DRAFT of a REPORT from the Swedish NGO Office for Nuclear Waste Review (MKG) with requests for supplementary information on the licence application for a repository for spent fuel at Forsmark

August 2015

This draft report contains information in English on two statements in June 2012 and October 2013 from the Swedish Society for Nature Conservation, SSNC, and the Swedish NGO Office for Nuclear Waste Review, MKG, submitted to the Swedish Environmental Court and the Swedish Radiation Safety Authority, SSM, on the need for supplementary information and work regarding the Swedish nuclear industry's application for a licence to build a repository for spent nuclear fuel in Forsmark.

The document is divided into three parts. First there is a background part (A). Then there is a part that includes a translation of the introductory parts of the statement in October 2013 (B). Finally in a third part the statement from June 2012 is translated as a whole (C).

A third statement has been submitted to the court and the regulator in June 2015. All statements are on the need for supplementary information and work that SSNC and MKG want to be done before the licence application can be considered complete enough to be put to "public notice" – a legal term – and thereby be ready for review on its merits. The court has given the Swedish nuclear waste company SKB, the applicant, until October 1, 2015, to answer to demands for supplementary information and work from all the parties involved in the review. The court is expected to come with important rulings after this.

News articles on the MKG web site on the statements:

In English

June 2015
http://www.mkg.se/en/swedish-society-for-nature-conservation-and-mkg-in-their-third-statement
October 2013
http://www.mkg.se/en/in-a-new-statement-the-swedish-society-for-nature-conservation-and-mkg-demand-completions-in-the-lic
June 2012
http://www.mkg.se/en/great-inadequacies-in-the-license-application-the-swedish-society-for-nature-conservation-and-mkg-de

In Swedish (with the complete Swedish texts including appendices

June 2015
http://www.mkg.se/yrkande-fran-naturskyddsforeningen-och-mkg-till-domstolen-och-ssm-avvisa-ansokan-om-ett-slutforvar-e
October 2013
http://www.mkg.se/naturskyddsforeningen-och-mkg-kraver-kompletteringar-av-slutforvarsansokan-i-ett-nytt-yttrande
June 2012
http://www.mkg.se/stora-brister-i-slutforvarsansokan-naturskyddsforeningen-och-mkg-kraver-omfattande-kompletteringar

A. BACKGROUND INFORMATION

1. History

Sweden's interest in nuclear technology dates back to the U.S. forces' bombing of Hiroshima and Nagasaki in 1945. Throughout the 1950s and into the 1960s, Sweden's ruling party, the Social Democrats, carried out research on, and planned for both civilian and military uses of the technology. The program was ambitious. The 1960s saw the establishment of four research reactors and a nuclear-fuelled co-generating power plant in a suburb of Stockholm. Uranium was mined and processed in south-central Sweden between 1960 and 1969 to secure a domestic fuel supply. The nuclear weapons program was abandoned in 1968 and the first commercial nuclear power reactor of modern design came on line in 1972.

But in the course of the 1970s, opposition to nuclear power grew. In 1977 Parliament ruled that no further nuclear power reactors would be allowed to be fueled and come on-line until the operators of the reactors could guarantee that they could handle and store the reactors' fuel waste in a safe manner. At the time of the act, six reactors were in operation, a seventh was completed and three more were nearing completion. In May 1979, in the wake of the accident at Three Mile Island power station in Harrisburg, Pennsylvania, and seeing no end to controversy on energy policy in Parliament, the Social Democratic government reluctantly agreed to arrange an advisory (not binding) referendum on the future of nuclear energy in Sweden.

The outcome of the referendum was equivocal: Sweden would continue to expand the nuclear energy park to twelve reactors, but would then proceed to phase out the program. Parliament then ruled that the phase-out would be completed no later than 2010 (the end-date would later be removed by act of Parliament in 1998).

The legacy of the referendum has proved divisive, as much within Sweden's political parties as between them. As a consequence the Parliament has found it difficult to chart a firm course for energy policy. Agreement has been reached on eliminating the country's dependence on fossil fuels, but policy on nuclear and renewable energy sources has been lacking in commitment.

There has been turbulence on the regulatory front, as well. In 1984, a new Law on Nuclear Activities took effect. The law specifically requires reactor owners to manage, and arrange for final storage of their nuclear fuel waste and to conduct the research and developmental work that the task requires. That same year, the Swedish nuclear power companies pooled their resources and formed a jointly owned subsidiary, Swedish Nuclear Fuel and Waste Management Company [SKB] for the purpose. In 1977 Work on their KBS project, which had started in 1977, took on a new urgency.

For many years, nuclear technologies were regulated under two laws: the Law on Nuclear Activities (KTL) and the Radiation Protection Act. In 1998, however, Parliament adopted the Environmental Code which took effect in January 1999. The Code applies to activities that may be presumed to have impacts on human health and the environment. In early years, there was some uncertainty as to the relationship between the Environmental Code and KTL. The Code does not specifically address nuclear technology, and the nuclear power companies were quick to claim that nuclear technology did not fall within its scope. SKB continues – most recently in their responses to the first round of comments in the so-called 'complementary phase' (April 2013) – to argue that it does not. Neither the Court nor the regulator have supported that opinion to date.

The situation is complicated by the fact that the two laws are administered by two different authorities – the Radiation Safety Authority in the case of KTL, and the Land and Environment Courts in the case of the Environmental Code.

2. The review process

One feature of the Environmental Code that has been hard for SKB to accept is the requirement of having to draft an environmental impact statement (EIS) for the KBS repository in dialogue with concerned groups in the general public. Consultations between SKB and regulatory authorities and the regional administrations have taken place since 2004. Local consultations began the same year, but initially participation was limited to local organizations only. The following year national environmental organizations and other organizations were admitted. The programs of the local and regional consultations differed.

The Swedish NGO Office for Nuclear Waste Review, MKG, was formed in 2004 to participate in the expanded EIA consultations. An umbrella organization, MKG comprises the Swedish Society for Nature Conservation (SSNC, a national organization having roughly 192 000 members), SSNC chapters in Kalmar and Uppsala counties, Nature and Youth Sweden, and 'Oss' a local campaign organization in the municipality of Östhammar (where

Forsmark is located). In recent years, SSNC and MKG have filed joint statements. In addition to participating in the consultations, MKG has built up a vital network of contacts in Academia and regulatory and administrative institutions. MKG also maintains a data base of documents relating to research on fuel waste management, the KBS method, and the progress of SKB's application.

The Environmental Code (chap. 6, sect. 3) sets out a dual purpose of the EIA consultations:

> *"The purpose of an environmental impact statement is to establish and describe the direct and indirect impact of a planned activity or measure on people, animals, plants, land, water, air, the climate, the landscape and the cultural environment, on the management of land, water and the physical environment in general, and on other management of materials, raw materials and energy. Another purpose is to enable an overall assessment to be made of this impact on human health and the environment."*

Conceived as a means to guarantee that proposals are assessed from multiple perspectives, the environmental impact assessment (EIA) consultations also provide an opportunity for learning – in theory. Issues raised in the consultations should be incorporated into the applicant's R&D agenda. Unfortunately, the consultations regarding the final repository project have not followed the intentions of the Environmental Code. It has been difficult for participants to get answers to their questions or access to documents that SKB is unwilling to share. Often, the meetings have been more confrontative than consultative. In May 2010, SKB unilaterally terminated the local consultations – before the publication of a long-awaited safety analysis, called SR-Site. The safety analysis was made public only when it was submitted to the regulatory authority together with the application for a permit to build. This move, if anything, reflects SKB's generally dismissive attitude to the EIA process.

Not surprisingly, insensitivity to the requirement of the law and a low estimation of the value of dialogue have affected the quality of the documents SKB has submitted to the Court. Many of the points of criticism and problems treated below – raised by regulators, administrators and civil society organizations alike – relate to environmental safety. These issues were raised on repeated occasions during the EIA consultations.

Particularly problematic is SKB's unwillingness to accept that both long-term environmental safety as well as the project's possible radiological consequences fall within the scope of the Environmental Code and the environmental impact assessment mandated in the Environmental Code. The consequences of SKB's 'state of denial' surface every now and then in the discussion here.

3. Where does the KBS concept stand today?

The process of review and possible approval of an application of this character is complex and is most easily described if we assume that the application is complete – which, unfortunately, this application is not. But, ignoring that fact for the moment, the process is this:

• The applicant submits an application with supporting documentation to the regulatory authority, SSM, for assessment under the provisions of the Law on Nuclear Activities. After examining the application and accompanying documents and/or requesting additional information, SSM makes a recommendation to the Government – it, too, circulated for comment – as to whether or not the application should be approved.

Parallel with this, the applicant submits an application with supporting documentation, including an environmental impact statement, to the Land and Environment Court, who examine it against the terms of the Environmental Code and make a determination of the permissibility of the project (the determination has the character of a recommendation).

The Environmental Court has circulated the documents to participants in the EIA consultations and asked them to point out gaps and omissions in the EIS that need to be filled. This, the so-called 'complementary phase', is where we are today.

• Both SSM and the Court have the authority to reject an application that is too incomplete to allow a proper assessment of it.

• Final permission to carry out the project is granted by the Government. The Government is not bound by the recommendations of the regulatory authority or the Court.

B. SUMMARY IN ENGLISH OF THE "IMPORTANT GENERAL ISSUES" PART OF THE SECOND STATEMENT ON COMPLETENESS FROM THE SSNC AND MKG TO THE ENVIRONMENTAL COURT AND THE REGULATOR, SSM – OCTOBER 2013

The full statement in Swedish can be found here:
http://www.mkg.se/naturskyddsforeningen-och-mkg-kraver-kompletteringar-av-slutforvarsansokan-i-ett-nytt-yttrande

An article on the statement in English can be found here:
http://www.mkg.se/en/in-a-new-statement-the-swedish-society-for-nature-conservation-and-mkg-demand-completions-in-the-lic

1. Introduction

The most important aspect from an environmentalist's point of view is, of course, the long-term safety of the repository and particularly the risk of radioactive contamination from it. Several factors of a more general nature play a role here. Two prime factors are characteristics of the site (the bedrock, local hydrology, etc.) and the choice of method (the Environmental Code requires use of the best available technology, BAT). Third, but not less important, there is 'corporate culture' things like the 'safety culture' and, in projects that are heavily dependent on R&D like this one, adherence/non-adherence to scientific tradition and ethics.

2. The site

The siting process leading up to the choice of Forsmark was not particularly systematic. The criteria applied changed with the progress of the process. In the end, public acceptance seems to have taken priority over geology. The final choice stood between two municipalities that host nuclear power stations, Östhammar (Forsmark) and Oskarshamn (Laxemar), both coastal, but having distinctly different bedrock as well as different geological and hydrological properties.

The coastal location has two drawbacks. For one, the repository is more likely at some time in its lifetime to be inundated with saline groundwater. Secondly, if one or more barriers should fail and leakage occur, radioactive contamination may be expected to reach the biosphere relatively quickly. Should the contamination enter the sea, it will diffuse even more rapidly.

Inland locations are, generally speaking, safer in these respects. Most zones of groundwater inflow are located further from the sea. SKB has not shown much interest in these factors. For example, Hultsfred, 20-40 kilometers inland from Oskarshamn, was among the municipalities initially selected as potential sites for the final repository.

The bedrock at Forsmark is much drier than that at Laxemar, where the KBS concept was tested out. The groundwater deficit in the bedrock at Forsmark may affect the performance of the bentonite clay barrier, which ideally, will swell as groundwater penetrates into the repository chamber. At present time no one can say for sure how the clay will behave, as no experimental tests using conditions at Forsmark have been conducted. SSNC/MKG have asked the company to conduct such experiments.

Secondly, the Forsmark site is located in a geotectonic shear zone (with lateral fault lines). In fact, the geologic formation in which the repository is to be installed is a lens, formed by shear lines on either side. Although the shear zone is currently relatively stable, it is prone to earthquakes, especially during ice ages, and was initially in the siting process by geologists considered inappropriate for a repository for spent nuclear fuel. Today, SKB points to the stability of the lens, which obviously has withstood considerable stress in past millennia. But, can its durability still be counted on after the repository chambers and tunnels have been excavated and then filled with heat-emitting metal canisters and water-absorbent clay? Is there not a risk that the repository will have introduced a fracture indication in the lens?

SSNC/MKG have asked SKB to state the criteria used in the siting process and explain how they have been applied. But no evidence has been produced as yet to show that Forsmark is the most suitable site that Sweden has to offer. SSNC/MKG's and others' requests have fallen on deaf ears.

SSNC/MKG have also pointed out that present safety analyses for Forsmark and Laxemar have not been carried to the same level of analysis; they do not permit a comparison of the two sites. In our most recent set of comments on the EIS, SSNC/MKG therefore urge SKB to present a comparative analysis of the sites that incorporates all the parameters that EIA participants have requested to be included in the application.

3. The KBS method, BAT and the 'zero alternative'

As noted in the Introduction, the Law on Nuclear Activities, introduced in 1977, suddenly made it necessary for the Swedish nuclear power industry to find a way to store nuclear fuel waste that would ensure that it would not come in human hands. After only a few years SKB, organized to solve the problem, came up with the KBS concept. SKB has single-mindedly pursued the KBS strategy ever since, showing that they are either unable or simply unwilling to consider any alternative solutions to the problem.

The Swedish Environmental Code, introduced in 1999, two decades after work on the KBS system had started, requires initiators of projects having substantial environmental impacts to explain why the method they propose is superior to all others, and to show that they have chosen the best available technology (BAT) to achieve their goals. But any claim that the KBS-3 method represents the best available technology presumes that SKB has evaluated other methods. SKB has not done this.

The Environmental Code also requires those who propose projects that have environmental impacts to discuss the consequences that would ensue if they did not carry out their project – the so-called 'zero alternative'. SKB appears to have taken 'zero' literally, for they only propose carrying on as at present: using, perhaps enlarging the intermediate storage in cooling pools adjacent to the Oskarshamn reactors. What is more, wet storage requires active cooling, which in turn means continuous access to a functioning power source. In case the final repository is not to be built and the operation of the current intermediate storage continues for years, SSNC/MKG is far from convinced that the current intermediate storage is the best solution. The ongoing disaster at Fukushima in Japan after an earthquake and tsunami (followed by powerful after-shocks) in March 2011 cautions against locating storage facilities very close to nuclear reactors and offers a strong argument for reliance on passive systems. Dry storage systems, making use of passive cooling by the air circulating around the canisters, have developed considerably over the past twenty years and are used for intermediate storage on a large scale in a number of countries.

In short, SSNC/MKG do not consider prolonged intermediate wet storage at Oskarshamn an acceptable 'zero alternative'.

The Environmental Code (chap. 6, sect. 7, para 2) is very specific about both the need to investigate alternatives to the main proposal and the 'zero alternative':

> *An environmental impact statement relating to an activity or measure that is likely to have a significant environmental impact shall contain the information that is needed for the purpose referred to in section 3* [1]*, including:*
> *...*
> *4. a description of possible alternative sites and alternative designs, together with a statement of the reasons why a specific alternative was chosen and a description of the consequences if the activity or measure is not implemented.*

SSNC/MKG have urged SKB to give more serious attention to alternative methods – storage in deep boreholes in particular – and to discuss other zero alternatives than simply ‘more of the same’. The regulatory authority, too, has pointed out that the law requires SKB to do both. Only very recently has SKB conceded that deep boreholes might be a viable alternative, but the company expresses no intention to follow the alternative up in a manner that would fulfill the requirement of the Code.

4. Accepted scientific praxis?

Finally: the question of observance of scientific tradition and ethics. One may ask what Science has to do with what may be seen as essentially an engineering project. The connection is this: the KBS project is a first-ever attempt to create a facility for final storage of nuclear fuel waste. It is a groundbreaking venture without precedent. Secondly, it is a project unparalleled in scope, with consequences extending millennia into the future. For these reasons, there is a burden of proof not generally attached to engineering ventures.

Scientific method has been developed for the purpose of systematizing proofs. Openness to criticism and to demands for documentation may be considered either too humble or too brave, but the fact is: it is also a key to inspiring confidence in one’s work. When research and development projects rely heavily on modeling, as is the case in the KBS project, documentation of the ‘in data’ on which the models are founded is especially important. Throughout the EIA consultations, however, SKB has been anything but open to criticism, and requests for hard data in problematic areas have not been welcome. Answers have been few.

[1] Section 3 is cited in the discussion of the EIA process, above.

SKB is a privately owned company, and not subject to Swedish freedom of information legislation. At the same time, the KBS project is one of great public concern. The ‘mismatch’ is especially troublesome with respect to the company’s work on the man-made barriers, vital to the KBS system: copper canisters and the clay buffer that should surround them. MKG and others have, for example, found it very difficult to gain access to data from experimental studies of copper corrosion. Either the studies have not been published or they have been published in heavily edited form, from which empirical data have been deleted.

For example: In 2009 the Radiation Safety Authority (SSM) discovered that SKB had suppressed certain findings from a long-term laboratory study of copper corrosion. When confronted with the fact, SKB answered that the findings in question were an aberration; that they could not be correct. The company refused to release the raw data. A highly placed spokesman for SKB added that *“as a matter of policy SKB publishes only findings they understand and find credible”*. Suppression of data may be SKB’s privilege, but it flies in the face of scientific ethics. (For further details see SSM Report 2010:17 *Quality Assurance Review of SKB’s Copper Corrosion Experiments*). This is but one example of SKB’s departure from accepted praxis.

Many studies of the more sensitive aspects of the project – especially studies having to do with the man-made barriers – have been commissioned from private consultants. SKB’s consultants are bound by contract not to divulge their findings to third parties, and SKB reserves the right to edit their reports or suppress them. What is more, several consultancies, including some university researchers, have become dependent on SKB for their livelihoods.

SSNC/MKG have asked SKB to release research findings on repeated occasions, but to no avail. The company responds that the regulatory authority can request whatever information they find necessary. But it is difficult to ask for data when there is little way to know that they exist. The Land and Environment Court is empowered to instruct the applicant to respond to EIA participants’ requests for complementary data in full. So far, the Court has not exercised that authority.

The bottom line: SKB’s attitude and behavior have eroded whatever credence the company once enjoyed. In their most recent comments SSNC/MKG write:

“We no longer have any faith in the results [SKB] publishes because there is no way of knowing whether they have been produced in accordance with accepted scientific praxis”.

5. Technical issues

We approach the more specifically technical aspects of the safety issue in two categories: issues concerning long-term safety in the first millennium of the repository’s existence, and safety in the even more distant future. The categories are hardly mutually exclusive; it stands to reason that any problems that occur early on may have far-reaching effects. In the shorter term, prime focus rests on (1) the man-made barriers, (2) characteristics of the bedrock at the chosen site, and (3) the need for scenarios other than the ideal development of the barriers. Later, there are the challenges of coming ice ages and the possibility of renewed seismic activity around the site. Finally, we briefly mention a couple of alternatives that might offer a greater measure of safety than the chosen site and method.

5. 1 Environmental safety in the first 1 000 years ...

The radiological safety of the project is the most important aspect with respect to environmental safety. The KBS system relies heavily on the man-made barriers of copper and clay to isolate the contents from humanity and the environment for hundreds of thousands of years. Any discussion of long-term environmental safety necessarily holds the quality of these barriers in focus.

Functional redundancy is a fundamental principle in all safety engineering. That is, all measures and installations of importance to safety should operate independently, each able to guarantee safety on its own. As the following points make clear, the KBS system falls short of this ideal. What is more, SKB has yet to demonstrate that the barriers of copper and clay perform as is posited in the company’s largely model-based safety analysis. Central issues are the rate of corrosion in copper in oxygen-free environments and the performance of the clay buffer in relatively dry rock. There are also questions about possible interactions between the two sets of problems: How will a longer period (longer than that envisaged when KBS was conceived) without the protection of the clay buffer affect copper corrosion? How may products released by the corrosion process affect the performance of the clay?

This area has hardly been studied to date. Despite SKB’s assurances to the contrary, there remain numerous uncertainties – both gaps in knowledge and statistical uncertainties – that might well result in leakage and major emissions of radioactivity from the repository even before the first thousand years have passed.

5.1.1 Corrosion of copper under oxygen-free conditions

The issue that has aroused the most controversy in academic circles concerns whether or not copper corrodes in oxygen-free environments. The KBS system is predicated on an assumption that it does not. The possibility of corrosive processes under oxygen-free conditions was raised as early as the mid-1980s, but SKB's chemists were so convinced of its impossibility that they chose not to pursue the issue. It surfaced again, however, in 2007, when a team of researchers at the Royal Institute of Technology in Stockholm demonstrated that copper placed in oxygen-free water produces hydrogen, a product of a reaction between the copper and the water. The oxygen molecules released in this reaction form corrosive agents on the surface of the copper, which in time penetrate into the metal.

SKB rejects these and consonant findings, claiming that they are due to flaws in the experimental procedure. On the other hand, the company has not been able to refute them conclusively (SKB's own empirical efforts have been flawed, but in ways that support the choice of copper). Otherwise, there is growing consensus that corrosion does take place.

As SSNC/MKG see it, it is impossible to estimate the likelihood of canister failure, i.e., the failure of one of the principal barriers in the KBS system. The missing links are:

- Not a single corrosion experiment has been conducted at Forsmark or in the environment in which the capsules are to be stored and surrounded by bentonite clay.
- The composition of the initial gas/liquid phase around the canister is not known in sufficient detail, nor is it known to what extent naturally occurring methane and hydrogen sulphide (sulphuric acid) will be concentrated.
- The copper canisters will have a surface temperature of up to 90° C in the first 1 000 years, which (given the pressure in the repository) implies some evaporation of groundwater and precipitation of salts on the copper surface and in the clay, which in turn may alter the functional properties of both the metal and the clay.

- Evaporation also implies an increase in the salinity of the groundwater that will later accumulate in the repository – which may hasten corrosive processes.

All these factors need to be thoroughly investigated before anyone can make claims as to the life expectancy of the copper canisters – which is to say, the safety of a KBS repository.

In addition to urging SKB to produce empirical support for their assumptions regarding copper, SSNC/MKG have also asked that they complement the analysis of previous metal samples with analyses using a light optical metal microscope and scanning electron microscope to check for the depth of corrosive damage and possible cracks in the metal.

5.1.2 Bentonite clay

Bentonite clay has the property of swelling in the presence of moisture. Contact with groundwater is what causes the clay buffer to expand in order to fill the cavities around the copper canisters in the repository. The rate of groundwater infiltration into the repository determines the time it takes for the clay to become saturated – that is, when the KBS system becomes fully functional.

Bentonite clay is not inert, however; both temperature (heat and frost) and contact with chemicals in its surroundings can alter its properties irreversibly. Exposure to radiation is another factor.

One such irreversible change is the formation of crystals in the clay as a result of exposure to heat. Crystallization impairs the clay's ability to swell. Channels may form so that groundwater flows quickly through its mass. On the other hand, swelling may occur in some parts of the repository, but not in others. The risk of this latter development is greatest when the surrounding bedrock is relatively dry.

Groundwater flow in the rock formation at Forsmark is limited. The regulatory authority has estimated that it may take longer than 1 000 years before the clay is saturated. Not only will it take longer before the clay begins to swell, but the clay closest to the canisters will also be exposed to humid heat from the copper canisters for a much longer time than was posited in the original KBS concept (1 000 years or more at Forsmark, as opposed to a few years at

Laxemar which has a much more watery bedrock - it is not until the clay has swollen that it offers a better protection to the canister).

SSNC/MKG have asked SKB to describe how corrosion and embrittlement processes can interact to weaken the copper. Mechanical stress, for example, is known to accelerate chemical degradation, and vice versa. Experiments in which copper is subjected to mechanical stress *and* corrosion simultaneously are therefore needed.

Clay and copper interact, as well. Published results from experiments conducted by SKB indicate that the presence of bentonite clay accelerates the degradation of copper, while the products of copper corrosion can impair the functional properties of the clay. There is also a possibility of the creation of highly corrosive electrochemical mechanisms between saturated bentonite and groundwater. It has been proposed that this agent might do severe local damage to the canister.

With these considerations in mind, SSNC/MKG have asked SKB to conduct experiments and construct models to identify what kinds of irreversible changes may be expected to occur in the bentonite due to heating, irradiation and exposure to salts and copper under the conditions prevailing at Forsmark during the first 1 000 years.

5.1.3 High rock pressures at Forsmark

Forsmark and Laxemar differ quite a lot in terms of their geological characteristics. We have discussed the history of seismic activity at the Forsmark site, and differences in groundwater flows at the two sites figured in the foregoing discussion of the clay buffer. We also noted that most of the early, fundamental research in the KBS project refers to prevailing conditions in the bedrock at Laxemar.

One aspect that has not been mentioned is the high rock pressure in the granite lens at Forsmark. High rock pressure in combination with few cracks explains why it will take so long for groundwater to reach the repository chamber. Other implications of high rock pressure are (1) a risk that cracks will form around the repository and (2) a likelihood that a good number of deposition chambers will crack open immediately or shortly after drilling. Many more chambers, perhaps even all, may crack open as a consequence of the heat the copper canisters give off. If and when these cracks open, groundwater flows may increase to an extent that has not been foreseen or planned for. The problem of too little groundwater will be ‘solved’, but cracks between the chambers may permit more rapid flows of groundwater, strong enough to erode the buffer instead of saturating it.

In the longer term – during, for example, periods of glaciation – the lens formation will have to withstand stresses of enormous proportions.

Surprisingly little research on this aspect of the lens at Forsmark has been published to date. SSNC/MKG have therefore requested that SKB complement their application with a thorough investigation of how the deposition chambers in the Forsmark formation are likely to develop over time.

5.1.4 To summarize

SSNC/MKG find a remarkable number of uncertainties and gaps in knowledge that relate directly to central safety features of the KBS system, not least to the man-made barriers. In our estimation there is a clear risk that a good number of copper canisters will begin to leak in the course of the first millennium. In combination with the choice of a coastal site, it may be no more than 50-100 years before the radioactive contents of the repository come into contact with human beings and the natural environment.

SSNC/MKG are not alone in drawing this conclusion. The regulatory authority SSM, too, has perceived numerous gaps in knowledge and has asked SKB to fill them. In September 2013, when SKB failed to respond, the regulator lodged requests for the complementary information in comments submitted to the Land and Environmental Court. The Nuclear Waste Council, an academic reference group independent of SKB, has also filed demands for more information relating to the man-made barriers.

Judging from the vague and inadequate responses that SKB has submitted to the Court, it seems that the company is unable to resolve these important outstanding issues. Instead – perhaps believing the old adage ‘offense is the best defense’ – the company continues to maintain that issues pertaining to radiological safety and the long-term environmental safety of the project fall outside the scope of the Environmental Code and thus the purview of the Land and Environment Court.

<u>5.2 Environmental safety in the longer term</u>

Glaciation and seismic activity

As the centuries pass, and barring a total failure of the repository in early years, whatever weaknesses in the system that existed initially will gradually worsen. The great foreseeable challenges in the longer term, otherwise, are climatological and geological. The repository has a planned lifetime of at least 100 000 years; a time span that encompasses at least one ice age. The geological evidence from past ice ages tells of tremendous stresses and dramatic changes in the landscape – as the ice pack forms, peaks (one or more times) and, not least, as it melts away and the earth's crust readjusts to the absence of ice is a process that is only now trailing off after the most recent period of glaciation (roughly 11 000 years ago at Forsmark).

It should be noted that according to SKB, none of these events and the stress factors they represent have any place in the assessment of the KBS project's environmental impact. Still, the company has taken pains to show that a KBS repository would survive an ice age.

The principal stresses are thermal (temperature), structural (weight) and seismic (earthquakes). Whereas events in the far distant future cannot be predicted with any certainty, the laws of physics remain the same as we know them today. That is to say, it is entirely possible to test materials in the repository for their ability to withstand various phenomena in the unknown future. It is precautionary measures of this kind that SSNC/MKG have urged SKB to undertake.

Key points of controversy are (1) whether or not permafrost will penetrate into the repository, (2) the magnitude of past earthquakes, judging from geological evidence, (3) the effects of glaciation on groundwater flows and (4) whether the most recent period of glaciation should be taken as a template for the course of events in future ice ages.

5.2.1 Permafrost

The KBS repository will be positioned at a depth of about 400-500 meters. SKB is confident that this depth is below the maximum frost level; others are not convinced. If, as SKB proposes, coming ice ages follow the same pattern as the most recent one, 400- 500 meters is a 'borderline case'; if glaciation is more severe, permafrost may be a problem, some geologists warn.

If the repository should freeze, wholly or in part, there are concerns about the function of the clay buffer. Will it continue to be impermeable after having been frozen? A second concern about the buffer arises in connection with a later phase, when the ice pack melts: Will the buffer be washed away, be partially eroded or remain intact?

5.2.2.Groundwater flows

SSNC/MKG find it troubling that SKB has not studied groundwater flows at greater depths, down to roughly 1 000 meters, in conjunction with the site inventories. The lack of such data limits the value of the models of groundwater flows presented in the safety analysis. The problem becomes acute in connection with assessing the ability of the repository to withstand an ice age. It would, for that matter, be good to know more about groundwater flows at depths down to 6 000 meters in order to be able be able to assess the safety of the deep borehole alternative at the two sites. (See more on deep boreholes below.)

SSNC/MKG made the following request for complementary studies in their EIA comments filed in June 2012:

> *SSNC/MKG demand that the Applicant […] complement their application with complete safety analyses for both Forsmark and Laxemar, so that all the additional information that is generated during the complementing phase may be incorporated into the analyses. Only when this has been done can the two analyses be used as a basis for judging the choice of site.*

So far, SKB has rejected all requests for complementary studies of groundwater flows.

5.2.3 Seismic events, past and future

The Forsmark site is located in a geo-tectonic shear zone, currently dormant. In a period of glaciation the zone is almost sure to be reactivated.

Much of the discussion of seismic events relating to the long-term safety of the repository has revolved around the probability of earthquakes of great magnitude (≥ Richter 8) in the Forsmark area. The estimates are largely based on evidence of past activity. Views differ widely as to both the likely range of magnitudes and frequency of the quakes. There is no assurance that the most recent pattern of glaciation (the Weichsel) will apply to coming ice ages.

SKB, for its part, is confident that the repository will survive future seismic events intact. So far, however, the company has been unable to produce evidence that allays skeptics' fears. SSNC/MKG have repeated their request for additional studies of the magnitudes of earthquakes that may be expected in conjunction with an ice age, and how these earthquakes can affect the final repository.

Earlier in the EIA process, SSNC/MKG requested a comparative analysis of the safety of Forsmark and Laxemar, respectively, in relation to seismic activity, and most recently we have requested additional analysis of the seismicity of the Forsmark area using GPS markers or other appropriate technology.

6. Alternatives that might enhance long-term safety

Uncertainties concerning groundwater flows, future seismic activity and the risk of permafrost in a repository at the Forsmark site inspire a certain uneasiness about both the chosen site and the chosen method. Two alternatives that SKB has not shown much interest in appear to offer a greater degree of safety in relation to the above-mentioned uncertainties.

<u>6.1 An inland site</u>

As noted earlier, SKB's siting process was not very systematic. Early on, the aim was to find solid (crack-free) bedrock in formations large enough to house a KBS repository. Several sites in the inland of northern Sweden were considered, and some exploratory drilling took place. In time, however, local public opinion turned against the repository project and SKB was forced to seek out other, less hostile municipalities; hence the choice of Forsmark and Oskarshamn.

In the early years of the present century doubts about the safety of coastal locations surfaced once again within the environmental movement. The interior of Sweden appears to offer better conditions in terms of long-term environmental safety. The prime parameter has to do with the pattern of groundwater flows. Inland one finds zones of groundwater inflow. That is, groundwater streams toward the site, rather than from it, meaning that any leakage from a KBS repository would not be transported as quickly away from the site. The time it would take for radioactive effluents to reach the biosphere differs considerably between zones of inflow and zones of outflow. Diffusion from an inland site to the biosphere is estimated to take tens of thousands of years, as opposed to hundreds of years from a coastal site.

In 2009, the municipality of Hultsfred (25–40 km inland from Oskarshamn and at elevations of 150–270 m) invited SKB to explore the suitability of local bedrock as a site for the repository. SKB declined the offer. As Hultsfred offers several zones of groundwater inflow, and in view of the uncertainties associated with the coastal site, SSNC/MKG urged SKB to complement the EIA with a thorough investigation of an alternative site in Hultsfred – a proposal SKB continues to ignore. In the interests of long-term environmental safety SSNC/MKG have repeated the demand in our most recent comments submitted to the Environmental Court.

6.2 Deep boreholes

SSNC/MKG has asked SKB to explore the possibility of final storage in deep boreholes as an alternative to the KBS method (an ‘alternative design’ in the language of the Environmental Code) since the early 1990s. SSM, too, has on several occasions urged SKB to include deep boreholes in the EIS that accompanies their application. But, until very recently SKB has maintained that storage in deep boreholes is neither a feasible nor a safe alternative. For example, in the application itself in 2011, the company portrays KBS-3 as the *only* viable method for geological storage. In short, for some twenty years SKB has refused to consider, let alone analyze and evaluate, deep boreholes as an alternative method.

As its name indicates, the method involves loading canisters containing nuclear fuel waste into bedrock at depths of 3 000 to 5 000 meters. The method relies not on man-made barriers, but natural barriers. Alongside the surrounding bedrock, the principal safety factor is the increasing salinity of groundwater under a pycnocline (a boundary separating fluids of different density) at a depth of between 1 000 and 2 000 meters. Due to the difference in density above and below this boundary water below this boundary does not mix with water above it. Provided the loading process does not disturb the layers of groundwater, the contents of the canisters will not reach the biosphere – i.e., humans and the natural environment – before millions of years have passed. Safety will be further enhanced if the repository can be sited inland, in a regional zone of groundwater inflow.

A second advantage of deep boreholes is that the contents are even less accessible than the contents of a KBS repository. Both accidental and deliberate intrusions are considerably less likely to occur.

In documents submitted to the regulatory authority (but not the Land and Environmental Court) in the latter half of 2013, SKB have brought themselves up to date about the deep borehole alternative. In these reports, SKB concedes that it would be possible to create a final repository for nuclear fuel waste in boreholes 44.5 cm in diameter. Having recognized that deep boreholes are viable, there is, in our view, no reason for SKB not to fulfill the letter of the Environmental Code and conduct a full evaluation of the alternative.

7. Other issues

7.1 Retrievability

One of the starting points for the KBS project was a requirement that it provide for *final* storage of Sweden's nuclear fuel waste. That is, the contents of the repository should not be accessible to anyone once the repository had been closed and sealed. Nuclear proliferation was a principal concern among Swedish legislators when they passed the legislation that guided the KBS project. For years, SKB has held forth the difficulty of accessing the contents of a sealed KBS repository as a 'selling point' for the project.

Recently, the Swedish Nuclear Waste Council, an academic reference group, resurrected the idea of retrievability as a more sustainable waste management strategy. Is it not more in keeping with the letter of the Environmental Code to make use of the residual energy in the waste, rather than bury it, they ask. The Council refers to the principle of economy in the use of natural resources set out in the Code (ch 2, para 5) The regulatory authority, SSM, seconding the Council, has since asked SKB to complement their application to the Land and Environment Court with an assessment of the feasibility of retrieving the contents of a KBS repository after it has been sealed.

SSNC/MKG reject the notion that isolating plutonium and other fissile materials should be considered 'wasteful'. We share the concerns of the members of Parliament back in the 1980s: preventing nuclear proliferation must reasonably override the desirability of economy in the use of resources.

We find support for our objection in the Government Bill that introduced the Environmental Code. Foreseeing that competing objectives might conflict, the authors of the Bill wrote:

> *"Balances between these principles will sometimes have to be struck when applying them. First, the consequences of various courses of action that affect the realization of the Code's objectives need to be weighed against each other. Second, the overall reasonableness of the alternatives […] has to be taken into account"* (Government Bill 1997/98:45, p 222).

In SNC/MKG's view, the principle of economy in the use of resources should not be taken as justification for choosing an environmentally hazardous alternative to final storage. In our most recent comments to the Land and Environment Court, we write:

> *"When exploiting the residual energy in the waste as an instance of economy in the use of resources is weighed against the extreme risks such exploitation would pose to the values the Environmental Code is intended to protect, use of the residual energy must reasonably weigh lighter"* (15 October 2013, p 18).

7.2 Deliberate intrusion

SKB's safety analysis estimates the likelihood of accidental intrusion into the sealed repository and finds it unlikely. The company concludes that no active surveillance of the repository will be necessary once it has been closed and sealed.

SSNC/MKG note that SKB has not considered the possibility of *deliberate* intrusion. The plutonium in the waste alone might lead some people to try to break into the repository to steal it. In our comments of June 2012 we urged SKB to formulate scenarios involving deliberate intrusion and to reconsider their opinion that long-term surveillance of the site would not be necessary.

7.3 Impacts on the local environment

In June 2012, SSNC/MKG set out a number of demands for complementing studies of the physical impacts on nature values in the Forsmark area that the KBS repository implies. The soil around Forsmark is rich in calcium, which is rare in Sweden. Consequently, the area hosts a number of rare and protected species of plants and animals, many of which are dependent on the existing water table and other natural features. In the comments we pointed out the inadequacy of the proposed mitigating measures, especially those relating to ponds and streams in the area.

Responsibility and financial liability for fuel waste management

In the comments of June 2012, SSNC/MKG asked SKB for clarification about how responsibility and financial liability for nuclear fuel waste management is shared among the applicant (SKB AB); the parties held responsible according to the Law on Nuclear Activities**,** viz., the power companies Vattenfall, Eon and Fortum; and the licensed operators, viz., the three subsidiaries of the power companies that operate nuclear power stations in Sweden,

SKB replied that liability is shared as set out in the Law on Nuclear Activities, sect. 10, para 2. The section reads:

> *"Any party that holds a license for nuclear activities shall be responsible for ensuring that all the necessary measures are taken for: ...*
> *2. Safe management and disposal of nuclear waste generated by the operation or nuclear material derived from the operation that is not reused."*

Puzzling is the fact that other sections of the law that have to do with responsibilities other than economic liability (sections 10a, 11, 12, for example) are more specific, specifying *"a party that holds a license to possess or operate a nuclear power reactor"***.**

SSNC/MKG maintain that the division of responsibility requires further specification. For example, what would happen if one or more of the licensed operators were to declare bankruptcy or be dissolved by the parent company?

8. Concluding remarks

SSNC/MKG's second set of comments to the Land and Environment Court (October 2013) concludes with the following observations:

"SSNC/MKG find that the needs of complements to the application are far too numerous and far too substantial to allow the application to be notified. There are still so many gaps in the environmental impact statement that it does not provide sufficient support for the application. Many of these gaps are of such

gravity that they require immediate remedy before a formally acceptable application can be said to exist.

"There are still grave omissions, not only in the discussions of alternative methods and the siting process, but also in the basic inventories of protected species in and around the site and the impacts of the proposed facility on nature values of national interest and local nature preserves.

"The evaluation of alternative methods lags so far behind the progress of the case as to cause wonder that the application should have been submitted. In a case of such importance as this, concerning the creation of a final repository for nuclear fuel waste, the Court should have been given a solid basis on which to form a considered opinion and pass judgment. The material submitted so far falls far short of the mark."

C. COMPLETE ENGLISH TRANSLATION OF THE FIRST STATEMENT ON COMPLETENESS FROM THE SSNC AND MKG TO THE ENVIRONMENTAL COURT AND THE REGULATOR, SSM – OCTOBER 2013

The full statement in Swedish can be found here:
http://www.mkg.se/stora-brister-i-slutforvarsansokan-naturskyddsforeningen-och-mkg-kraver-omfattande-kompletteringar

An article on the statement in English can be found here:
http://www.mkg.se/en/great-inadequacies-in-the-license-application-the-swedish-society-for-nature-conservation-and-mkg-de

From: The SSNC and MKG

COMMENT
Stockholm 1 June 2012

To:
Land and Environment Court,
Nacka District Court
Box 1104
131 26 Nacka
nacka.tingsratt@domstol.se

Land and Environment Court
Docket no. 1333-11

Swedish Radiation Safety Authority
17116 Stockholm
registator@ssm.se

The Comments of the Swedish Society for Nature Conservation (SSNC) and Swedish NGO Office for Nuclear Waste Review (MKG) to the Land and Environment Court and the Swedish Radiation Safety Authority concerning necessary complements to the applications for permits to construct a final repository for nuclear fuel waste: "Final repository near Forsmark nuclear power plant and a combined intermediate storage facility and encapsulation facility at Oskarshamn nuclear power plant (Clink)".

On 16 April 2011, Svensk Kärnbränslehantering AB, SKB ('the Applicant' in the following), submitted an application as required by the Swedish Environmental Code[2] to the Land and Environment Court at Nacka District Court. The application concerns plans to construct a system for final storage of nuclear fuel waste at the nuclear power facility in Forsmark (County of

[2] Environmental Code (SFS 1998:808).

Uppsala), referred to as 'the final repository' in the following, and an encapsulation facility and central intermediate storage facility at the nuclear power facility in Oskarshamn (County of Kalmar), the latter generally referred to as 'Clink'. On the same date, the Applicant also submitted applications for said two installations to the Radiation Safety Authority, as required by the Act on Nuclear Activities[3]. The Radiation Safety Authority also assesses the applications in relation to the requirements of the Radiation Protection Act[4].

SSNC and MKG ('SSNC/MKG' in the following) have opted to submit joint comments in response to the Land and Environment Court's solicitation of comment in the case (Docket no. 1333-11) relating to the need for additional information to fill perceived gaps in the applications relating to the final repository and Clink before the applications can be notified and the Radiation Safety Authority's comments expressed in SSM 2011-3522 and SSM 2011-3833, which solicit views on the quality of the information provided in the application with regard to the final repository and Clink. In material terms, the assessments of the Court and the Authority are linked through the Environmental Impact Statement (EIS), which is identical in both submissions, and through the application of the Environmental Code, Ch 2, on General rules of consideration. The points of inquiry in both assessments largely coincide, and SSNC/MKG therefore find it appropriate to issue comments that relate to both assessments in one and the same document. In the following we make explicit note of points where the assessment relates to only one or the other assessment.

1. General comments

The Act on Nuclear Activities assigns responsibility for the safe handling and storage of nuclear fuel waste to the operators of nuclear power plants in Sweden. As a consequence, responsibility for designing an appropriate facility for this purpose, and appropriate siting of the installation, rests in the hands of the Swedish nuclear power industry. The industry has formed a jointly owned company to devise a solution to the storage problem, namely, Svensk Kärnbränslehantering AB (SKB). The provisions of the Act imply high expectations of the company: to work comprehensively to create a system for handling and storage of the fuel waste that affords the least environmental impacts and the greatest safety. The Applicant has since the 1980s borne a responsibility to study and develop alternative methods and to consider alternative sites, and to evaluate the strengths and weaknesses of both methods and sites.

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[3] Act on Nuclear Activities (SFS 1984:3).

[4] Radiation Protection Act /SFS 1988:220).

SSNC/MKG find that the Applicant has failed to live up to its responsibility to produce an objective and comprehensive basis for the choices of both method and site. There are serious gaps in the applications and the EIS, particularly with regard to the treatment of alternative methods and technologies for the final repository, and the process by which the proposed sites were selected. We doubt that the gaps can be filled within the time frame of the present process. From our vantage point, the Applicant appears in early days to have fastened on one method and on certain principles for the choice of site and has since been unable to see the faults in the chosen method and to analyze alternatives to it.

Criticism raised by authorities and other parties to the process has been ignored. As a consequence, there is now considerable scientific controversy with regard to key portions of the application relating to the final repository: the safety of the KBS method, whether the site is appropriate, if safer sites and safer methods may exist.

One principal reason why it has proved difficult to resolve the questions raised in the scientific community is that it has been impossible to determine whether the Applicant's work is scientifically well-founded. An important part of the assessment of the applications is therefore to ensure that the scientific fundaments are thoroughly and objectively assessed in such a way that the quality of the Applicant's work to date can be verified. This vital part of the assessment will also make it possible to determine whether there are issues of which the Applicant is aware, but which have been suppressed in the applications. In order to facilitate this essential verification process, SSNC/MKG call upon the Applicant to make the supporting documentation that the company has produced over the years available to the scientific community. We have expressed our perceived need of such transparency to the Swedish Radiation Safety Authority in an earlier phase of the EIA consultations (see annex 1).[5],[6] SSNC/MKG find it imperative that this material be made available for external review; under present circumstances it is impossible to rest assured that the documents supporting the application have been produced through scientifically acceptable procedures. SSNC/MKG have earlier expressed our concern that certain consultancy firms and individual researchers that the Applicant has commissioned to perform analyses and experiments have developed close ties to the Applicant, so that the degree of objectivity that should be strived for in any process of this kind cannot always be taken for granted. The material presented in the application

[5] SSNC/MKG expressed this need to the Radiation Safety Authority in a communiqué dated 3 April 2012, where we urged that the Applicant be required to make public all technical working papers and research findings concerning the final repository, which still, to this day holds to be confidential.

[5] The five annexes to the original document are listed, some with links to where they can be accessed, at the end of these Comments.

raises the question. In sum, we find it imperative for the supplementary data and information requested in the following pages – whether produced through experiments, analyses or otherwise – be produced in an independent, transparent, objective and comprehensive manner.

Despite repeated admonitions on the part of the government, regulatory authorities and others, that the Applicant conducts its studies relating to the final repository in a broad, objectively verifiable and comprehensive manner, the Applicant has devoted very little attention to alternative methods or sites. SSNC/MKG note that the Applicant early on focused exclusively on the KBS method, which has resulted in the flaws in the application we see today. This unilateral narrowing of focus flies in the face of the demand that the Applicant conduct a comprehensive, multifaceted program of research, as set out in the Act on Nuclear Activities (para. 12). On many occasions through the course of the project, we and others have posed questions to the Applicant that, had they been looked into, would have made the Applicant aware of weaknesses in the KBS method.

In SSNC/MKG's assessment, the siting process, too, is flawed and appears to have been guided by other considerations than the most suitable bedrock and the best prospects of long-term safety. The siting process has not been guided by criteria that would ensure the ability of the man-made barriers of copper and clay to guarantee optimal safety. As in the case of the choice of method, the Applicant has not responded to criticism of the siting process. An example of this nonchalance is the discussion around the turn of the century of the possibility that an inland site might provide a greater degree of long-term environmental safety.

SSNC/MKG urges the Court and the Authority to consider not only the EIA consultations held since 2003, but also to include the viewpoints put forward in consultation-like discussions from the mid-1980s forward, in which the Applicant on repeated occasions received comments from the government, the regulatory authorities and organizations.[7] The views put forward over the years have raised issues of importance to the long-term safety of the final repository, the summary treatment of alternative designs and the choice of site. In a remarkable number of cases, the Applicant has failed to respond with complementary studies or base data.

[7] Since 1986, the Applicant has been required every third year to submit a progress report and program for research in the coming interval concerning the final storage of nuclear fuel waste and the decommissioning of reactors. These reports, known as 'Fud' [an acronym for Research, Development and Demonstration] have been reviewed by the regulatory authorities, who circulated them to numerous institutions and organizations for comment. After the period of solicited comment the Government has taken decisions on each report, some of which included demands for supplementary information. Two of the Government's decisions initiated consultations between the regulatory authorities and the Applicant.

The applications are voluminous, both in terms of the number of pages and the subjects covered. SSNC/MKG have focused primarily on the portions relating to the final repository, and chiefly issues relating to its design, the site and safety issues. There may be a need for additional supplementary data and information on points that we have not yet identified or been able to explore more fully. Also, the Applicant’s responses in this phase of the EIA process may raise new questions and additional needs of supplementary data and information.

2. Supplementary information and data needs

In this phase of the examination of the applications, the Land and Environment Court and the Radiation Safety Authority have solicited comment on the applications. The comment should focus on perceived gaps in the application, i.e., needs for more data and information, and the quality of the applications. In this section we list our requests for supplementary information and data. We introduce each item with a brief resumé of the issue at hand and the flaws and perceived gaps we have identified. Thereafter, we specify our demands.

2.1 Starting points for the examination of the fundaments of the applications

The environmental and public health aspects of construction and operation of a final repository for nuclear fuel waste and an encapsulation facility and intermediate storage facility are regulated in three principal laws – the Environmental Code, the Act on Nuclear Activities, and the Radiation Protection Act – and in regulations issued by the Radiation Safety Authority.

The principal purpose of the Environmental Code is to “promote sustainable development which will assure a healthy and sound environment for present and future generations” (MB chap. 1, sect. 1). The Act on Nuclear Activities is primarily concerned with assuring the safety of the operation of nuclear installations, with a prime focus on radiation protection and the fulfillment of Sweden’s international obligations (prop. 1983/84:60, p 80[8]). The Act does not, however, contain regulations pertaining to radiation protection, but refers instead to the Radiation Protection Act. The main purpose of the Radiation Protection Act is to protect human beings, animals and the environment against the harmful effects of ionizing and non-ionizing radiation.

[8] “Prop.” stands for “proposition” or Government Bill, i.e., the bill put before Parliament which, if passed, results in an Act. Government Bills contain the arguments behind the proposed legislation and its intentions.

In principle, the Environmental Code shall apply parallel with other legislation (MB chap. 1, sect. 3) – in this case the above-mentioned Acts. Legal precedent (MÖD 2006:70) indicates that Land and Environment Courts, when assessing a matter under the Environmental Code, may impose conditions that relate to nuclear safety and radiation protection. The Government has in practice applied rules set out in the Environmental Code in assessing the allowability of various nuclear activities in light of the radiation hazards associated with the activity (Government decision 2005-10-20, M2005/2913/F/M). The legislative history behind the Code indicates that it is in the purview of the Land and Environment Courts, in the course of assessments on the basis of the Environmental Code, to take account of all emissions and impacts from nuclear installations, including emissions of radioactive substances and ionizing radiation (prop. 1997/98:90, p 271).

When approval of plans for the final storage of nuclear fuel waste is granted under the Act on Nuclear Activities and throughout the term of the permit, the government or a designated agency may set out conditions that are deemed necessary to ensure safety (Act on Nuclear Activities, para. 8). The documents preliminary to the Act make it clear that the assessment of any application to construct and operate a nuclear installation shall be carried out "on the basis of the basic safety requirements set out in the Act on Nuclear Activities, the requirements of basic radiation safety set out in the Radiation Protection Act, and regulations that specify these requirements. The assessment shall also take account of the General rules of consideration set out in the Environmental Code, Chapter 2, the EIS submitted by the applicant, and a preliminary safety analysis, accompanied by technical and other descriptions of the planned facility or activity and its operations" (prop. 2009/10:172 p 22).

In the event that the provisions of the Environmental Code conflict with the provisions of other legislation or ordinances, the basic point of departure is that the rule that provides the greatest environmental protection shall be applied (prop. 1997/98 p 275). Thus, the demands of legislation that apply to any given kind of activity shall be considered cumulative, i.e., the activity must fulfill all of them, unless the rules are materially incompatible, in which case the rule that best protects the environment shall take precedence.

The General rules of consideration set out in the Environmental Code (chap. 2, sect. 2) contain a set of principles to be observed when assessing activities. Of these principles, the precautionary principle, the requirement that the Applicant possesses the knowledge needed to perform the activity, the requirement that the best available technology (BAT) be used, and the best site be chosen are particularly relevant to the assessment of the proposal to construct a final repository. These principles shall be applied in the assessment processes of both the Land and Environment Court and the

Swedish Radiation Safety Authority/the Government. It is established praxis that the EIS that is appended to any application submitted to the Court, etc., shall contain all the information that is necessary for the assessment according to the General rules of consideration in the Environmental Code, chapter 2, which shall be carried out in each and every case. The Environmental Court of Appeal has ruled that applicants shall demonstrate that their plans fulfill the requirements set out in the chapter (MMÖD 2012:5).

The Environmental Code (chap. 2) requires that the Applicant shall possess the knowledge needed to undertake the proposed project in a manner that does not adversely affect human health or the environment. The Supreme Court has ruled that the 'knowledge requirement' shall be defined in relation to the nature and extent of the project in question, and to the possible impacts it may have on human health and the environment (NJA 2010 p 516). Few, if any, activities have a greater extent or a greater potential impact on health and the environment than a final repository for nuclear fuel waste, particularly in view of its extent in time and the period during which it poses a hazard to human health and the environment. It follows that anyone who plans a final repository for such waste will be expected to live up to the highest standard of requisite knowledge.

The 'general rules of consideration' – precautionary measures, requisite knowledge, BAT and appropriate siting – shall be applied to the extent it is deemed reasonable to fulfill them. In this determination particular attention should be paid to the balance between the potential utility or advantage of the protective measure or other precaution and the cost of undertaking them. The legislative history behind the Environmental Code recognizes the decisive importance of attaining the nation's overall environmental objectives (Government Bill 1997/98:45 p 231). Thus, the calculation of cost-utility should not be allowed to stand in the way of attaining sustainable development.

The law on financing the management of nuclear waste[9], commonly referred to as the 'Financing Act', provides that the licensed operator of nuclear facilities shall finance the final storage of waste and the decommissioning/demolition of the facilities. The Act affords no leeway for setting the fee to cover these costs at a level below what is needed to finance the safe handling and storage of wastes (para. 4 and 6). Thus, there is no provision that would allow reference to costs to justify lowering the standard of management called for in chapter 2, sections 2, 3 and 6, of the Environmental Code, inasmuch as the financing of all such costs is assured under the Financing Act. In short: cost-utility calculations can never lessen the

[9] Act on financing the management of waste from nuclear activities (SFS 2006:47)

Applicant's responsibility for the safe handling and storage of the waste required in the Environmental Code, chap. 2.

In this connection it should also be noted that the Council Directive 2009/71/EURATOM on the establishment of Community-wide framework regulation of radiation safety at nuclear facilities requires each Member State to ensure that national legislation and ordinances call upon operators of nuclear facilities, to the extent reasonably possible and under the supervision of the regulatory authority/authorities, to periodically review, check and continuously take measures to improve the safety of their nuclear facilities in a systematic and verifiable manner (art. 6.2). The provisions of the Directive have been incorporated into Swedish law since mid-2011. Relevant Swedish rules, including those set out by the Radiation Safety Authority, should be interpreted in light of the Directive.

Directive 2011/70/EURATOM on the establishment of Community-wide framework regulation of the safe handling of nuclear fuel waste and radioactive waste, the provisions of which shall have been incorporated into Swedish law no later than 23 August 2013, contains similar requirements. According to this Directive, national legislation and ordinances shall require that operators of nuclear facilities under the supervision of competent regulatory authorities, periodically review and evaluate, and in reasonable measure constantly improve the safety of their nuclear facilities in a systematic and verifiable manner. This shall be achieved through appropriate assessments of safety and other arguments and evidence (art. 7.2).

The Supreme Court has noted that when the Environmental Code was adopted it was deemed vital that any faults in an EIS should be identified and remedied early in the EIA process (NJA 2009 p 321). The Land and Environment Court should instruct the Applicant as to how the flaw should be remedied. Failure to remedy serious faults may be grounds for rejection of the application. Instruction to remedy the fault presumes, of course, that the fault can be remedied within a reasonable period of time. Should this not be feasible, there is no point in issuing an instruction, in which case the application may be rejected out of hand.

2.2 General issues

2.2.1 The assignment of responsibility for the handling and storage of the nuclear fuel waste

The Applicant, Svensk Kärnbränslehantering AB, is jointly owned by the companies that own and operate nuclear power reactors in Sweden. According to the Act on Nuclear Activities, responsibility for the safe handling and final storage of the waste or nuclear material not for re-use that is produced by the reactors, rests with those who are licensed to undertake nuclear activities. The licensees' responsibility also encompasses decommissioning and demolition of facilities no longer used for nuclear activities until all activity in the installation has ceased and all nuclear material and nuclear waste has been deposited in a final repository and the repository has been closed and sealed (KTL, para. 10). SSNC/MKG find that the application is unclear about the distribution of responsibility between the Applicant and the licensees.

SSNC/MKG ask that the Applicant specify the legal responsibility borne by the Applicant, the licensed operators and those who are responsible for the final repository according to the Act on Nuclear Activities (the power companies) and the distribution of responsibility between the parties.

2.2.2 Incomplete documentation for assessment according to the Environmental Code

SSNC/MKG have noted that the Applicant has submitted different documentation in support of the application for assessment by the Land and Environment Court and the Radiation Safety Authority, respectively. The material submitted to the Court is relatively limited in scope. In SSNC/MKG's view it is important that all supporting documentation that can have bearing on the assessment of environmental impacts be submitted for assessment according to the Environmental Code. The fact that provision for public participation in the assessment differs between the two institutions makes it even more important that the assessment according to the Environmental Code be as comprehensive as possible.

SSNC/MKG ask that the Applicant submit all documentation that has been, or will be, submitted for assessment according to the Act on Nuclear Activities, to the Land and Environment Court.

2.2.3 Unclear structure of the application and relation of annexes to the EIS

SSNC/MKG find that the application is poorly structured and needs to be rearranged. The Applicant has placed the environmental impact statement (EIS) on a par with other annexes to the principal document, i.e., alongside the safety analysis, SR-Site, the siting report and the methods report. In our view, these latter documents should be linked to and introduced as annexes to the EIS, so as to specify more clearly how the EIA, the safety analysis and the presentation of alternative designs and sites relate to the EIS.

SSNC/MKG ask that the Applicant revise the structure of the application so as to specify how the annexes – particularly the safety analysis, SR-Site, the *siting report and the methods report – relate to the EIS. We recommend that these annexes, currently appended to the* principal document*, be appended to the EIS, instead.*

2.2.4 Financial aspects of the final repository project

According to the Environmental Code, an applicant's ability to furnish security to cover the costs of the consequences of possible accidents and mitigating measures that the activity in question may call for is one of the criteria of validity of the application. Applicants that are required to pay a fee or to furnish security under the Financing Act are, however, exempted from the Code's requirement of security for the activities to which the Financing Act applies (MB chap. 16, sect. 3).

The purpose of the Financing Act is to assure the financing of the responsibilities set out in the Act on Nuclear Activities, para. 10-14. These include the safe handling and storage of radioactive waste and material that will not be re-used which the nuclear activity in question produces (para. 1). The legislative history makes it clear that the financing system shall, to the greatest extent possible, minimize the risk that government will be forced to pay costs that are the legal responsibility of the licensed operator (prop. 2005/06:183 p. 22). The Act requires licensed operators of nuclear facilities that produce, or have produced, radioactive waste to pay a nuclear waste fee. The amount of the fee shall be proportionate to each facility's share of the total amount of radioactive waste to which the fee applies (para. 6).

In addition to the licensee's costs for safe handling and final storage of waste, the fee shall cover the licensee's costs for the research and development activities required to achieve safe final storage of the waste; the costs of public sector institutions' research and development activities; and all information to the public about nuclear waste management and storage produced by the licensee and national and local government (para. 4).

Should it prove necessary in order to fulfill the purpose of the Act, the economic risk to the state that the costs to be covered by the nuclear waste fees imply, shall be estimated and specified. Licensees shall in that case be required to pay a risk surcharge in order to protect the state against the specified economic risk (para. 13-14).

In the event that the financing provided by the Financing Act proves to be insufficient to achieve the standard of safety that the nature of the activity and the protection of coming generations requires, it is unquestionably so that the responsibility to supply the necessary funds as set out in the Act on Nuclear Activities rests with the licensed operators in whose facilities the waste has originated (para. 10).

SSNC/MKG have in numerous submissions to the regulatory authorities (the Radiation Safety Authority and its predecessors) over the years pointed to shortfalls in the financing system and called for rises in the nuclear waste fee. Since its creation, the new Authority has undertaken a comprehensive review of the financing system, in recent years in collaboration with the National Debt Office and the Nuclear Waste Council. In the course of the review the Authority has discovered shortfalls in the financing and has recommended that the Government raise the level of the fee. The Government has responded to the recommendation only in part; meanwhile, the Authority has been commissioned to propose amendments to the Act.

SSNC/MKG have had some insight into the work undertaken by the Radiation Safety Authority, the National Debt Office and the Nuclear Waste Council. It is our understanding that the three authorities will propose a change in the law that is designed to limit the economic liability of the state. Such a proposal indicates that the financing system is severely underfinanced, which may imply a substantial shortfall in the Nuclear Waste Fund. Estimates published by the Nuclear Waste Council in early 2012 put the shortfall at SEK 30 thousand-million, at the least. The current balance in the Nuclear Waste Fund is SEK 48 thousand-million.

In the light of the foregoing, there is a need to show that the financing of Sweden’s nuclear waste management can be assured, and how a substantial shortfall in the financing system can be remedied. This implies that the Applicant should also be called upon to specify the distribution of economic liability between the Applicant and the licensed operators of nuclear power reactors in Sweden.

SSNC/MKG ask that the Applicant explain how financing of the project can be assured and how the project will be financed, should the monies set aside in the financing system prove insufficient. The Applicant also needs to specify how financial liability for the project is distributed between the Applicant and the companies licensed to operate Sweden’s nuclear reactors.

2.2.5 The eventuality that other countries’ waste may be stored in a Swedish final repository or that Swedish nuclear waste may be exported

The Act on Nuclear Activities prohibits the final storage of nuclear fuel waste and other nuclear waste of foreign origin in Sweden without special dispensation. Permission may be given only given extraordinary circumstances and provided the import implies no impediment to the research and development program (the Fud programme) set out in Sections 12 and 5a of the Act. The legislative history contains an extensive discussion of whether or not the prohibition violates European law. The conclusion is that it does not, but the conclusion is not unquestioned.

According to article 86 of the Euratom Treaty, most fissile materials are the property of Euratom; the Community has first option on them. Historically, this provision has had little practical importance. In connection with Sweden’s entry into the European Union (and Euratom) the Commission explained that each Member State has discretion over the final stages of the nuclear fuel cycle was adopted. We note, however, that the statement has been variously interpreted. The question, whether or not the Euratom Treaty may impinge on Sweden’s autonomy regarding nuclear fuel waste needs to be penetrated thoroughly, taking particular account of the consequences of future technological advances and possible changes in public attitudes and policy vis-à-vis nuclear power due to concerns about climate change.

One possible scenario is that some Member States opt to invest in so-called fourth generation reactors and therefore will want to use the plutonium in Swedish fuel waste to fuel them. Consequently, SSNC/MKG call for a thorough study of the possibility that the Euratom Treaty may limit Sweden’s autonomy over nuclear fuel waste.

SSNC/MKG ask that the Applicant to undertake a study of amendments to current law that may reasonably be expected as a consequence of developments in the areas of new technology and energy policy as outlined above and, secondly, how such amendments might affect assessments of the safety and appropriateness of the proposed method of final storage.

2.3 The Applicant´s discussion of design criteria for the final repository

A final repository for nuclear fuel waste is a project that will continue to be of public concern for countless years to come. The project will affect thousands of generations and poses an environmental hazard hundreds of thousands of years into the future.

In the EIS the Applicant offers its conception of the purpose of the final repository on the basis of a survey of national legislation and the principles established by international nuclear power organizations and institutions. The Applicant refers to the principles and rules set out in the documents as “requirements and starting points” for the final repository, and the Applicant states that their objective has been to develop a system for final storage that fulfills these rules and principles.

SSNC/MKG take this discussion of the objective of the project as a statement of preconditions for the design of the final repository. In our view, the

Applicant's discussion of these preconditions needs to be further developed in two particular areas.

First, the Applicant states that the safety of the system shall rely on multiple barriers. Barriers are of crucial importance to the long-term environmental safety of the repository. Therefore, they must be robust, preferably be based on natural (rather than man-made) systems; furthermore, each barrier should function independently, i.e., irrespective of the status of other barriers. The Applicant argues that the alternative system, deep boreholes, fails to fulfill the requirement of multiple barriers. SSNC/MKG argue that the Applicant needs to make a careful analysis of how *both* the KBS method and a deep borehole system fulfill the requirement of multiple barriers. The analysis should determine which barriers are robust, which are based on natural systems and/or dependent on each other.

Secondly, the Applicant does not address the question of retrievability as a public policy objective. The reason it is important to explore this alternative is that there is an implicit conflict between the objective of retrievability and the stated starting points of the final repository project. In SSNC/MKG's view, the Applicant needs to discuss the conflict more explicitly in the application. Retrievability can be good; some claim that it is important and must not be ruled out. In France, for example, retrievability is a criterion for the design of final repositories. One of the principal arguments for retrievability is that the plutonium in nuclear fuel waste is a potential energy resource, which humanity may wish to make use of in the future. Another argument in favor of retrievability is that it makes it possible for people to change to a better method, should one be developed. It also permits removal and relocation of the waste should the final repository prove to be less safe than expected.

There are, however, principal risks involved with retrievability. The principal risk is that the plutonium in nuclear fuel waste may be used to produce nuclear weapons. This implies a need for constant surveillance of any final repository that is designed to permit retrievability. Furthermore, it is easier for intruders to enter the repository, which can endanger both the environment and human health.

When considering retrievability, it is also important to distinguish between retrievability prior to sealing and retrievability in the longer term. The advantages mentioned above decrease over time, whereas the risks remain. The risk of nuclear proliferation actually increases as the radiation from the fuel waste subsides, since it becomes feasible to retrieve and process the waste, e.g., to extract the plutonium with simpler protective equipment and fewer precautionary measures after a millennium, more or less, has elapsed.

SSNC/MKG find it necessary for the Applicant to include analyses of the above-mentioned areas in their application and to discuss more exhaustively the prerequisites for, and the KBS repository's potential for goal fulfillment, with particular reference to multiple barriers and retrievability.

2.4 An overall lack of transparency with respect to the bases, scientific and other, for the calculations and conclusions presented

The Applicant has worked to develop a system for the final storage of nuclear fuel waste since the 1970s, in the course of which time they have carried out and commissioned a considerable body of R&D and other studies. The results of all this work have been published only selectively, however. Inasmuch as the final repository project is being undertaken in the public interest, SSNC/MKG are of the opinion that the company should observe the highest degree of transparency – comparable to that provided for in the Freedom of Information Act – particularly with respect to the company's scientific work.

So far, however, much of the scientific material remains unpublished and closed to external review. This practice flies in the face of scientific praxis, which is based on verifiability and peer review.

Looking back in time and throughout the EIA consultations, the only scientific material that the Applicant has made public is that published in SKB report series. SSNC/MKG have become aware of the existence of a number of reports of commissioned studies that the Applicant has kept confidential, i.e., held within the company. Many of these reports contain research data and findings that have only been made known in the form of edited references in the company's publications, or not at all. In cases where the findings are mentioned in published reports, the source is not cited. Again; a radical departure from scientific praxis.

SSNC/MKG have also become aware that the Applicant has carried out research projects, the results of which have never been made public in any form. All the reports from experiments at the Äspö laboratory[10] have been held in confidentiality until immediately before the application was submitted, and the only material released were reports in SKB's IPR series. Consultants' work that is not included in the IPR series remains confidential.

In a quality assurance project conducted by the Radiation Safety Authority in 2009-2010, it was revealed that the Applicant failed to include any reference to results from a commissioned study (the MiniCan experiment[11] at Äspö

[10] Äspö Hard Rock Laboratory (HRL) north of Oskarshamn is an underground laboratory located at a depth of 460 m in the bedrock. Research and technology development for the final repository project are conducted there.
[11] For more on the MiniCan project, see section 2.5.2.8 below.

laboratory) in a published report, despite the fact that the results had been reported to the Applicant. When the Applicant made the consultant's reports available to the Authority for examination, it was discovered that the Applicant had suppressed findings that they found inaccurate or unlikely. In a minuted meeting between the Authority and the Applicant after examination of the documents, the Director of Research at SKB explained that it was company policy to report only data that the company could understand and trusted.[12] SSNC/MKG find this policy both astounding and deeply worrying in that it makes it extremely difficult, if not impossible, for anyone outside the company to review the Applicant's choice of technology.

Nor can we exclude the possibility that the Applicant has published scientific results relating to other parts of the project in an equally subjective and selective manner. SSNC/MKG therefore conclude that the Applicant, as part of the application process, must release *all* results obtained in its work over the years, not just those that they say they can understand and trust. Only the Applicant has the responsibility and the resources to carry out a comprehensive research program of this kind. That fact alone makes it imperative that the Applicant be fully transparent in the documentation of its work.

In SSNC/MKG's view, the Applicant should open their research documentation system to other participants in the application evaluation process. In addition to all the confidential consultants' reports, the documentation system contains working papers and notes from meetings in the course of the research projects. These documents, too, may contain information of relevance to the assessment of the application.

In a comment to the Radiation Safety Authority dated 3 April 2012, SSNC/MKG expressed their views on this issue. The document, appended to these comments as annex 1 contains, among other things, a list of reports relating to problems associated with the man-made barriers to which SSNC/MKG would like to have access.

SSNC/MKG demand that the Applicant make public all research reports and other working papers that contain or describe scientific findings from the Applicant's work with the final repository project. We recommend that the Applicant do this by making their research documentation system generally accessible.

2.5 The KBS method

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[12] Notes from a Meeting on quality control relating to corrosion experiments LOT and MINICAN, 17 June 2010, Swedish Radiation Protection Authority, reg. no. 2009/4300. [In Swedish]

2.5.1 General comments regarding functional criteria and technical descriptions of the chosen method

The Environmental Code, chap. 2 sect. 3, states that anyone who plans to pursue an activity or take a measure shall “implement protective measures, comply with restrictions and take any other precautions that are necessary in order to prevent, hinder or combat damage or detriment to human health or the environment as a result of the activity or measure”. When the activity is conducted on professional or commercial terms, “the best possible technology shall be used”. Furthermore, such precautions shall be taken “as soon as there is cause to assume that an activity or measure may cause damage or detriment to human health or the environment”.

The concept, “best possible technology”[13] applies not only to the technology used, but also to the design, layout, construction, maintenance, management and eventual decommissioning and dismantling of the facility in question. The technology must be feasible from a technical and economic standpoint and appropriate for use in the branch of industry. This means that it is available technology that is in practical use, and not just a prototype used experimentally. The technology need not exist or be used in Sweden. Several alternative technologies that meet the same environmental standards may exist, in which case any one of them may be used.

Inasmuch as there is currently no technical solution for final storage of nuclear fuel waste “in practical use”, the criterion, “best possible technology” cannot be fulfilled. This applies also to the KBS-3 method, when one considers the experiments relating to vital elements such as the copper and clay barriers that are currently in progress. There is no industrial application of the technology anywhere in the world. The absence of a technology that fulfills the criterion for ‘best possible technology’ does not in itself pose any absolute hindrance to the final repository project, but it does underline the need for the most comprehensive and independent analysis and empirical verification of the selected technology as is possible, short of applying the technology on an industrial scale. The absence of any ‘best possible technology’ that might be used as a benchmark also calls for very far-reaching requirements regarding the analysis and evaluation of alternative designs and technologies. The uncertainties surrounding a technology in its primary developmental phase may also warrant extra precautionary measures.

The Regulations on safety in nuclear facilities set out by the Radiation Safety Authority specify that a nuclear facility shall be constructed so that it shall:

[13] In Sweden ‘best possible technology’ is generally taken to be synonymous with ‘best available technology’ or ‘BAT’.

“ – be able to withstand component and system failures,
– be reliable and have operational stability, and
– be able to withstand events and conditions which can affect the safety functions of the barriers or those of the defense in depth system” (SSMFS 2008:1, chap. 3 sect. 1).

Standards for the design, construction and function of barriers are set out in the Authority’s regulations on safety of final repositories for nuclear fuel waste (SSMFS 2008:21). Among other things, safety after the repository has been sealed shall be maintained by a system of passive barriers; each barrier shall contribute in one or more ways to contain, hinder or delay the spread of radioactive substances, either directly or indirectly, by supporting other barriers in the system.

Furthermore, the Regulations relating to nuclear fuel waste require that any failure or malfunction in the barrier function, beyond what is foreseen in the safety analysis, that is observed under the construction period or operations prior to closure and sealing shall immediately be reported to the Radiation Safety Authority. The same applies to suspected malfunctions or suspicions that a malfunction may occur in the future (paragraphs 2-4).

In this connection we should recall what was noted in section 2.1 above regarding the EU Directives on pan-European rules for the safety of nuclear installations and safe management of nuclear fuel waste and other nuclear waste (2009/71/EURATOM and 2009/70/EURATOM).

For those who have followed the Applicant’s work to develop a system for final storage of nuclear waste from the start, it is clear that the KBS method was in focus and was presented early in the process as the only alternative. Over the years, various parties have directed the Applicant’s attention to issues which, had they been looked into early on, might have brought certain flaws in the KBS method to light. In SSNC/MKG’s view, the Applicant did not explore these issues to the extent they merited, despite the requirement in the law that the Applicant shall conduct the R&D program in a comprehensive manner. One such issue is the question whether copper can corrode in an oxygen-free environment. Questions about this possibility were raised in the mid-1980s.

SSNC/MKG find a number of gaps in the research reported in support of the KBS method, which is the Applicant’s principal proposal for the final repository. In the following, we discuss some of the areas where we feel the Applicant has not done enough to verify the safety of the method in either the short term (a 1 000-year perspective) or the long term (a 100 000-year perspective).

2.5.2 The environmental safety of the KBS-3 method in a 1 000-year perspective

The KBS method is based on a system of man-made barriers of copper and clay, which together shall isolate the nuclear fuel waste from the groundwater that streams through the bedrock. The waste must remain isolated hundreds of thousands of years, a period which means that the repository will have to be able to withstand the stress of repeated ice ages. When the method was chosen in the 1970s, it was considered important to find a material for the canisters that would resist corrosion under the groundwater conditions that prevail deep down in Swedish bedrock. Titanium was the first choice, but it was subsequently abandoned. In the process focusing on choice of materials in the late 1970s and early 1980s, copper was chosen for the canisters. The choice was based on theoretical arguments based on the presumption that copper was – like gold – 'immune' to corrosion in the oxygen-free groundwater that would fill the final repository after it was closed and sealed. Thermodynamic research was said to support the presumption. Groundwater was perceived to be the prime threat. Therefore, the canisters would be additionally protected by a clay buffer. Bentonite clay absorbs water and swells in a wet environment. 'Cat sand' is often bentonite clay. The idea is that the clay buffer will swell after the repository has been filled, closed and sealed until it fills the entire repository, thereby protecting the canisters from damaging agents.

The Swedish KBS method for final storage of nuclear fuel waste differs from solutions currently being developed in other countries in that it is primarily dependent on man-made barriers to keep hazardous substances in the fuel waste from impacting on human health and the environment.[14] Thus, it is absolutely essential that these barriers function as planned. In the course of EIA consultations leading up to the submission of the application, questions have arisen concerning the environmental safety of the method. The most serious of the questions concerns whether the barrier system will actually reach the so-called 'ideal condition' after the repository has been loaded and the tunnels are sealed. Doubts have been raised about the risk that the copper canisters may corrode and physical impacts on the ability of the clay buffer to swell and shield the canisters as planned.

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[14] France, Belgium and Switzerland are planning final repositories in clay formations; Germany is planning for storage in salt formations. In both kinds of solutions the capsule is secondary to natural barriers. The now abandoned Yucca Mountain project in the state of Nevada, USA, was based on the fact that the mountain was located in an arid desert, so that the waste would not be affected – this, too, a 'natural barrier'. The long-term safety of the deep borehole method, too, is based on a natural barrier, namely, the progressively more saline water at greater depths, which hinders groundwater near the repository from rising toward the surface. The KBS method, with its man-made barriers, interests a number of countries, however, in many cases because it affords greater flexibility in siting. Canada, Great Britain and Finland have participated in the R&D behind the KBS method, and other countries have expressed interest.

The Applicant refers to the period immediately after deposition as the ’initial condition’, but in order for this initial condition to be achieved the clay that surrounds the copper canisters after the tunnel has been sealed must have absorbed water from the surrounding bedrock and swelled to fully fill the deposition chamber. Unless the ideal condition is achieved, the models in the long-term safety analysis will not apply.

Until a few years ago, the copper canister was considered the primary factor in the barrier system. It was believed that even if the clay barrier did not function perfectly, the 500 mm copper surrounding the fuel waste would remain intact, withstanding, for example, sulfide corrosion. With new awareness that more corrosion processes may be at play than the Applicant has considered in their safety analysis, and that these processes may interact, the importance of a perfectly functioning clay barrier in the long term has increased. If copper once was ‘King’, clay has now assumed the throne.

Thus, the most important factor for achieving the ‘ideal condition’ is that the clay buffer around each canister is and remains impermeable. It is the buffer’s impermeability that assures that the copper canister will not deteriorate too quickly due to substances that enter the repository. In the first millennium, however, both the clay and the canister will be both heated and subject to ionizing radiation from the waste. Both these factors impact on the ability of the clay to swell and augment the stress on the canister. Heat can inhibit the function of the clay, and corrosion processes accelerate markedly at high temperatures.

Because there is relatively little groundwater in the bedrock at Forsmark, the clay in most of the deposition chambers will not swell before the canisters have cooled, which can take a thousand years or more. In the meantime, the dry clay will be heated, which can affect its ability to swell, in which case the copper canisters, left without a buffer, can corrode. There is considerable scientific controversy about the amount of corrosion canisters may experience in the Forsmark bedrock. In the ‘worst-case’ scenario the canisters may corrode much more quickly than the Applicant considers possible. In this case the capacity of the clay to attain the ideal condition will be additionally reduced by the copper released from the canister through corrosion. It is entirely possible that radioactive substances will begin to leak out of the canisters during the first thousand years.

SSNC/MKG find that the Applicant knows surprisingly little about how the clay may be expected to perform in the Forsmark bedrock, particularly during the first millennium. The presumption in the safety analysis, that the clay buffer in all the deposition chambers will attain the ideal condition, is highly theoretical and has very little empirical support. We find that knowledge of how the copper canister will fare in the repository environment the first thousand years, too, is very limited. Here, too, the prognosis is largely theoretical and lacks empirical support. On the contrary, the results of experimentation suggest that the Applicant's expectations regarding the canisters' resistance to corrosion may be incorrect. SSNC/MKG conclude that the applicant presents an incorrect account of how copper will perform in the repository environment, and that a correct account might very well lead to a determination that the canisters should not be made of copper.

In the following, we discuss some gaps in knowledge that, unless they are filled, should bring further assessment of the application to a halt. SSNC/MKG have followed the issue of copper corrosion for some years, and we have a fairly good grasp of the subject and of the scientific controversy that surrounds it. We have also worked hard to gain access to the results of the Applicant's scientific work on copper corrosion – but with limited success.

In order to fill out the basis for our judgment of the feasibility of the man-made barriers we have turned to docent Olle Grinder at PM Technology AB. Dr Grinder has many years' experience of corrosion studies, both at the Royal Institute of Technology and in the capacity of independent consultant. He has a thorough knowledge of the research area.
Dr Grinder's report (annex 2) discusses a number of issues relating to the use of copper for the canisters in a final repository, but also comments on how the Applicant has gone about investigating the problem – which speaks to the discussion in section 2.4 above, on the lack of an objective, comprehensive and transparent reporting of the scientific basis for various judgments and assurances.

Here we itemize the principal areas in need of additional knowledge and/or better documentation.

2.5.2.1 Assumptions about the bentonite buffer

As far as SSNC/MKG have been able to determine, the Applicant has not reported any objective and comprehensive basis on which to determine whether the bentonite clay can be expected to attain the ideal condition. No empirical results are reported in the application to support the account of how the clay will swell in the bedrock at Forsmark. The longitudinal experiments carried out at the Äspö laboratory relate to an entirely different bedrock formation that carries much more groundwater.

In SSNC/MKG's view there is a need for a scenario covering how bentonite swells given uneven access to water, varying over both time and space; how the clay is influenced by copper freed from the canister through corrosion and infiltrating through the clay; how the clay responds to both heat and radiation;

and the influence of all these factors on microbial life in the clay. All these factors and processes need to be coupled to the conditions prevailing in the bedrock at Forsmark. Furthermore, the studies should be conducted in a transparent manner by methods that are not influenced by the Applicant's interests.

SSNC/MKG ask that the Applicant complement the application with data that support the supposition that the bentonite buffer will attain the ideal condition in the bedrock at Forsmark.

2.5.2.2 Absence of oxygen gas in the final repository

It is necessary to know exactly what corrosion processes can take place in the repository environment, and in order to know this, it is necessary to know at what point oxygen no longer is present in the various parts of the deposition chamber/clay buffer and the tunnels leading to them. This knowledge is also prerequisite to an understanding of microbial development in the repository, since microbial life in oxygen-free environments differs from that in oxygenous environments.

It seems that the Applicant knows too little about this aspect, in view of its importance to the proper function of the final repository and its relevance in the interpretation of the results of copper corrosion studies performed in a repository-like environment. Without such knowledge it is impossible to offer conclusive explanations of any results of experiments relating to the repository.

SSNC/MKG ask the Applicant to specify at what point the deposition chamber, the clay buffer and the tunnels in the repository become oxygen-free.

2.5.2.3 Poor knowledge about copper corrosion processes in oxygen-free water

The Applicant was made aware of the possibility that copper can corrode in water, even in the absence of oxygen gas as early as the mid-1980s. The Applicant denied that this was possible, and continues to do so despite mounting evidence, both empirical and theoretical, that such processes exist. In SSNC/MKG's view this issue has to be thoroughly explored inasmuch as the process, and interaction with other processes, may explain the elevated rates of corrosion noted in some experiments, but which the Applicant discounts on the grounds that the results are due to the presence of oxygen in the experimental material.

SSNC/MKG ask the applicant to study how copper can corrode in an oxygen-free environment, including the processes that are currently the subject of controversy among researchers in the field.

2.5.2.4 Evaporation of water after deposition of the copper canisters

After the canisters have been deposited in the repository water that comes in contact with the canisters will turn into steam. SSNC/MKG find no description of this process in the application and, above all, how water condenses on the surface of the canister.

SSNC/MKG ask the Applicant to specify the processes by which water can evaporate upon contact with the canisters in the repository, and how water may condense.

2.5.2.5 The effects of evaporated groundwater on copper and clay

When groundwater evaporates in the interface between copper and clay in the deposition chamber, it leaves a salty residue. These salts can both concentrate on the surface of the clay buffer and precipitate on the copper surface. The rate of corrosion is normally high when heated metal with salt on its surface is exposed to an environment that is warm and moist. In our opinion, the Applicant does not offer any objective and comprehensive analysis of the impact that heightened salinity in the clay buffer or salt precipitation on the copper surface may have on the two man-made barriers.

SSNC/MKG urge the Applicant to supplement their application with an analysis of the influence of salt residues from the evaporation of groundwater on the surfaces of the clay buffer and the copper canister, respectively.

2.5.2.6 Corrosion of the copper canister due to heightened salinity of the groundwater that remains after evaporation of groundwater

The groundwater that remains in liquid form after the evaporation of water has a heightened salt content. When such groundwater comes in contact with a copper surface, high rates of corrosion may result. SSNC/MKG find that the Applicant does not offer any objective and comprehensive analysis of the process by which groundwater of higher salinity due to evaporation may give rise to corrosion on a copper surface.

SSNC/MKG ask the Applicant to supplement their application with an analysis of how heightened salinity in the groundwater, due to evaporation, can give rise to corrosion of the canister's copper surface.

2.5.2.7 The need for realistic experiments that specify the behavior of copper and clay in the repository environment

In the 1970s, when the Applicant was evaluating the suitability of titanium for the canisters, experiments were conducted to study the metal's performance in a simulated final repository environment. When copper replaced titanium as the metal of choice, no such experiments were conducted – at least, none have been reported. SSNC/MKG find the lack of such experiments astounding. There is not a single empirical study that supports the proposition that the rate of corrosion declines to the nanometer level in the repository environment, other than experiments carried out in confined and totally closed systems, which have no relevance as a representation of the final repository environment. Experiments have been conducted in other countries, but the results have been equivocal, mainly because it has been difficult to determine whether the experiments have been free of oxygen or what the electrodes used actually measure. What is more, the experiments have been of very short duration.

The feasibility of controlling whether an experiment is oxygen-free may be greater in a laboratory than in the experiments carried out at Äspö (see note 10). It is vital, however, that the experiments are so designed or of such a scale that they cannot be considered closed systems. That is, the experiments should allow the hydrogen that may be produced to leave the copper surface. It is also important for the experiments to be carried on over a longer interval.

SSNC/MKG demand that the Applicant conduct realistic laboratory experiments to study how copper and clay behave in a simulated final repository environment.

2.5.2.8 The need for realistic experiments conducted in the Äspö laboratory to study how copper and clay will behave in the final repository

The MiniCan experiment carried out at Äspö actually mainly focuses on what happens to the cast-iron cassette, should there be a hole in the copper canister. At the same time measurements are taken that can provide data on how copper behaves in the presence of clay in a final repository environment that has become oxygen-free. The problem is that this is not the focus of the study, and the results allow somewhat different interpretations.

An experimental packet removed from the MiniCan experiment in fall 2011 is now being analyzed. This makes it feasible to use this environment for experiments that specifically study the behavior of copper and clay in a final repository environment that becomes oxygen-free, including how quickly the environment becomes oxygen-free and through what mechanisms. In

SSNC/MKG's judgment, such experimentation, which must be allowed to take the time required to produce objective, comprehensive and independent findings, has to be undertaken and the results evaluated before the KBS application can be considered sufficiently complete to be assessed.

SSNC/MKG demand that the Applicant conduct an experiment in the Äspö laboratory that specifically focuses on how copper and clay behave in an oxygen-free final repository environment.

<u>*2.5.2.9 The need to remove and analyze the LOT S2 packet in the Äspö laboratory before the application can be assessed*</u>

One of the best experiments for studying how copper and clay behave in the final repository environment is the LOT project carried out in the Äspö laboratory. The Applicant's intention in the experiment is to study the behavior of clay, but there are pieces of copper that can be studied in each of the packets, and definitive data as to how copper behaves may be obtained by studying the surface of the copper pipe in the experiment – which, however, the Applicant has refrained from doing. There are three pairs of packets in the experiment; the intention was that the pairs would be retrieved and examined at different points in time. The experiment started with the deposition of all six packets in 2000. The pairs consisted of one packet at a higher temperature (A) and one packet at the temperature expected in the final repository (S). Pair no. 2 were to be retrieved after 5 years. Packet LOT A2 was taken out in early 2006; LOT S2 was to be taken out when the analysis of the A2 packet had been completed, which was expected to take roughly one year.

It is SSNC/MKG's understanding that when LOT A2 was retrieved, it was discovered that the rate of copper corrosion had been much higher than expected and that the clay had been damaged in an unexpected and irreversible way. Since the packet had been exposed to high temperatures, the temperature might explain the phenomena, yet it was not until late 2009 that the Applicant published a report of the findings. In that report the Applicant stated that the high rate of corrosion was most probably due to oxygen that had been trapped in the clay when it swelled. No more in-depth analysis of the corrosion phenomenon and its probable cause has been presented.

After the report on packet LOT A2 had been published, the Applicant decided not to retrieve the second packet, LOT S2, as originally planned. The packet has now been in the experimental environment at Äspö over ten years, more than twice as long as planned. According to the original plan the third pair of packets, LOT A3 and S3, were to have been retrieved and studied after ten years.

SSNC/MKG believe that many of the questions that arose after the retrieval of LOT A2 might be answered, were LOT S2 to be retrieved and analyzed with the genuine purpose of finding the answer to how copper and clay behave in a final repository environment. These data are needed for the purposes of assessing the application. Among other things, it may afford an understanding of how infiltrating copper from the corrosion of the copper pipe influences the clay. Furthermore, more extensive cross-sectional metallographic studies using, for example, an electron microscope must be carried out on the pipe surface to check for pitting – a measure the Applicant has consistently refrained from taking in any of the experiments performed at the Äspö laboratory.

SSNC/MKG urge the Applicant to retrieve and analyze the LOT S2 packet in the Äspö laboratory.

2.5.2.10 The need to know more about the effects of radiation on copper and clay in a final repository environment

Despite the fact that copper and clay will be exposed to radiation in the final repository for the first 1000 years, the Applicant has shown little interest in finding out how radiation affects the two materials.

Only a year or so ago, researchers at the KTH Royal Institute of Technology, acting on their own initiative, conducted an experiment in which they irradiated copper in an oxygen-free aqueous environment. They observed extensive corrosion of the copper. This contradicts the description offered by the Applicant in the application. The research team is now continuing their experiments, commissioned by the Applicant.

SSNC/MKG find it remarkable that the Applicant has not investigated how radiation affects copper in their own research program. The effects of irradiation, the factor that renders the KBS project unique, is obviously a question that should have been thoroughly penetrated early on in the project, not simultaneously with the application to build. We find this yet another example of how the Applicant has relied on theoretical assumptions without carrying out the necessary empirical work to verify or falsify them.

SSNC/MKG also urge the Applicant to partake of the research data produced by organizations in the USA and Russia, where the effect of radiation on copper has been studied in connection with space exploration and in nuclear-powered submarines. It is our understanding that copper is not to be recommended in environments where it is exposed to high levels of radiation.

SSNC/MKG demand that the application be supplemented with studies of copper corrosion in radioactive environments.

SSNC/MKG also urge the Applicant to produce supporting documentation that takes account of international findings concerning how copper behaves when exposed to high levels of radiation.

2.5.2.11 Stress corrosion of copper

SSNC/MKG have become aware of research results that indicate a risk of stress corrosion in copper caused by the presence of sulphur. It is our understanding that the Applicant is conducting studies on this subject. These studies must be completed and the data analyzed, reported and published before there is any basis for an assessment of the risk. In our view, there is also a need for additional studies to determine whether other elements besides sulphur may cause stress corrosion.

SSNC/MKG ask the Applicant to produce a basis for a determination of how the presence of sulphur can result in stress corrosion of copper.

SSNC/MKG ask the Applicant to undertake a study that identifies other elements that may induce stress corrosion.

2.5.2.12 Embrittlement of copper due to sulphur and hydrogen

SSNC/MKG find the Applicant's knowledge of how sulphur and hydrogen can induce embrittlement of copper to be grossly inadequate. The Applicant needs to conduct experiments to show the effects of sulphur and hydrogen on copper; the Applicant also needs to follow up, in a systematic manner, existing findings that show embrittlement in copper as a result of exposure to sulphur. Since copper corrosion in an oxygen-free environment appears to produce hydrogen, it follows that the Applicant needs to investigate how the corrosion process in an oxygen-free environment influences embrittlement of a canister that is electrochemically charged with hydrogen.

Research in Finland has found that substantial amounts of copper oxides are produced during friction welding of canister lids and bottom to the cylindrical casing. It is a well-known fact high copper oxide content in metallic copper induces hydrogen embrittlement. This issue needs to be investigated more thoroughly.

SSNC/MKG ask the Applicant to complement their application with a study of the phenomenon of embrittlement of copper due to exposure to sulphur and hydrogen.

SSNC/MKG ask the Applicant to study how the production of copper oxides during friction welding of the canister's parts influences its durability.

2.5.2.13 The combined effect of multiple embrittlement mechanisms on copper

To the extent that the Applicant at all has studied corrosion and embrittlement phenomena for copper, the mechanisms are treated singly, each on its own. In SSNC/MKG's view, the respective processes can interact, and it is therefore necessary to examine how they interact and take into consideration their combined and cumulative effects. This knowledge will improve the understanding of empirical results.

SSNC/MKG ask that the Applicant complement their application with a description of how various corrosion and embrittlement processes can interact and the cumulative effects that can arise.

2.5.2.14 The need to know more about creep ductility in copper

SSNC/MKG have become aware of a controversy within the scientific community as to the degree of creep ductility in the copper intended for use in the final repository.

SSNC/MKG ask that the Applicant complement their application with an analysis of creep ductility in the copper intended for use in the final repository.

2.5.2.15 The need to know more about the infiltration of hydrogen through clay

SSNC/MKG have noted that an important parameter for judging the effect of copper corrosion processes that produce hydrogen gas is how quickly hydrogen can infiltrate through bentonite clay. The question is important since hydrogen transport through compact clay can influence the rate of copper corrosion in an oxygen-free environment. The Applicant bases their assumptions of rates of infiltration on theoretical calculations. In our opinion, they should substantiate their assumptions through experiments.

SSNC/MKG ask that the Applicant complement their application with empirical data that describe the passage of hydrogen through bentonite clay.

2.5.2.16 The risk of corrosion due to leakage currents from underwater cables carrying direct current electricity

During the site inventory undertaken at Forsmark in 2005 leakage currents were detected in the bedrock. They are caused by the Fennoscan high voltage DC transmission line that runs from Forsmark to Finland. Leakage currents have been shown to cause considerable corrosion of stainless steel at exposures of as little as ten days. In our view, the Applicant should offer an objective and comprehensive description of how these currents, as an additional corrosive agent, may affect the copper canisters in the final repository.

SSNC/MKG demand that the Applicant undertake studies of leakage currents in the bedrock at Forsmark and the impact these currents may have on the copper canisters. These studies should be undertaken now, in the complementing phase of the project.

2.5.2.17 The lack of scenarios and environmental impact assessments for leakage before 1 000 years have elapsed

Having studied the Applicant's current documentation in support of the application, and in view of the above-listed phenomena, SSNC/MKG conclude that there is a risk that the final repository may suffer substantial leakage even before 1 000 years have elapsed. This risk means that there needs to be a description of different scenarios, with impact analyses, about what may happen if some – say, 25 per cent – of the canisters begin to leak before 500 years have elapsed and all the canisters leak after 1 000 years.

SSNC/MKG ask the Applicant to elaborate scenarios, with accompanying impact analyses, that describe what happens if some of the copper canisters start leaking within the first 1 000 years of the life of the repository.

2.5.3 The long-term safety of the KBS method (a 100 000-year perspective)

A final repository for nuclear fuel waste will have to keep its contents isolated from human beings and the environment for hundreds of thousands of years. Assuming that the clay buffer and copper canister in each deposition chamber attain ideal conditions – cf. section 2.5.2 above – the greatest stress the repository will face, and thus the greatest risk of leakage, may be expected in connection with repeated periods of massive glaciation ('ice ages') during the lifetime of the repository.

The amassing of glacial ice may give rise to powerful movements and earthquakes that can damage the repository structure. Secondly, the temperature in the surrounding bedrock may fall to the point that the clay buffer in the repository freezes, which can alter the clay. Finally, glaciation may imply radical changes in groundwater flows and the chemical composition of the groundwater itself, which, too, may have a negative impact on the man-made barriers.

2.5.3.1 The need for further analysis of the depths permafrost may reach during an ice age

In SSNC/MKG's view, one issue in particular that can be of great importance in the analysis of the long-term safety and the impact of the next ice age is if there is a risk that the repository reaches the freezing point. One possible cause of freezing is the permafrost that builds up during a glaciation cycle. The Applicant claims that models show that the temperature in the final repository will never fall below 0° C. Permafrost can never extend deeper than just over 250 m down, and the repository will be located at a depth of 450 m. Consequently, there is no risk of freezing.

SSNC/MKG have been given to understand that the Applicant's models may be faulty on this point. Other models show that permafrost may reach much deeper. Therefore, we have asked Professor emeritus Matti Saarnisto, formerly of the Geological Survey of Finland, to review the Applicant's work on this issue. The findings of that review are reported in annex 3.

Professor Saarnisto has examined the Applicant's data and compared the prognoses made in a broader scientific context about the depth of permafrost during ice ages. Contrary to the Applicant, he concludes that the temperature in a final repository at Forsmark can very well fall below the freezing point and that the repository may freeze, in which case clay in the buffer and sealing may lose its impermeability.

SSNC/MKG conclude that the Applicant needs to conduct new studies of the depths to which permafrost may be expected to extend.

SSNC/MKG ask that the Applicant complement their application with new calculations of the risk that permafrost can reach the depth of the repository during a glaciation cycle and assessments of the consequences.

2.5.3.2 Threats to the stability of the lens formation during an ice age

The Applicant plans to locate the repository within a geotectonic lens, despite the fact that the current tensions around the formation may change significantly in conjunction with future periods of glaciation and movements of tectonic plates. The Applicant states that the lens in question has survived repeated ice ages without having been influenced by them. Even if this is true, there is no assurance that it applies to the future, especially if the repository in itself may introduce a new indication of fracture, which under the influence of massive glaciation may cause the lens to crack. Such a scenario implies a total failure of the repository.

SSNC/MKG have raised this issue in the EIA consultations. In response the Applicant commissioned a study.[15] We are concerned, however, that the study may not have been conducted in an objective manner. The consultancy that was commissioned to perform the study works solely for the Applicant and would appear to be so closely linked to the Applicant that the independence of the study cannot be guaranteed.

SSNC/MKG have also been made aware of the presence of pore water in the granite at Forsmark that was introduced into the formation under considerably higher pressures than are attained in a simulation of Weichselian glaciation.[16] In our view, it is vitally important to gain an understanding of the conditions under which the pore water was pressed into the formation, and why the Applicant argues that testing the final repository under pressures of that magnitude has no relevance. If the water was pressed into the granite under the Saale[17], a more severe ice age than the Weichsel, then the Forsmark lens may be subject to far greater pressures in the future than the Applicant presumes. It follows, we argue, that if the next period of glaciation can be more severe than presumed, these more severe conditions need to be factored into the assessment of the likelihood that the repository will fail.

The possibility that the lens formation may crack recurs in section 2.8 on the Applicant's choice of site and description of alternative sites.

SSNC/MKG ask that the Applicant complement their application with analyses of the risk that the repository may constitute a indication of fracture in the Forsmark lens during a future ice age.

2.5.3.3 The need to know more about groundwater flows at great depths during a glaciation cycle

SSNC/MKG find that too little is known about how groundwater moves during periods of glaciation, especially at depths of under 1 000 m. The lack of knowledge has implications for modeling, for example, modeling of how groundwater of different chemical composition can affect the repository during ice ages, models of regional groundwater circulation, models relating to the possibility that an inland site might afford greater environmental safety even

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[15] SKB R-10-36 Assessment of a KBS-3 nuclear waste repository as a plane of weakness, M Lönnqvist, O Kristensson, B Fälth, Clay Technology, June 2010.

[16] The Weichselian period is the most recent period of glaciation in Scandiniavia and northwestern Europe.

[17] The Saale Glacial Stage, the last period of glaciation before the Weichsel, started about 300 000 years ago and consisted of three main phases. It was far more extensive than the Weichsel. Saale deposits are correlated with those of the Gipping Glacial Stage (a.k.a. Wolstonian) in Great Britain and the Riss in the Alps. The Saale coincided more or less with the Illinoian Glacial Stage in North America.

under glaciation and how groundwater displacement during glaciation can affect the alternative storage solution, deep boreholes.

SSNC/MKG have asked Professor Karl Inge Åhäll of Karlstad University to produce a paper on deep groundwater circulation and the chemical composition of groundwater at great depths. The study was initially commissioned in connection with the deep borehole alternative, but Professor Åhäll notes in the report that the Applicant seems to lack objective and comprehensive knowledge of deep groundwater. His report (in Swedish only) is appended as annex 4 to these comments.

SSNC/MKG find gaps in the Applicant's knowledge of groundwater circulation at great depths during an ice age; in our view such knowledge is needed as a foundation for several models.

SSNC/MKG ask that the Applicant complement their application with studies of groundwater circulation at great depths during an ice age and that the findings of these studies be used as a basis for modeling.

2.5.3.4 The magnitude of earthquakes that may be expected during an ice age

In the course of the EIA consultations it has become apparent that there is some controversy surrounding the magnitude of earthquakes that can take place in conjunction with glaciation and how these quakes may affect the final repository. SSNC/MKG find a need for objective and comprehensive studies of this issue.

SSNC/MKG ask that the Applicant complement their application with studies of the magnitudes of earthquakes that may be expected in conjunction with an ice age and how these earthquakes can affect the final repository.

2.5.3.5 Alternative glaciation scenarios

In their safety analysis, the Applicant offers a glaciation scenario based on the assumption that the next ice age will have the same characteristics as the most recent one, the Weichsel, which encompasses the last 120 000 years. But, only 20 000 years earlier there was a much more severe ice age, the Saale. In SSNC/MKG's view, the Applicant needs to carry out safety analyses with a glaciation scenario that may have more severe effects on the repository than the Applicant has envisioned to date.

We also find that the Applicant needs to undertake independent analyses of how warming of the planet in the long term may influence the incidence and severity of future ice ages, including the possibility that warming may trigger a period of glaciation much sooner than has been assumed to date.

SSNC/MKG ask that the Applicant carry out safety analyses using a glaciation scenario that might have a more severe impact on the final repository.

SSNC/MKG also ask the Applicant to produce estimates of how global warming can affect the incidence and severity of future ice ages, including the possibility that warming may trigger an ice age much earlier than has been assumed to date.

2.5.3.6 The comparison of nuclear fuel waste to natural uranium

In the EIS (page 36) the Applicant states that after 100 000 years the radioactivity in the nuclear fuel waste will have subsided to the level of activity in the amount of natural uranium used to manufacture the fuel. A diagram in the safety analysis, SR-Site (page 15 in the English version, page 17 in the Swedish) is offered as an illustration of the relationship. SSNC/MKG find the comparison and the diagram misleading. The Applicant compares the hazard posed by the nuclear fuel waste with the corresponding amount of natural uranium. In our opinion, the object of the comparison should be the corresponding amount of uranium ore as it occurs in nature in Sweden. That would demonstrate how dangerous the fuel waste in the repository is in relation to the most radioactive natural rock in Sweden – in terms of radon, for example.

SSNC/MKG ask the Applicant to compare the hazard posed by nuclear fuel waste over time, not with a like amount of natural uranium, but with a like amount of Swedish rock that has the richest uranium ore content.

2.6 Alternative designs and the 'zero alternative'

In this chapter SSNC/MKG comment on the Applicant's treatment of alternative technology/designs/methods for the final repository, and the complements to the application that we find necessary.

Among the specifications pertaining to the environmental impact statement (EIS) in Swedish law is the requirement that alternative designs be presented. The presentation of alternatives must contain enough information to permit a comparison of the alternatives' and the proposed solution's environmental impacts. Argumentation in support of the chosen alternative must always be offered (prop. 1997/98:45 pt 2 p 63). The Supreme Court has ruled that it is important that the Applicant not be unwilling to consider alternatives to the solution they propose and that the material be presented in such a way that other interested parties and, ultimately, the court that is charged to examine the application has a basis on which to make their own assessment (NJA 2009 p 321). As a consequence, the treatment of alternatives – sites as well as designs – is commonly expected to be comprehensive and objective. The EIS must also be formulated in such a way that persons who lack the Applicant's prior knowledge and expertise can use it to reach an informed decision.

The Act on Nuclear Activities states that holders of licenses to own and operate a nuclear power reactor shall undertake an R&D program to devise appropriate solutions for the handling and final storage of nuclear waste or nuclear materials that the operations produce. The obligation includes a responsibility to study alternative designs and technologies for storing the waste. Responsibility for this research has been assigned to SKB AB.

The final storage solution using deep boreholes is to be considered an alternative design (and not a 'similar way of achieving the same purpose' mentioned in chap. 6 sect 7 third para.) to the proposed KBS-3 method. This conclusion is supported by the example of 'similar ways' offered in the legislative history of the Act (prop. 1997/98:45 pt 2 p 64), viz. air transport vs. a railroad, or a hydroelectric vs. a gas-fired turbine. Although deep boreholes do involve some technology that differs from that called for in the KBS-3 method, the differences are hardly of the same dignity. Both solutions involve isolation in bedrock at considerable depths, based on the proposition that geological deposition will hinder the diffusion of radioactive substances. Thus, the provision in chap 6 sect 7 of the Environmental Code implies an obligation on the part of the Applicant to study and evaluate alternative storage methods such as deep boreholes. The conclusion is also supported by a determination made by the County Administrative Board, County of Uppsala, on 31st January 2006 (dnr 559-11339-05), that of the alternative solutions, only transmutation is to be considered a 'similar way of achieving the same purpose'.

The principle of 'best available technology' and the specifications for the EIS mean that the study of the alternative technology/designs/methods for final storage of nuclear fuel waste as well as the presentation and analysis of them have to be in-depth and comprehensive in scope. This is supported by the above-mentioned determination of the County Administrative Board in Uppsala County as well as a statement of 4th April 2005 (dnr 559-10719-04), where the Board pointed to the need for reporting and evaluation of all possible methods that had been brought up in the EIA consultations and/or considered in the Applicant's RD&D reports.

It is important to bear in mind that the assessment of nuclear waste storage project is unique inasmuch as it is about finding a long-term solution that is acceptable to many different actors to a problem that is intimately linked to several decades of Swedish industrial and energy policy. The project is a national undertaking of the highest dignity, and all who take part in the assessment should therefore feel duty-bound to identify and implement a solution that fulfills the national goal of sustainable development. Therefore, the KBS method as outlined in the Application has to be considered in a broader perspective. Only then can one hope to identify the long-term solution that best meets the challenges that nuclear fuel waste implies.

To be able to compare the KBS method for which the Applicant seeks a permit with alternative designs, the alternatives need to be explored in a both comprehensive and objective manner. Should any alternative appear to afford a higher degree of long-term safety or some other advantage, in SSNC/MKG's view, it merits further study. Given that the Applicant according to Swedish law bears sole responsibility for such studies and is the only actor that has the resources to carry them out, it is the Applicant's duty to see to it that alternative methods are given proper treatment.

From the 1980s and forward, participants in the EIA consultations and other consultation-like discussions have commented on the Applicant's treatment of alternative methods. That is, 'alternative designs' have long been brought up by authorities and others, who have reminded the Applicant of their responsibility to study, analyze and report on all the solutions for a final repository that have been brought up over the years.

In their application the Applicant state that there are no alternative ways to fulfill the task of handling and storing nuclear fuel waste in a safe manner, because the alternative designs brought up by others either do not correspond to the Applicant's formulation of the purpose of the final repository or are "not available". Therefore, the Applicant terms these alternatives "other methods". It is not, however, the Applicant's prerogative to make such a new categorization. The methods the Applicant calls "other methods" should in the application and the EIS rightly be considered alternative methods in the current environmental juridical sense, in other words, "alternative designs" and thus be eligible for evaluation in the assessment of "best possible technology" (BAT).

The fact is: no available technology for final storage of nuclear fuel waste exists. The KBS system itself is no more than a concept. Only if the KBS method had been applied in a final storage system somewhere in the world and then been closed and sealed might one consider it 'available' in any industrial sense.

The KBS method is based on the premise that man-made barriers of copper and clay shall guarantee the long-term safety of the repository. This engineering-oriented premise is typical of Sweden of the 1970s. Other countries that have developed systems for final storage of nuclear fuel waste have chosen concepts based on natural, rather than man-made, barriers. Geological clay and salt formations or arid desert environments are relied on to assure long-term safety.

To anyone who has followed the Applicant's work on this project, it is quite clear that the KBS method, and the KBS method alone, has been in focus. The applicant has given other alternatives very little attention. Over the years the applicant has also been asked to look into issues which, had they been studied, might have revealed some of the shortcomings the KBS method suffers today.

Furthermore, the objectivity of the studies that nonetheless have been done – often in response to urgings on the part of the regulator or the Government – may be questioned. For example, several of the studies commissioned by the Applicant have mentioned geological deposition in deep boreholes as an interesting alternative to the KBS system. Still, the Applicant has refrained from studying deep boreholes. For this reason the Applicant cannot be said to have fulfilled the requirement of studying alternative designs. We shall return to the treatment of the deep boreholes alternative in section 2.6.2.

In a table presented in both the EIS[18] (page 40 of the English version) and the annex on choice of methods (page 20 of the Swedish edition), the Applicant offers a typology of methods described under the heading, "Other methods for geological disposal". The typology is the result of what the Applicant calls "an evaluation of strategies and systems for disposing of nuclear fuel waste". The table lists the three methods involving geological deposition that the Applicant has considered. In SSNC/MKG's estimation it would be more appropriate to refer to the methods as "alternative designs for geological deposition".

Of the three alternative geological strategies (alternative to KBS-3), the deep borehole alternative differs from KBS, long tunnels and WP-Cave in one principal respect. The deep boreholes strategy envisions storage at much deeper levels. The greater depth implies major differences in the chemical composition of groundwater, which in turn influences long-term safety because groundwater at great depths is inhibited from moving upwards. Furthermore, the great depth affects the feasibility of retrieving the fuel waste after sealing, which in turn reduces the need to keep the contents of the

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18 Environmental Impact Statement. Interim storage, encapsulation and final disposal of spent nuclear fuel. SKB 2011, page 40.
The table may be accessed at http://www.mkg.se/mkb-miljokonsekvensbeskrivning.

repository under surveillance (safeguards). In the methods annex[19], page 36, the Applicant points out that the deep boreholes alternative “differs fundamentally” from the other methods, but discusses neither natural barriers nor the issue of retrievability/need for surveillance. None of these issues is addressed in the EIS.

Different scenarios of future energy use affect the respective alternative designs differently. One important question is whether the global energy supply system will include nuclear energy in the long term. The answer to this question has implications for whether nuclear fuel waste should perhaps be regarded as a resource since the plutonium in the fuel waste might in the distant future be used to fuel reactors. There would still be a need for a final repository, but the volume of waste and the length of time it poses an environmental hazard will depend on the extent to which future nuclear energy technology makes use of transmutation.

In one sub-scenario one might posit that Sweden chooses to abandon nuclear energy, but other countries to continue to use the technology. In that case foreign countries may want to import Swedish fuel waste in order to use the energy in the plutonium in it. This would make a final repository in Sweden superfluous, since the importing country would most likely assume responsibility for the waste from reprocessing. SSNC/MKG urge the Applicant to complement their application with a variety of scenarios of future energy supply – in Sweden, Europe and globally – with an analysis of the implications each scenario has for a final repository.

We also urge the Applicant to study and describe how final storage of high-level nuclear waste and nuclear fuel waste in clay formations works – a method planned for use in France and Switzerland – and to assess the feasibility of using this alternative form of geological deposition in southern Sweden.

It is also important that the ‘summary assessment’ of alternative designs for geological deposition presented in the above-mentioned table be updated to include the knowledge that will be generated in the complementing phase relating to the KBS method and the alternative design of geological deposition in deep boreholes.

SSNC/MKG demand that the Applicant treat the deep borehole method as an alternative design for the final repository and that this status shall be made clear in both the application and supporting documents through the

[19] Metodval – utvärdering av strategier och system för att ta hand om använt kärnbränsle [Choice of methods– evaluation of strategies and systems for the management of nuclear fuel waste], October 2010 (In Swedish only).

identification of both the KBS method and deep boreholes as alternative designs for geological deposition.

SSNC/MKG demand that the Applicant complement their application with thorough studies of alternative designs, and especially the deep borehole alternative, so as to permit a comprehensive and objective presentation of the alternatives in the EIS, thus making it possible to evaluate alternative methods on a par with the KBS method.

SSNC/MKG demand that the Applicant complement their application with national, European and global energy supply scenarios. The scenarios are needed to inform an evaluation of the ability of the alternative designs to serve the purposes that the respective scenarios imply.

SSNC/MKG ask that the Applicant describe final storage in clay formations as an alternative design for geological deposition and evaluate the feasibility of using the method in southern Sweden.

2.6.2 Gaps in the Applicant's treatment of deep boreholes as an alternative design for geological deposition

A final repository in deep boreholes has been discussed as a possible alternative to the KBS method since the late 1980s. Both are methods for final storage in geological formations. The methods differ, however, in three principal respects: first, the KBS method calls for a repository depth of 400–800 m, whereas deep boreholes envision deposition at depths of 3 000–5 000 m. Second, the KBS method relies principally on man-made barriers to assure the long-term environmental safety of the repository, whereas the deep borehole alternative relies primarily on the function of natural barriers. Third, the feasibility of retrieving the contents of the repository after closure and sealing is significantly greater in the case of the KBS method than in the case of deep boreholes, which implies the need for long-term safeguards in the case of the KBS system, but not the deep borehole alternative.

Ever since the late 1980s, the Government, regulatory agencies and others have repeatedly called upon the Applicant to carry out a comprehensive research program for final storage of nuclear fuel waste that includes a thorough discussion of alternative methods. Deep boreholes were considered the most promising alternative among methods involving geological deposition as early as the late 1980s. In their response to the Applicant's R&DD report in 1992, SSNC pointed out that there was good reason to investigate deep boreholes as an alternative. And, in its statement on the R&DD report for 2007, the Government instructed the Applicant to include studies of alternative methods, and particularly the deep borehole alternative, in its research program. All these years, the Applicant has done as little as possible to study alternatives to the KBS method. In conjunction with the R&DD report of 1992 the Applicant carried out the PASS study, the apparent purpose of which was to dismiss the alternatives that had been proposed at that point, including deep boreholes.

Because the Government and various authorities have repeatedly asked for studies of the alternatives, the Applicant has from time to time published reports on them. In some cases the studies have resulted in positive assessments of the long-term environmental safety of deep boreholes, but in its summary reports the Applicant has instead stressed the disadvantages of the method. While the Applicant in our estimation has shirked its responsibility to study the alternatives in a comprehensive and objective manner, deep borehole technology has made significant advances.

In the USA, for example, several studies were undertaken in the 1990s to explore the feasibility of using deep boreholes for final storage of surplus plutonium from dismantled nuclear weapons. The results of the study were positive, particularly with respect to the difficulty of retrieving the plutonium in the long term, but when a decision was taken to process the plutonium so that it more resembled nuclear fuel waste – either by using it to manufacture MOX fuel or through anti-enrichment – interest in the deep borehole alternative cooled. The processed plutonium could instead be stored in the planned repository for high-level nuclear waste at Yucca Mountain in the Nevada desert. When the Obama administration abandoned the plans for Yucca Mountain in 2010, interest in deep boreholes revived. High-level studies are currently under way under the auspices of the Sandia National Laboratories. The 'Blue Ribbon Commission' appointed by President Obama to study the possibilities to move forward with a final repository for high-level waste recommended the following "short-term action":

"DOE should develop an RD&D plan and roadmap for taking the borehole disposal concept to the point of a licensed demonstration."[20]

Further progress in the development of the method in the USA will depend on political, administrative and budgetary decisions taken in the U.S. Department of Energy.

Two other developments should have spurred the Applicant's interest in studying the deep borehole alternative. First, toward the end of the 1990s,

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[20] Blue Ribbon Commission on America's Nuclear Future. *Report to the Secretary of Energy,* January 2012, p 118.
http://cybercemetery.unt.edu/archive/brc/20120620220235/http://brc.gov/sites/default/files/documents/brc_finalreport_jan2012.pdf
'DOE' stands for Department of Energy, the agency responsible for research on nuclear waste management in the USA. 'RD&D' stands for Research, Development and Demonstration.

there was confirmation of the stability of layers of saline groundwater at great depths. As salinity increases with depth, the stability of these layers may be relied on as a ‘barrier’ that enhances long-term safety. Secondly, advances in drilling technology have made drilling to great depths much more reliable. Routines for lowering equipment into deep boreholes and retrieving it from great depths have also been developed.

SSNC/MKG find the Applicant’s description of the deep borehole alternative in the application both sketchy and out-of-date. We draw this conclusion after our own analysis and on the basis of two statements we solicited from Professor Karl Inge Åhäll of Karlstad University, Sweden, and Professor emeritus Fergus Gibb at Sheffield University, England, respectively. Their statements are attached to this document as annexes 4 and 5.

The critical comments in these statements underline the need for complements to the application and supporting documents with respect to the deep borehole alternative. It would appear that the Applicant has not kept abreast of developments since 1992, when the PASS study was carried out. As a consequence, the account offered in the application does not provide a proper basis for any comparison of the deep borehole method and the KBS method.

2.6.2.1 The need of a comprehensive and objective description and analysis of the deep borehole method

Any objective comparison of the two alternatives for final storage through geological deposition, i.e., the KBS method and the deep borehole method, requires a comprehensive and objective description of both methods. The assessment of the two methods has to be based on current scientific knowledge. SSNC/MKG find it important that the Applicant use the best expertise in the field to draw up the basis for comparison. Thereafter, the application will need to be revised to take account of the new information that is gathered.

SSNC/MKG demand that the Applicant complement their application with a comprehensive and objective treatment of the deep borehole alternative, and that the new information be incorporated into the application.

2.6.2.2 The need to revisit the Applicant’s estimate of the cost of implementing the deep borehole method

Of decisive importance in any assessment of the final repository is its long-term environmental safety and the assurance it offers that the contents will not burden future generations. In order to be able to compare the alternative designs, the KBS method and the deep borehole method, it is also important to take account of the cost of implementing each. The cost estimate for deep boreholes noted in the application is neither objective nor founded in the best current knowledge. The Applicant needs to recalculate the costs.

SSNC/MKG demand that the Applicant draw up a new estimate of the costs of implementing the deep borehole method.

2.6.3 The need for a higher level of ambition regarding the 'zero alternative'

The 'zero alternative', i.e., the account of the environmental impact and likely scenario if the final repository is *not* constructed, in the Applicant's EIS displays a very low level of ambition. The Applicant considers only continued wet intermediate storage of the accumulated fuel waste and continued deposition of future waste in the Clab facility at Oskarshamn. In the Applicant's judgment, the nuclear fuel waste can lie in the pools at Clab without implying any environmental hazard, and the capacity of the Clab facility will accommodate waste deposition for a considerable time to come.

In SSNC/MKB's assessment it is far from certain that continued storage in Clab is the best solution, should the final repository not be constructed. The events at Fukushima in Japan show that storage of fuel waste in pools, as is the case at Clab, can pose a hazard. The intermediate storage facility requires continuous active cooling, and the possibility that such cooling can fail cannot be excluded.

Over the past twenty years, technology for dry storage of nuclear fuel waste has been developed, and dry storage is used on a large scale in many parts of the world today. In the case of dry storage, the fuel waste is put into containers that are cooled passively by the circulation of air around the container. The nuclear fuel waste cannot heat up so that a risk of releases of radioactivity to the environment arises – as can happen in the case of wet storage.

In SSNC/MKG's estimation dry storage is the best possible technology for intermediate storage of nuclear fuel waste today. We therefore urge the Applicant to study the feasibility of converting to dry storage and to include the alternative in their discussion of the 'zero alternative'.

SSNC/MKG ask the Applicant to complement their application with an evaluation of other, safer technical solutions for intermediate storage of nuclear fuel waste. In their discussion of the 'zero alternative' the applicant should describe how a transition to dry intermediate storage might be undertaken.

2.7 Gaps in knowledge of the chemical composition of groundwater and groundwater flows at great depths

The documents supporting the application give no indication that either groundwater chemistry or flows have been studied at greater depths than about 1 000 m. SSNC/MKG consider it necessary to have a grasp of both the chemical composition of groundwater and groundwater flows down to depths of 2 000–4 000 m. We have commissioned Professor Karl Inge Åhäll, Karlstad University, to write on this subject; see annex 4.

SSNC/MKG find this knowledge important in order to be able to assess the long-term environmental safety and siting choices for deposition in deep boreholes as an alternative design, see section 2.6.2 above. The knowledge is also needed to assess the long-term environmental safety of the KBS method during periods of glaciation, see section 2.5.3.3. And it is of key importance to assessments as to whether a coastal or an inland siting of a KBS repository affords the greatest environmental safety in the long term, see section 2.8.5 below.

The Applicant has not sought this knowledge, despite the fact that the company's modeling clearly requires it, and despite their responsibility to conduct a comprehensive research program. The Applicant's assumptions about groundwater conditions at great depths are poorly founded and have varied over time. Still, no studies have been undertaken to correct this situation.

Since this knowledge also is of more general scientific interest, the Swedish scientific community started the Swedish Deep Drilling Project, SDDP, in 2007 to study Swedish bedrock and groundwater conditions at great depths (http://www.sddp.se). The Applicant has shown surprisingly little interest in the project, considering the contribution it might make to the research program for the final repository project. SDDP has purchased drilling equipment that permits drilling to a depth of 2 500 m.

SSNC/MKG find that the Applicant should, in this complementing phase, carry out research to gain a better understanding of groundwater conditions at great depths, to fill the needs outlined above. Collaboration with SDDP might facilitate such a research program and possibly fill the gaps in knowledge evident in the application that we have pointed to here.

SSNC/MKG demand that the Applicant complement their application with findings from a research program that investigates groundwater conditions at great depths. The new knowledge should be used to fill the knowledge gaps indicated in the foregoing.

2.8 The siting process and the discussion of alternative sites

2.8.1 General comments on the treatment of alternative sites

Assessments under chapter 2 section 6 first paragraph of the Environmental Code shall include a determination as to whether the proposed site is appropriate for the purpose in question and whether the activity can be carried out there with the least possible impact on human health and the environment. Accordingly, the Environmental Code requires that an EIS contain consideration of alternative sites, if such exist. In order to be able to compare the proposed site with the alternatives, the alternative sites need to be described in such detail as permits an evaluation of their environmental impact, as well. The applicant shall always offer a rationale for their choice of site (prop. 1997/98:45 pt 2 p 63).

According to common praxis the EIS should at the minimum identify the possible alternatives and explain why they were not explored more fully (NJA 2009 p 321 p 337).
Normally, a comparison of the different alternatives presumes that the Applicant describes the alternative sites, giving enough information to allow an assessment of their likely environmental impact and economic consequences (MMÖD 2012:5). Praxis also indicates that the Applicant's siting report should be particularly detailed when the proposed siting is controversial (MÖD 2009:48).

In view of the hazards associated with a final repository for nuclear fuel waste in both the long and short term, the arguments in support of the chosen site's prospective safety should be subject to the most exacting requirements. SSNC/MKG find the account of siting considerations in the application entirely too limited, nor is it clear that long-term safety played any role in the siting process.

Criticism of the siting process has been raised during the EIA consultations. In particular, the need to analyze inland sites has been brought up. SSNC/MKG find no satisfactory response to the views put forward in the consultations in either the application or the supporting documents.

SSNC/MKG attach great importance to both breadth and depth in the siting process as a guarantee that the site chosen is most appropriate for the purpose. In this regard, questions may be raised as to how the siting process has been conducted and whether it has been guided by clear and relevant criteria. Therefore, we find it of importance that the Applicant discuss the factors taken into consideration during the process in greater detail in the application.

In the following section, we set out our demands regarding complements to the application with respect to the siting process and descriptions of alternative sites for the final repository. First, to provide context for the demands we make, we offer a few words about the process that preceded the choice of the proposed site.

The work to find a site for the final repository got started under strong political pressure in the late 1970s. The pressure was related to an act of Parliament (the so-called Conditional Act; SFS 1977:140) that barred bringing the last phase of the Swedish nuclear park on line unless totally safe bedrock could be located in Sweden. In early days, the emphasis was on the bedrock rather than man-made barriers. The rock should have very few fissures so as to retard the diffusion of radioactive substances. In the 1980s the search focused on 'solid rock'.

In the mid-1980s the initial siting process was broken off; now the guiding principle was the willingness of municipalities to host a final repository. At the same time, the Applicant reduced their emphasis on the quality of the bedrock as a factor for long-term environmental safety. In the early 1990s, the theoretical (model-based) safety analyses developed in the SKB 91 project were interpreted to show that the man-made barriers would isolate the fuel waste in just about any granite. Ultimately, the subsequent siting process settled on the bedrock at Forsmark.

In SSNC/MKG's view, voluntarism and local public acceptance is an important factor in choosing a site. But, we note that as late as the mid-2000s a municipality in the interior, Hultsfred (adjacent to Oskarshamn in the County of Kalmar) declared its willingness to host the repository. The Applicant rejected an inland site, despite the admonishment of the Reactor Safety Inspectorate in 2001 that Hultsfred should continue to be considered a candidate until outstanding questions concerning regional groundwater flows and the salinity of deep groundwater had been answered.[21] At the same juncture the Swedish Radiation Protection Authority expressed the view that the site's ability to maintain the long-term environmental safety of the repository should be in focus when assessing the suitability of the site.[22]

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[21] Comments on SKB's supplement to the RD&D report 1998 (FUD-program 98), SKI report 01:20, Swedish Reactor Safety Inspectorate, June 2001.
The Inspectorate (SKI) and the Swedish Radiation Protection Authority were fused to form the Swedish Radiation Safety Authority in 2010.

[22] SSI:s examination of SKB's supplement to the RD&D report 1998, SSI report 2001:12, Swedish Radiation Protection Authority, May 2001.
The Authority (SSI) and the Reactor Safety Inspectorate were fused to form the Swedish Radiation Safety Authority in 2010.

2.8.2 A lack of criteria relating to the long-term function of the man-made barriers of clay and copper

SSNC/MKG have followed the process the Applicant has used to choose the site for the final repository for many years. The original ambition was to find “the best bedrock” in Sweden. Initially, the bedrock was considered more important than the man-made barriers. Suitable bedrock should have relatively few fractures in order to delay the diffusion of radioactive substances. The criteria for the characteristics of the bedrock were therefore crucial to the future of nuclear energy in Sweden, since identifying a place for the safe final storage of high-level nuclear waste was, as noted above, an absolute precondition for continued expansion of the nuclear program.

Starting in the mid-1970s and continuing more than a decade thereafter, the Applicant searched for the ‘best bedrock’, which in practice meant rock having the fewest fractures or fissures. With time, however, test drilling operations met with increasing popular resistance. After the Government’s urging, the Applicant shifted over to a process based on voluntary acceptance. Having failed to carry out site studies in the municipalities of Malå and Storuman in the north of Sweden, the Applicant chose to focus on municipalities that hosted, or were close to, nuclear power plants. Ultimately, the number of candidates narrowed to two: Oskarshamn and Östhammar. Sites directly adjoining the nuclear power plants in Oskarshamn and Forsmark were inventoried.

Considering that the original focus rested on the ‘best bedrock’ to assure maximum long-term safety, it is strange indeed that the choice fell on a site immediately south of the Forsmark plant. The main problem is that the Applicant has not considered the bedrock’s ability to provide optimal conditions for the function of the man-made barriers, clay and copper. As to its ability to provide ‘ideal conditions’ for the function of the barriers, the bedrock at Forsmark is very poor.

What caused the original criteria referring to the solidity of the bedrock to be downgraded was a determination based on the first theoretical safety analyses that were made in the early 1990s. The analyses were interpreted to show that the man-made barriers would function in just about any bedrock. As stated in the introduction to the summary of the safety report, *SKB 91* (p. i): “The assessment shows that the encapsulated fuel will, in all likelihood, be kept isolated from the groundwater for millions of years. This is considerably longer than the more than 100 000 years that are required in order for the toxicity of the waste to have declined to a level equivalent to that of rich uranium ores.

However, in order to be able to study the role of the rock as a barrier to the dispersal of radioactive materials, calculations have been carried out under the assumption that waste canisters leak. The results show that the safety of a carefully designed repository is only affected to a small extent by the ability of the rock to retain the escaping radionuclides. The primary role of the rock is to provide stable mechanical and chemical conditions in the repository over a long period of time so that the function of the engineered barriers is not jeopardized."

Thus, the Applicant shifts the emphasis from the bedrock to the man-made barriers. This change simplified the siting process.

Unfortunately, the Applicant never formulated criteria that related to the ability of the rock to produce groundwater conditions – either the water's chemistry or flows – that would be optimal for the most important guarantor of long-term environmental safety, namely, properly functioning man-made barriers. That is to say, the factors that assure that the barriers attain 'ideal conditions' (described in section 2.5.2 above) within the first 1 000 years.

Over the years, the Government, authorities and participants in the EIA process have urged the Applicant to formulate criteria for the choice of site. Such criteria have been produced from time to time, but the criteria have not focused on the factors that assure the function of the man-made barriers of copper and clay. On occasion criteria for the chemical composition of groundwater have been noted with respect to copper corrosion, but as far as SSNC/MKG have been able to determine, there have been no criteria whatsoever that relate to the performance of the clay – factors like groundwater flows in the deposition chambers. The safety analysis should have a strong focus on the conditions needed for the clay to swell and fill the chambers, i.e. attain 'ideal conditions' (see 2.5.2 above). The existence of an impermeable clay buffer has become even more important in recent years, the more is known about the risk of corrosion of the copper canisters.

That the Applicant instead downplays the importance of the bedrock and groundwater to the proper function of the man-made barriers is puzzling. In safety reports and siting documents alike they have suggested that the character of the bedrock and groundwater conditions are of little importance in the choice of rock. In, for example, *SR-97,* a safety report published in 1999, the Applicant writes (pt. 1, p. 17):

"The three analyzed sites reflect reasonable variations of the conditions in granitic bedrock in Sweden. The analysis does not provide support for attaching any significant importance to differences in long-term safety between sites in a weighing together of all the factors that influence the siting of a deep repository."

At the same time, an important conclusion is stated only a few lines later (pt. 1, p. 17):

"The results of the assessment also serve as a basis for formulating requirements and preferences regarding the bedrock in site investigations, for designing a programme for site investigations, for formulating functional requirements on the repository's barriers, and for prioritization of research."

Yet no specific criteria to assure the proper function of the man-made barriers are set out in the RD&D document supporting the choice of Forsmark and Oskarshamn for further site investigation, published in 2000.[23] As a consequence, factors of lesser importance to the long-term safety of the repository have come to guide the siting process.

One reason why the Applicant has neglected to formulate siting criteria that relate to the function of the man-made barriers is that the two latest safety reports, *SR-Can* (2006) and *SR-Site* (2011), the latter of which accompanies the application, simply express the Applicant's firm conviction that the clay will swell to fill all the chambers with an impermeable mass, irrespective of groundwater flows into the chambers. This will hold true, even if it may take up to 1 000 years before the process is complete. Similarly, the Applicant assigns less importance to the possibility that groundwater may contain corrosive agents, inasmuch as the clay will have formed an impermeable protective barrier around the canisters. The presumption that the barriers will attain 'ideal conditions' virtually irrespective of the characteristics of the rock has led the Applicant to conclude that the site may be chosen without applying criteria for the conditions that have to be in place so that the barriers can attain those ideal conditions.

In the discussion of the choice between Forsmark (Östhammar) and Laxemar (Oskarshamn), the prime difference with respect to the long-term safety of two sites that is noted in the report is the average distance between water-bearing cracks in the bedrock. This is a throwback to the discussion carried on in the 1970s. Any assessment of long-term safety in connection with siting requires an analysis that has the requirements of the man-made barriers in focus. And, last but not least specific criteria for both bedrock and groundwater.

Another thing that SSNC/MKG find remarkable is the choice of Forsmark, despite the fact that it lies in a major deformation zone, a geotectonic shear zone. Several such zones cross Swedish territory, as is clearly indicated in figure 3.9 in the EIS (p. 49 in the English version). These zones are annotated

[23] Samlad redovisning av metod, platsval och program inför platsundersökningsskedet [Integrated report on method, siting and R&D program for the site inventory phase], Svensk Kärnbränslehantering AB, December 2000. The document is generally referred to as "Fud-K".

on the map as having “probably unsuitable bedrock”. The reason why is that the zones are presumed to be more prone to earthquakes, etc., in periods of glaciation, perhaps even more generally. SSNC/MKG cannot understand why the Applicant nonetheless has chosen a site in a geotectonic shear zone, particularly when there were early indications that the zones should be avoided.

SSNC/MKG demand that the Applicant complement their application with specific criteria relating to the bedrock conditions, groundwater flows and groundwater chemistry that are necessary in order for the man-made barrier to attain ‘ideal conditions’. This demand is related to the demands expressed in section 2.5.2 on the short-term (1 000 years) environmental safety of the KBS method, that call upon the Applicant to gain better knowledge of the behavior of copper and bentonite clay in the final repository environment. The choice of site must then be made on the basis of these criteria.

SSNC/MKG demand that the Applicant complement their application with an explanation of how the choice of a site in a deformation zone (a tectonic shear zone) conforms to criteria of suitability for the siting of a final repository and early advice that such locations should be avoided.

<u>2.8.3 The need of a safety analysis for both Forsmark and Laxemar</u>

A safety analysis for Forsmark is attached to the application, but there is no corresponding information on the Laxemar site. In order to be able to make an independent assessment of the choice of Forsmark one needs access to complete data on both sites. A new safety analysis for Laxemar must – as must a revised safety analysis for Forsmark – take account of all the knowledge that comes to light during the complementing phase.

SSNC/MKG demand that the Applicant, within the scope of the complementing phase, complement their application with complete safety analyses for both Forsmark and Laxemar, so that all the additional information that is generated during the complementing phase may be incorporated into the analyses. Only when this has been done can the two analyses be used as a basis for judging the choice of site.

<u>2.8.4 The need for a new and independent evaluation of the implications of an inland site for long-term environmental safety</u>

The question of how regional groundwater flows influence the long-term environmental safety of a KBS repository was raised as early as the mid-1990s. The proposition is that localization of a final repository in an area characterized by influx of groundwater deep in the bedrock might imply that possible leakage from the repository would have to travel a longer distance, and take longer, before it reaches an outflow that leads to the biosphere, i.e., to human beings and the environment. The so-called ‘breakthrough time’ at a coastal location is relatively short. In the EIA consultations the Applicant estimated it to be on the order of 50–100 years. Modeling of an inland location has indicated considerably longer times, up to 50 000 years or more.

The Applicant has consistently rejected this question as irrelevant to the long-term environmental safety of a final repository. But even after the siting process narrowed to focus on the nuclear installations at Forsmark and Oskarshamn for full site inventories in the early 2000s, the Municipality of Hultsfred (inland from Oskarshamn) – which had declared itself willing to accept a full-scale site inventory – was considered interesting because an inland location might be presumed to offer longer breakthrough times. An inland location in northern Uppland (near Forsmark) was also looked upon as interesting for the same reason. Especially the Swedish Radiation Protection Authority attached importance to this aspect and in 2004-2005 the Authority urged the Applicant to explore it.

In hopes of being rid of the question once and for all, the Applicant commissioned two studies, one in 2006 and a follow-up, made public only in conjunction with the submission of the application, with a comprehensive model of groundwater flows in eastern Småland [eastern/coastal County of Kalmar].[24] The Radiation Protection Authority and the Reactor Safety Inspection criticized the first study for not using the data assembled to draw conclusions regarding possible advantages of an inland site, which the data would have supported.[25] Instead, the discussion in the report tried to give the impression that no conclusions about the advantages or disadvantages of any given prospective site could be drawn. The authorities advised the Applicant to revisit the subject and submit another report prior to or simultaneous with the application.

In the second report in 2010 the models had been made more complex, but the authors reached the same result: no conclusions could be drawn.

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[24] Lars O Ericsson, Lars O Ericsson Consulting AB; Johan Holmén, Golder Associates; Ingvar Rhén, Niklas Blomqvist, SWECO VIAK.Storregional grundvattenmodellering – fördjupad analys av flödesförhållanden i östra Småland: Jämförelse av olika konceptuella beskrivningar [Models of regional groundwater flows – a closer analysis of groundwater conditions in eastern Småland]. SKB R-06-64 , maj 2006.

Lars O Ericsson, Lars O Ericsson Consulting AB; Johan Holmén, Golder Associates. Storregional grundvattenmodellering –en känslighetsstudie av några utvalda konceptuella beskrivningar och förenklingar [Models of regional groundwater flows – a sensitivity analysis of selected conceptual descriptions and simplifications]. SKB R 10-43, december 2010

[25] SKI:s and SSI:s gemensamma bedömningar från granskningen av SKB:s redovisning av storregional grundvattenmodell för östra Småland [SSI and SKI joint assessment of SKB’s report on models of regional groundwater flows in eastern Småland]. Joint letter [to SKB AB] within the framework of EIA consultations in the site inventory phase, 2007-10-22, SKI dnr 2007/598, SSI dnr 2007/1562/26, Swedish Reactor Safety Inspectorate and Swedish Radiation Protection Authority.

SSNC/MKG find that the Applicant used considerable resources to explore the question, but did so in such a way that it clouded the issue rather than clarify it. It is easier for a complicated model to 'lift off' from reality and produce equivocal results than it is for a more straightforward and tightly focused one.

The role of regional groundwater flows in relation to long-term environmental safety is too important to be handled the way the Applicant has done, and the situation demands a more independent analysis of the issue. Such an analysis should also incorporate an improved understanding of groundwater flows at great depths (cf. SSNC/MKG's demands in section 2.7). Among other things, the models need to take account of findings concerning density-based layering of groundwater, which indicate that water in the upper zone cannot easily be displaced by the denser water at greater depth.

SSNC/MKG demand that the Applicant complement their application with a new analysis of regional groundwater flows in both eastern Småland [County of Kalmar] *and northern Uppland* [County of Uppsala] *and of the importance of the flows to long-term safety. This analysis shall be undertaken and completed during the complementing phase.*

2.8.5 The need for more knowledge about groundwater salinity at great depths, given an inland site and the feasibility of placing a final repository at a deeper and safer level

Not enough is known about the variation in groundwater salinity at greater depths and possible differences in the degree and distribution of salinity at these depths in coastal and inland locations, respectively. A final repository placed at a deeper level – 700-800 m, for example – at an inland site may afford a higher degree of long-term environmental safety. The number of open and linked cracks in the bedrock is known to decrease with increased depth, which means that groundwater flows are slower, which suggests that the leakage from a repository to the biosphere would be significantly slower.

At the same time, there may be disadvantages associated with a deeper placement if the more saline water at greater depths might reach the repository more easily, for example during a period of glaciation. As noted in section 2.7 above, little is known about deep groundwater flows during an ice age. The information SSNC/MKG ask for in section 2.7 would form a good basis for the study of groundwater mobility during glaciation, and can also cast light on the likely impact of glaciation on a final repository at greater depth.

In SSNC/MKG’s assessment, more needs to be known about how groundwater conditions affect the relative safety of a deeper repository at an inland site.

SSNC/MKG ask that the Applicant complement their application with studies of the implications for long-term safety of a deeper final repository (500-1 000 m) at an inland site, with particular attention to the role of groundwater salinity.

2.8.6 The question of whether or not the deformation zone/geotectonic shear zone around the Forsmark site is active

One issue that has been raised, and is discussed in section 2.8.2 concerning the criteria for the choice of site, is the fact that Forsmark is located in the midst of a geotectonic shear zone, a zone roughly 50 km in length that stretches across Sweden in an east-west direction. The zone is one of several deformation zones that can from time to time be activated by the movement of tectonic plates on a global scale. Irrespective of their current status, the zones represent deep-reaching weaknesses in the bedrock. Two similar zones cross Sweden to the north and south, in Skåne in the far south of the country and in subpolar northern Norrland. These latter zones are considered active; earthquakes are registered from time to time in both.

All deformation zones of this kind are characterized by dynamic metamorphism and recrystallization of mineral that result in deep fault planes in the bedrock. In future earthquakes, whether due to glaciation or larger-scale tectonic movements, these planes are likely to be activated.

The Applicant claims that the deformation zone through Forsmark is dormant, but offers no support for the claim. This is a serious gap in the application. The Applicant presents no serial GPS data from lenses in the area which might verify dormancy. Nor have they produced topographic data that either indicate or refute that movement has taken place in the post-glacial period. Whether the Applicant has conducted studies of these phenomena or otherwise verified their assumptions remains unclear.

SSNC/MKG demand that the Applicant in the complementing phase conduct studies, using GPS or other techniques, to determine whether or not the geotectonic shear zone that crosses the Forsmark area is active.

2.8.7 The question of the appropriateness of a coastal site in view of the risk of corrosion due to leakage current from submarine cables carrying DC electricity

In the course of the site inventory at Forsmark, current leakage from the Fennoscan high voltage DC transmission line that runs from Forsmark to

Finland was detected in the Forsmark bedrock. This was discussed earlier (section 2.5.2.16) in connection with the risk of corrosion, but current leakage also has bearing on the choice of site: both the question, whether Forsmark is particularly affected and, more generally, if coastal sites risk such influences due to other underwater DC transmission lines. SSNC/MKG find the question well worth an independent investigation.

It is our understanding that there are plans to lay an additional DC cable between the island of Gotland and the nuclear plant at Oskarshamn. It is also important to determine whether and how current leakage from this new cable might influence intermediate storage of nuclear fuel waste in Clab in Oskarshamn.

SSNC/MKG demand that the studies of current leakage in the bedrock at Forsmark and, more generally, how a coastal siting may imply greater risk of impacts from current leakage than inland sites be undertaken during the complementing phase.

SSNC/MKG demand that studies are conducted during the complementing phase concerning the possible impact of the planned high-voltage cable between Gotland and Oskarshamn on intermediate storage of nuclear fuel waste at Clab.

<u>2.8.8 The question of whether a site adjacent to a nuclear power plant is appropriate</u>

The Applicant plans to locate the final repository and the encapsulation facility in direct proximity to nuclear power plants. The application points to the advantages of locating the facilities near power plants, but there are also disadvantages. A major nuclear emergency in one of the reactors might have severe impacts on the handling of nuclear fuel waste and the work on the repository. SSNC/MKG consider it important to evaluate these risks very carefully.

SSNC/MKG demand that the Applicant assess the possible impact of a major nuclear emergency at Forsmark or Oskarshamn on the construction and operation of the final repository and the encapsulation facility at the respective sites.

<u>2.8.9 The appropriateness of siting a repository in an area rich in mineral assets</u>

The Applicant plans to locate the final repository in Forsmark even though the area is uncommonly rich in mineral deposits which may be of interest to future generations. SSNC/MKG find that the suitability of siting a repository in a region that may be the object of mining interest in the distant future has not received enough attention. Furthermore, we have doubts as to the quality of the surveys of mineral resources in the area that have been done. For example, the continued post-glacial uplift in Scandinavia may make deposits that are under the sea bottom today accessible to exploitation in the distant future.

SSNC/MKG demand that the Applicant complement their application with new studies of the mineral resources in the Forsmark area, including resources under the sea.

2.9 The risk of deliberate intrusion, the need for surveillance and the need to convey information to future generations

This section is about the risks of deliberate intrusion into the final repository after its closure, the need to keep the repository under surveillance after closure, and the need to convey information about the hazard the contents represent to future generations.

First of all, it should be noted that Swedish radiation protection legislation and ordinances do not offer clear guidance about how the risk of deliberate intrusion shall be handled.

The issue of deliberate intrusion is discussed only in an annex to the safety report, *SR-Site.* There, the Applicant notes that it is praxis in the nuclear power industry worldwide to stress that future generations have to assume responsibility for their actions. Thus, the Applicant reasons, the application need not treat the issue of deliberate intrusion into the final repository.[26]

SSNC/MKG cannot reconcile this reasoning with the generally accepted notion that present-day society should do what it can to minimize the hazards that our activities imply for coming generations. Deliberate intrusion into a final repository and removal of its contents can lead to the spread of radioactive materials that pose a serious hazard to human health and the environment – whether or not the intruder is aware of the hazard. Intruders' health and well-being are also at risk.

The possibility that someone sometime in the future can decide to break into the repository cannot relieve the Applicant of their responsibility to do what they can do today, through appropriate siting and design of the repository, to prevent the damage to public health and the environment that intrusion can cause. To reason otherwise would entail a conflict with the principle of

[26] *Handling of future human actions in the safety assessment SR-Site,* TR-10-53, section 2.2. Svensk Kärnbränslehantering AB, December 2010.

sustainable development and our society's commitment to protect future generations. Neither is it reasonable to hold entire future generations responsible for the act of a few individuals; the consequences of such an attitude are clearly unacceptable. Thus, in order to fulfill the requirements of the Environmental Code the Applicant needs, in the application, to analyze and seek to minimize the hazards that future deliberate intrusion might entail.

2.9.1 A general neglect of issues relating to deliberate intrusion

There is no discussion of long-term environmental problems relating to decisions on the part of future generations to enter into the repository after it has been closed and sealed. Since the repository will be only approximately 450 m below the surface and a number of access tunnels to it will have been created, there are numerous scenarios involving intrusion. Deliberate intrusion may occur with or without knowledge of the hazard the contents of the repository pose.

In their application, the Applicant discusses only accidental or inadvertent intrusion, e.g., that someone happens to drill into the repository. The risk that this might happen is treated as a residual scenario in the safety report. The Applicant states in the safety report: "In general intrusion to several hundred metres is considered unlikely in resource poor rock" (sect. 14.3.4, p 772 in the English version). It should be noted, however, that the bedrock around Forsmark is relatively rich in minerals. Still, in SSNC/MKG's view, the factor associated with perhaps the greatest risk of major damage to the environment and human beings is *deliberate* intrusion, a risk that will persist at least the next 100 000 years.

A particular problem is the fact that the plutonium in the fuel waste may be used to make nuclear weapons. Use of nuclear weapons clearly poses a threat to both human beings and the environment. Still, the Applicant chooses to ignore the possibility of deliberate intrusion in the EIS – other than in a table (Table 3.1, p 40). There, however, the Applicant simply states that only the alternative method, deep boreholes, is superior to the KBS method in terms of deterring deliberate intrusion to acquire plutonium.

When the Applicant has to discuss the feasibility of entering into the repository after closure, as when comparing the deep borehole alternative to the KBS method, the Applicant claims that it would require considerable resources to be able to gain access to the repository. No empirical support for this claim is given. SSNC/MKG are of the opinion that a set of scenarios needs to be developed to provide a better understanding of the resources required, relative to the desire to get at the contents of the repository.

SSNC/MKG understand that it can be difficult to quantify the risk of deliberate intrusion or the environmental consequences of such intrusion. The application presents a number of scenarios for inadvertent intrusion and has incorporated them into the safety analysis. The most likely – and most readily imaginable – case is that someone drills a well into the repository, and this is the example cited in the safety report.

In our view, even though it may be difficult to quantify the risk of deliberate intrusion, such intrusion must be taken account of as a possible cause of environmental impacts. The Applicant should therefore elaborate a number of scenarios in which deliberate intrusion can affect human health and the environment. SSNC/MKG consider the inclusion of such scenarios, and analyses of the consequences of each scenario, absolutely necessary in order for the application to be properly assessed.

Possible scenarios include:

1. The final repository contains plutonium that can be used for nuclear weapons. In what scenarios might the repository be looked upon as a ‘plutonium mine’? What factors affect the time and effort required to gain access to the plutonium?

2. The final repository contains radioactive materials that might be used to cause injury or damage. In what scenarios might such a motive figure?

3. The final repository contains considerable amounts of metal. In what scenarios might the metal justify intrusion into the repository?

4. The final repository may be the stuff of legends and myths. What scenarios might lead to intrusion, when knowledge of the contents may be poor?

In the “methods annex”[27] to the application (sect. 2.2.2 Construction Principles, p. 24) the Applicant writes that “a facility for final storage of nuclear fuel waste should be so constructed that it, after closure, provides the safety required without surveillance or maintenance”. In SSNC/MKG’s view, any facility of this description needs to be designed so that it prevents or deters deliberate intrusion to the greatest extent possible.

SSNC/MKG demand that the Applicant complement the application with scenarios for deliberate intrusion into the repository after closure, with an analysis of the possible consequences such intrusion might have.

[27] Svensk Kärnsbänslehantering AB. Metodval – utvärdering av strategier och system för att ta hand om använt kärnbränsle [Choice of methods– evaluation of strategies and systems for the management of nuclear fuel waste], October 2010 (In Swedish only; our translation).

SSNC/MKG demand that the Applicant complement the application with an analysis of the kinds of resources that would be required for intrusion into the repository after closure.

SSNC/MKG demand that the Applicant complement the application with a description of the barriers that can be constructed so as to offer the greatest hindrance or deterrent to deliberate intrusion into the repository.

2.9.2 Neglect of the need for long-term surveillance in order to provide necessary safeguards

In a discussion of the demands made of a final repository the Applicant writes that "the system shall be so designed as to hinder unauthorized handling of nuclear materials or nuclear waste" (EIS, English version, p. 12, pt. 4) .[28] As noted above, the application offers no analysis or description of how 'unauthorized handling' might occur. Neither does it discuss the need for surveillance as a deterrent to such action.

Inasmuch as repositories for nuclear fuel waste contain plutonium that can be used to produce nuclear weapons, ways to assure physical protection and safeguards after closure have been discussed in international fora, e.g., in the IAEA projects, SAGOR and ASTOR. The work has focused on drafting principles for implementing surveillance in order to deter or prevent deliberate intrusion with the aim of retrieving the fuel waste.

In SSNC/MKG's opinion, the Applicant needs to describe how surveillance may be implemented after closure of the final repository. Furthermore, the Applicant should discuss the resources that would be required to put the necessary safeguards in place.

SSNC/MKG demand that the Applicant complement the application to describe how safeguards may be implemented after closure of the final repository.

SSNC/MKG demand additionally that the Applicant indicate the amount of resources that would be required to put the necessary safeguards in place.

2.9.3 Too little attention to the need to communicate the hazard that the final repository poses to future generations

The Applicant makes only brief mention of the need for a system for conserving awareness of, and knowledge about, the final repository in order

[28] SKB's EIS (English version), p 12, pt 4. The EIS may be read at www.mkg.se/mkb-miljokonsekvensbeskrivning.

to avoid inadvertent intrusion. Deliberate intrusion is not discussed at all, nor is the need to conserve the knowledge required to keep nuclear safeguards in place.

In SSNC/MKG's view, the Application is not complete and should not be assessed until an objective and comprehensive description of how the transmission of this information to future generations can be assured. Particularly important is the information required to maintain nuclear safeguards.

SSNC/MKG demand that the Applicant complement the application with a thorough penetration of how information about the final repository can be communicated far into the future, including the knowledge required for the maintenance of nuclear safeguards.

2.10 Impacts on the natural environment and noise

The soil and wetlands in the area around Forsmark are very rich in calcium and
overall form a unique biotope that supports many species that are protected under the Habitats Directive[29], a good many red-listed species and other species protected under Swedish law.

This calciferous environment was created during the most recent ice age, when ice transported lime from the sea bottom north of Öland and Gotland [limestone islands in the Baltic]. Forsmark hosts a great number of orchids, even more species than the island of Gotland. Among rare plant species that thrive in the area is the fen orchid *(Liparis loeselii)*, which is protected under the Habitats Directive and is becoming increasingly rare in southern Sweden.

Another rarity, the pool frog *(Pelophylax lessonae)* – it, too, strictly protected under the Habitats Directive – has been found at seven different locations in the area. In Sweden pool frogs are endemic to coastal Uppland, and the species is endangered. Two aspects of the planned repository will severely affect the pool frog: many of the pools in its habitat will be filled, and more generally, the need to divert groundwater away from the repository means that the water table will sink.

<u>2.10.1 Issues not treated in the application</u>

The Applicant has sought a dispensation from the Swedish Species Protection Ordinance in connection with the impact the repository project will

[29] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, adopted in 1992.

have on protected species in the area. In the opinion of SSNC/MKG, this application for dispensation should also be submitted to the Land and Environment Court and be included in the assessment of the application for a permit to build the final repository for nuclear fuel waste. In that case the application for a dispensation would also be open to public scrutiny.

The area surrounding the industrial zone at Forsmark is of public interest for its wealth of species. Three areas adjacent to the zone are Natura 2000 Special Areas of Conservation ***alt.*** sites.[30] In the Applicant's report, "Hydraulic operations in Forsmark, Part I"[31] the Applicant admits that the project will have a severe impact on the nature preserve known as Forsmark-Kallrigafjärden, a stretch of coast and archipelago that is classed as an object of public interest. The reason the impact is to be considered severe is that it is irreversible and the natural assets most affected are the reason why the area is classed as an object of public interest. In our reading, this negative impact on an object of public interest is not manifest in the EIS. It should be made explicit in order to permit a weighing of the damaging impact against competing public interests, as set out in the Environmental Code (chap 2, sect 10).

SSNC/MKG demands that the Applicant submit a copy of their application for a dispensation from the requirements of the Species Protection Ordinance to the Land and Environment Court, which renders it accessible to the public.

SSNC/MKG demands that the Applicant complement the EIS with a more explicit description of the impact of the proposed project on features of the natural environment that have been deemed to be of public interest in order to make it possible to weigh these impacts against other, opposing public interests.

<u>2.10.2 Natura 2000</u>

The report "Hydraulic operations in Forsmark, Part I"(p. 96f) clearly states that model-based estimates of the effects on groundwater indicate that the water table will be lowered in parts of the Kallriga Natura 2000 nature preserve. SSNC/MKG find that the impacts described on these pages imply that the Applicant must apply for a Natura 2000 permit for their proposed activity, as set out in the Environmental Code, chap. 7 sect 28 a. This is especially important in view of the uncertainty surrounding the model's estimated effects on groundwater. In other words, the Applicant's application needs to be complemented with an application for a Natura 2000 permit, including an EIS that permits a determination as to the possibility that habitats or species in the

[30] Natura 2000 is a network of nature protection areas in Europe established under the Habitats Directive (1992/44/EEC).
[31] Vattenverksamhet i Forsmark, del I: Bortledande av grundvatten ..., SKB AB R-10-14,December 2010.

area will be damaged. The Applicant is required to do so even if the proposed activity *only is considered likely to have impacts* on a Natura 2000 site. That is, the requirement applies even where there is no certainty of impacts; a likelihood of impacts is sufficient. At present, there is no discussion of this likelihood or other basis for such an assessment in the application. A determination cannot be avoided simply because there is no certainty of substantial impacts. The process of drafting a Natura 2000 EIS shall be preceded by EIA consultations.

SSNC/MKG demand that the Applicant, in the complementing phase, apply for a Natura 2000 permit for the proposed activity in accordance with the Environmental Code, chap. 7 sect. 28 a, and that the application and supporting documents be submitted to the Land and Environment Court.

2.10.3 Impact on the water table

Obviously, the task of modeling and calculating the magnitude of changes in the water table as a consequence of the final repository is necessarily fraught with uncertainty. For one thing, the inventory of the network of cracks in the bedrock and how they are interconnected is far from complete. In keeping with the precautionary principle, this uncertainty must be taken into account in any analysis of the consequences for the nature preserve and the species that live there of diverting groundwater away from the final repository. The consequences of lowering the water table for surface water (streams, etc.) outside the area for which consequences have been calculated cannot be specified. For that reason, these streams need to be monitored, and measures be taken, if necessary. Preventive measures need to be put in place, and binding rules for these measures need to be in place.

The uncertainty is particularly great in the case of Fiskarfjärden, a lake which, unlike the other bodies of water in the surroundings, receives all of its water from artesian aquifers in the lake bottom. This circumstance may make Fiskarfjärden particularly sensitive to changes in the water table. Further study is needed to gain a better understanding of the effects lowering the water table may have on the lake, and the results shall be included in the EIA assessment.

As a means to mitigate the effects of diverting groundwater, the Applicant proposes to convey water to pools and lime-rich marshes. But this good intention is limited to only five of the area’s wetlands, despite the fact that 31 bogs, marshes or pools are expected to be affected, 14 of which severely or very severely. Clearly, the Applicant needs to raise their level of ambition and include more of the area’s wetlands. The area contains many natural values. According to the document supporting the Applicant’s application for dispensation from the Species Protection Ordinance, the most important features from the point of view of nature preservation are the lime-rich marshes and pools. Lime-rich marshes are rare in Sweden, and when many occur close together, as at Forsmark, they provide unique conditions for a number of different habitat types. This must be borne in mind when assessing the extent of mitigating measures required. This is not a matter of five individual marshes or pools, but a *system* of wetlands and lakes that must be preserved as a whole.

The mitigating measures the Applicant has in mind with regard to restoring water to the wetlands are not clearly described. The measures are novel, and there is considerable uncertainty as to their effectiveness, the assurances that the Applicant puts forward in the application and supporting documents notwithstanding. Adding water to the wetlands, and the procedures to be followed to do so, need to be studied more carefully and specified more precisely before permission can be granted. The Court must be provided with enough information to permit the formulation of specific conditions for the activities in question. The documents submitted in support of the application for dispensation from the Species Protection Ordinance mention that a pilot study is to be conducted. The Applicant needs to report the results of this pilot study and more clearly describe how they intend to add water to the wetlands. This information is important to make it possible for the Court to formulate appropriate conditions so that the process of restoring water to the bogs and pools in the area can be closely regulated in the permit, should a permit be granted. The application is comprehensive and difficult to survey. For that reason, setting out rules in the permit or in the control program should be avoided. All parties – the concessionaire, the regulatory authority, and the public – should have a full understanding of what needs to be fulfilled in order for the activity to be permitted.

The Applicant also needs to describe additional measures to mitigate the consequences of diverting the groundwater, besides restoring water to wetlands by artificial means. This is necessary in view of the great uncertainty surrounding the effectiveness of the proposed measures.

Forested areas may also be affected by the project. According to the report “Hydraulic operations in Forsmark, Part I” the surface of the forests that lie entirely or partly within the area that will be affected will in general become dry, which obviously will result in changes in the vegetation. Several of the forested areas are key biotopes, identified in the Natura 2000 typology as ‘Fennoscandian herb-rich forests with Picea abies’. There are a good number of red-listed species in the forested areas, species of fungi in particular. The Applicant has not indicated any mitigation of the effects of diverting groundwater on either the forest as such or these red-listed fungi. The company needs to submit plans for mitigating measures for the forested areas that are detailed enough to permit the formulation of binding rules. They also need to present the program for the maintenance of forests and wetlands which, according in the application for dispensation from the Species Protection Ordinance, should have been drafted in 2011.

SSNC/MKG demand that the Applicant complement their application with a description of how areas adjoining the indicated area of impact will be monitored, and the mitigation measures for these areas, should the need arise.

SSNC/MKG demand that the Applicant describe the impact on Fiskarfjärden of lowering the water table, in view of the fact that the lake receives its water from aquifers in the lake bottom.

SSNC/MKG demand that the Applicant complement their application with a study of the mitigation that can be implemented for many more than the five wetland objects specified in the application. The Applicant also needs to describe additional measures besides irrigation of the objects.

SSNC/MKG demand that the Applicant conduct analyses of the procedures by which objects in the area may be irrigated and the environmental impacts of those procedures. The results of the analyses shall be included among the documents supporting the application for the final repository.

SSNC/MKG demand that the Applicant complement their application with a proposal of mitigating measures for forested areas that are sufficiently detailed as to provide a basis for drafting binding rules. Furthermore, the Applicant shall outline a program of measures for the maintenance of forests and wetlands in the zone of operations.

2.10.4 Severe impacts on bodies of water in the zone of operations

The Applicant intends to fill several pools in the zone of operations. The pool frog has been found in two of the pools. The Applicant’s documents indicate that pools 12, 13 and 36 will be filled. However, the document is not at all explicit about how and the extent to which the pool 13 b will be affected. The Applicant’s application for dispensation from the Species Protection Ordinance indicates that the pool will be partially filled, but much of it will, *if possible,* be left intact. At the same time, the pool will clearly be affected during the construction phase, which will render it unfit as a habitat for the pool frog. Neither does the document specify how long the construction phase may be expected to last. The EIS and the application for dispensation state that three pools are to be filled. Both the extent to which pool 13 b will be damaged by the creation of the zone of operations, and the measures the Applicant intends to take to compensate the loss, need to be specified. Even if the pool frog has not been identified in pool 13 b, there is a likelihood that the species nonetheless inhabits the pool since it is found in pool 13 a, and the two pools are connected. Applying the precautionary principle, the pool frog should be assumed to be there.

In the Applicant's documents the mitigation for the filling of pools in the zone of operations consists of creating new pools for the pool frog. According to the plans submitted, four new pools, with a total surface area of 1 000 to 1 500 m2, are to be created on the Applicant's property in Forsmark. In the report "Hydraulic operations in Forsmark, Part II"[32] we find that of the pools slated for destruction the northern pool alone has a surface of 1 600 m2, while the two other have a combined surface area of 10 800 m2. In our view, the pools that are created to provide a habitat for the pool frog must be of at least the same size and have the same ecological quality as the pools that are to be destroyed by the construction of the final repository. The Applicant needs to demonstrate that the planned compensation fully satisfies the habitat requirements of the pool frog population in Forsmark today.

Three new pools have been created to date. In order to assess the need of additional compensatory measures, the quality and appropriateness of the new pools as habitats for the pool frog and other species need to be assessed. The results of the assessment should be submitted to the Land and Environment Court. The Applicant should also submit proposals for additional measures to compensate for the habitats their operations have destroyed.

SSNC/MKG demand that the Applicant complement their application with a specification of the nature and extent of the impacts the construction of the zone of operations will have on pool 13 b, and the measures the Applicant intends to take to compensate the loss.

SSNC/MKG also demand that the Applicant demonstrate that the compensatory pools they plan to create will be of the same size and provide habitats of the same quality as the pools they plan to destroy.

SSNC/MKG demand that the quality and appropriateness of the pools created to date as habitats for the pool frog be evaluated, and that the Applicant propose additional compensatory measures.

2.10.5 Polluted water

The construction of the final repository will entail the release of leach water from tailings and water used in the building process. There is a risk that this water may pollute the sensitive natural surroundings.

[32] Vattenverksamhet i Forsmark, Part II: Verksamheter ovan mark, SKB AB R-10-15, September 2010.

2.10.5.1 Proposed treatment of leach water

The Applicant proposes to use the vegetation in the lake, Tjärnpussen, for secondary treatment of leach water from the excavation tailings through a process of metabolic purification. The Applicant's application for dispensation from the Species Protection Ordinance states that larvae of a rare species of dragonfly, the Dark Whiteface *(Leucorrhinia albifrons)*, was found in the course of the site inventory. Tjärnpussen is the only site in the area where the species was found. The Dark Whiteface is protected under both the Species Protection Ordinance and through the Habitats directive (Annex 4), which requires especially strict protection. The Applicant states that the species *probably* will survive in the lake, but does not exclude the possibility that it may suffer an impact. A *presumption* that a species that the EU has determined should be strictly protected will not be severely affected is, in our opinion, hardly sufficient.

The Yellow-spotted Whiteface *(Leucorrhinia pectoralis)* –it, too, protected under the Species Protection Ordinance and considered worth of especially strict protection under the Habitats Directive – has been found at Tjärnpussen, as well.

What is more, the County Administrative Board's inspectors discovered the rare fen orchid *(Liparis loeselii)* at Tjärnpussen. The Habitats Directive sets out that the fen orchid shall be strictly protected and special protection areas shall be created to secure its survival. The species is becoming increasingly rare in southern Sweden. The fact sheet for the fen orchid of the Swedish Species Information Centre notes that the orchid is sensitive to the chemical composition of water and cautions that eutrophication may lead to its extinction.

Against this background, it is hardly appropriate to use Tjärnpussen to reduce the nitrogen content of leach water.

SSNC/MKG demand that the Applicant propose another means to reduce the nitrogen content of leach water from tailings.

2.10.5.2 The water from dewatering

The water that leaks into the repository area and the water used in drilling and excavation is planned to be diverted to a release point in Söderviken [the sea]. The EIS states that the water will only be sedimented and cleansed of oil; no measures to reduce the nitrogen content are planned. That the water is not cleansed of nitrogen implies an increase in the nitrogen content of waters around the release point, in Asphällsfjärden and Söderviken. Inasmuch as eutrophication is already a major problem in the Baltic Sea, the release of additional nitrogen to the sea is hardly desirable. Locally, the release can affect the ecological status of the waters of the inlet and sound.

SSNC/MKG demand that the Applicant complement their application with a proposal for reducing the nitrogen content of the water from dewatering.

2.10.6 Fulfillment of environmental quality standards

The EIS does not discuss how impacts of the final repository project affect fulfillment of national environmental quality standards relating to water resources. The Environmental Code (chap 6, sect. 7) requires such a discussion. According to a ruling of the Land and Environment in the case of Ladvattenån (M 568-11), the requirement applies to multiple dimensions of the standard: so-called limit value standards (in re the chemical status of surface water) as well as norms relating to ecological status and the requirement to prevent further deterioration of waters. The standard applies to releases both to streams and lakes and to Söderviken. The assessment of impacts in relation to the standards of environmental quality for Söderviken must include all effluents from the project – water from dewatering (pumping), leach water and waste water.

SSNC/MKG demand that the Applicant complement their application with an analysis of how the proposed project – the release of effluents to streams and lakes and to Söderviken – affects the prospects of fulfilling national standards of environmental quality for water resources.

2.10.7 Light pollution

Together, present lighting at the Forsmark nuclear power plant and the lighting required for the proposed final repository project will have a negative impact on a great number of bird species, especially migrant species, in the area. The Applicant has not deemed the impact to be substantial, but in response to demands voiced in the EIA consultations a few lines about the problem are included in the EIS in connection with the planned illumination of the repository site. We find the discussion inadequate. The EIS should include an analysis of the influence on birds and the natural environment – among other things, how birds are attracted to the light and are disturbed by it. Also, the plan for illumination of the site needs to be specified in greater detail. The Applicant should also study the feasibility of offsetting the additional light from the repository project by upgrading the illumination of the Forsmark power plant, replacing existing lighting with modern fittings.

SSNC/MKG demand that the Applicant complement their application with an analysis of how the environment and birds will be influenced by the additional *light that the repository project will entail, and a detailed plan for illumination of the repository site.*

SSNC/MKG ask the Applicant to explore the possibility of offsetting the additional light from the repository project by upgrading existing lighting fixtures at the Forsmark nuclear power plant.

<u>2.10.8 Noise and traffic</u>

The impact of noise needs to be analyzed in terms of both the impact on human health and the impact on the natural environment. Neither in the EIS nor in the documents supporting the application for dispensation from the Species Protection Ordinance has the Applicant described the impact of excessive noise on animal life in the area. This is remarkable, considering the fact that the area hosts a number of species that are protected under the Habitats Directive. These species are likely to be disturbed by the noise from blasting and crushing machines. The application needs to be complemented with an analysis of the impact of noise on the animal species in the surroundings. Such an analysis is especially urgent in the case of the Natura 2000 Special Areas of Conservation that adjoin the Forsmark site.

The Applicant discusses noise in terms of an average decibel value per 24-hour period. Traffic to and from the site will not be evenly distributed over the 24-hour period. Therefore, the units of measure should reflect traffic at different times of day, e.g., mornings, afternoon/evenings and nights. SSNC/MKG find it much more appropriate to use shorter periods as the unit of measure for calculating equivalent decibel levels, both for traffic to and from the site and for the noise of the operations on site. Similarly, the application should offer some indication of under what conditions neighboring residents may experience a nuisance due to noise, expressed in terms of times of day and times of the year. These calculations should include both current noise levels and the additional noise that the repository project will entail.

In addition, the Applicant should propose measures to mitigate the noise from the project. In our view, there should also be some proposal of compensatory measures to reduce noise in the area, such as constructing a noise barrier at the rectifier station at Dannebo, which is the main source of noise today.

SSNC/MKG furthermore recommend that a majority of the heavier transports – tailings from the excavation and bentonite clay in particular – be transported to the site by sea via the harbor at SFR[33]. Sea transport would be much better from the point of view of climate, noise and traffic.

SSNC/MKG demand that the Applicant complement the application with an analysis of how noise affects the animals and birds in the area; furthermore, that they develop and propose possible measures to compensate for the noise generated by the final repository project, by reducing the level of noise from current operations.

SSNC/MKG demand that Applicant differentiate their description of the noise generated by the repository project, calculating the noise levels at different times of day rather than for whole 24-hour periods, and for different seasons of the year rather than whole years. We also demand that the Applicant describe the conditions under which noise from the project may be expected to be a nuisance to residents of the area at different points in time, and thereafter propose mitigating measures.

SSNC/MKG asks the Applicant, within the scope of the complementing phase, to explore the possibility to transport heavy materials, tailings and bentonite clay in particular, by sea.

3. Concluding comments

There are far too many and too serious gaps in the applications for it to be seen as complete enough to formally announce. The EIS has serious shortcomings that must be rectified. All things considered, SSNC/MKG find it likely that a considerable length of time may be needed to fill the gaps to a satisfactory degree. In most cases, e.g., issues relating to the barrier systems of copper and clay or lacking knowledge about the chemical composition and flows of groundwater at great depths, the time required may exceed three years. Even more time may be needed for complementary study and presentation of alternative designs and alternative sites. What is more, SSNC/MKG do not exclude the possibility that once all of the complementary information has been assembled, the KBS method may be judged not safe enough to be given a permit, or Forsmark may be deemed an inappropriate site for a final repository. SSNC/MKG find it remarkable that the applications have been submitted before the scientific controversy on key aspects of the KBS method have been resolved. These issues should have been resolved *before* the applications were submitted.

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[33] SFR is an underground repository for short-lived isotopes at Forsmark. The contents are mostly low- and medium-active waste from the operation of power reactors, e.g., irradiated protective clothing and discarded parts of the reactor.

SSNC/MKG urge the Swedish Radiation Safety Authority and the Land and Environment Court, Nacka District Court, to instruct the Applicant to *complement the application* in accordance with the demands set out in these Comments. *Should the complementary information not be supplied, the application cannot be properly assessed and must be rejected.*

// Joanna Cornelius,
Legal Advisor, Swedish Society for Nature Conservavation

Five Appendices available at:

http://www.mkg.se/stora-brister-i-slutforvarsansokan-naturskyddsforeningen-och-mkg-kraver-omfattande-kompletteringar