity of the BVG at depth) Nirex have utilised the most appropriate testing equipment and approaches currently available to them. In many cases they have identified complementary tests such as estimates of hydraulic conductivity from physical testing in boreholes, as well as estimates derived from groundwater chemistry.

3.7 The research is widely acknowledged to be of exceptionally high quality. For example, both the Radioactive Waste Management Advisory Committee *(RWMAC Fourteenth Annual Report)* (para 3.10, page 11) [GOV/406] and the Royal Society *(Disposal of Radioactive Wastes in Deep Repositories) ("The Royal Society, November 1994")* (Section 1.9, page 10) [COR/605] have commented very favourably on the scope and quality of the testing and data interpretation undertaken by Nirex, as have individual scientists at professional meetings where Nirex have displayed the results of their investigations.

3.8 The Nirex approach involved the formulation of a conceptual geological and hydrogeological model of the site at an early stage of the programme. This was done in order to guide the programme of measurement and testing at the site, with the results then being used to update the models in an iterative manner. Without such an approach the project would have been difficult to focus.

3.9 The conceptual model has received criticism from some quarters from the time the first version was published. There has been a tendency for critics to treat the conceptual model as a 'finished product', rather than a model to be continuously updated, validated and modified as scientific understanding increases

3.10 Prior to the commencement of the Sellafield site characterisation programme views of the geology and hydrogeology of the site were based essentially on surface observations. There are now many well-understood features of the site, such as the distribution and stability of saline water at depth which could not have been predicted without the extensive programme of borehole drilling and testing. Nirex have therefore built into their programme a well-managed flexibility which has enabled them to adjust their programme as new and sometimes unexpected observations are made and understanding increases.

3.11 Again from an early stage in the site characterisation programme Nirex have investigated the hydrogeological flow regime using models of groundwater flow, partly empirical and partly theoretical. The objective is to refine the conceptual model and the key parameters determining the groundwater flow and to build confidence progressively in the post-closure safety performance assessment. The Nirex approach has been sophisticated and sound. However, there have been recommendations from the Royal. Society (*The Royal Society, November 1994*) (Section 8.5, page 143) [COR/605] and Nirex Review Panel (*Nirex Review Panel Annual Report, 1994*) (Section 3.l.1, pages 4 and 5) [COR/516], to explore alternative approaches. To their credit Nirex have been sufficiently flexible to adjust their approach and accept recommendations from their peers.

4. THE NEED FOR THE RCF

4.1 This Section provides an opinion on the scientific need for the RCF within the context of further assessing the post-closure safety performance of a repository and on the expectations that should be held at present for the site.

4.2 The observations, testing and interpretation achieved from surface observation are amongst the most advanced and comprehensive undertaken at any geological site in the world. From a purely scientific standpoint the results are spectacular.

4.3 From the standpoint of the site characterisation, and initial assessments of post-closure safety performance the Sellafield results available so far show that the site certainly has the potential to host a repository with an appropriate safety performance.

Amongst the important observations behind this statement the following are given as examples:

- The abundances of rare gases and oxygen-18/oxygen-16 isotope ratios suggest groundwater recharge occurred in a cooler climatic regime than the present one. Furthermore, preliminary age estimates for deep ground-waters based upon carbon-14 abundances support the view that waters are old. The first results of chlorine-36 isotope measurements suggest that they could be very old, possibly around 1 million years *(Sellafield Hydrogeological Investigations: The Hydrochemistry of Sellafield 1995 Update)* (Section 5, pages 26 to 29) [NRX/17/1].
- Groundwater flow models based on physical estimates of hydraulic conductivity, and geochemical observation all point to low flow rates from the BVG to the surface.
- There is no evidence for major perturbation of the deep groundwater system during the glacial/ interglacial climate cycles that the site has been subjected to.
- There is no evidence for significant perturbation of the site by seismic activity over the last 100,000 years or more.

4 4 Despite the encouraging progress made so far, there is still uncertainty in a number of key areas, which reduces confidence in the evaluation of post-closure safety performance. These include the characteristics of the fracture network in the BVG and their influence on the rate of groundwater flow. It is necessary to gain an increased understanding of the likely dispersion and dilution of radionuclides by the groundwaters emerging from the repository, as well as the retarding effects of the repository near field itself

4.5 Although considerable progress has been made from borehole and surface observations, there are diminishing returns in this approach simply because the system is sampled in a vertical dimension with horizontal length scale of centimetres. It is essential to examine the performance of much larger rock volumes, both to validate models based on borehole observation and to undertake new tests and experiments not possible from boreholes.

4.6 From a purely scientific standpoint the only reason for not progressing to construct the RCF would be if the presently available information demonstrated that the site was unsuitable. This is not the case. The site has geological and hydrogeological attributes which show that it has the potential to host a repository.

4.7 There are a large number of additional benefits that arise from the construction of an RCF. These include the opportunity for investigating mechanical properties of the specific rock types involved, which will be relevant to finalising the design and the construction of a repository.

4.8 Experimental underground laboratories have been constructed in other parts of the world and some experiments of the type proposed by Nirex carried out. Nirex have participated in some of these. The results of these generic experiments have been of considerable value to Nirex. They are however inadequate for a full characterisation of the rock volume under consideration at Sellafield. Specific experiments on the rock mass within which the RCF will be constructed are required for a post-closure safety assessment of the repository.

It will be impossible to build sufficient confidence without the site specific information obtained from the RCF.

5. THE SCIENTIFIC PROCESS AND EXPECTATIONS

5.1 This Section provides an opinion on the likelihood that sufficient scientific understanding of the site will be forthcoming to assess confidently the post-closure safety performance of the site, given the nature of the scientific process.

5.2 The scientific process involved in site characterisation at Sellafield and the assessment of the post-closure performance of a repository involves a prediction of the flow rate of water through the repository and the return of radionuclides into the human environment. Furthermore, the response of the system to possible future changes in the environment must be predicted with confidence.

5.3 The scientific process involves the development of conceptual models for the site, the identification of key uncertainties in the model, and the adjustment of the characterisation programme to reduce these uncertainties. Thus at any point in time some aspects will be better understood than others and gaps in understanding will be present. This is both a necessary and also an inevitable part of a scientific investigation of this sort.

5.4 The question must be therefore whether sufficient scientific understanding of the site can be achieved on a reasonable time scale to assess its performance. This process involves the identification of where the key uncertainties are, and the design of a scientific programme to reduce them. It is appropriate to proceed if there is a reasonable expectation that a significant reduction in uncertainty will be achieved.

5.5 At this stage in the programme there are a number of key areas of uncertainty and these have been identified above. The construction of an RCF should allow these uncertainties to be reduced. This point has been fully recognised by RWMAC, *(RWMAC Fifteenth Annual Report)* (para. 4.11, page 14) [G0V/407], the Royal Society *(The Royal Society, November 1994)* (Section 1.6, pages 6 and 7) [COR/605] and the Nirex Review Panel *(Nirex Review Panel Annual Report 1994)* (Section 3.2, page 6) [COR/516] amongst others, all of whorn endorse the construction of an RCF as the next step. Implicit in these views is the assumption that sufficient understanding will accrue to make possible a final scientific decision on the Sellafield site as a potential location for a repository.

5.6 The construction of the RCF will inevitably perturb the site in a number of respects. It is important therefore that key observations on the unperturbed system are completed prior to the construction of the RCF. The opinion is expressed above that there will be diminishing returns from more surface observations alone and from a scientific standpoint the merits of RCF construction are compelling

6. CONCLUSIONS

6.1 This Proof of Evidence has summarised the scientific approach adopted by Nirex, the case for the construction of the RCF as the next logical phase of the site characterisation programme, and commented on the nature of the scientific process involved and the way in which uncertainties are reduced.

6.2 The Proof of Evidence endorses the scientific approach adopted and recognises the necessary flexibility built into it.

6.3 The Proof of Evidence argues that from a scientific standpoint there is a diminishing return to be gained from more surface observations alone and that construction of the RCF is necessary if an assessment of post-closure performance of a repository at Sellafield is to be made.

6.4 The Proof of Evidence expresses the opinion that the results available so far for the Sellafield site show that it has the potential to host a repository with an appropriate safety performance and sufficient potential for development of the RCF to be justified in scientific terms.

6.5 The Proof of Evidence indicates that the nature of the scientific process itself involves the emergence of key areas of uncertainty as the iterative approach of model validation and experiment, testing and modelling progresses. In order to reduce the uncertainties at present limiting confidence in the post-closure performance construction of the RCF is required.

7. REFERENCES

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