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SSI's review of SKB's RD&D programme 2001

Statens strålskyddsinstitut
Swedish Radiation Protection Authority

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SUMMARY: In the report SSI's review of SKB's RD&D programme 2001 is presented. In the review SSI comments, among other things, the decision making process, the need for a strategy document, SKB's safety and system analysis and SKB's biosphere studies.

SAMMANFATTNING: Rapporten återger Statens strålskyddsinstituts (SSI) granskning av SKB:s program för forskning, utveckling och demonstration, FUD-program 2001. Rapporten utgör SSI:s remissvar till SKI i ärendet. I granskningen kommenterar SSI bland annat beslutsprocessen, behovet av ett strategidokument, SKB:s säkerhets- och systemanalyser och SKB:s biosfärsforskning.

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SSI's overall assessment and proposals for government conditions

SSI considers that through the RD&D programme 2001 SKB has fulfilled the requirements specified in the legislation. In its statement SSI comments on the reported research and development programme. An overall assessment is recorded below. SSI has also identified in its review a number of questions that require statements from the government.

Proposals for conditions for SKB's continued programme

SSI proposes that the government stipulate the following conditions for SKB's continued research and development programme:

- SKB should, no later than in connection with the reporting of RD&D programme 2004, report which results in the RD&D programme need to be achieved prior to the forthcoming stages of SKB's programme for handling spent nuclear fuel and other long-lived waste. The report should specify what kind of knowledge is needed for the decisive questions relating to long-term safety and radiation protection, when this knowledge needs to be acquired and how it is to be acquired.
- The method report (SR-MET) proposed by SKB should be issued in conjunction with the RD&D programme 2004. SKB should have an international expert review of this method report carried out.
- SKB should produce an annual report of all ongoing consultations on environmental impact statements for the purpose of cross-checking the environmental impact statement work in relation to SKB, the authorities and other parties involved.

SSI also feels that it is essential that the government specify a timetable and terms for SKB's programme for handling other long-lived waste.

Overall assessment

The decision-making process

Several consultation and decision-making processes will be ongoing during the site investigation stage. These include the RD&D process and a very wide-range of environmental impact consultation with the parties specified in the Environment Code, in up to four municipalities in two counties. In addition to this, SKB should, in accordance with the government decision, consult with SSI and SKI, partly concerning the site investigations and partly concerning the formulation of future system and safety reports.

SKB intends to highlight questions relating to the localisation process from future RD&D programmes and report these questions instead in the environmental impact statement (EIS) process. It is therefore important that SKB has good coordination and feedback between the different processes. SSI feels that SKB should produce an annual report of all EIS consultations in order to achieve cross-agreement of the EIS work in relation to SKB, the authorities and other parties involved.

SSI believes that the RD&D programme's new structure, which is based on the reviews of the authorities in earlier inspections, is good but that it can be further developed. SKB should therefore develop the structure of future RD&D reports to describe how the authorities' questions and criticisms have been dealt with, partly to clarify which questions SKB feels remain, and partly to give the authorities and government an opportunity to decide which questions can be removed from future reviews and consultations.

Strategy document needed

SKB's final disposal programme has now been concretised with site investigations and a tight timetable for the expansion of final disposal with accompanying installations. SSI feels that SKB should clarify which results need to be produced within the sub-programmes for development of the technical barriers, long-term research and safety and system analyses, prior to the successive stages of the final disposal programme. SSI believes that such a clarification should be made by producing a strategy document, which concretises for the most critical questions what kind of knowledge is needed, when this knowledge is needed, and how it is to be acquired.

SSI believes that a strategy document would clarify the links between the different parts of the final disposal programme and make it easier to assess whether the RD&D activities that SKB is reporting are sufficient and suitable for the purpose. SSI gives examples in this statement of questions that should be included in a strategy document. SSI would like to stress that it is SKB's responsibility to produce delimitations and content. SKB should record a strategy document for the handling of spent nuclear fuel no later than in connection with RD&D programme 2004, and subsequently carry out regular updates as SKB's final disposal programme progresses.

SKB should also draw up in a corresponding manner a strategy document for the handling of other long-lived waste, partly to clarify which objectives and part-objectives need to be achieved for the design of the site and understanding of the process, and partly to clarify when these objectives need to be achieved.

System analysis

A system analysis should describe links between the design and location of the different sites. SSI believes that SKB's stated system analysis which, as far as SSI can tell, will only cover the encapsulation plant, is not sufficient to act as a basis on which to test applications for a license for its construction. The system analysis that is submitted with the application for a permit for the encapsulation plant should include, among other things, analysis of questions relating to manufacturing technology and methods for non-destructive testing. The function of the capsule should also be analysed on the basis of the short and long-term requirements imposed upon it from both a transport point of view and a final disposal point of view. Only with a more complete analysis can one ensure that the deadlocks that occur as a direct consequence of building the encapsulation plant are acceptable.

Safety analysis

Programme for development of methods for safety analysis

As far as SSI can tell, SKB has in its development programme for safety analysis covered most of the views raised in the inspections of the safety analysis SR 97. SSI's most important views relating to the programme are that SKB should:

- Prioritise the production of a systematic description of processes in the biosphere and the transition between geosphere and biosphere in order to provide an adequate foundation from which to carry out site investigations that are geared to the purpose.

- Devise and evaluate a method of risk analysis that illustrates how the different parts of the safety analysis can be designed to provide a good basis for the assessment of risk in accordance with SSI's instructions. The method should be recorded in SKB's planned method report.

Planned safety reports

SSI feels, in conformity with the views expressed previously by the authorities and the international group of experts in the review of SR 97, that SKB should clarify the role of the safety analysis for integration of the different parts of the final disposal programme and what needs to be achieved with future safety reports.

SKB's stated method report should undergo a formal authority review. The report should therefore be linked to RD&D programme 2004. SKB should also carry out an international expert review of this report.

The preliminary safety assessments of the sites included in the site investigations should be as exhaustive as possible in order to provide a good basis for planning the continued complete site investigations. SSI feels that it may be necessary to carry out simplified scenario and consequence analyses to test the adequacy of the data and models produced for such things as the biosphere and the transition between geosphere and biosphere.

The safety analysis that will be included with the application for the encapsulation plant should assess the new observations and experimental data, with concomitant uncertainties, primarily arising from both the manufacture and testing of copper canisters, and also take into account new knowledge from the development work with buffer and backfill. SSI also feels that SKB should clarify how the site-specific data and conditions arising in the site investigations will be taken into account.

Canister production and design of final disposal

The report of the research programme relating to canister production is scantily worded in RD&D programme 2001. The capsule production and the non-destructive testing have a central role in the KBS-3 method. SSI feels therefore that clear objectives and part-objectives need to be specified for all parts of the development work and be linked to the development of the safety analysis. An initial report of the remaining development work should be produced during 2002, after which the plans should be incorporated into the proposed strategy document.

SKB needs, according to SSI's regulations, to record how the final deposit system has been optimised. It is therefore important that SKB concretises its plans for evaluating the importance of repository depth, access alternatives (ramp or shaft) and alternative repository design variants. SKB should also identify at an early stage the development/demonstration/research needs that exist with regard to the optimisation of the final disposal facility. In particular, it is important that SKB identifies at an early stage the need for long-term experiments. SKB has produced at a very late stage in SSI's review process a proposal for the RD&D programme for the variant KBS-3-MLH (depositing in medium-length holes). SSI is glad to see that SKB is considering studies of this variant of KBS-3, which may have safety advantages compared with the main variant with vertical depositing holes.

Research – final disposal and geosphere

SSI feels that in future safety analyses, in addition to an evaluation based on input data from the non-destructive testing, SKB also needs to evaluate the importance of defects that are below the detection limit for the non-destructive testing. Against the background of such an analysis SKB needs to evaluate the preliminary acceptance criteria and design conditions for the canister. Af-

ter such an analysis SKB may also need to revise its criteria for the canister, e.g. through tougher manufacturing requirements and improved precision in the non-destructive testing.

For the development work with the buffer and the refilling SSI feels that SKB should produce a collective report that illustrates more effectively:

- How initial defects and the short-term development of the buffer, the resaturation phase, can affect the long-term function of the storage system and to what extent the experiments at Äspö might be expected to yield answers to these questions.
- The degree of importance given to the backfill in terms of the long-term protective capability of the final disposal plant and which research/development/demonstration measures are needed to build up the level of knowledge required for the safety analysis.

Research – biosphere

In spite of the fact that the basic view is that SKB is now carrying out methodical, ambitious work with the biosphere issues, questions still remain. In brief, SSI believes that SKB should:

- Record the degree of importance given to the biosphere issues in the selection of a final site and how the importance of the biosphere issues is evaluated in the safety report.
- Devise a timetable clearly showing how far the biosphere work needs to have come prior to the complete site investigations.
- Present concrete plans or views within the areas specified below.

Description of biosphere processes

SSI supports the method that SKB has chosen for the conceptual ecosystem description but stresses that SKB needs to put together complete documentation of the processes involved in the used interaction matrices. SKB should also record the research requirements for processes in the biosphere in a corresponding manner to the methods used for the other parts of the final disposal system in RD&D programme 2001.

Ecosystems and system-ecological models

SKB's choice of specific ecosystems is well motivated, but SKB should also record how they intend to model transitions between ecosystems induced, for example, by land elevation or climate changes.

SSI views positively SKB's work to develop system-ecological models based on circulation of nutrients. These are a good complement to the compartment models that were used previously. However, a clear report is lacking on the continued method of approach to model development and a timetable for the work. SSI therefore considers that SKB, at the latest prior to the complete site investigations, should report on its plans for the process-based system-ecological model development, and the importance that this has for the design of complete site investigations.

Protection of the environment

It is valuable for SKB to participate in international research projects such as FASSET, to be able to produce development programmes for protection of the environment. However, SSI lacks a discussion as to how the results of the project will be used in practice in a safety analysis and within the site investigation programme. SSI takes the view that SKB, prior to the complete site investigations, should report on how the environmental protection aspects will be complied with, and the significance of this for the complete site investigations. SSI also considers that SKB, at the latest in conjunction with an application on the construction of a facility, should

present all relevant documentation concerning the anticipated environmental concentrations of radioactive substances and documentation of the model tools.

Transport processes

SKB should in conjunction with the development of methods for safety analysis develop its analysis of radionuclide transport in the transition between geosphere and biosphere, in order to be able to present a credible safety analysis in connection with an application. SKB should also further develop its analysis of the relation between the most exposed individuals and a regionally exposed group.

Climate

SSI views it as positive that SKB is planning both the collection of data and modelling to increase understanding of climate issues. At the same time, SSI takes the view that SKB's choice of two sites close to the coast sites makes great demands on a report on the climatic effect and the role of the biosphere in the safety report. SKB should therefore:

- Evaluate, in its research on the future of the Baltic, the importance of changes in the sea level for the radiological consequences, e.g. release of radionuclides that have earlier accumulated in the sea sediment.
- Report on expert assessments on the choice of climate scenarios that shed light on discharges in the Baltic, including the possibility that discharges alternatively take place to a terrestrial environment.

The special report that is required in accordance with SSI's regulations for the first thousand-year period, should contain an assessment of possible climatic variations during the period.

Site investigations

SKB states that, unlike other subject areas, they have relatively little experience of collecting biosphere data, so that methods must be developed at the same time as available knowledge and resources are put together. SSI wishes to emphasise the importance of SKB giving priority to research and development work in this field bearing in mind that it has planned to start site investigations already this year.

SSI considers that so-called base-line measurements and selection of reference areas should take place at an early date and that SKB should also investigate the need for future environmental monitoring in this context also.

SSI has brought to the fore and intends to follow up issues relating to site investigations within the established consultation on site investigations between SKB and the authorities (SKI and SSI). These issues are also taken up in the ongoing inspection of the renewed safety analysis for SFR 1. SSI will present further points of view at a later date.

Recharge and discharge areas

SSI considers that it is good that SKB is now planning to produce a better documentation to be able to assess the importance of in and outflow conditions and salt content conditions in the selection of sites for site investigations. It is important that the analyses are designed in such a way that they provide a perspective on the selection of sites for site investigations, and that the localisation alternative Hultsfred can be assessed in a more satisfactory way than has been the case in the complementary report of the RD&D-programme 98. These issues have been brought

to the fore in the ongoing consultation on site investigations which SKB carries out with SSI and SKI.

SSI regards it as positive that SKB, in conjunction with these analyses, is also planning detailed studies of hydrogeological conditions in the transition between geosphere and biosphere. This is an area where SKB should prioritise its research work, in order, among other things, to obtain access to the knowledge and modelling tools required for carrying out site investigations.

Alternative methods

It is important that decision-makers and referral bodies at the time of licensing detailed site investigations have the opportunity to contrast KBS-3 with another method, where the safety is allocated differently than for the KBS-3 method. In SSI's view, a report, that, among other things, contains a safety analysis of the alternative very deep holes on the basis of existing data, could correspond to the demand for an alternative report according to the environmental code. SSI makes the assessment that SKB's level of ambition for the alternative report should be higher than simply monitoring the international work.

The question of alternative methods affects in a general way all concerned municipalities and county councils. There are therefore reasons for SKB to consider co-ordinating these discussions in future consultation.

Other long-lived waste, SFL 3-5

SSI does not consider that the analysis of safety for SFL 3-5 can serve as a planning prerequisite for location or for the design of the site investigation programme. SSI therefore considers that SKB needs to present an action plan for continued RD&D-work and to update the safety analysis. SSI considers that SKB should start this work immediately so that SKB after carrying out the site investigation can produce a new safety analysis.

In the renewed analysis, alternative forms of repository layout need to be evaluated and the need of additional technical development work identified. SKB should also produce guidelines for conditioning and characterisation of the radioactive waste and documentation for site selection and site investigations on the basis of this safety analysis.

In the light of this, SSI considers that it is important that the government clearly states a timetable and the conditions for SKB's continued work.

Decommissioning and dismantling

SSI lacks a thorough clarification of how the waste volumes that arise in decommissioning and dismantling of nuclear power stations are to be dealt with, in particular with regard to the large quantities of very low-active waste that can be expected. There is still lacking, despite SSI having pointed this out previously, for instance, dose calculations and descriptions of environmental consequences in the biosphere from the decommissioning and dismantling programme. SKB should present concrete plans taking into consideration different scenarios for the operating time of the plant. It is important that work on intermediate storage of the long-lived waste from the decommissioning programme is started and treated as a priority.

Contents

1 Introduction

1.1 The matter under consideration

According to the Nuclear Activities Act (1984:3) and the Nuclear Activities Ordinance (1984:14), The Swedish Nuclear Fuel and Waste Management Company (SKB) is to make a report every third year on planned research and development activity, the results obtained from research, alternative management and disposal methods, and the measures that are intended to be taken within a period of at least six years.

This report presents the Swedish Radiation Protection Authority's (SSI) review of SKB's programme for research, development and demonstration, the RD&D programme 2001. The report is SSI's referral reply to the Swedish Nuclear Power Inspectorate (SKI) on this matter.

SKI reviews and evaluates the submitted research programme (RD&D programme) and submits its own statement on this matter to the government, which can impose the conditions that are required for continued research and development work.

1.2 Background

The RD&D programme 2001 is the sixth research programme, which SKB has submitted a report on since 1986. In addition, the government has requested that the research programme be supplemented on two occasions. The report on the RD&D programmes is an important part of SKB's activities since it makes possible insight into and control of SKB's work.

SKB has made proposal for three sites (in Oskarshamn, Tierp and Östhammar municipalities) where they want to start site investigations. Provided that the municipalities concerned are positive to continued participation, the government takes the view that SKB can begin these site investigations. If Tierp municipality comes into consideration for site investigations, Älvkarleby municipality will also be affected due to possible transport of spent nuclear fuel through the municipality.

SKB calculates that the site investigations will take approximately five years. SKB is planning around 2005 to submit an application to construct an encapsulation plant, and an application for a detailed site investigation around 2007, which entails a first step in erection of a final disposal facility for spent nuclear fuel.

Östhammar municipality have decided to continue to participate in the site investigation phase. Other municipal decisions are expected during spring 2002. In preparation for the site investigations, the formal Environmental Assessment Process will be started in accordance with the Environmental Code. Early consultation has started in Oskarshamn municipality. This early consultation will be followed by expanded consultation during the site investigation phase. These consultations will be an important part of SKB's work to produce an environmental impact assessment, EIA, which is to accompany an application for a detailed investigation.

2 The decision-making process

2.1 Introduction

In the preparatory legal documents on the provisions of the Act on Nuclear Activities on the research and development programme (RD&D programme) that SKB is to make a report on every third year, attention is drawn to the very great importance that this programme has for making possible control and supervision. This is also stated as being a prerequisite for being able to control planning activities relating to the final disposal of nuclear waste [1]. Furthermore, in 1992, it was made possible for the government to make decisions on conditions for further research and development work. This right to impose conditions is not restricted to the main direction of activities but can also stipulate that a particular part of the programme is to be complemented in some way [2].

It can be noted that the RD&D process – at any rate with regard to the programme in recent years – has developed from being a technical report to a broader report that will be read by a considerably larger group than previously (municipalities, opinion groups, universities, etc.). The points of view that have then emerged in the process of referral for comment have been a valuable contribution to the authorities' review. The review statement has not only served the purpose of presenting the positions adopted by the authority to SKB but has also been communicated to a great extent to the affected municipalities and opinion groups who have in this way been able to obtain a good idea of the view taken by the authorities on SKB's activities.

However, the prerequisites for SKB's continued RD&D and consultation activities have been successively changed recently. This is due, in particular, to the government's decision on SKB's supplementary report on the RD&D programme 98 (RD&D-K) [3], and to the siting process – in a formal sense – arriving at the point when it is subject to the requirements of the Environmental Code on an environmental impact assessment consultation. The government decided that SKB was to consult the authorities on the prerequisites for site investigation consultation, which is assumed to continue throughout the entire site investigation phase. Moreover, the government assumes that SKB will consult the authorities as to when and how renewed system and safety analyses are to be reported. SKB states in the preface to the main report on the RD&D programme 2001, that issues concerning siting of installations will be reported in the EIA documentation to be submitted in conjunction with the application and that the RD&D programmes will focus on technological and research issues.

A number of different processes can thereby be identified: the RD&D process, environmental impact assessment (EIA) consultation, site investigation consultation and consultation on system and safety analysis. The forms for how these processes and consultations are to interact and be linked back to one another are very unclear. In all essentials, SKB is responsible for implementation of all processes. However, one difference could be said to be that the authorities and the government in a certain sense control the RD&D process (report requirements and the possibility of imposing conditions), but not the other consultations that are instead to be initiated by SKB.

2.2 The environmental impact assessment process

Since SKB is not intended to report on issues relating to siting as of RD&D programme 2001, it can be assumed that there will be less interest in the affected municipalities for future RD&D reports. The – from a municipal point of view – important siting issues will be taken up instead in the EIA process. The benefits of this are evident since questions can be taken up continuously and close to those who are affected by a siting. If all of the municipalities asked by SKB (Oskarshamn, Östhammar,

Tierp/Älvkarleby) accept further investigations, local EIA consultations will be initiated in up to four municipalities in two counties with the parties mentioned in the Environmental Code (county administrative board, particular municipalities affected, organisations, relevant government authorities). This accordingly involves a very extensive procedure. As applicant, it is SKB that is responsible for this consultation to take place. An ambitious EIA programme is also presented in SKB's report on EIA [4].

The above description makes some reflections apposite. Although SSI's presence is not always requested in connection with SKB's EIA consultation, there is nevertheless a risk that the demand will exceed SSI's capability due to the large number of meetings that can be anticipated. SSI may be forced to limit the extent of its participation. A situation of this kind not only means that SSI will not be 'on site', but also that SSI cannot obtain a full picture of what was discussed at these meetings. The fact that the complete report on consultation and environmental consequences will be formally required only in conjunction with SKB's application means, in SSI's view, that there is reason to consider other forms for reporting.

SSI considers that SKB should report all of the EIA consultations in the past year once a year in a special report series, a kind of successively reported consultation report. In this ways, authorities can step by step be informed of and incorporate the results of the EIA consultation in their reviews, and to check off the EIA work between SKB and the authorities. This could be regarded as a component of the delimitation process described in paragraph 6.1 of the Supplementary Directive 97/11 on environmental impact assessments [5]. An important example of what needs to be co-ordinated in the various consultations and which is also included in the RD&D report is the report on alternatives to the KBS-3 method. This is described in more detail in Chapter 12.

SSI assumes that SKB in the EIA consultation with the affected municipalities will continuously report the results of the site investigation consultations with the authorities. Furthermore, SSI assumes that research initiatives from SKB that have been initiated within the EIA consultation, will be reported in future RD&D programmes. The same applies to major research inputs that can be initiated within the site investigation consultation.

2.3 Site investigation consultation and consultation on system and safety analysis

As regards the site investigation consultation decided upon by the government and the continued consultation on system and safety analyses – between SKB and the authorities – it is correspondingly the case that matters of importance for SKB's method and siting process are to be dealt with in tandem with the RD&D programme. There are also evident advantages here in an ongoing consultation between SKB and the authorities on technical issues in conjunction with the site investigation phase and for production of system and safety analysis.

SKB's complete report on methods for implementation and the report on future safety analyses, the so-called method report, is an example of what should be taken up in consultation on system and safety analyses. This report should be reviewed by the authorities and should therefore be reported in conjunction with RD&D programme 2004. This is described in Chapter 6.

SSI considers that SKB should make a report on the important results from the site investigation consultations and consultations on system and safety analysis in the future RD&D programmes.

2.4 The RD&D programme

It might be true to describe the situation by saying that a competitive situation has arisen between, on the one hand, the demand for long-term, complete RD&D activity in accordance with the Act on Nuclear Activities, and, on the other hand, the demands for local EIA consultation in accordance with the

Environmental Code and the government decision on continuous consultation between SKB and the authorities. As has already been mentioned, this situation can lead to a fragmentation of SKB's R&D activity and in that way also the state of knowledge, and to the RD&D programme being impoverished and declining in importance, both as a tool for delivering a complete report and as an instrument to control SKB's activity. If this is regarded as a probable development, it may possibly be in conflict with the regulations on RD&D in the Act on Nuclear Activities [1] (sections 11, 12) as these have been motivated in the preparatory documents pertaining to the law [2].

RD&D programme 2001 differs in structure from previous programmes through SKB basing itself on the authorities' points of view in previous reviews, and referring to previous review results on the RD&D programmes 98 and SR 97. SSI considers that this is a good structure, which should be retained and developed in future RD&D reports. SSI therefore recommends that SKB develop this structure to describe how the authorities' questions and criticism have been responded to, to clarify the issues that remain and those that the authorities and government can remove from the agenda for future reviews and consultation.

In its statement on the supplementary report on RD&D programme 98 [6], SSI suggested that SKB should present an action plan for the work that remained to be done with the focus on strategic issues and issues that are particularly critical for the long-term functioning and protective capability of the repository. SSI considers that SKB should do this in the form of a strategy document, which concretises the knowledge that needs to be obtained for the most critical issues, and when and how this knowledge needs to have been attained. This is described more clearly in Chapter 3.

2.5 SSI's overall assessment

Several consultation and decision-making processes will take place during the site investigation phase. These include the RD&D process and a very extensive EIA consultation with the parties named in the Environmental Code, in up to four municipalities in two counties. In addition, according to the government decision, SKB is to consult SSI and SKI, on site investigations and on the design of future system and safety reports.

SKB is intending to remove issues relating to the siting processes from future RD&D programmes and instead report these issues in the EIA process. It is therefore important that SKB has a good coordination with and link back to the various processes. SSI considers that SKB should make an annual report of all EIA consultations to co-ordinate EIA work between SKB, the authorities and other parties.

SSI makes the assessment that the new structure of the RD&D programme, based on the authorities' points of view in earlier reviews, is good but that it can be further developed. SKB should therefore develop the structure of future RD&D reports to describe how the authorities' questions and criticisms have been responded to and to clarify the questions that SKB considers remain, and to give the authorities and government an opportunity to determine the issues that are to be removed from future reviews and consultation.

3 The need for a strategy document

3.1 Background

SSI's review statement on the supplementary report to the RD&D programme 98, RD&D-K, was not only based on SKB's complete report on methods, choice of site and programmes in preparation for the site investigation phase [1] and its underlying reports, but also on the safety analysis SR 97 for fuel storage [2], SFL 2, and the safety analysis for final disposal of other long-lived waste [3], SFL 3-5, on which a report was made after the RD&D programme 98. In the statement on RD&D-K [4], SSI could note certain deficiencies relating to the integration of different parts of SKB's programme. In particular, the inputs concerning the areas safety analysis, system analysis and technological development seem to be insufficiently integrated.

In the light of the deficiencies noted, SSI recommended in its statement on RD&D-K that SKB should present an action plan for the work that remained to be done during the period up to the application. SSI wrote:

> *The action plan should include development work on the technical components such as the copper canister and other engineered barriers. It should also be made clear the speed at which work needs to progress and when the objectives and sub-objectives stated in the action plan need to be achieved.*

Similar proposals were put forward by the international expert group from OECD's nuclear energy agency (NEA) in conjunction with the review of SR 97 [5]. NEA pointed out the desirability of a document describing safety strategy and how it is to be successively developed.

The question of preparing a strategy document was also taken up by SKI in the statement on RD&D-K [6], where it was stated that a document of this kind would have to be produced in consultation with the authorities and reported at the latest in connection with the next safety and system analysis, i.e. after conclusion of the initial site investigations.

3.2 SKB's report

SKB does not take up the issue of production of a strategy document in RD&D programme 2001. This question has been discussed at a meeting between SKB and SKI [7], where SKB stated that it hoped that the work in process on design prerequisites (an interim report is expected to be produced during 2002), together with RD&D programme 2001, can meet the need for a strategy document.

3.3 SSI's proposed strategy document

3.3.1 PURPOSE

SSI's and SKI's reviews of SKB's safety and system analyses have identified a number of important safety and radiation protection issues, issues that remain to be clarified by further research, development or demonstration inputs. Together with the fact that SKB's final disposal programme is now being concretised with site investigations and a tight timetable for construction of repository installations with the appurtenant nuclear technical installations, this means, in SSI's view, that SKB needs to set clearer objectives and sub-objectives on what is to be achieved at different stages of the final disposal programme.

In the light of this, SSI considers that SKB should produce some kind of action plan or strategy document which concretises the knowledge that needs to be obtained for the most critical issues, and when and how this knowledge needs to have been attained. The intention with a strategy document of this kind is to clarify the expectations on SKB's planned reports and development work and to clarify the connections between the different parts of the final disposal programme (e.g. development of the engineered barriers, long-term research, safety analyses and site investigations). The document would thereby also make it easier for the authorities and others to assess the suitability for its purpose and adequacy of the activities reported in SKB's RD&D programme.

3.3.2 CONTENT

In this statement on RD&D programme 2001, SSI gives examples of issues that would be suitable for reporting in a strategy document for final disposal of spent nuclear fuel. These are briefly summarised below. The contents and delimitations of a strategy document must be developed by SKB, however, and should, in SSI's view, be based on evaluations of safety analyses carried out and the authorities' reviews of SKB's RD&D programme, etc.

Development work with the engineered barriers

The development of technology for manufacture and testing of canisters, manufacture of buffer and emplacement technology are evident examples of issues where SKB should specify clear requirements that have to be achieved in the successive stages of the final disposal programme. There are clear links here to the assumptions made on the characteristics of the barriers in safety analyses and to work on evaluating and setting acceptance criteria and requirements for quality control, etc. SSI states its point of view in Chapters 5 and 7 on issues that should be clarified, inter alia in preparation for the application on siting of the canister encapsulation plant.

Safety and system reports

As stated in Chapter 6 of this statement SSI considers that SKB needs to clarify the role of the safety analysis for integration of the various parts of the final disposal programme. This can be done by a summary description of the intentions and aims of the planned safety reports in a strategy document. For each safety analysis, SKB should also report on the data, modelling tools, and other documentation that needs to be produced for these intentions to be fulfilled. In this way, the requirements for what is needed to be achieved in the RD&D programme could be clarified. SSI reports in Chapter 8 on issues concerning the biosphere and its role in the safety analysis that SSI considers should be clarified in future safety reports.

In a corresponding way as for the safety analyses SKB should report on the expectations on planned system reports. Issues that may come to the fore are, for instance, the sub-objectives that need to be achieved as regards development and optimisation analyses of alternative system designs for the KBS-3-method, i.e. alternative disposal methods, backfill materials, entrances, repository depth, tunnel boring methods, etc.

Long-term experiments

Long-term experiments have an important part to play in demonstrating that the engineered barriers and backfill comply with the requirements arising from the safety analysis. For natural reasons, it is necessary to analyse at an early stage the needs for long-term experiments and to define clear objectives as to what is to be achieved. SSI considers that SKB should report in a clearer way the aims for the ongoing or planned long-term experiments at Aspö, which are to be used in evaluation and define the criteria to be used in evaluation. An important example is the long-term experiments used to demonstrate the resaturation of the buffer in the so-called prototype depository where the final results of the experiment will be obtained only five years after disposal has started.

Research and model development

In SSI's view, the RD&D programmes provide a good overview of SKB's ongoing and planned research programme. In the current programme SKB has also produced an overview table showing SKB's assessment of the relative needs for research in different areas. SSI considers that this is a step forward in relation to previous reports (even though SSI considers that questions relating to the biosphere should be reported in the same way). However, SSI considers that SKB should supplement this report so that it is also made clear when and prior to which stages of the programme critical results or models must be produced and evaluated, e.g. to be able to carry out appropriate site investigations and safety analyses. This can suitably be done in a strategy document. In Chapter 8, SSI gives examples of research issues relating to the biosphere and the transition between the geosphere and biosphere that need to be clarified during the site investigation phase. The corresponding points of view on methods for safety analysis are reported in Chapter 6.

3.3.3 REPORTING

In SSI's view, SKB should produce and submit a report on a strategy document for final management of spent nuclear fuel at the latest in conjunction with the next report on the RD&D programme, i.e. 2004. SSI considers, in agreement with the international expert review of SR 97 [5], that the strategy document needs to be subsequently updated as SKB's final disposal programme is developed (e.g. be linked with increased information and in conjunction with regular safety analyses).

A possible basis for structuring of a strategy document might be to start from the overall timetable for the site investigations and the construction of the repository and to report, for each major step, the most critical issues that need to be solved for the programme to be able to make further progress. The report would then have a similar structure to the parameter tables that SKB has already produced for the site investigations [8].

3.3.4 THE NEED FOR STRATEGY DOCUMENTATION FOR OTHER LONG-LIVED WASTE

SSI puts forward the view in Chapter 13 that SKB should give higher priority to work of developing methods for final disposal of other long-lived waste. SSI considers that SKB should also prepare a strategy document for the final management of that waste. This document would clarify the objectives and sub-objectives that need to be achieved with regard to installation design and process understanding, and when these objectives need to be achieved. SSI also considers that SKB in a document of this kind should clarify any connections with the ongoing siting work for spent nuclear fuel.

3.4 SSI's overall assessment

SKB's final disposal programme is now being concretised with site investigations and a tight timetable for construction of a repository with appurtenant installations. SSI considers that SKB should clarify the results that must be produced in the sub-programmes for development of the engineered barriers, long-term research and safety and system analyses, prior to the successive stages of the final disposal programme. SSI considers that a clarification of this kind should be made by producing a strategy document which clarifies the knowledge that needs to be obtained for the most critical issues, and when and how this knowledge needs to be attained.

SSI considers that a strategy document should clarify the connections between the various parts of the final disposal programme and make it easier to assess whether the RD&D activities SKB reports serve their purpose and are sufficient. SSI gives in this statement examples of issues that should be included in a strategy document. SSI wishes, however, to underline that it is SKB's responsibility to produce delimitations and content. SKB should report a strategy document for management of spent nuclear fuel at the latest in conjunction with RD&D programme 2004, and subsequently carry out regular updates as SKB's final disposal programme progresses.

SKB should in a corresponding way also prepare a strategy document for the final management of other long-lived waste, which clarifies the objectives, and sub-objectives that need to be achieved for the design of the installation and process understanding, and clarify when these objectives need to be achieved.

4 System analysis

4.1 Background

In the government decision on RD&D programme 95 [1], SKB was requested by the government to prepare a system analysis for the whole final disposal system (encapsulation plant, transport system and repository). SKB submitted a progress report on this in conjunction with the report on RD&D programme 98 and an update of this in conjunction with SKB's supplementary report on RD&D programme 98, the so-called RD&D-K. The authorities reviewed the former analysis jointly and a review statement is included in SSI-report 99:12 [2]. SSI reviewed the latter analysis separately. A statement is included as an annex to SSI's statement on RD&D-K [3].

SKB reports in RD&D programme 2001 on the future system analyses that are planned as well as the work that is in process on technological development and installation design of canister plants, encapsulation installation and repository and the appurtenant transport system.

As regards future system analyses, SKB is planning to submit an initial analysis in conjunction with the application for an encapsulation plant in 2005 and which, as far as SSI is able to judge from RD&D programme 2001, will only deal with the design and siting of the encapsulation plant. It is planned to submit a second system analysis together with the application for a licence for detailed investigations in 2007 and deal with the design of the repository at the places that are under consideration for detailed investigations and the consequences of siting at these places. With regard to the description of the transport system, this will be specified when the siting of the repository has been decided upon.

Bearing in mind that SSI recently reviewed the system analysis for the KBS-3 method that was reported together with RD&D-K, there has been no reason to review in detail SKB's reports on planned installations and system designs. SSI expects, as is made evident in SSI's statement on RD&D-K, that SKB in future development work and future analyses will take into consideration the points of view that SSI then put forward, and to the points of view that the authorities put forward in conjunction with the review of the system analysis presented in conjunction with RD&D programme 98. This review has instead been focused on SKB's planning and approach to future system analyses. In Chapter 5 SSI comments on the research programme that has been presented for canister manufacture and repository design.

4.2 Plans for future system analyses

SKB intends to submit an application in 2005 to construct an encapsulation plant. It is therefore planned to focus RD&D programme 2004 on encapsulation technology. At this time, it is also planned to present a new system analysis and a safety analysis with the focus on method issues, SR-MET. With regard to expectations on these reports, SSI stated as its conclusion in the review of RD&D-K that:

> *SSI considers that SKB at the latest in conjunction with an application pursuant to the Act on Nuclear Activities for a licence for erection of an installation or sub-system, needs to submit a report on an updated safety analysis linked with an updated system analysis. A future report should be based on data from the sites that can be of interest for erection of canister plant, encapsulation plant and repository and on the knowledge obtained during the ongoing development work on encapsulation and repository technology.*

The background to SSI's request is the insufficient integration between the safety analysis and system analysis that could be noted, as well as the lack of evaluation and analysis of the importance of the proposed siting, the design of the installations and the link between the parts of the system.

More detailed points of view on the content of future analyses will be contained in SSI's statement on SKB's supplement to RD&D programme 98. With regard to the content of, and design of, future system analyses (as well as safety analyses) the government has requested SKB to consult both authorities. It is very important that SKB plans and takes initiatives in this issue.

4.3 SSI's overall assessment

A system analysis is to describe the links between the design and siting of the different installations. SSI considers that the system analysis announced by SKB which, as far as SSI is able to judge, will only include the encapsulation plant, is insufficient as a basis for considering the application for a licence to erect this installation. In the system analysis that is submitted with the application for a licence for the encapsulation plant, issues relating to manufacturing techniques and on methods for non-destructive testing should be analysed inter alia. The analysis should also analyse the function of the canister on the basis of the short and long-term requirements made on it both from the point of view of the transport system and from the point of view of final disposal. Only on the basis of a more complete analysis can assurance be obtained that the locking-in effects that follow from building the encapsulation facility are acceptable.

5 Canister production and repository design

5.1 Background

In the system for management of the Swedish nuclear fuel, most installations are not included at present: canister plant, encapsulation plant, repository and transport system. Research and development is taking place at the Encapsulation Laboratory and Äspö Laboratory and also to some extent at other places, for instance at The Welding Institute (TWI) in England. SSI makes an assessment in the following section of the research programme reported on by SKB in RD&D programme 2001 for installation design and appurtenant technological development. A starting point for SSI's review is how well SKB's reported research relates to production of the reports that are needed as a basis for future applications.

5.2 Canister production

5.2.1 SITING AND DESIGN OF THE INSTALLATIONS

As regards the siting of the encapsulation plant, SKB refers to two commission of enquiry reports [1, 2], that evaluate different aspects of the joint siting of the encapsulation plant and the repository compared with siting at CLAB. The reports describe the benefits and disadvantages that various conceivable sitings of the encapsulation plant may have and the possible design of an encapsulation plant jointly located with the repository.

SSI's assessment

SSI considers that issues relating to the design and siting of the encapsulation plant and the canister plant must be clarified together with the design and the siting of the rest of the system, including the transport system. The reports that SKB refers to do not clarify this matter. Also, an evaluation is lacking of the effects different siting alternatives and designs may have on long-term safety and radiation protection.

5.2.2 WELDING, ACCEPTANCE CRITERIA AND NON-DESTRUCTIVE TESTING

Comments on the research that is in process and planned on the expected initial state of the canister and the expected development in the repository are taken up in Chapter 7. With regard to the technological development programme that is taking place primarily at the Encapsulation Laboratory, issues relating to development of welding technology and non-destructive testing are of particular interest.

In general, reporting on the research programme relating to canister manufacture in RD&D programme 2001 is very brief. A supplementary, but partly different description of the development work is given in progress report R-01-39 [3]. Unfortunately, this report was only made available to SSI at a late stage of the review work. SSI has therefore only been able to make a summary assessment of this report.

One difference between the presentations in RD&D programme 2001 and R-01-39 concerns the development work in process for welding the lid on the copper canister. Unlike R-01-39, which is wholly focused on development of the FSW technology (friction stir welding), RD&D programme 2001 also reports on the development of EBW technology (electron beam welding).

As regards bottom welding of copper pipes, R-01-39 reports the results from the welding experiments that have taken place using EBW technology at TWI's high vacuum chamber. Unlike the welding that takes place at SKB's Canister Laboratory, welding takes place at TWI on a horizontal canister. SKB notes that certain differences exist among the welds made at TWI and that these differences were due to the direction of the electron beams in relation to the canister. No comparison was made with the result of the experiments using EBW technology at the Canister Laboratory, however.

During 2002, SKB intends to publish a first compilation of design prerequisites that is to include issues relating to canisters. The content and scope of this compilation is not shown in detail in the report in RD&D programme 2001, but SKB states that the production of criteria for considering applications is intended to take place in a dialogue with the authorities.

SKB states in RD&D programme 2001 that it is intended to adopt acceptance criteria for all parts of the canister including any welds. For welds, it is intended to produce criteria both for superficial defects and for defects within the material. SKB states that it intends to carry out an impact analysis '… showing what would happen if there were more or larger defects than specified by the acceptance criteria'.

The final acceptance criteria must be verified by non-destructive testing, OFP. SKB is planning to use several different methods for OFP, including testing by ultra-sound, eddy current and radiography measurements. SKB provides a brief report of these techniques but does not give any references to development work.

SSI's assessment

In general, SSI lacks an integrated evaluation of the results of the different welding experiments. SKB does not report the quantity of trace substances of other characteristics of the welds, for instance, the particle size, in the same way as is done for manufacture of copper pipes. Bearing in mind that SKB notes differences in welds depending on the direction of the electron beams, SSI considers that a comparison made between welds made at TWI and those made at the Canister Laboratory would have been of interest.

SSI considers that there is lack of clarity in SKB's report of the development work for the copper canister, for instance the approach adopted for development of work on the lid weld, since the report in R-01-39 gives another picture than in RD&D programme 2001.

SSI states in Chapter 7 that SKB needs to report in future safety analyses on the development of all canisters, i.e. also the canisters with defects that are less than what is stated in the preliminary acceptance criteria, and evaluate their importance for long-term radiation protection. The result of such an evaluation needs to be taken into consideration when acceptance criteria for canister manufacture and the non-destructive testing are to be finally established. SSI considers therefore that it is of great importance that the production of criteria for acceptance testing take place primarily in a dialogue between personal who work with safety analysis issues and personnel who work with technology development issues at SKB and only in the second place in consultation with SKI and SSI.

The results of the development work on canister manufacture will in the near future be an important basis for SKB's future application for a licence to erect an encapsulation plant. SSI considers that SKB should clarify the plans for the remaining development of the work during 2002. These plans should then be included in the strategy document that SSI proposed that SKB should prepare, see Chapter 3.

5.3 The repository

5.3.1 BACKGROUND

It is stated in SSI's regulations on protection of health and the environment in final disposal of spent nuclear fuel and nuclear waste [4], that optimisation is to take place. Moreover, consideration is to be taken to the best available technique (BAT) in the final disposal of the waste. A report on how the final disposal system has been optimised should be included in a future application.

In the system analysis, R-00-29 [5], of the KBS-3-method which SKB submitted a report on in conjunction with the supplementary report on RD&D programme 98, RD&D-K, SKB reported on a number of studies carried out with the intention of optimising the repository facility. These studies included:

- disposal method
- choice of repository depth
- entrance via shaft vis à vis different forms of ramps
- techniques for boring tunnels
- disposal techniques
- buffers and backfill material.

The choice of access (ramp or shaft) will be very important for the system design and can also be important for the long-term protective capability of the repository. The depth of the repository also affects the long-term protective capability of the repository. An increased depth of the repository may have advantages for the long-term protective capability of the repository, for instance through lower hydraulic conductivity, longer transport route, lower hydraulic gradient and lower groundwater flow can be expected with increased depth. The risk for human intrusion as well as the effect of glaciation or permafrost is expected to reduce at increased repository depth at the same time as it can be expected to lead to higher salt content in the groundwater and a greater proportion of alien material (e.g. cement reinforcement), changes that SKB states as being negative from a long-term safety aspect.

In the light of these questions, SSI stated in its statement on RD&D-K [6] that:

> *SSI considers that the issues relating to the long-term protective capability at the repository for the ramp and shaft alternative respectively need to be evaluated in detail at the latest in conjunction with application for a licence. Moreover an analysis needs to be carried out where the depth of the repository's effect on the protective capability is examined together with costs, ability to construct, etc. In addition, SKB should carry out further work in seeking the optimal design of KBS-3, e.g. for different variants of horizontal repository (e.g. medium-length tunnels) compared with vertical repositories.*

5.3.2 SKB'S REPORT

SKB states in RD&D programme 2001 that it is intended in the next six-year period to report on the method for repository optimisation and to successively reduce the number of alternatives. SKB states that the analysis of alternative repository designs is intended to take place on the basis of the design prerequisites that are being produced at present. A first draft of these is planned during 2002. At the end of the coming six-year period, the design prerequisites needed for the detailed investigation phase are to have been produced. SKB states that the development of method for site adaptation and optimisation of the repository is to take place in consultation with the authorities.

As regards variants of the KBS-3 method, it has emerged from SKB's earlier reports that KBS-3-MLH (disposal in horizontal, medium-long tunnels) can have advantages from a long-term safety aspect, although also from an environmental point of view and moreover entails lower installation costs. SKB

states in R-00-29 that the variant requires extensive technical work and full-scale demonstration to reach the same level of maturity as the main variant of KBS-3. SKB has started the work by producing a research, development and demonstration programme for MLH, although it is not intending to carry out action relating to demonstration in the next six-year period, according to RD&D programme 2001. The reason for this is that SKB wishes to prioritise the ongoing experiments at Äspö Laboratory and is of the opinion that new experiments would perhaps change the boundary conditions for the experiments now in process.

However, SKB did submit a proposal to the RD&D programme for MLH [7] late during SSI's review process. SSI has therefore not been able to carry out other than a very superficial review of the report. SSI can state that [7] provides a more comprehensive description of MLH in comparison with the RD&D programme 2001. According to the proposed R&D programme, a programme of this kind, including demonstration experiments, could be started in 2002 and have been partially evaluated by the time of the application.

SSI's assessment

Bearing in mind what has been said above, SSI considers it very important that SKB makes its plans concrete with regard to evaluations of different variants of system designs and identifies at an early stage the development, demonstration and research requirements that exist taking into consideration the need to optimise the repository installation. This is particularly the case when documentation can only be obtained through demonstration and long-term experiments.

One such example concerns the medium-long hole, MLH, variant. If it is to be possible to evaluate MLH in a proper way, an R&D programme needs to be evaluated in an early phase. SSI considers therefore that it is satisfactory that SKB according to [7] is now considering taking such an initiative.

5.4 SSI's overall assessment

The report on the research programme on canister manufacture is very brief in RD&D programme 2001. Canister manufacture and the non-destructive testing have a key role in the KBS-3-method. SSI considers therefore that clear objectives and sub-objectives need to be set for all parts of the development work, and be linked to the development of the safety analysis. A first report on the remaining development work should be produced during 2002, after which the plans should be included in the proposed strategy document.

SKB needs, according to SSI's regulations, to report on the way in which the final disposal system has been optimised. It is therefore important that SKB concretises its plans for evaluation of the importance of repository depth, entrance alternatives (ramp or shaft) and alternative variants of repository design. Moreover, SKB should identify at an early stage the developments, demonstration and research requirements that exist, taking into consideration optimisation of the repository installation. It is particularly important that SKB identify at an early stage the need for long-term experiments. SKB submitted a proposed RD&D programme for the KBS-3-MLH (disposal in medium-long holes) variant very late during SSI's review process. SSI regards it as positive that SKB is considering studies of this variant of KBS-3, which can have safety-related benefits compared with the main variant of vertical emplacement holes.

6 Safety analysis

In this chapter, SSI provides general points of view on SKB's programme for development of methods for safety analysis, as reported in Chapter 2 in RD&D programme 2001. SSI's points of view on the biosphere and its role in the safety analysis is mainly described in Chapter 8 in this report since SKB has opted to take up these issues in a separate chapter (Chapter 9) in RD&D programme 2001. In this chapter, SSI also gives its points of view on SKB's planned safety reports.

6.1 General points of view

SSI regards it as positive that SKB in its report on the development programme for safety analysis, bases itself on SKB's own experiences from SR 97 [1] and the authorities' points of view in the reviews of this safety analysis [2] and earlier RD&D programmes. SSI considers that a corresponding approach should also be adopted in future FUD-reports.

6.2 Programme for development of methods for safety analysis

6.2.1 SYSTEM DESCRIPTION

By system description is meant the basic documentation on all the conditions, processes and characteristics that need to be taken into consideration to be able to describe the development of a repository and to be able to assess future radiological consequences. SKB states in its development programme that the method with THMC-diagrams (thermic, hydraulic, mechanical and chemical processes) presented in SR 97 will be updated and further developed on a number of points.

SSI's assessment

SSI notes that SKB when formulating objectives for the programme has taken into consideration the most important points of view from the authorities' review of SR 97, e.g. the connection between processes and models, motivation and documentation of expert assessments of the importance of different processes and procedures for internal review [2]. SKB's report provides limited information, however, on the concrete initiatives planned. Instead, SKB refers to the so-called method report, which, according to information in notes from a meeting on 25 September 2001 between SKI and SKB [3] is planned to be reported on in 2004.

SSI regards it as positive that SKB has now started the work of systematising the description of biosphere processes in the form of process descriptions and interaction matrices, in the same way as for the engineered and natural barriers. SSI considers that this work must be prioritised for two reasons. Firstly, the system description is an important basis for determining the processes and parameters that need to be determined in a site investigation. Secondly, it provides a basis for identifying the needs for model development and knowledge build-up for the biosphere and the transition between geosphere and biosphere (see Chapter 8 in this statement).

6.2.2 CHOICE OF SCENARIOS

SSI and SKI stated in their review of SR 97 that SKB's choice of scenarios needs to be improved on a number of points, for instance, SKB was urged to:

- develop the choice of scenarios so that it is more evident how well the chosen scenarios cover the processes and events (system description) that can affect the functioning of the repository
- produce more comprehensive scenarios to ensure that the effect of important disturbances such as earthquakes and glaciation can be evaluated in a complete way
- clarify scenario safety in a more complete way, e.g. alternative climate developments
- clarify the link between choice of scenarios and evaluation of risk.

SSI notes that SKB states in RD&D programme 2001 that they are planning to evaluate the possibility of making a more systematic selection of scenarios based on the so-called THMC-diagrams and that earthquakes will be integrated in all scenarios for specific sites in future analyses.

SSI's assessment

SSI considers that SKB should develop a strategy for how scenarios are to be selected to provide a good basis for evaluation of risk. The strategy for selecting scenarios is linked to how probabilities are dealt with, how a weighing together of risks from different scenarios is made and the evaluation of scenario uncertainties. SSI assumes that SKB will shed light on these issues in the method report. SSI's points of view on biosphere issues in the safety analysis are reported in detail in Chapter 8.

6.2.3 RISK ANALYSIS AND ASSESSMENTS

SSI's regulations [4] state inter alia that the consequences of emplacement after sealing are to be reported in the form of risk. In the safety analysis, SR 97 [1], SKB has made a first interpretation of these regulations.

SSI and SKI provided in the review of SR 97 [2] detailed points of view on SKB's need to further develop models and methods to be able to carry out risk analyses for emplacement. SSI stated inter alia that SKB should develop a more well-defined strategy for calculation and presentation of risk that clarify:

- the link between choice of scenarios and the overall evaluation of risk
- handling risk contribution from FEPs (features, events and processes) and scenarios which can be deemed to have a low probability but which result in high doses
- methods for probabilistic calculations
- handling parameter uncertainties, e.g. choice of parameter distributions and variability
- the role of the biosphere in different time periods of the safety and risk analysis
- report of risk as a function of time and space.

In the research programme for the next three-year period SKB briefly states that it is planning to develop a strategy for both non-probabilistic and probabilistic calculations, as well as how data for these are to be determined. SKB states furthermore that it is planning to update the so-called data report [5] with input data for more models and scenarios and that the documentation of conceptual models will be improved. The results will be presented in the planned method report.

The main part of SKB's report describes, however, newly developed and simplified analytical models for consequence calculations that can be run on an ordinary personal computer. According to SKB, the

purpose of the analytical models is inter alia to serve as a complement to the more detailed numerical models and to make possible fast probabilistic calculations and sensitivity analyses. Models have been used, for instance, to evaluate the importance of different distribution assumptions and parameter correlations in SR 97. The results indicate that uncertainties in these factors are small in relation to uncertainties in the estimation of average values and variability.

SSI's assessment

SSI views positively the preliminary work on analytical calculation models reported in RD&D programme 2001. SSI agrees with SKB that these models can serve as a good complement to the more detailed numerical calculation models used in the safety analysis. SSI also agrees with SKB that great attention must be devoted to the central values and variability of parameter distributions used in the safety analysis. Many of the critical points of view that were put forward by the authorities and the international expert group in the review of SR 97 concerned exactly such assumptions, e.g. frequency and type of initial defects in canister and buffer and the time taken before a defective canister would leak [2, 6].

The fact that SSI's radiation protection requirements are expressed in the form of a risk criterion does not necessarily mean that SKB must carry out a complete probabilistic safety analysis. However, there is a need for SKB to review how this affects the arrangement and reporting of all parts of a safety analysis. SSI considers that SKB at an early stage and at the latest in conjunction with the next safety report, should present and evaluate a complete strategy for risk analysis that, among other things, sheds light on the issues that have emerged in the review of SR 97 (see above). Other examples of issues that should be clarified are:

- the need for formal procedures for expert judgement (e.g. expert elicitation) in estimation of difficult-to-measure parameters and conditions
- handling of combined deterministic and probabilistic calculations
- use of maximum conditioned risk and average risk in probabilistic calculations
- use of alternative safety indicators as a complement to risk for long time periods and as a basis for evaluation of environmental impact.

SSI is at present working on developing the approach and requirements on risk analyses and assessment of risk and has taken the initiative to an international exchange within the framework of OECD's nuclear energy agency (NEA). SSI is also intending to carry out a dialogue with SKB on these issues, but wishes at the same time to stress that this does not exempt SKB from the responsibility of pursuing this work.

6.3 Planned safety reports

SKB states that the next major safety analysis for final disposal will be carried out when data from the site investigations is available. A report will be made on the analysis in conjunction with the application for a licence for final disposal, which is planned for 2007. Before this, the following reports are planned:

2004 Preliminary safety assessments – based on data from the initial the site investigations. The assessments will serve as the basis for decisions on complete site investigations and include comparisons with the criteria set by SKB and simpler analyses.

2004 The method report (SR-MET) – which reports on method development for safety analyses, including scenario and risk analyses. The report will not make use of data from the site investigations.

2005 Safety report for licence application for siting and construction of encapsulation plant – the analysis is an update of SR-MET and is to be focused on the function of the canister in final disposal. Data from the site investigations will not be used.

Furthermore, SKB states that the next safety analysis for final disposal for other long-lived waste is planned to take place after the licence application for final disposal of spent nuclear fuel.

SSI's assessment

SSI, like SKI and the international expert group, stated in their review of SR 97 that SKB in its continued work should reinforce the role of safety analysis for integration of different parts of the final disposal programme. SSI considers that the report in RD&D programme 2001 is far too brief to be able, today, to assess whether SKB's plans comply with this objective. However, SSI has experienced that SKB during 2002 is intending to produce more detailed reports of intentions, scope and what is to be achieved with the planned safety reports. As is shown in Chapter 3 SSI considers that it would be appropriate to summarise these descriptions in a strategy document.

SSI has in another place in this document given examples of concrete issues that should be derived from or evaluated in safety analyses. Chapter 8 contains a discussion on the link between the need of data for the safety analysis and the development of measurement methods and models for characterisation of the biosphere and the transition from geosphere to biosphere. In Chapter 7 SSI reports points of view on the need to evaluate acceptance criteria for copper canisters in the safety analysis. The question of how SKB intends to make use of the recurrent function and safety analyses to guide the continued site investigations programme is discussed in an ongoing consultation on site investigations between SKB, SKI and SSI. Below, SSI gives some preliminary points of view on some of the announced safety reports in RD&D programme 2001.

SSI considers that it is important to clarify the scope of the preliminary safety assessments at an early stage. The evaluation should in SSI's view be as comprehensive as possible to provide a good basis for planning of the continued complete investigations. SSI considers that site data should at least be entered into the complete calculations carried out in SR 97 to provide a good clarification of the critical uncertainties in different geosciences models, and to be able to assess whether the data complies with the needs of the safety analysis. This applies not least to the assessment of the adequacy of the data and models produced for the biosphere, since an assessment of this kind requires that possible transport routes to the ecosystems close to the surface are known.

SSI supports SKB's work on producing a complete report of methods for implementation and reporting of future safety analyses in a method report (however, it is not clear to SSI whether the method report is to be regarded as a further development of the earlier reported templates for safety analyses, SR 95). SSI assumes that SKB in the method report reports how they have taken into consideration the authorities' review of SR 97 and the points of view given above. The method report is SKB's final report of methods for safety analysis prior to production of the final safety report for the licence application for final disposal. SSI considers therefore that it is necessary that SKB has some kind of free-standing international expert review of this report carried out. SSI considers also that the method report should be submitted to a formal review by the authorities and that this should be done in connection with review of RD&D programme 2004.

SSI considers that the safety analysis which will be included with the application for the canister encapsulation plant should be based on the new findings and experimental data that have emerged from manufacture and testing of copper canisters and development work on the buffer and backfill (see Chapter 7). Furthermore, the safety analysis, should, in a better way than in SR 97, take into consideration reasonable uncertainty intervals relating to the achieved test results from development work on canisters and the buffer. If the application is submitted before SSI has taken a position on an application on siting of a repository SSI considers that it may be reasonable, as SKB states, to base this safety analysis on generic data (e.g. from SR 97). A minimum requirement should then be that SKB take any discrepancies in the parameter intervals, etc., into consideration, which are used in SR 97 in

discrepancies in the parameter intervals, etc., into consideration, which are used in SR 97 in relation to what has emerged in the site investigations.

SSI intends to follow up the above issues relating to renewed reports of system and safety analyses in the consultation which SKB, in accordance with the government decision on the complementing RD&D programme 2001, is to carry out with the authorities [7].

6.4 SSI's overall assessment

Programme for development of methods for safety analysis

As far as SSI can judge, SKB in its development programme for safety analysis has covered the major part of the points of view that have emerged in the reviews of the safety analysis SR 97. SSI's most important points of view on the programme are that SKB should:

- Prioritise production of a systematic description of processes in the biosphere and the transition between geosphere and biosphere to obtain a sufficient basis to be able to carry out site investigations that serve their purpose.
- Produce and evaluate a method for risk analysis that clarifies how the various parts of the safety analysis can be designed to provide a good basis for evaluation of risk in accordance with SSI's regulations. The method should be described in SKB's planned method report.

Planned safety reports

SSI considers, as has been said previously by the authorities and the international expert group in the review of SR 97, that SKB should clarify the role of the safety analysis for integration of the different parts of the final disposal programme and what needs to be achieved with future safety reports.

SKB's announced method report should be submitted to formal review by the authorities. The report should therefore be linked to RD&D programme 2004. SKB should also carry out an international expert review of this report.

The preliminary safety assessments of the sites included in the site investigations should be as comprehensive as possible to provide a good basis for the planning of the continued complete site investigations. SSI considers that it may be necessary to carry out simplified scenario and consequence analyses to test the adequacy of the data and the models produced for, for instance, the biosphere and the transition between geosphere and biosphere.

The safety analysis which will be included with the application for the canister encapsulation plant should evaluate the new findings and experimental data, with the appurtenant uncertainties, which have emerged in the first place from both manufacture and testing of copper canisters, and also take into consideration new knowledge from development work on buffers and backfill. SSI also considers that SKB should clarify the way in which they are going to take into consideration the site-specific data and conditions that have emerged in the site investigations.

7 Research – final disposal and the geosphere

7.1 General

7.1.1 SKB'S REPORT

SKB's report on the research programme that is in process and is planned for the coming years for fuel, the engineered barriers and the geosphere, consists of several chapters in RD&D programme 2001. The report includes all processes in the so-called process report from SR 97 [1], and moreover a description of research relating to the initial state of the repository. The starting points are given as the uncertainty discussion in the process report and the comments contained in the joint authority review report on SR 97 as well as the statement by the international expert group appointed to review SR 97. SKB's report in RD&D programme 98 and the points of view given on this report are also taken up by SKB where deemed relevant.

In Table 3-1 in RD&D programme 2001 the processes are indicated by colour marking, which is to provide a rough estimate of the size of the planned research inputs during the next three-year period. In Table 3-2 the corresponding information is given on the research that is intended to take place on the initial state of the repository.

7.1.2 SSI'S ASSESSMENT

SSI considers that the arrangement in SKB's presentation is an improvement compared with earlier reports. Clarity has increased by the structured description and by referring back to the authorities' points of view on RD&D programme 98 and SR 97. This will also facilitate follow-ups of the research results. SSI wishes at the same time to point out that it is unfortunate that the points of view advanced in the review of SKB's supplementary report on RD&D programme 98, RD&D-K, could not be included in RD&D programme 2001 for reasons of time. The comments put forward in conjunction with RD&D-K must be taken into consideration by SKB in the ongoing R&D work. Review of RD&D-K was particularly important since this review took place after both the safety analyses, for SFL 2 and SFL 3-5, had been reviewed. It was first in the review of RD&D-K that it was possible to comment on SKB's work as a whole.

Despite the indication of the research activities prioritised in the coming three-year period in Tables 3-1 and 3-2 in RD&D programme 2001 being illustrative, the report is not sufficient. SSI considers that RD&D programme 2001 lacks a clear account of the overall objectives for SKB's research, development and demonstration activity and the research priorities linked thereto. SSI considers that SKB must report what needs to be achieved in a much clearer way, how it is to be achieved and when this has to be done in the ongoing siting process. This can be done in the so-called strategy document that SSI wishes to see, see Chapter 3. Such a strategy document is also advocated by the international expert group in its statement on SR 97 [2].

7.2 Copper canister

7.2.1 INITIAL STATE OF THE CANISTER

In Section 5.1.2 ('Geometry') SKB gives an account inter alia on matters relating to initial defects. Moreover the research programme is discussed in Chapter 15 ('Encapsulation').

Background

SSI has stated in the statement on RD&D-K [3]:

> *SSI considers, like the international expert group that reviewed SR-97, and a number of referral bodies, that alternative canister damage than that postulated in SR-97 needs to be analysed. Moreover SKB needs to clarify issues relating to material characteristics of the canister, the arrangement and function of the non-destructive testing, and how the results are to be integrated in the safety analysis. On the basis of these analyses, the design prerequisites for the canister can then be derived. SSI considers that these analyses need to be ready at the latest in conjunction with application for the encapsulation plant.*

The background to the statement was the deficiencies that could be noted with regard to prerequisites of the so-called canister defect scenario in SR 97. In the canister defect scenario, only the importance of one, or five, canisters having initial defects were evaluated. This defect was assumed in the analysis to be greater than the detection limit for non-destructive testing. The other 3,999 (or 3,995) canisters were regarded as 'whole' in SR 97 and dealt with in the so-called base scenario.

SSI considers that it cannot be excluded that these canisters also have defects, although the type of defects and/or their size is under the detection threshold for the non-destructive testing. It must even be considered probable that this is the case. SSI considers that SKB in future safety analyses needs to describe the development of these canisters as well and their importance for the long-term radiation protection. The results of the safety-analytical evaluation need to be taken into account when the acceptance criteria for canister manufacture and the non-destructive testing are finally to be established.

SKB's report

SKB's report on how criteria are to be set for the initial defects of copper canisters are brief and are not clearly stated in RD&D programme 2001. To determine criteria for initial defects SKB refers to future investigations including the design prerequisites for the repository that are to be issued during 2002.

As regards the evaluations that SKB intends to carry out, it is stated in Chapter 15 that acceptance criteria will be set for all parts of the canisters, including for future welds. The acceptance criteria that are formulated are linked to the chosen method for acceptance testing, which SSI interprets as the non-destructive testing of welds. This is in agreement with the information in Chapter 5 ('Canister'), where SKB states that the assumptions on initial defects in future safety analyses are to be derived from among other places test statistics from the non-destructive testing and the set acceptance criteria. SSI interprets RD&D programme 2001 as in data for future safety analyses, as well as acceptance criteria for the weld, which will be derived from the non-destructive testing. SKB intends furthermore to carry out a consequence analysis that shows what happens if there are several or larger defects than stated in the acceptance criteria.

SSI's assessment

In the light of the brief description given in RD&D programme 2001 and in the absence of the report on design prerequisites for the canister inter alia which is planned to be reported on in 2002, it is difficult for SSI to judge which strategy and planning SKB has for the research and development programme.

As mentioned above, SSI considers that an evaluation based on in data from non-destructive testing needs to be supplemented with an evaluation of the long-term importance and the development of the defects, which are less than the detection threshold for the non-destructive testing. In the light of such an evaluation SKB can then evaluate the preliminary acceptance criteria and design prerequisites for the canister. SSI does not exclude that SKB after such an evaluation may need to revise these criteria for the canister, e.g. through more stringent requirements on manufacture as well as improved accuracy in the non-destructive testing.

7.2.2 RADIATION INTENSITY

SKB states in RD&D programme 2001 that if the external dose rate on the canister does not exceed 1 Gy/h radiation-induced effects can be disregarded.

SSI's assessment

In interaction with copper, photoelectric effect is dominant at lower photon energies than approximately 120 keV [6]. This means that due to the higher atomic number of the copper there will be established a very high secondary electron flow in water-filled copper cavities and at the border surface between canister and water. For hydrogen-filled cavities, the effect is even greater. In assessment of radiation-induced effects, such as radiolysis, one cannot automatically disregard the layer closest to the copper.

SSI has not made any assessment of the impact of the effect on water or hydrogen in border surfaces/cavities but considers that it should be taken up in a review of processes that can affect the engineered barriers.

7.3 The buffer

7.3.1 INITIAL STATE OF THE BUFFER

SKB's report

Section 5.1.2 only takes up issues concerning the dimensions of the buffer. SKB states that no comments have been made on review of SR 97. Given the structure that SKB has in RD&D programme 2001, the issue of initial defects in the buffer should have been taken up in Section 5.1.2. SKB's assumptions in SR 97 that the buffer did not have any defects was called into question both by the international expert group [2], by GRAM (expert group appointed by Oskarshamn municipality) [7] and by the authorities [5].

In SR 95 SKB cited as example of defects in the buffer: impure bentonite, incorrect construction of the barrier and too quick or poor remoistening of the barrier. In RD&D programme 2001 SKB gives a report on the research programme concerning the course of resaturation as well as on the issue of pollution in the buffer.

SSI's assessment

SSI would like there to be a systematic scenario analysis of the importance that the buffer's short-term development can have in a more long-term perspective. SKB needs to evaluate the effect of possible defects in the buffer, for instance, the consequences of:

- uneven or slow resaturation (changes in the buffer due to heating up in unsaturated conditions)
- structural damage, for instance caused by damage on deposit
- geochemical effects, for instance, due to exposure to groundwater with high salinity or low-ion groundwater.

The results from a scenario analysis of this kind need then to be related back to development work and production of the final design prerequisites and acceptance criteria which are needed for the adjacent area (e.g. criteria for the deposition holes) and the buffer.

7.3.2 THE BUFFER'S FUNCTION AFTER PENETRATION

SSI's regulations on protection of health and the environment for final disposal of spent nuclear fuel and nuclear waste require a report on the repository's protective capability after intrusion [8]. In SR 97 SKB has assumed that the buffer would expand and reseal itself after being penetrated. The authorities considered in their review that SKB had not produced any support for the claim that the buffer would function like this after such damage.

SSI considers that SKB should consider carrying out experiments with a view to clarifying the issue and strengthening the arguments for future safety analyses.

7.3.3 COLLOID TRANSPORT

SKB is planning an experimental demonstration project to investigate the formation of colloids from bentonite buffer. The purpose is to study the conditions in which colloids are formed and are stable and the potential they have to transport radionuclides. SKB is also planning some model development with a view to being able to quantify the importance of colloid transport for the repository's protective capability.

SSI's assessment

In the review of SR 97 [5] SSI and SKI pointed out that SKB should evaluate the effect of colloids in the eventualities of the buffer not working as intended, e.g. depending on faults in manufacture or emplacement. SSI means that it is not clear how SKB intends to take up the effect of colloids when the buffer is defective in its research programme.

7.4 Resaturation

7.4.1 ALTERNATIVE METHODS OF RESATURATION

SKB puts forward arguments on the main alternative, which is a mixture of crushed rock and bentonite (15–30 % MX-80-clay + the rest crushed rock), but also discusses a possible alternative, namely backfill with 100 % natural clay. As an advantage SKB states that the alternative, unlike the main alternative, will establish a swell pressure in resaturation in brackish groundwater as well. According to SKB salt groundwater can have a negative effect on backfill consisting of a mixture of MX-80-clay and crushed rock, which can contribute to problems with a greatly increased porousness in the backfill and channel formation between the backfill and the tunnel ceiling. SSI put forward similar points of view in the statement on RD&D-K [3]:

> *SSI considers that it must be ensured that the development of the backfill of the tunnels does not eventually lead to a 'short circuit' between the repository and the biosphere. SSI sees a potential problem with this for a ramp alternative and in particular in the case of placing in salt groundwater.*

SSI's assessment

The question of the long-term function of backfill and its links to the operational issues are important, in SSI's view. SKB needs to make these issues a priority in future. The results from the research that is taking place needs to be evaluated and the principal choice of system design needs to be made in a not too distant future. The need for long-term experiments needs therefore to be identified at an early sta-

stage, in particular for the alternative backfill with pure clay, see below. SKB must therefore describe how and in what stages matters of this kind need to be clarified in the requested strategy document.

On application of backfill, consideration has to be taken to the buffer's resaturation process. If backfill is done with pure clay, instead of a mixture of crushed rock and bentonite, it has to be clarified to an even higher extent that the system will function as intended and that a counter pressure is established by the backfill in relation to the buffer. The problem is accentuated possibly if the buffer has already been moistened in conjunction with deposit, which has been discussed.

Finally, SSI can note that SKB's arrangement in RD&D programme 2001, with the continually recurring section 'Conclusions in SR 97 and its review', are misleading for the description of backfill since its long-term development has not been explicitly dealt with in SR 97.

7.5 Research and development of disposal technology at Äspö Laboratory

SKB's report

Parts of the research relating to the initial licence in the adjoining area and its development are carried out at Äspö Laboratory. SKB describes these experiments in Section 12.3 in RD&D programme 2001. Many of the issues described in this section are closely related to the system and safety analysis issues and make up an important part of the strategy document. SSI therefore also takes up the issues dealt with in other parts of this statement.

SKB presents four projects that have started in recent years, or which will start during the next few years: prototype repository, backfill and plug test, retrieval and long-term testing of the functioning of the buffer material. Only an overview description of experiments are given in RD&D programme 2001. A more detailed description of the experiments was given in RD&D programme 98.

The prototype repository consists of six deposit positions, in which canisters with electric heaters have been installed to simulate the residual effect of spent nuclear fuel. The canisters have then been deposited with bentonite around them and the tunnels refilled with a mixture of bentonite and crushed rock. It is planned that the experiments should continue for five years for the four outer canisters and a further 15 years for the two inside canisters. SKB stated in RD&D programme 98 that the main objectives of the prototype repository were to demonstrate the function and interaction of the parts of the repository and to compare the outcome with models and assumptions as well as to develop and test appropriate criteria and quality systems. No more detailed description of the objective was given.

SSI's assessment

The final results from these long-terms experiment will be ready only approximately five years after SKB plans to have started operation of the repository. On this basis and in the light of the fact that points of view have been raised on the development of the adjacent area both by the authorities and the international expert group in the review of SR 97, it is of key importance that SKB clarifies already now the purposes of and expectations on the experiment and the evaluation criteria that will be used. SKB needs furthermore to consider supplementing the experiment, inter alia to provide a better statistical basis for the conclusions that need to be drawn.

Similar needs to clarify purposes and expectations exist for the long-term experiments made on the function of backfill and the plug test. SSI notes that SKB has not reported on any research projects for the alternative backfill with pure clay. Bearing in mind the needs that SKB's report in RD&D programme 2001 reflect to find a viable backfill alternative for deposit in salt or brackish groundwater, the planned research programme should focus considerably more on this issue.

7.6 Modelling

In SSI's review of the geosphere, the models have not been reviewed but here only general comments are made on modelling of the geosphere.

In the review of SR 97 the authorities pointed out that the hydrology modelling is generally more thoroughly worked out than the modelling of adjacent areas. In RD&D programme 2001 SKB describes an extensive research programme with regard to radionuclide transport in the adjacent area including development of COMP23 (SKB's computer code for calculation of radionuclide transport in the adjacent area).

SKB states both in Chapter 2 and Chapter 8 in RD&D programme 2001 that a validity document will be prepared for the most important models for consequence calculations, i.e. models for groundwater flows in the geosphere and for radionuclide transport in the adjacent area, the geosphere and the biosphere. SKB is planning in this document to report on the scientific support that exists for a model and to discuss the conceptual assumptions and mathematical formulations made. This planned documentation is not taken up explicitly in Chapter 9.

SSI's assessment

SSI considers that it is important that SKB's planned research programme on radionuclide transport in the adjacent area leads to hydrology modelling and adjacent area modelling has a comparable level of ambition.

SSI supports SKB's plans for documentation of models and considers that this is in accordance with requests from earlier reviews. SSI considers that biosphere models should be documented in a comparable way as other models and that the transition between geosphere and biosphere should be taken into consideration.

7.7 SSI's overall assessment

SSI considers that SKB in future safety analyses, in addition to an evaluation based on in-data from the non-destructive testing, also needs to evaluate the importance of defects that are under the detection threshold for the non-destructive testing. In the light of such an analysis, SKB needs to evaluate the preliminary acceptance criteria and design prerequisites for the canister. SKB can after such an analysis also need to revise these criteria for the canister, e.g. through more stringent requirements on manufacture and on improved accuracy in the non-destructive testing.

For development work on the buffer and the backfill SSI considers that SKB should produce a complete report that better clarifies:

- How initial defects and the short-term development of the buffer, the resaturation phase, can affect the long-term function of the repository and the extent to which experiments at Äspö can be expected to provide answers on these issues.
- The importance of the backfill for long-term protective capability of the repository and the research, developments- and demonstration inputs required to build up sufficient knowledge for the needs of the safety analysis.

8 Research – the biosphere

8.1 Introduction

The biosphere can briefly be described as the part of the environment that organisms (including human beings) can use to sustain and reproduce life. The consequences of a discharge of radioactive substances from a repository, in the form of radiation doses to organisms and the appurtenant biological effects, can thus only arise in the biosphere. The biosphere has therefore a self-evident place in the safety analysis, and a correct analysis of the function of the ecosystems as transport and exposure routes for radioactive substances is absolutely necessary to understand the protective capability of the repository. This also emerged from SKB's safety analysis SR 97 [1], where considerable differences, up to seven orders of magnitudes, in the outcome could be obtained depending on the ecosystem that was analysed.

The biosphere's role in the safety analysis does not differ fundamentally from the geosphere's, as both rock and ecosystems are transport routes for radioactive substances. Both rock and ecosystem can also delay and limit effects by retaining radioactive substances. However, there is a difference between the importance of the rock (adjacent area) and the ecosystems for the physical integrity of the repository, where the role of the biosphere is considerably more limited. In addition, the ecosystems are a lot more changeable in the short-term time perspective than the rock provided that no disruptions take place in the form of earthquakes or the like. Ecosystem conditions are also greatly dependent on climate and affected by local processes of change in inter alia, hydrology and the shoreline.

A new assessment of SKB's biosphere research is made in this chapter on the basis of the existing research programme, RD&D programme 2001 (mainly Chapter 9). Biosphere issues and radiation protection in an international perspective are taken up in Section 8.3 of this statement. In Section 8.4 a review is then made of the description of the conceptual ecosystem, models, transport processes and specific ecosystems. SSI's previous review and the biosphere-related environment and health protection requirements in SSI FS 1998:1 [2] are taken up in Section 8.2.

8.2 SSI's previous review

SSI has consistently pointed out the need for careful biosphere studies with regard to final disposal [3, 4]. SSI has inter alia pointed out that the study of the biosphere has had too low a priority. In conjunction with the review of RD&D programme 98 [5] SSI noted however that SKB now 'has satisfactory ambitions' in its biosphere studies, and that an overall characterisation of the biosphere needed to be made in conjunction with the choice of site (which is also confirmed by the major ecosystem-dependent differences that can be noted in SR 97 [1]). A characterisation of this kind was not made by SKB in conjunction with the choice of site and the issue was not taken up in the government's decision on the choice of site [6]. A review of SSI's requirements on SKB's biosphere report is contained in Table 8.1.

8.3 International overview

SSI initiated the international BIOMOVS-project (Biosphere Model Validation Study) in which different models for biosphere modelling were compared and 'validated' (validation means here to check that predictions comply with observations). The project had an international follow-up, BIOMOVS-II with SSI as one of the controlling organisations.

Table 8.1 Overview of SSI's environment and health protection requirements in disposal of spent nuclear fuel and nuclear waste.

	LONG-TERM PROTECTIVE CAPABILITY		PROTECTIVE CAPABILITY DURING OPERATION	PROTECTIVE CAPABILITY PRIOR TO SITE SELECTION
	SSI FS 1998:1 [2] and SSI-report 99:03 [7]	**Review of SR 97 SSI-report 2000:17 [8]**	**SSI FS 2000:12 [9]**	**SSI's review of FUD-98 and FUD-98 Supplement SSI-report 99:11, 99:12, 2001:12 [5,10,11]**
HEALTH	The risk for most exposed <10^{-6} y^{-1}. The risk includes the probability for the event and the probability of the event leading to injury in the form of cancer or genetic defects. Relates to a large population. For the most exposed, 10^{-5} y^{-1} can be used. The relevance to the protected object 10^{-6} for a large population is to be motivated in this case. The tolerable risk range is a factor 10 around the average value 10^{-6} y^{-1}.	*SKB should*: * Clarify the position of the human being in the affected ecosystems. * Improve the picture of exposure via peat. * Improve the motivation for an assumed relationship between the most exposed individual and the exposed group.	Optimisation and BAT are to be applied to keep doses as low as possible, based on the limit 0.1 mSv/year for critical groups. Also System-PM 98 [10] makes requirements for a report on radiation protection during operation.	*SKB should:* * Clarify how SSI's protection criteria could be complied with at the sites involved in the site selection. * Give preference to the long-term protective capability of the repository when assessing site suitability.
ENVIRONMENT	Biological diversity and biological resources are to be protected. Detailed analysis of the affected ecosystems is required.	*SKB should:* * Develop the work on exposure routes to other protected species besides human beings. * Develop environmental protection work to the level required in SSI FS 1998:1.	Environment monitoring is to take place to provide a basis for assessment of the environmental impact.	*SKB should:* * Clarify how SSI's protective criteria can be assessed on the sites included in the site selection. * Give preference to the long-term protective capability of the repository when assessing site suitability.
BIOSPHERE CHARACTERISATION	Characterisation of present biosphere incl. known trends (e.g. land elevation).	*SKB should:* * Confirm assumptions on transition geosphere-biosphere. * Continue to describe relevant ecosystems. * Develop analysis of possible exposure scenarios in a thousand-year perspective. * Describe processes more systematically. * Develop the ecosystem-specific dose conversion factors (EDF).	Hypothetical critical group can be applied. In the event of doses >10 microsievert or increased environmental values, realistic evaluations are to be made of the consequences in the most affected area. Before new installations are commissioned, the environment and dispersion routes are to be surveyed.	*SKB should:* * Study and report current ecosystems, to provide a picture of how radionuclides behave. * Clarify how biosphere conditions could be used as site selection criteria.
BIOSPHERE-DEV.	Possible development of the repository and its surroundings are to be described in qualitative terms. Indicators for assessment of the repository's protective capability can be used.	*SKB should:* * Better characterise long-term changes including alternative ecosystems.		

Subsequently further projects have been carried out within the framework of IAEA, e.g. BIOMASS (Biosphere Modelling and Assessment) where a systematic examination has taken place of important factors in the biosphere for modelling of health consequences of a repository [12]. IAEA recently carried out at the request of the US Department of Energy (DOE) a peer review of biosphere modelling for the planned repository at Yucca Mountain, Nevada, USA [13], where the BIOMASS-project served as a basis.

Additional guidance within the field of radiation protection concerning long-term disposal has been provided by the International Radiation Protection Commission, ICRP [14, 15].

It is significant that the biosphere issues have become integrated in the context of general environmental protection in recent years. This development is international and Sweden has been a driving force. ICRP is at present reviewing its radiation protection recommendations with a view to have completed revision by 2005. Protection of the environment against ionised radiation is expected to be an important component of the new recommendations. International initiatives are also being taken within IAEA and OECD-NEA. SSI is co-ordinating the project FASSET (Framework for Assessment of Environmental Impact) within EU's fifth framework programme, which aims at building up a framework for assessment of environmental consequences (with the focus on other organisms than the human being) of the occurrence of radioactive substances in the environment (website: http://www.fasset.org). SKB is participating in this project, which in all includes 15 organisations in seven European countries. In addition, SSI has become involved nationally and internationally in the radioecological research, e.g. in the LANDSCAPE project [16].

These international studies provide a basis for both development and review of SKB's work on biosphere analyses. In an international comparison, biosphere issues in conjunction with emplacement issues have a high priority in Sweden.

8.4 Review

8.4.1 CONCEPTUAL ECOSYSTEM DESCRIPTION

In SR 97 [1] SKB made a systematic description of processes in the repository and the adjacent area, with the exception of the biosphere. SKB has now started this work. The systematic description is made in the form of general and special interaction matrices, where both ecosystem components and processes (interactions) between ecosystem components can be visualised.

The description of the interactions between components of the ecosystems requires basic knowledge of the structure and function of the ecosystems. To this end SKB is co-operating with a number of research institutions in Sweden, and they are also participating in international research projects. SKB is emphasising the advantages of this method, i.e. that it is based on understanding of the component processes and thereby realism in the assessments, that processes can be quantified and that they support the model development.

SSI's assessment

SSI supports the methods selected by SKB for conceptual ecosystem description. SSI has good experiences of the methods, that are used in the Authority's own development of models for radionuclide transport in forest ecosystems [17].

SSI considers that it is important that a complete documentation be prepared in support of the interaction matrices. For this SKB needs to report the sources that are used to describe processes (e.g. international compiled lists of 'features, events and processes', so-called FEP-lists), the processes that have been considered and the basis for including or eliminating them from the

matrices. A documentation of this kind [18] has been submitted by SKB in conjunction with production of a new safety report for SFR 1, SAFE. SSI is at present reviewing SAFE.

There is reason for concern about the timetable in SKB's development work since the biosphere work has not previously been given priority. The conceptual analysis is of the greatest importance for the site investigations to be carried out in the best way. SSI has previously pointed out that SKB at the latest in conjunction with the transition to the complete site investigations should report a detailed investigation programme with links to the radiation protection requirements required by SSI and the requirements on a safety analysis. This comment is still valid. It is important that an investigation programme of this kind also contain a report on how the site investigations are linked to the development of understanding the ecosystem.

8.4.2 MODEL DEVELOPMENT

SKB's modelling of transfers of radioactive substances in the biosphere is based to a great extent on BIOPATH and PRISM models developed by Studsvik Eco & Safety. The models were produced in the 1970s and have been successively further developed since then. These so-called compartment-models describe the transfer of radioactive substances between different compartments with the aid of transfer factors.

SKB intends to reduce uncertainties in the biosphere by in-depth study of processes and construction of process-based modelling tools. The models are based on flows of, for instance, carbon dioxide and nutrition substances, to which are linked proportional flows of radioactive substances. An example is the modelling based on carbon flows (C-14) at Öregrundsgrepen, which is included in the material in SAFE, the updated safety report by SFR 1.

SKB reports that they are taking part in the EU-project FASSET (Framework for Assessment of Environmental Impact). This project is intended to compile knowledge about the radiological effects on the environment, i.e. flora and fauna, and aims at recommending a framework for how such issues can be dealt with by industry and the authorities. SKB is participating in the working groups within the project that are studying dispersion models in different ecosystems, biological effects and the framework itself.

SSI's assessment

The total uncertainty in the consequence calculations can be substantial, and the uncertainty in biosphere modelling itself can be a predominant factor in this uncertainty. However, the international validation studies that have been carried out showed that the models developed by Studsvik Eco & Safety stand up well in comparison with other models for the cases studied.

SSI considers that the so-called system-ecological model development is a good complement to the compartment-models that have been used to date. The benefits are that models are based on a mechanical estimate of the flows in the ecosystems and that the limits for the flows are determined by the productivity of the ecosystem. The processes are measurable, and the basic mass balance in the ecosystem can therefore be determined with a high level of reliability, which can thus also reduce parameter uncertainties. A basic difficulty for all types of models is, however, to determine the proportionality between mass flow and radionuclide flow for the large number of radionuclides that are of interest. Here SKB intends to use the studies of the Chernobyl precipitation and the environmental monitoring carried out (and required by SSI's regulations) around nuclear power plants. This means that the model tools can be expanded by possibly some ten radionuclides for the aquatic environment; very few radionuclides are detected in the land environment and only in insignificant quantities. As regards discharges from nuclear power plants, they are also dominated by radionuclides with a relatively short half-life, which is not particularly interesting in a long-term perspective. However, uncertainties remain, which mean

that the process-based models do not necessary improve the forecasting ability and/or reduce uncertainties in a decisive way.

SSI supports the further development of process-based models as they are based on:

- a fundamental understanding of the ecosystem's structure and function, and they can make
- important contributions to validation and verification of compartment models, and thereby also
- improvement of compartment models.

SSI lacks, however, in RD&D programme 2001 a clear report on selection of radionuclides and further approaches to model development. Furthermore, a timetable is lacking, and a documentation of the concrete link to the site investigations (see furthermore, SSI's comments on site investigation consultations in the statement on SKB's supplementary report on RD&D programme 98 [11]). This connection must be clear, documented and reviewed, before the site investigations move on to complete site investigations.

It also needs to be pointed out that the international development, as well as the concrete requirements made in SSI FS 1998:1 [2], point to the need to take into consideration protection of the environment, not only protection of human health. This requires a development programme to:

- identify protection end-points from an environmental perspective
- characterise the exposure situation for these protected end-points
- develop relevant dosimetric models
- characterise the conceivable biological effects in the affected ecosystems.

SKB participates, as previously mentioned, in the international research project FASSET coordinated by SSI. The project works on four main lines:

- exposure
- dosimetry
- biological effects
- development of a system for assessment of environmental consequences.

SKB's participation in this project, which includes representatives of research institutions and authorities and industry in the participating countries, is valuable both for the project and for SKB. SSI lacks, however, in RD&D programme 2001 a discussion on how results within the project will be put into practice in an updated safety analysis and in the site investigations programme. It is of very great importance for assessment of the overall environmental consequences that the calculations lead to a developed description of concentrations of radionuclides in different compartments in the environment. SKB needs at the latest in conjunction with an application for erection of an installation to document these environmental concentrations, since they serve as the basis for reasoning on both health and environmental protection. Likewise, the modelling tools need to be documented. SSI has access to the documentation produced for the SAFE-project [19].

SSI agrees with SKB's complaint that the basis for radioecological competence in Sweden is in the process of being undermined. This is in the long-term serious for the basic understanding of transport mechanisms in the environment and ecosystems, and for application in the form of model development. The lack of competence also affects other areas, such as readiness to deal with nuclear accidents.

8.4.3 TRANSPORT PROCESSES

SKB states that some efforts have been made within the SAFE-project to increase understanding of the near-surface hydrology and the transition between geosphere and biosphere. SKB reports also that these initiatives will be followed up and studied in the field as well. SKB is also planning research relating to transport of radioactive substances within the biosphere. SKB is to supplement models by field studies, make systematic literature reviews and experimental studies.

SSI stated in the review of SR 97 [8] that SKB should better motivate the assumption that SKB makes as regards the relationship between most exposed individual and the exposed group. In RD&D programme 2001 SKB reports that they will carry out a model and literature study of transport of human beings in different conditions to find out how large a population can be affected by a contaminated area. The study aims to investigate representativeness of the most exposed group in accordance with SSI's regulations.

SSI's assessment

SSI considers that SKB's planned research relating to near-surface hydrology, the transition between geosphere and biosphere, and the transport of radioactive substances within the biosphere is promising. In the review of SAFE, SSI will come back with viewpoints within these areas. SSI lacks, however, in RD&D programme 2001 a clear plan for how SKB intends to carry out this research. SSI wishes to see focused inputs with clear objectives and timetables. SKB needs moreover to clarify the needs for data and models on the basis of safety analyses and to clarify the measurement inputs that are required in the site investigations, i.e. when, for instance, critical R&D results and models need to have been produced taking into consideration the needs in connection with the site investigations.

SSI regards it as positive that SKB is planning studies to investigate how large a population can be affected by a contaminated area and believes that it can contribute to meeting the requirements that concern protection of human health in SSI FS 1998:1 [2]. SKB reports no more detailed timetable for the studies. SSI underlines therefore the importance of the result being needed already during the site investigation phase to be able to compare sites in this perspective.

A crucial difficulty with regard to final disposal is to clarify the transfer of radioactive substances between geosphere and biosphere. In SR 97 [1], the assumption has been made that radionuclides in the biosphere will be accessible at a depth of 30 metres under the surface, which can lead to considerable uncertainties in the following calculations. SSI considers, also in conjunction with review of SR 97 [8], that SKB needs to deepen its analysis of radionuclide transport in the interface between geosphere and biosphere, to be able to present a credible safety analysis.

In the review of SR 97 [8] SSI emphasised that SKB only used alternative measures of the protective capability of the repository to a limited extent. SSI considers that alternative safety indicators, such as the flow of radionuclides from geosphere till biosphere and concentrations of radionuclides in the environment, are important complements to dose and risk and can be used to obtain information that differentiates between sites. In RD&D programme 2001 SSI lacks a description of how SKB intends to handle alternative measures of the repository's protective capability.

8.4.4 ECOSYSTEM-SPECIFIC DEVELOPMENT PROGRAMMES

In its presentation of specific ecosystems where additional research inputs are prioritised, SKB points especially to forest ecosystems, mires and sediment. The choice of ecosystem is motivated by the forest being the dominant ecosystem at the conceivable sites, mires are important

recipients at these sites and sediment is an important area that affects the transport of radionuclides in biota.

SSI's assessment

This selection is well motivated in SSI's view, since these ecosystems at an installation close to the coast can be expected to converge on one another in the vicinity of the repository due to changed coastlines. On the basis of research carried out to date, it can also be expected that the highest radiation doses will occur in these ecosystems, or above all, when e.g. sediment becomes wetland to later become forest. Moreover SKB lacked in conjunction with implementation of SR 97 [1] models for forestland, which it is now intended to rectify.

The work is planned to take place through development of process descriptions for the specific ecosystems. It is also satisfactory that SKB stresses the need of differentiation within ecosystems (i.e. the concept 'forest' includes a lot of different forest types). SSI considers that the models that are developed, and which can be directly applied within a thousand-year perspective up to the approach of the next ice age, are also valuable reference examples for a generic biosphere analysis in a very long time perspective.

SSI lacks a report on how SKB intends to deal with the transitions between ecosystems, which are induced by, for instance, land elevation or climate change.

8.5 SSI's overall assessment

Despite the basic assessment that SKB is now carrying out a methodical and ambitious work on biosphere issues, questions remain. To sum up, SSI considers that SKB should:

- Report on the importance of biosphere issues for the final choice of site and how the importance of biosphere issues is evaluated in the safety report.
- Prepare a timetable where it is clearly stated how far biosphere work needs to have progressed before the complete site investigations.
- Present concrete plans or positions in the areas stated below.

Description of biosphere processes

SSI supports the method adopted by SKB for the conceptual description of ecosystems but stresses that SKB needs to prepare a complete documentation of the processes included in the interaction matrices used. SKB should furthermore, report on the research needs for processes in the biosphere in a corresponding way as has been done for other parts of the final disposal system in RD&D programme 2001.

Ecosystem and system ecological models

SKB's choice of specific ecosystems is well motivated, but SKB should also report on how it intends to model the transitions between ecosystems, which are induced by, for instance, land elevation or climate change.

SSI takes a positive view on SKB's work on developing system-ecological models based on circulation of nutrition substances. These are a good complement to the compartment models previously used. What is lacking, however, is a clear report of the continued approach to model development and a timetable for the work. SSI considers therefore that SKB, at the latest in preparation for the complete site investigations, should report on the plans it has for the process-

based system-ecological model development, and the importance this has for the design of the complete site investigations.

Protection of the environment

It is valuable that SKB participates in international research projects such as FASSET, in order to be able to produce a development programme for protection of the environment. SSI lacks however a discussion on how results from projects will be applied practically in a safety analysis and within the site investigation programme. SSI considers that SKB, prior to the complete site investigations, should report on how the environmental protection aspects will be satisfied, and the importance of this for the design of the complete site investigations. SSI considers also that SKB, at the latest in conjunction with an application on construction of an installation, should produce all relevant documentation concerning expected environmental concentrations of radioactive substances, and documentation of the model tools.

Transport processes

SKB should in conjunction with the development of methods for safety analysis develop its analysis of radionuclide transport in the transition between geosphere and biosphere, to be able to present a credible safety analysis in conjunction with an application. SKB should also develop its analysis of the relation between the most exposed individuals and a regionally exposed group.

9 Climate development

9.1 The next glaciation cycle

Background – SKB's report i SR 97

In SR 97 [1], SKB drew the conclusion that climate-related changes should not affect the safety of the repository. This conclusion was criticised by the authorities in conjunction with review of SR 97. Among other things, the authorities [2] commented that only one climate development was studied and that alternative developments must be illuminated.

In the climate scenario in SR 97 A-berg has been assumed to be under water already after 20,000 years, and assumed to still be under water for a further 100,000 years. Discharges from the repository are thereby diluted by a factor of 100,000 or more. This is, of course, very important for the assessment of consequences. Another limitation with the analysis in SR 97 was that the climate developments affecting the long-term safety were only evaluated for A-berg.

SKB's reported programme

SKB underlines the importance of a better description of geohydrology in permafrost and glaciation, the impact of a future ice load on rock and barriers, and changes in the coastline in a glaciation perspective. In terms of time, SKB focuses on the importance of climatic changes in a 100,000-year perspective.

In RD&D programme 2001 it is stated in Chapters 9 and 10 inter alia that some new research has started, and that some has been reported on. SKB considers that research can lead to a deeper understanding of salinity and precipitation in coming phases for the Baltic. SKB will also study and carry out model calculations for areas that have permafrost today.

SSI's assessment

SSI takes a positive view on the reported programme for climate development, which contains both data collection and modelling within important areas of research. SKB's RD&D programme covers areas which can shed better light on the integrity of the repository and transport in the rock of any discharge from the repository.

For repositories in areas near the coast, the future position of the coastline and its effect on the biosphere and groundwater conditions is an important safety and radiation protection issue. This implies that SKB's choice of two sites close to the coast in its programme makes great demands on the report on climate impact, both for the repository and rock and the biosphere.

SSI considers that the biosphere has an important place in the safety report. A particularly important question is whether a discharge of radionuclides takes place to a marine or terrestrial environment, i.e. whether SKB can count on a dilution of a discharge with a factor of 100,000, which is assumed in the climate scenario in SR 97, all the way up to the next ice age. SKB must take a position on these uncertainties in future safety reports to enable SSI to assess whether the requirements in SSI's regulations [3] have been complied with. SSI considers therefore that SKB in its future research programme should produce methods to make these expert assessments.

In the light of the above points, SSI considers also that SKB's research on the future of the Baltic should include an evaluation of the effects of a discharge in the Baltic, which would result in an accumulation in sediment, and the importance of that in the perspective of possible changes in the coastline. This area is lacking in the RD&D programme.

9.2 Climate changes in a 1,000-year perspective

SSI will, in accordance with SSI's regulations [3], demand a special report on the repository's protective capability during the first 1,000 years and this report should include an assessment of climate variations during the period.

In the review of SR 97 SSI took up the effects of greenhouse gases, which can lead to global warming, as an example of a climate change that can affect the repository's protective capability or the consequence of a discharge from the repository via changed exposure routes. These issues should be included in the special report in accordance with SSI's regulations.

9.3 SSI's summary assessment

SSI regards it as positive that SKB is planning both data collection and modelling initiatives to increase understanding of climate issues. At the same time SSI considers that SKB's choice of two sites close to the coast makes great requirements to account for the effect of the climate and the role of the biosphere in the safety report. SKB should therefore:

- Calculate, in its research on the future of the Baltic, the importance of changes in the sea level for the radiological consequences, e.g. release of radionuclides that have previously accumulated in the sea sediment.
- Present expert assessments for choice of climate scenarios that clarify dilution of discharges in the Baltic, including the possibility that discharge will alternatively take place to a terrestrial environment.

The special report required in accordance with SSI's regulations for the first thousand-year period, should contain an assessment of possible climate variations during the period.

10 Site investigations

10.1 Background

SKB states that they gave a complete report in the supplement to RD&D programme 98 in preparation for the site investigation phase and does not go into further detail on this programme in RD&D programme 2001. Instead SKB focuses its report on supporting research and development of methods for site investigations including data processing and long-term observations.

SKB presents in chapter 13 an overview of conceivable needs for continuous and periodical observations and measurements in different phases. The four phases that are reported on are: The site investigation phase, The detailed site investigation phase, Initial operation, regular operation, sealing and After sealing. The biosphere is taken up in all phases and flora, fauna, earth layers and land use are listed as areas with a possible need for continuous and periodical observations and measurements.

According to a government decision on 1 November 2001 on the supplementing RD&D programme 98 [1] SKB is to consult the authorities about the content of the site investigation programme. Consultation of this kind between SKB and the authorities has been initiated. The site investigation programme will only be commented on in general outline here therefore.

10.2 SSI's overall assessment

SKB states that, unlike other subject areas, they have relatively little experience of collecting biosphere data, so that methods must be developed at the same time as available knowledge and resources are compiled. SSI wishes to stress the importance of SKB giving priority to research and development work within this field bearing in mind the fact that the site investigations are planned to start this year.

SSI considers that so-called baseline measurements and choice of reference area should take place at an early stage, and that SKB should then also investigate the need for future environmental monitoring.

SSI has brought to the fore and intends to follow up issues relating to site investigations within the established consultation on site investigations between SKB and the authorities (SKI and SSI). These issues are also dealt with in the ongoing review of the updated safety analysis for SFR 1. SSI will therefore submit additional points of view at a later date.

11 In and outflow areas

11.1 Background

In the review [1] of the supplement to RD&D programme 98 [2], RD&D-K, SSI stated that SKB should to a greater extent have evaluated and reported any advantages with an inland site prior to choice of sites for site investigations. SSI pointed out the possible characteristics that differentiated sites in flow patterns and depth to saline groundwater, for sites close to the coast and inland locations.

Similar points of view were also put forward by SGU [3], which drew the conclusion that Hultsfred East showed clear advantages over Tierp North. SKI also stated [3] that these factors need to be clarified in a better way and recommend that '… Hultsfred not be removed from the programme before issues concerning inflow/outflow and salinity, etc. have been further investigated'. SKI based its points of view inter alia on a research report [4] produced by United States Geological Survey, USA's equivalent to SGU, on behalf of SKI.

In the decision on SKB's supplement to RD&D programme 98 [5], the government stated that it is important that the work to find a suitable site for a repository be pursued further, although it also stated that 'it is assumed that the company [SKB] are considering the points of view which have emerged during review of the company's documentation for choice of site investigations'.

In the light of the debate which has taken place in the media on the USGS-report [4] and SKB's discussion on recharge and discharge areas in their site selection report, SSI wishes to start by putting forward its view on these issues. SSI considers it is evident that the flow patterns of the groundwater and depth of salt groundwater are important for long-term safety and that they therefore should be taken into consideration in the siting of a repository. The USGS-report indicates in SSI's view a possible method to make a preliminary assessment of these issues on the basis of existing pre-study data, i.e. map material, generic hydrogeological data and the National Land Survey's topographical databases.

SSI agrees with SKB and SKI that the uncertainties of such preliminary assessments are great but wishes at the same time to point out that there are corresponding uncertainties in the pilot study phase for many other siting factors. This applies, for instance, to the assessments that SKB has made of the characteristics of the rock at the repository depth, based on overview geological map information. SSI's view is that SKB should make the analyses that can be made from existing data to obtain as good a basis as possible to make an overall assessment of all the siting factors that affect the suitability of a site for a repository.

11.2 SKB's report

SKB states in Chapter 8 in RD&D programme 2001 that they are planning a project on recharge and discharge areas and the link between groundwater close to the surface and deep down. The purpose is inter alia to study the interaction between the hydrology close to the surface and the deeper groundwater flow. SKB has at a consultation meeting on 27 November 2001 [6] on site investigations with SKI and SSI stated that the project will include simulations of regional groundwater flow and of the biosphere-geosphere interface and a follow-up of the points of view put forward in the review of RD&D-K. SKB plans to report the results in a memorandum in September 2002.

11.3 SSI's overall assessment

SSI considers that it is good that SKB is now planning to produce a better basis for being able to assess the importance of recharge and discharge conditions and salinity conditions in the choice of sites for site investigations. It is important that analyses are designed in such a way that they give a perspective on the choice of sites for site investigations, and that the siting alternative Hultsfred can be assessed in a more satisfactory way than was the case in the supplementary report on RD&D programme 98. These issues have been brought to the fore in the ongoing consultation on site investigations that SKB is engaged in with SSI and SKI.

SSI regards it as positive that SKB, in conjunction with these analyses, also plans detailed studies of hydrogeological conditions in the transition zone between geosphere and biosphere. This is an area where SKB should prioritise its research work, in order inter alia to obtain access to the knowledge and modelling tools that are needed for conduct of the site investigations.

12 Alternative methods

12.1 The requirement for an alternative report

12.1.1 BACKGROUND

In RD&D programme 2001 SKB states that Sweden has in practice already chosen the strategy of geological emplacement. SKB states further that the analyses made give a strong support for deep emplacement in accordance with the KBS-3 method. SKB has, however, decided to continue to follow and support the development of the two alternatives separation and transmutation and deposit in very deep holes.

In the above government decision, it was emphasised that a method is only finally approved in conjunction with a future position on application for a licence. Moreover, it is the case that SKB regardless of SSI's and the government's support for the geological deposit strategy according to the KBS-3 concept needs to report alternative methods. This follows directly from the requirements in legislation, see Table 12.1. In the following, SSI reports its view on the purpose of the alternative and how they consider that SKB should report this.

In conjunction with the review of the supplement to RD&D programme 98, the issue of alternatives was discussed by many referral bodies. SSI and SKI have also taken a different view on the method issue. There is therefore reason to report in detail how SSI considers that SKB should treat alternatives. During SKB's successive research efforts relating to the waste issue, requirements for a report on alternatives have subsequently arisen. In the mid-1980s when the new Nuclear Activities Act (1984:3) came into force, requirements were introduced that the licence holders should present a comprehensive research programme (Section 12). In the Nuclear Activities Ordinance (1984:14) it is indirectly defined what is meant by comprehensive, namely inter alia. alternative handling and deposit methods (Section 26). With the introduction of the Environmental Codes in 1998 clear requirements on the alternative report have arisen through the rules on environmental impact assessment (EIA).

Table 12.1 Requirements on reporting alternatives.

The Nuclear Activities Act (1984:3), Sections 12 and 10	The Nuclear Activities Ordinance (1984:14) Section 26 (relating to RD&D)	The Environmental Code Chapter 6, Section 7	Reg. decision on SKB's supplement to RD&D 98
The holder of a licence shall draw up or have drawn up a 'programme for the all-round research and development work' (Section12) relating to 'safe final disposal, decommissioning, and dismantling' (Section 10).	The statement shall contain a review and evaluation of the programme relating to '… alternative handling and deposit methods' (Section 26, Point 3).	'A report on alternative sites, if such are possible, and alternative designs together with a motivation why a particular alternative has been chosen'.	The alternatives are to be discussed within the prescribed consultation (the paragraph refers to the EIA consulation).

The requirements are only commented on below as regards alternative methods. According to the provisions on EIA in the Environmental Code, the applicant is to report on alternatives. In

SSI's interpretation, the purpose of the alternative report is primarily to be able to verify the main proposal by comparison.

12.1.2 SSI'S ASSESSMENT

Report on distinguishing methods

The concept KBS-3 includes a number of variants, e.g. the orientation of the tunnels, length and emplacement technique. SSI considers that a report of this kind is necessary to make possible an optimisation analysis, although this is not sufficient as an alternative report. In SSI's view, if the intentions of the alternative report according to the Nuclear Activities Act and the Environmental Code are to be complied with, SKB's research programme should be implemented on a broader front and not reduced to alternative detailed designs.

It is important that all decision-makers and referral bodies a the time of decision on detailed investigations have the opportunity to expand their views in the decision by contrasting KBS-3 with another method where the burden of safety in the system is distributed in another way than for KBS-3. The natural barriers are more important for very deep holes in contrast to KBS-3, where the engineered barriers have greater weight. SKB has previously in accordance with the government decision on RD&D programme 98 reported certain costs for implementation of techniques for very deep holes. The level of ambition in this work must be higher than just monitoring international work, which SKB proposes in RD&D programme 2001.On this point SSI considers that SKB's programme is insufficient.

SSI considers that SKB should carry out a safety analysis for very deep holes on the basis of existing data, which SSI realises cannot be as reliable as that for KBS-3.

In SSI's view, a safety analysis of this kind on the very deep holes alternative could correspond to the requirements for an alternative report as required in the Environmental Code. A comparison of this kind would not mean choosing between KBS-3 and very deep holes, but SSI's intention is that the comparison would give relief to and deepen the view on KBS-3. This can in turn lead to a more comprehensive and deeper understanding of the safety and risk of the recommended solution.

Co-ordination for reporting on alternative methods

SKB needs to discuss and report on alternatives in different contexts. The siting issue primarily has a local and regional dimension. The issue of alternative methods concerns all affected municipalities and counties, however. It would therefore be inappropriate for the issue only to be taken up in local EIA consultations within the selected municipalities. This could lead to an unequal treatment of the report on the alternative.

SKB should therefore consider forms of consultation for a more general discussion relating to the question of alternative methods. The forms of such co-ordination should be produced in consultation between SKB, the authorities and municipalities (see also the discussion in Chapter 2).

12.2 SSI's overall assessment

It is important that decision-makers and referral bodies at the time of a decision of a detailed investigation have the opportunity of contrasting KBS-3 with another method, where the burden of safety is distributed in the system in another way than for KBS-3. In SSI's view, a report, which includes inter alia a safety analysis of the very deep holes alternative on the basis of existing data, could comply with the requirements for an alternative report in the Environmental

Code. SSI makes the assessment that SKB's level of ambition for the alternative report should be higher than only monitoring international work.

The question of alternative methods affects in a general way all concerned municipalities and counties. There is therefore reason for SKB to consider a co-ordination of these discussions in future consultation.

13 Final disposal of other long-lived waste, SFL 3-5

13.1 SKB's report

In the system which SKB intends to develop for the final disposal of the radioactive waste arising from the Swedish nuclear power programme, there is lacking as was pointed out earlier, inter alia, a repository for spent nuclear fuel (SFL 2), a repository for other long-lived waste (SFL 3-5) and a repository for low and medium-active short-lived decommissioning waste (SFR 3).

SKB has in the supplement to the RD&D programme 98, RD&D-K, listed the sites that are of interest for site investigations for a repository for spent nuclear fuel [1]. SKB does not exclude that a repository for other long-lived waste can subsequently be co-located with the fuel repository. Alternatively, the installation can be jointly located with the repository for radioactive operational waste, SFR 1. SKB states that since conditioning and final disposal of internal parts from nuclear power stations do not need to start before around 2045 at the earliest, the issue of the siting of the repository will not come to the fore before 2035.

SKB submitted a preliminary safety analysis for final disposal in January 2000 [2]. SKB proposes in the safety analysis that the repository parts SFL 3 and 5 be designed in principle as rock chambers for intermediate level waste (BMA) at SFR 1. On the basis of the experiences considered to have been obtained from this safety analysis SKB states in RD&D programme 2001 that they intend furthermore to develop the concept for future analyses, and to develop methods to handle the waste. The work on a renewed safety analysis is planned to accelerate first after SKB has concluded the site investigations and then submitted to the authorities a couple of years into the next decade. SKB states that the same site data can be used as for the fuel repository since it is in principle the same type of data that is needed, although the material may have to be supplemented with additional geochemical analyses [3].

SKB states in RD&D programme 2001 that one reason for the repository design recommended in the safety analysis was to reduce the number of components in the repository, and in this way facilitate analysis of long-term safety. SKB states at the same time in the conclusions of the safety analysis a number of possible improvements of the concept. The recommendations that are mentioned are to increase the thickness of the concrete barriers, to use clay instead of crushed rock as backfill and to clad the rock chambers with a diffusion-proof material. SSI can note that the research programme given in RD&D programme 2001 includes neither diffusion-proof material nor issues concerning bentonite in an alkaline environment. The research programme is focused instead on the long-term development and repository conditions that can be thought to exist in a cement repository.

13.2 SSI's previous reviews of SFL 3-5

SSI and SKI made a joint review of the safety analysis for final disposal SFL 3-5 and the authorities' review statement is reported in [4]. SSI later commented on SKB's work in SSI's statement on RD&D-K [5]. SSI could there state that:

There are a lot of reasons why SKB in the near future needs to produce and further develop the concept:

- *The safety analysis which has been reviewed has shown that a lot of research and development work remains to be done.*
- *If joint localisation of SFL 2 and SFL 3-5 comes into question the site investigations that are deemed necessary SFL 3-5 are to have been carried out before the area is disturbed by construction of SFL 2.*
- *The long-lived waste which already exists at the nuclear power stations needs to be conditioned in a suitable way. The guidelines for this conditioning can only be developed when a complete safety analysis has been produced. From a radiation protection point of view, it is unsuitable to have to recondition this waste in future.*
- *In conjunction with production of long-lived waste and in conjunction with characterisation of existing long-lived waste, guidelines need to be given for the waste characterisation that it is necessary to perform. These guidelines need to be based on a safety analysis that is appropriate for its purpose.*

According to the timetable presented by SKB in Chapter 1 and the research programme for SFL 3-5 which is included in Chapter 18 of RD&D programme 2001, the greatest part of resources in the next ten-year period will be placed on the site investigations and analyses that are planned to be made for the fuel repository. The work on final disposal for other long-lived waste is expected to accelerate only after the site investigations for the fuel repository have been finished.

SSI's assessment

SSI maintains all its earlier assessments as above, also after review of RD&D programme 2001.

SSI has previously not had points of view on the actual construction date for SFL 3-5, although it has had points of view on SKB's planning of the work which must precede construction of a repository for the long-lived waste. SSI considers that the repository design presented in RD&D programme 98, and which served as the basis for the safety analysis, cannot serve as a planning prerequisite for the continued work. SSI considers, as was pointed out in the statement on RD&D-K, that it is unacceptable not to raise the level of ambition to solve the problem.

SSI considers that SKB needs to focus the work on further developing the repository concept. The authorities considered in their review of the safety analysis that SKB only partially achieved the explicit aim of investigating the importance of the current repository design. The authorities' stated, as was put forward by the international review group, that considerable deficiencies were associated with SKB's motive for selection of repository design and large parts were lacking. The authorities took up the issue of whether the design of the repository was sufficiently robust and had sufficient protective capability for the long time period necessary. SSI finds it remarkable that the research programme presented does not include research relating to the long-term function and the development of diffusion-proof material as well as the long-term development and the functioning of a bentonite barrier in an alkaline environment. SSI considers that it is important that SKB clarifies at an early stage which R&D initiatives are required, and in particular to identify the need of long-term experiments that exists. SSI considers that SKB needs to produce a strategy document for these issues, see Chapter 3.

During the coming six-year period, SKB states that they will only further develop methods to determine the content of radionuclides that the safety analysis has shown to be most important and also to develop the design of the waste container. SSI agrees with SKB about the importance of this work and means that the work of continuing to characterise the content of mobile and long-lived radionuclides in the repository environment needs to be given priority. SSI considers at the same time, as was stated in SSI's statement on RD&D-K, that the safety analysis on

which this conclusion is based is altogether too incomplete for SKB to be able to draw the conclusion yet that other long-lived radionuclides than the mobile, are of subordinate importance for long-term radiation protection. This conclusion also emerged in the authorities' joint review report.

13.3 SKB's continued work

SSI stated in its statement on RD&D-K that:

> *SSI considers that the obligation to take care of waste from the nuclear power companies' installations, and the so-called historic waste for which SKB has been corresponding tasks through special decisions, must mean that a system should be developed without delay which has reasonable prospects of complying with the authorities' requirements. To deliberately wait several tens of years is not compatible with the provisions of the Radiation Protection Act. As mentioned above, such a delay risks creating radiation protection problems for several reasons. It is incontestable that Sweden must have a repository for this long-lived waste.*

A report is needed on the requirements and criteria that are relevant for the siting of SFL 3-5. It is important to point out that the requirements made on a site for SFL 3-5 are not necessarily the same as those made on a repository for spent nuclear fuel, but are dependent on the repository concept finally adopted by SKB. Bearing in mind that SKB's proposed repository design has not proven to be adequate as a prerequisite for planning for further work, it is not possible either to determine the actual site selection criteria.

13.4 SSI's overall assessment

SSI does not consider that the analysis of safety for SFL 3-5 can serve as a basis for planning for siting or for the design of the site investigation programme. SSI considers therefore that SKB needs to present an action plan for further RD&D work, and to update the safety analysis. SSI considers that SKB should start this work immediately so that SKB after implementation of the site investigations can produce an updated safety analysis.

In the updated analysis, alternative repository designs need to be evaluated and the need of further technical development identified. SKB should produce guidelines for treatment and characterisation of the radioactive waste and material for selection of site and site investigations based on this safety analysis.

In the light of this, SSI considers that it is important that the government clearly states a timetable and conditions for SKB's continued work.

14 Decommissioning and dismantling

14.1 SKB's report

In its report on decommissioning and dismantling of nuclear power plants, SKB follows the main line that the operational life of the plants will be around 40 years. SKB's explicit main principle is that demolition and decommissioning should be started as soon as possible after ceasing operations. This principle complies with SSI's view. SKB states that there is expected to be a large portion of low-active radioactive waste, although the focus is wholly on such demolition waste that is intended to be placed in SFR or an intermediate layer for long-lived waste. The use of final disposal of low-active demolition waste in ground repositories is not dealt with.

SKB states in the report that no demolition and decommissioning can begin before there is a repository for short-lived demolition waste (SFR) and an intermediate repository for long-lived demolition waste. The time of completion of the repository for short-lived demolition waste is stated at around 2015 – it is planned to deposit demolition waste in an extension of SFR. The long-lived demolition waste is stated at small volumes (less than 1,000 tonnes per nuclear power plant) and is intended to be placed in intermediate storage until the major part of the nuclear power stations have been demolished and decommissioned. The date for completion of the intermediate repository for long-lived demolition waste is also given here as 2015 for operation start. CLAB is mentioned as a possible site for intermediate storage of long-lived demolition waste. However, in this case, it would need to be extended. SKB will therefore also investigate dry intermediate storage as an alternative to intermediate storage at CLAB.

14.2 SSI's assessment

14.2.1 THE RESPONSIBILITY OF THE WASTE PRODUCERS

The following comments are directed at the waste producers, who have the main responsibility for management and final disposal of demolition waste. Although the waste producers have delegated parts of this responsibility to SKB, this division of responsibility is disregarded here.

The waste producers should adopt a holistic approach to the final disposal of the different fractions of demolition waste. It is, for instance, probable that the waste producers intend to place certain fractions of demolition waste in a land repository. The waste producers should therefore report on the extent to which they intend to use land repositories and how these are to be organised and located. SSI agrees with SKB about the need to account for the final disposal of inactive demolition waste. The waste producers should make a report on the quantities that are created, where they are to be kept and how they can be recycled bearing in mind the relatively new international and national environmental protection legislation.

A separate question concerns final disposal of reactor tanks. An alternative approach that has been put forward is to deposit these intact at a very late stage in conjunction with sealing of the repository. In this case, any intermediate storage of complete reactor tanks is a special question important that the waste producers shed further light on.

The final disposal of scrap should be separately investigated further. The waste producers should prepare alternative methods for disposal in the event of recycling via the steel industry being limited.

14.2.2 REPORT IN THE RD&D PROGRAMME 2001

Bearing in mind the great volumes of waste created during the whole extensive programme, of demolishing and decommissioning all reactors in Sweden, it is surprising that all the issues that then arose have not been more thoroughly clarified in SKB's report. As SSI pointed out previously, estimates of staff doses and an account of the environmental consequences of the demolition and decommissioning programme are still lacking.

SSI considers that SKB should present concrete plans or positions in the field of demolition and decommissioning that clarify the management of alternative scenarios with regard to the operational life of the plants, e.g. how demolition waste is to be dealt with if several reactors cease operating *before* 40 years of operation and how demolition waste is to be dealt with if operations in some cases continue substantially *beyond* 40 years.

SSI also regards it as important that the issue of final disposal of long-lived waste be given priority treatment. The main principle of fast demolition and decommissioning cannot be realised if the solution to this question is delayed. Taking into consideration the time-consuming procedures that may be required inter alia for siting and EIA, time may be short, if an intermediate store is to start operating in 2015.

14.3 SSI's overall assessment

SSI lacks a thorough clarification of how the waste volumes that arise on demolition of nuclear power plants are to be handled, in particular with regard to the large quantities of low-active waste that can be expected. There is still lacking, despite SSI having pointed this out previously, for instance, dose calculations and descriptions of environmental consequences in the biosphere from the demolition and decommissioning programme. SKB should present concrete plans taking into consideration different scenarios for the operational life of plants. It is important that a start is made on the work on intermediate storage of the long-lived waste from the demolition and decommissioning programme and that this be made a priority.

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SSI är ansvarig myndighet för det av riksdagen beslutade miljömålet *Säker strålmiljö*.

SSI sätter gränser för stråldoser till allmänheten och för dem som arbetar med strålning, utfärdar föreskrifter och kontrollerar att de efterlevs. Myndigheten inspekterar, informerar, utbildar och ger råd för att öka kunskaperna om strålning. SSI bedriver också egen forskning och stöder forskning vid universitet och högskolor.

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Myndigheten har idag ca 110 anställda och är beläget i Stockholm.

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The Swedish parliament has appointed SSI to be in charge of the implementation of its environmental quality objective *Säker strålmiljö* ("A Safe Radiation Environment").

SSI sets radiation dose limits for the public and for workers exposed to radiation and regulates many other matters dealing with radiation. Compliance with the regulations is ensured through inspections.

SSI also provides information, education, and advice, carries out its own research and administers external research projects.

SSI maintains an around-the-clock preparedness for radiation accidents. Early warning is provided by Swedish and foreign monitoring stations and by international alarm and information systems.

The Authority collaborates with many national and international radiation protection endeavours. It actively supports the on-going improvements of radiation protection in Estonia, Latvia, Lithuania, and Russia.

SSI has about 110 employees and is located in Stockholm.

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