Interim storage facility, encapsulation plant and final repository for spent nuclear fuel

Safety and radiation protection

Svensk Kärnbränslehantering AB

May 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

Samråd 0801-2 E

Contents

Reading instructions

This is background material for consultations under Chapter 6 of the Environmental Code held in May/June 2007. The consultations are a part of the preparations for applications for licences/permits under Chapters 9 and 11 of the Environmental Code to operate an interim storage facility for spent nuclear fuel and to build and operate facilities for encapsulation and final disposal of spent nuclear fuel. The consultations are also part of the preparations for an application for a licence under the Nuclear Activities Act for final disposal of spent nuclear fuel.

The material contains a general description of SKB's work with safety and radiation protection.

The material was prepared during the spring of 2007 and reflects the state of knowledge at that time. It is based both on previously done work and ongoing work that has not yet been published.

The background material was presented in connection with the public consultation meetings in Oskarshamn (28 May) and Forsmark (31 May). It was also made available on SKB's website, *www.skb.se*, about three weeks before these meetings. Furthermore it was sent out for written consultations to the county administrative boards in Kalmar and Uppsala counties, other concerned government agencies, the municipalities of Oskarshamn and Östhammar, and the organizations that obtain funding from the Nuclear Waste Fund to participate in the consultations.

1 Introduction

SKB (Swedish Nuclear Fuel and Waste Management Co) has been assigned the task of managing and disposing of the radioactive waste from the Swedish nuclear power plants. We have developed a method for final disposal of the spent nuclear fuel known as the KBS-3 method (KBS stands for Kärnbränslesäkerhet = Nuclear Fuel Safety). The method entails that the spent nuclear fuel is placed in copper canisters with cast iron inserts and then deposited, embedded in bentonite clay, at a depth of about 500 metres in the bedrock. The KBS-3 method requires an encapsulation plant where the spent nuclear fuel is encapsulated, and a hard rock facility (a final repository) where the canisters are deposited.

Today the spent nuclear fuel is temporarily stored in Clab (Central interim storage facility for spent nuclear fuel), which is situated on the Simpevarp Peninsula in Oskarshamn Municipality. SKB's proposal is to locate the encapsulation plant adjacent to Clab. Site investigations are being conducted in the municipalities of Oskarshamn and Östhammar as a basis for the siting of the final repository.

1.1 Spent nuclear fuel

Nuclear fuel is fabricated from natural radioactive uranium mineral. The radioactivity of the fuel increases sharply during the operation of a nuclear reactor. After about five years of use, the fuel is taken out of the reactor and is then at its peak radiotoxicity. Its radioactivity and thereby its toxicity declines with time as the radioactive substances decay. After about 30 years of interim storage in Clab only one or two percent of the radioactivity remains.

The risks associated with spent nuclear fuel can be described in terms of radiotoxicity and accessibility. Radiotoxicity describes the harm ionizing radiation can cause if people are exposed to it. Accessibility describes the degree to which a person can be exposed to radiation in different situations, for example during transport, interim storage or final disposal.

Most radionuclides in spent nuclear fuel decay within a few hundred years. After that the radiotoxicity of the fuel is dominated by substances that will remain for a very long time. After about 100,000 years the radiotoxicity of the spent fuel will have declined to a level that is equivalent to that of the natural uranium mineral from which it was originally fabricated.

1.2 Applications and licensing review

The encapsulation plant, Clab and the final repository require permits/licences under the Environmental Code and the Nuclear Activities Act. In November 2006, SKB submitted an application under the Nuclear Activities Act for a permit to build and own an encapsulation plant for spent nuclear fuel and a licence to operate it integrated with Clab.

Since the encapsulation plant will be integrated with Clab, Clab's existing permits under the Nuclear Activities Act and the Environmental Code are affected. At the end of 2009, SKB plans to apply for permits under the Environmental Code for the encapsulation plant, Clab and the final repository. At the same time, SKB will apply for a permit under the Nuclear Activities Act to build the final repository and a licence to operate it, see Figure 1-1. Due to this procedure, all background material will have been presented before any decision is taken. The Government will have an opportunity to decide at one and the same time on both a permit under the Nuclear Activities Act and permissibility under the Environmental Code.

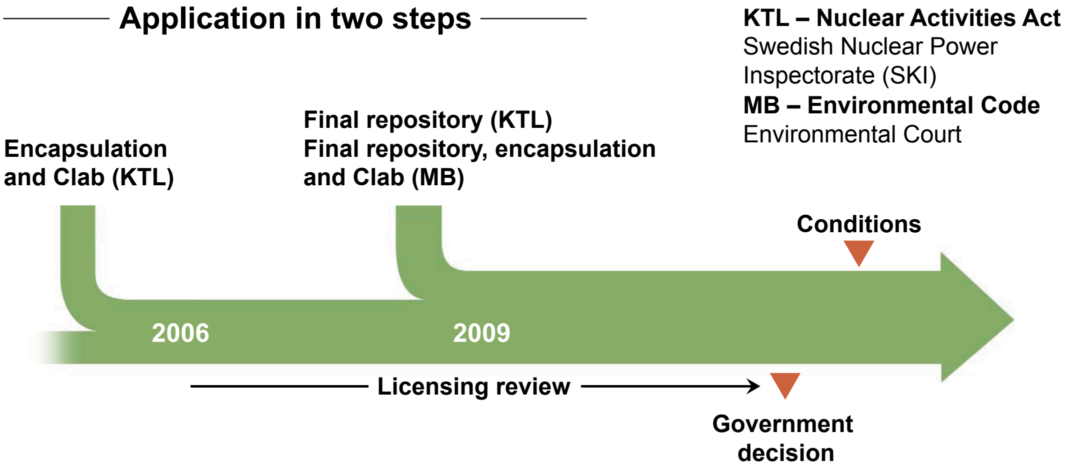

Figure 1-1*. Schematic plan of the licensing process.*

1.3 Consultations

An environmental impact statement (EIS), as described in Chapter 6 of the Environmental Code, must be appended to the applications under the Environmental Code and the Nuclear Activities Act. Besides compiling the EIS, the EIA (environmental impact assessment) work includes both studies and consultations.

According to the provisions of the Environmental Code (Chap. 6, Sec. 4), the consultations shall be concerned with the siting, scope, design and environmental impact of the activity and the content and design of the environmental impact statement. Another important purpose is to take advantage of the local expertise possessed by individuals and organizations. SKB's goal with the consultations is that everyone who wants to get involved is given an opportunity to do so. This applies to both private citizens and organizations as well as local and national authorities.

The consultation process leading up to the applications for permits for the final repository and the encapsulation plant was begun during 2002 and 2003 in the municipalities of both Oskarshamn and Östhammar. Early consultations have been completed. In accordance with a decision by the County Administrative Board in Kalmar County and the County Administrative Board in Uppsala County, SKB also commenced extended consultations. The consultations will continue until the applications for the encapsulation plant, Clab and the final repository are submitted.

Changes were made in the Environmental Code in 2005. The terms "early" and "extended" consultations were then removed. Now only the concept "consultations" is used.

Disposal of the spent nuclear fuel is a large project that generates a great deal of material to deal with in the consultations. Studies, site investigations, design work etc have been under way for many years and will continue for several more years to come. It is not possible to consult about everything involved in the project on a few isolated occasions. SKB has therefore tried to arrange consultations on different themes as the relevant studies have been completed. The theme for this consultation is safety and radiation protection. Questions and discussions at a consultation meeting are not limited to this theme, but focus on the participants' questions and viewpoints. All matters pertaining to interim storage, encapsulation and final disposal of spent nuclear fuel can be brought up.

From now on we plan to hold 1–2 public consultation meetings per year in Oskarshamn and in Forsmark up until the time the applications are submitted. When more results pertaining to safety and radiation protection are available, we will hold an additional consultation with this theme. The current consultation plan is available on SKB's website, *www.skb.se*.

2 General requirements and points of departure

The general requirements and points of departure for the management and disposal of spent nuclear fuel are found in Swedish legislation and international agreements.

The purpose of the Environmental Code (SFS 1998:808) is to assure current and future generations a healthy and good environment.

According to the Nuclear Activities Act (SFS 1984:3) with associated regulations, the holder of a licence for nuclear activities shall make sure that any resulting spent nuclear fuel is disposed of in a safe manner. Post-closure safety shall be based on a system of passive barriers, and the final repository shall not require monitoring or maintenance.

According to the Radiation Protection Act (SFS 1988:220) with associated regulations, radioactive waste shall be handled so that an acceptable level of protection is ensured for human health and the environment.

In addition to Swedish legislation there are international agreements and conventions with which Sweden has undertaken to comply, for example:

The UN nuclear watchdog agency IAEA's (International Atomic Energy Agency) nuclear waste convention says that appropriate steps shall be taken to avoid imposing undue burdens on future

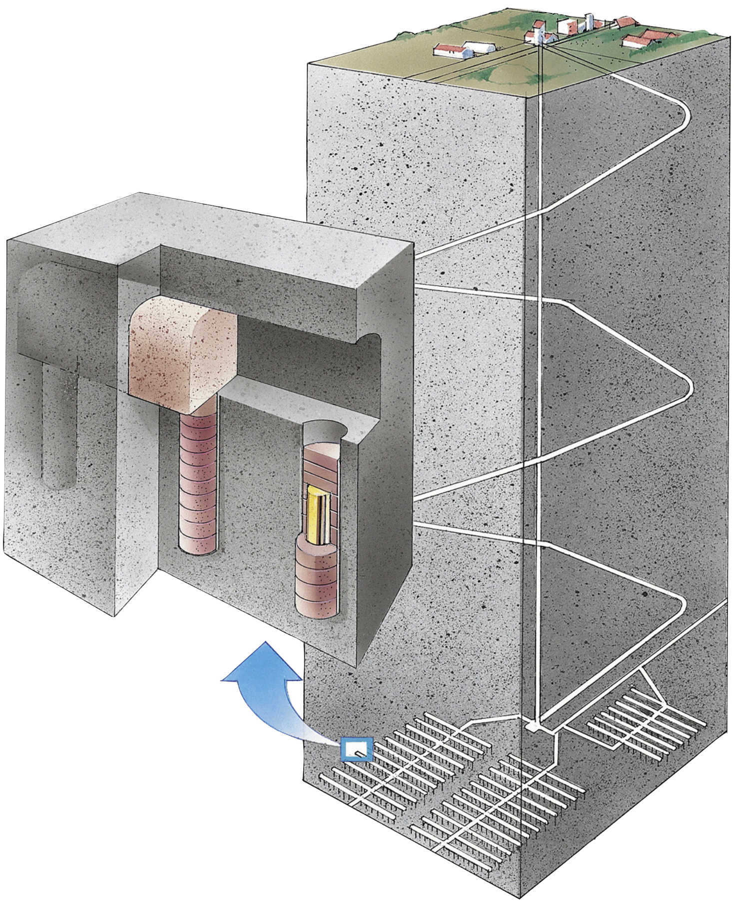

***Figure 2-1**. Final repository according to the KBS-3 method.*

generations. This means that the waste problem should essentially be solved by the generation that utilizes the electricity generated by the nuclear power plants. Furthermore, it says that waste should be disposed of in the State in which it was generated.

Sweden signed the Non-Proliferation Treaty (NPT) in 1968, which means we have undertaken to use nuclear energy solely for peaceful purposes and have consented to submit Swedish nuclear material to IAEA safeguards. According to the NPT, the system for disposal of spent nuclear fuel shall be designed to prevent illicit tampering with nuclear materials or nuclear waste.

Primarily based on these requirements and points of departure, SKB has defined the purpose of the work for the disposal of the spent nuclear fuel:

SKB's purpose is to build, operate and close a final repository with a focus on safety, radiation protection and environmental considerations. The final repository is being designed to prevent illicit tampering with nuclear fuel both before and after closure. Long-term safety will be based on a system of passive barriers.

The final repository is intended for spent nuclear fuel from the Swedish nuclear reactors and will be created within Sweden' boundaries with the voluntary participation of the concerned municipalities.

The final repository will be established by those generations that have derived benefit from the Swedish nuclear reactors and designed so that it will remain safe after closure without maintenance or monitoring.

3 Safety work with different time perspectives and purposes

3.1 General about concepts and reports

The safety work for SKB's nuclear facilities is based on legislation and regulatory requirements. SKB's highest body for safety matters is the safety committee, which is chaired by SKB's president. The safety committee deals with safety matters of a fundamental and strategic nature. SKB also has a special department – Nuclear Safety – that develops and oversees safety matters. Day-to-day responsibility for the safety of the facilities is included in operation.

SKB performs several different types of assessments and reports regarding safety and radiation protection for the encapsulation plant, Clab, the final repository and the transportation system. They deal with different time scales and have different purposes.

Preliminary safety analysis reports

A facility's safety analysis report describes how safety and radiation protection in a nuclear facility are arranged to protect human health and the environment. The safety analysis report is prepared in the following steps:

1. Preliminary safety analysis report.
2. Renewed safety analysis report prior to trial operation.
3. Supplementary safety analysis report prior to routine operation.
4. Constantly updated safety analysis report.

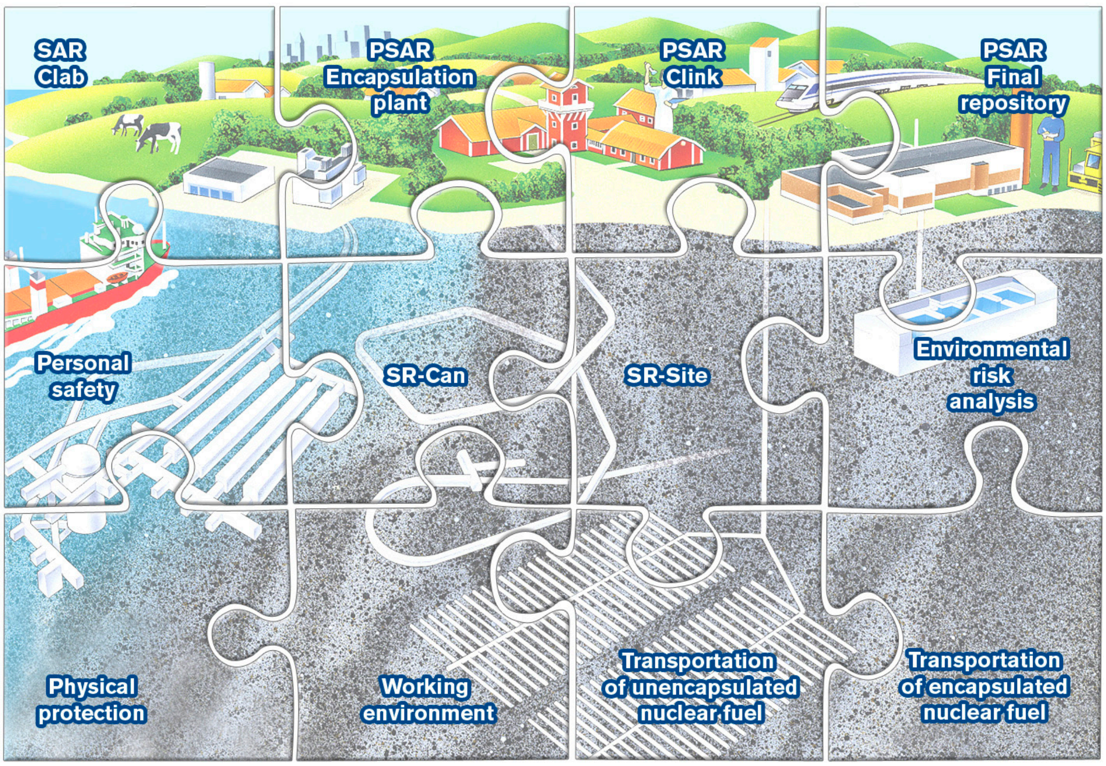

***Figure 3-1**. Schematic illustration of concepts and reports which SKB uses in its work with risk and safety matters.*

The safety analysis reports are prepared according to steps 1–4 and undergo review, which is done in two steps. The first step is performed by the departments within SKB that are in charge of the particular issue at hand. The second step is performed by the Department of Nuclear Safety, which is independent in relation to the above departments. The Department of Nuclear Safety reports directly to SKB's top management. This procedure is regulated by the Swedish Nuclear Power Inspectorate's (SKI) regulation SKIFS 2004:1, which deals with safety in nuclear facilities. SKB's review is supplemented by review and approval by SKI and the Swedish Radiation Protection Authority (SSI).

The purpose of the *preliminary safety analysis report* is to give an account of safety and radiation protection during normal operation and to evaluate the risks of disturbances and mishaps in and around a facility and their consequences. The report is supposed to show that the facility meets the requirements of the Swedish authorities. It must be submitted along with applications under the Nuclear Activities Act. In the autumn of 2006 SKB submitted a preliminary safety analysis report for the encapsulation plant, called "PSAR encapsulation plant". In 2008 it will be supplemented by a joint report for the encapsulation plant and Clab, "PSAR Clink" (Clab/encapsulation plant).

When the application under the Nuclear Activities Act for the final repository is submitted, a preliminary safety analysis report for the final repository will be appended. Besides an account of the safety of the final repository during the operating period (operational safety), it will also include an account of the post-closure safety of the final repository (long-term safety). SKB has chosen to submit separate safety analysis reports for operational safety and post-closure safety. The account of operational safety is called "PSAR final repository". The preliminary safety analysis report for the long-term (post-closure) safety of the repository is submitted pursuant to the requirements in SKIFS 2002:1 and SSI FS 1998:1. It is called "SR-Site".

The renewed safety analysis report describes the pre-operational state of the facility and is submitted to receive a permit for trial operation. For natural reasons it is more detailed than the preliminary report. Changes that have occurred since the PSAR are described along with the reasons for them.

Subsequently, before the facility is allowed to be put into routine operation, the safety analysis report must be augmented. *The supplementary safety analysis report,* SAR, is a living document that describes the actual facility and is updated as changes occur.

Transportation of spent nuclear fuel

Since transportation of spent nuclear fuel is classified as a nuclear activity, special permits are required from SKI and SSI according to the Nuclear Activities Act. There are also other regulations that govern the transportation of radioactive material, mainly the Transport of Dangerous Goods Act (SFS 2006:263) and a number of national and international regulations. SKI's and SSI's supervision of nuclear shipments also includes certification of the containers to be used. Other applicable regulations include, for example, the Swedish Rescue Services Agency's regulations on safety advisers for transport of dangerous goods (SRVFS 2006:9).

Some of the combined safety analysis report for the existing transportation system is included in SKB's most recent safety report for the transportation system /SKB 2005/. The report contains a description of the transportation system in its entirety with requirements, functional description, description of technical components and description of completed safety assessments. It is not formally an SAR since the transportation system is not a facility. There are no special safety reports for transport casks.

As supporting material for the application for the encapsulation plant, SKB has prepared a report that describes an envisioned transportation system for encapsulated fuel with requirements, technical data for a fuel transport cask, functional description of the transportation system and safety aspects /Broman et al. 2005/. We will prepare a new report for the application for a permit to build the final repository. The siting of the final repository, as well as the transport logistics within the repository, will have been decided by then.

Physical protection for facilities

Physical protection is the part of the system for protective security aimed at preventing theft of nuclear material and nuclear waste in various ways, but also at protecting against sabotage and attack that could lead to radiological consequences. The governing legislation for SKB's work with physical protection is the Protective Security Act (SFS 1996:627), the Protective Security Ordinance (SFS 1996:633) and SKI's regulation on physical protection (SKIFS 2005:1).

SKI's regulation contains provisions for background checks (for example search of public records, interviews, references), study visits, handling of information on security measures and IT security. The provisions are based on a design threat scenario of a violent and well-equipped attacker. The design threat scenario should not be confused with the actual threat scenario, which varies over time and is in principle only valid on the date it is described.

The greater part of the report dealing with physical protection is classified, since the information in the report could facilitate theft or sabotage.

Environmental risk analysis

In an environmental risk analysis SKB has determined the risks of non-radiological consequences for the construction phase, the operating phase and decommissioning of the encapsulation plant, Clab and the final repository, as well as for closure of the repository. The analysis comprises a basis for an assessment of the consequences for the natural environment, the cultural environment and health in the EIS. It also serves as a basis for an assessment of possible risk reduction in the form of accident-preventive and damage-mitigating measures in the design of the facilities.

Working environment

The framework for work environment management is laid down in the Work Environment Act (SFS 1997:1160). The purpose of the Act is to prevent ill health and accidents at work and to otherwise ensure a good working environment. The Swedish Work Environment Authority issues general regulations and recommendations defining what requirements are made on the working environment. The construction and operation of the encapsulation plant and the final repository are governed primarily by the provisions regarding Systematic Work Environment Management (AFS 2001:1), the provisions for Building and Civil Engineering Work (AFS 1999:3) and the provisions for Rock Work (AFS 2003:2).

All working environment aspects are included in the design of the facilities. Aspects that tie in with the areas of responsibility of the Swedish Rescue Services Agency, for example fire protection, are also included in the design process. These matters, as well as working environment matters, lie outside the EIA work and the consultations and are not included in the applications.

3.2 KBS-3 and long-term safety

Development of the KBS-3 method for final disposal of spent nuclear fuel has been going on since the late 1970s. The scientific and technical basis for the method has been successively developed and reported to the regulatory authorities and the Government every third year in the RD&D programmes. Over the course of the years SKB has carried out several analyses of the long-term safety of the final repository.

KBS-3

The results of the KBS-3 study /SKBF/KBS 1983/ served as a basis for the applications for permits to fuel the Forsmark 3 and Oskarshamn 3 nuclear power reactors. After a comprehensive review process the Government found that "the method in its entirety has been found essentially acceptable with regard to safety and radiation protection" and approved the fuelling permit applications for the two reactors in June 1984.

SKB 91

The safety assessment SKB 91 /SKB 1992/ differs from the KBS-3 study in several ways. The knowledge base was greater and the computers had greater computational power. Furthermore, there were new models that made it possible to take into account the variability in the permeability of the rock and a site-adapted repository geometry. The conclusion in SKB 91 is that a repository built deep down in the Swedish crystalline bedrock with durable engineered barriers meets the safety requirements stipulated by the regulatory authorities with good margin.

SR 95

The main purpose of SR 95 /SKB 1995/ was not to carry out a "real" safety assessment, but to prepare a template for how assessments of long-term safety should be carried out and reported. The methodology and the proposed template in SR 95 were then applied in SR 97.

SR 97

Prior to the start of the site investigations in the work of siting the final repository, the Government and the regulatory authorities requested an assessment of the repository's long-term safety. The requested safety assessment has the working name SR 97 and was published in 1999 /SKB 1999/. The main purposes of the assessment were:

- to determine whether spent nuclear fuel can be safely disposed of in Swedish bedrock over a very long period of time,
- to demonstrate the methodology for the safety assessment.

The methodology that was applied in SR 97 was to first describe the properties of the repository when it has just been closed. Then we analyzed how the system changes with time as a result of both internal processes in the repository and external forces. The future evolution of the repository system was analyzed in five scenarios. The first was a base scenario where the repository is built according to specifications and where present-day conditions in the surroundings, including climate, persist. The four other scenarios showed how the evolution of the repository differs from that in the base scenario if the repository contains a few initially defective canisters, in the event of climate change, in the event of earthquakes, and in the event of future inadvertent human intrusion. The evolution of the repository was broken down into thermal, hydraulic, mechanical and chemical sub-evolutions. The ultimate purpose of the analyses was to examine the ability of the repository to isolate the waste in the canisters and to delay a possible release of radionuclides if canisters are damaged. The time perspective for the analyses was (in accordance with the regulations) up to a million years.

The results show that there are good prospects for disposing of spent nuclear fuel in the Swedish bedrock. SR 97 comprised an important basis for formulating and quantifying requirements and preferences regarding the rock in which the final repository is built based on the perspective of long-term safety. Experience from SR 97 was used to formulate an integrated programme for investigation and evaluation of sites /SKB 2000/.

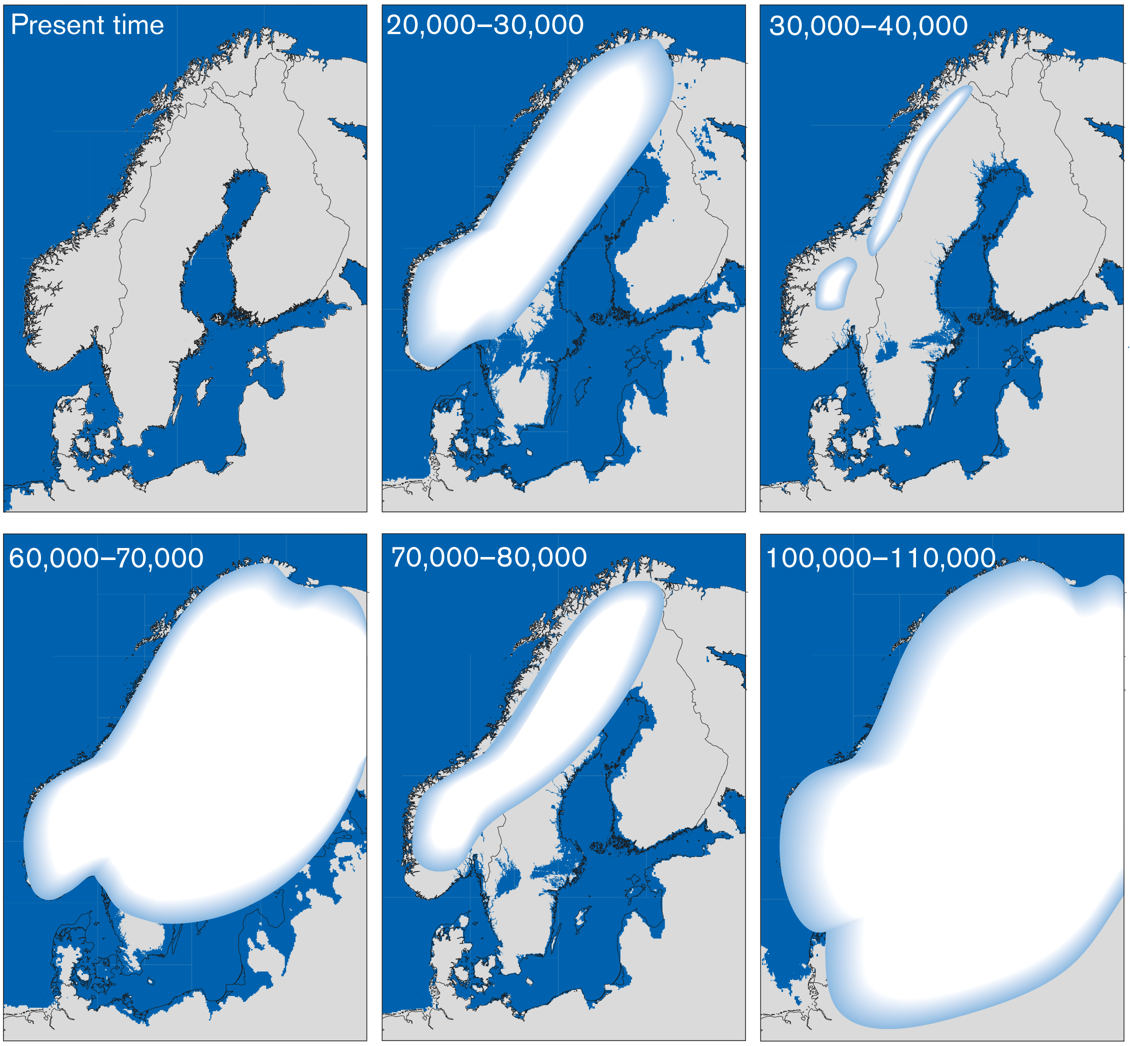

***Figure 3-2**. Assumed extent of ice sheet and changes in coastline during future ice ages.*

4 Safety analysis reports for the operating period

4.1 SAR for Clab

Clab is a facility that is in routine operation. Safety and radiation protection at Clab are described in the safety analysis report, SAR. Clab's first SAR was produced in 1983–85 and has been updated several times since then /SAR Clab/. Major revisions have been made on several occasions in the light of new experience and to meet modern reporting requirements. Such a revision is currently being undertaken.

Actual releases of radioactive substances from the operation of Clab to air and water as well as radiation doses to personnel are given in section 4.2 and are compared to estimates of the emissions from the encapsulation plant. A description of SKB's safety management procedures for the operation of Clab is provided here.

Clab is built on the principle that all safety systems are passive. This means that the systems do not have any moving components and do not require an external power supply to work. The storage canisters in which the spent nuclear fuel is stored can be mentioned as an example. They ensure that the fuel is always kept subcritical, in other words it cannot start a nuclear reaction on its own, and that it is protected from mechanical impact. Clab has many systems – design, safety barriers and safety organization – that interact to provide a robust defence-in-depth, so that the safety features with which the facility is equipped should never need to enter into play.

Management of the safety work is subject to a special safety management. Under this management model, all safety-related decisions are re-examined by a higher level in the organization to broaden the decision base and obtain as broad an illumination of the safety issues as possible. The shift leader is responsible for ensuring that the facility is operated according to the Operational Limits and Conditions, OLC. The OLC is a controlling operational document that contains a condensate of SAR. Each 24 hours of operation are re-examined daily at an operations meeting. Here the shift leader gives an account of the operating events of the past 24 hours and presents a plan for the activities of the next 24 hours. Clab's plant manager then judges the facility's operational readiness, i.e. whether the facility is working as intended.

Abnormal events are dealt with in a forum called the event evaluation meeting. Here the impact of the event on nuclear safety is evaluated. The event evaluation meeting judges the safety-related significance of the event and whether the event has caused the facility to deviate from the OLC. The event is reported to SKI if it has led to a deviation from the OLC. Then the event is reported as a reportable occurrence (RO) within 30 days. The event evaluation meeting decides on measures to be taken so that the event will not be repeated.

Decisions made at the operations meeting and the event evaluation meeting are re-examined each month at the operations management meeting, which is led by the head of SKB's operations department. Decisions are made at this meeting regarding safety at all facilities operated by SKB.

4.2 PSAR for the encapsulation plant

SKB submitted a preliminary safety analysis report for the encapsulation plant /SKB 2006c/ to SKI in the autumn of 2006 in conjunction with the submission of an application under the Nuclear Activities Act. In this report we analyzed the radiological impact on the ambient environment associated with normal operation, disturbances and mishaps, in accordance with SKI's regulations. The calculations are based on conservative assumptions. This means that the actual activity levels are expected to be much lower than those calculated in the event of an accident.

Figure 4-1. *Illustration of the encapsulation plant adjacent to Clab.*

Normal operation

The radiation in the encapsulation plant mainly comes from the spent nuclear fuel. However, it can be noted that the strongest radiation source in the facility is the X-ray machine for non-destructive testing. Release of radioactivity in the encapsulation plant can take place to water, as long as the spent nuclear fuel is being handled in the plant's pools, or to air in the plant's handling cells. All handling of the nuclear fuel takes place in isolated and radiation-shielded areas with controlled ventilation.

Different areas are classified based on the risk of contamination and the radiation level. This classification determines how access is limited to different areas. Once the fuel has been encapsulated it is no longer a source of airborne activity, but radiation shielding is nevertheless required during its further handling.

The maximum quantity of spent nuclear fuel that will be handled in the encapsulation plant at any given time is about 70 tonnes. By comparison it can be mentioned that just over 4,000 tonnes is stored in Clab today. Before the nuclear fuel is taken into the encapsulation plant, its radioactivity has declined after about 30 years of interim storage.

Small quantities of activity are emitted to the water in the handling pool when the nuclear fuel is standing in the pool in the encapsulation plant. The encapsulation plant will be connected to Clab's purification system. When necessary, surplus water will be released together with the cooling water from Clab into Hamnefjärden. Activity levels are checked after each release. Further purification takes place as needed, and water is not released to Hamnefjärden until it meets limit values for release levels /SKB 2006b/.

The releases to water from the encapsulation plant have been estimated at 157 MBq per year, which is equivalent to an annual dose to the critical group of 4.81×10^{-7} mSv. The estimate is based on experience of releases from Clab during the past five years and on a conservative assumption that the release from the encapsulation plant is of the same size as that from Clab.

Airborne releases take place via the encapsulation plant's ventilation stack. An estimate of the airborne release is based on experience from the operation of Clab. In view of the fact that fuel handling and maintenance are on a smaller scale in the encapsulation plant, the releases have been assumed to be half of the releases from Clab. Based on this assumption the annual releases have been estimated to be 12 MBq, which is equivalent to an annual dose to the critical group of 1.4×10^{-6} mSv.

A study of possible measures to reduce activity releases to water and air has been conducted /ALARA 2006/. The study resulted in a number of possible measures to reduce activity releases to water. If all measures can be adopted without impairing safety in the plant, it is estimated that releases can be reduced by 95–99%. In the case with the integrated facility (Clab and the encapsulation plant), releases could be reduced to between 6 and 10 MBq per year.

A possible large point source for atmospheric emissions in the encapsulation plant is the dry handling of spent nuclear fuel in the handling cell. Assuming a separation efficiency of 99.999%, as proposed in the study, the assumed release from the handling cell is 0.1 MBq. This is equivalent to an annual dose to the critical group of 9.3×10^{-9} mSv.

The personnel in the encapsulation plant will be exposed to radiation in connection with normal operating duties and maintenance work. The collective dose, expressed in manSv, is the average dose to individuals in a group multiplied by the number of individuals in the group. The activities in the encapsulation plant are estimated to give rise to a collective dose of 22 mmanSv per year. The collective dose in Clab in 2004 was 14 mmanSv /SSI 2005/. According to SSI's regulation (SSI FS 1998:4), the dose limit for single years is 50 mSv per individual, and for a five-year interval 100 mSv per individual. The estimated collective dose to the personnel in the encapsulation plant is thus on a level with the dose limit per individual, regarded as a mean value during a five-year interval. This is well below the limit. The collective dose to Clab's personnel may increase as a consequence of the increased waste handling when the encapsulation plant is in operation.

By comparison it can be mentioned that the average annual radiation dose to people in Sweden is approximately 4 mSv per person. Nearly half is from radon in the indoor air.

Disturbances

Disturbances are events that can occur at some time during the operating period of the encapsulation plant. Examples of disturbances that are analyzed in PSAR Clab are loss of power supply, component malfunction in the process and handling systems (for example loss of ventilation and loss of cooling in pools), operator error, water leakage and internal flooding, activity release, computer failure and limited fire.

The disturbances may require the process to be stopped and the fuel to be returned to Clab. But they do not lead to fuel damage or radiological consequences for the surrounding environment /SKB 2006b/.

Mishaps

Mishaps are unlikely events which are not expected to occur, but which must be analyzed to demonstrate the ability of the plant to handle them with acceptable consequences for the personnel and surroundings. Mishaps analyzed in PSAR Clab include major fire, operator error that can damage the fuel and handling mishaps (for example dropped transfer canister or fuel assembly) /SKB 2006b/.

In order to estimate the maximum impact of a handling mishap in the encapsulation plant, a purely hypothetical case can be assumed where all fuel that is being handled or kept in the plant is damaged, except for the fuel that is encapsulated. This type of mishap will be included in PSAR Clink.

4.3 PSAR for Clab and the encapsulation plant

The encapsulation plant is planned to be integrated with Clab. Some systems will be interconnected to supply both plant parts. This means that the safety analysis report, PSAR Clink, should apply to both plants.

PSAR Clink should show what requirements apply to all items and systems included in the plant. It also describes how the plant is built and will work when the encapsulation plant has been connected to Clab. The report will be based on an updated SAR for Clab and PSAR for the encapsulation plant. PSAR Clink is supposed to be finished and submitted to SKI in 2008.

4.4 PSAR for the final repository

The preliminary safety analysis report for the final repository includes two parts: one that describes the safety of the repository during the facility's operating period (operational safety) and one that describes the facility's post-closure safety (long-term safety). The report on long-term safety is called SR-Site, see section 5.

The preliminary safety analysis report will be submitted in 2009 in conjuction with the application under the Nuclear Activities Act. The radiological conditions associated with normal operation, disturbances and mishaps are analyzed in the PSAR for the operating period. Approximate assessments have already been done, however.

Normal operation

The design of the final repository is based on the assumption that the copper canisters that enclose the fuel are absolutely leaktight and that the fuel has decayed for many years before it is handled. No radionuclides can escape from the canisters, to either air or water, during normal operation of the final repository. The only releases of radioactive substances during operation will be the radon that is present naturally in the rock and is ventilated out to maintain a good working environment, see section 9.

Ionizing radiation will occur in the final repository and comes from the spent nuclear fuel that is contained in copper canisters. All handling of the copper canisters takes place with radiation shielding. The personnel in the final repository will be exposed to some radiation in connection with normal operating duties and maintenance work. The collective dose will be studied during the period up to when an application is submitted in 2009, but is estimated to be low.

Disturbances

Disturbances are events that can occur on rare occasions during the final repository's operating period. Disturbances can in some cases necessitate an interruption in the deposition process and return of fuel to the encapsulation plant. Examples of disturbances analyzed in PSAR final repository are loss of power supply, operator error, failure of handling equipment and limited fire.

No disturbances have so far been identified that lead to canister damage with radiological consequences for the surrounding environment.

Mishaps

Mishaps that are analyzed include large fire and handling mishaps. Handling mishaps include dropped copper canister and collision during underground transport.

No mishaps during the operation of the facility that could lead to a release of activity from the canisters have as yet been identified. This does not mean that there is no risk of environmental impact due to release of activity from the final repository during the operating phase of the facility.

5 Long-term safety

SKB is conducting an ongoing assessment of long-term safety for a final repository for spent nuclear fuel. The most recent safety assessment, SR-Can (Can = canister), was submitted to SKI in early November 2006 /SKB 2006a/. It is an initial evaluation of how the repository sites in Forsmark and Laxemar function together with the copper canisters that will be sealed in the encapsulation plant. Preliminary data from the Forsmark and Laxemar sites are used in the assessment. The assessment shows that the canister functions as it should in the final repository and the repository has the potential to satisfy the regulatory requirements on safety regardless of whether it is built in Forsmark or Oskarshamn.

SR-Can is a preparatory step for the SR-Site safety assessment, which is planned to be published in 2009. SR-Site is the part of the preliminary safety analysis report for the final repository that deals with long-term safety. SR-Site will be based on the total body of data gathered during the site investigations and the design of the final repository.

Within the framework of the Nuclear Fuel Project, a study is being conducted to show how SKB will ensure that the initial state assumed in SR-Site will be achieved during construction and operation of the final repository. This study includes an account of how the barriers are being handled within the entire KBS-3 system and by its suppliers in relation to stipulated requirements. This entails documentation of the entire handling chain, quality assurance, acceptance criteria, requirements and design premises for canister, buffer, backfill, rock works and final closure. A report on the results of this study will be submitted in conjunction with the applications in 2009.

6 Transportation of spent nuclear fuel

SKB owns and operates a transportation system for shipments of spent nuclear fuel from the nuclear power plants to Clab in Simpevarp and of low- and intermediate-level operational waste to SFR in Forsmark. Sea shipments are performed by SKB's specially designed vessel m/s Sigyn. Overland shipments are performed by slow-moving terminal vehicles. The spent nuclear fuel and operational waste is enclosed in transport casks during transport.

Operation of the transportation system includes design, procurement, operation, maintenance and renewal of transport casks, ships and terminal vehicles. It also includes permits and procedures.

Unencapsulated spent nuclear fuel is transported from the nuclear power plants to Clab. Encapsulated fuel will be transported from the encapsulation plant to the final repository. If the encapsulation plant is not sited adjacent to Clab, unencapsulated fuel will have to be transported from Clab to the encapsulation plant.

Transport casks

The transport cask that is used today for shipments between the nuclear power plants and Clab meets the requirements for "type B packages" according to IAEA rules. This means that extensive calculations as well as physical tests on a prototype cask are performed in order to guarantee that the cask can prevent contact between the contents of the cask and the environment. This also applies in the event of severe accidents.

Figure 6-1. *Terminal vehicle with transport cask for spent nuclear fuel.*

The requirements on a type B package have been applied to shipments of spent nuclear fuel for many years all over the world. The strength requirements included in calculations and tests are chosen to ensure that the cask is capable of withstanding a wide variety of conceivable and inconceivable stresses. As far as is known, such a cask has never been involved in an accident resulting in a release of radioactivity. SKB has many years of experience of using such casks, and no incidents have ever occurred that have affected their function.

The transport cask that is planned to be used for the shipments between the encapsulation plant and the final repository (regardless of siting) will also meet the requirements for type B packages.

6.1 Transportation of unencapsulated fuel

Environmental safety in connection with shipments of unencapsulated fuel from the nuclear power plants has been analyzed for normal operation, design-basis accidents and hypothetical accidents.

Normal operation

For normal operation it has mainly been a question of determining the radiological premises for designing radiation shields. The function and reliability of the system has been verified in actual operation (about 20 years so far).

The radiological conditions, as well as the stresses and disturbances that have occurred, show that environmental and safety requirements can be met in connection with both normal operation and disturbances and stresses to which the system is subjected.

Figure 6-2. *Lashing of casks for spent nuclear fuel on m/s Sigyn.*

Design-basis accidents

Regarding accidents, an inventory of the events, courses of events and conditions that could lead to a radiological accident was performed in conjunction with the procurement of the transportation system. Most conceivable ship accidents do not result in any damage to the cargo and the ship remains afloat. The studies were concentrated on such serious mishaps that the damage to the ship could affect the casks. The consequences of the cargo being dropped from the ship or the ship sinking as a result of a collision, as well as the ship being damaged or burning after a collision, were analyzed.

The cask is expected to remain intact in all design-basis accident situations, so that accidents do not have any radiological consequences. The ship meets the rules on buoyancy with ample margin. A radiological accident would not occur even if the ship were to sink.

Hypothetical accidents

The assessment of environmental safety for the transportation system /SKB 2005/ includes an environmental impact scenario in the event of a radiological accident. Such an accident requires a barrier breach, i.e. the transport cask must be damaged so that radioactive substances can escape. This type of damage to the cask lies beyond the design criteria, but must be assumed in order to show radiological consequences. Events of this type are therefore assumed to be possible, and are designated hypothetical accidents. The hypothetical accidents that have been analyzed are mechanical damage to a cask, fire of long duration, and sinking of the cask to the bottom of the sea.

The assessment shows that the consequences for human health and the environment are negligible, despite very conservative assumptions with regard to releases of radioactivity.

6.2 Transportation of encapsulated fuel

The point of departure for transport of encapsulated fuel is that the canisters are absolutely leaktight and that the fuel is encapsulated and has decayed for about 30 years. These transport casks are also designed to withstand very severe stresses. This means that no radioactive release can occur as a consequence of conceivable accidents during transport.

The calculations that have been carried out /Ekendahl and Pettersson 1998/ are therefore based on purely hypothetical assumptions, in this case that neither the transport cask, the canister nor the fuel cladding are completely leaktight. Even in these scenarios, which are very unlikely to occur, the dose impact is extremely small – far below dangerous levels. The conclusion of the assessment is that the consequences for human health and the environment as regards releases of radioactivity are negligible, even in the event of improbable accidents.

7 Protective security

Based on the legal requirements, SKB has designed a protective security system consisting primarily of three parts: physical protection, personal security and a scanning of the world around.

Physical protection of nuclear facilities includes fencing, alarm, entrance control, camera surveillance etc and has two overall purposes. One is to contribute to general security by preventing deliberate acts from leading to radiological accidents, while the other is to prevent illicit tampering with nuclear material and nuclear waste.

SKI's regulations apply to all nuclear facilities that have permits under Section 5 of the Nuclear Activities Act, including Clab, the encapsulation plant and the final repository. For security reasons it is not possible to describe in detail the measures that are adopted to protect the facilities against hostile actions and threats. One purpose of the measures is to make the time it takes to gain entrance to the facility as long as possible so that the police can deploy their resources.

Personal security includes, for example, screening of employees and visitors. SKB carries out background checks on its own personnel and contractors. This background check also includes a check by Säpo (the Swedish Security Service) under the Protective Security Ordinance (SFS 1996:633).

The scanning of the world around includes studying what is happening in the surrounding region, in Sweden and in the world. The scanning includes regular contacts with the police, Security Service, SKI and other nuclear licensees in Sweden, such as the nuclear power plants, Studsvik and the Westinghouse fuel factory.

7.1 Physical protection for Clab and the encapsulation plant

Clab and the encapsulation plant will have a common physical protection system. A special plan has been drawn up for the construction phase. Preliminary physical protection plans have been drawn up for the operating phase and were included as classified material in the application under the Nuclear Activities Act for the encapsulation plant in November 2006.

7.2 Physical protection for the final repository

A preliminary plan for physical protection during the construction and operating phases will be drawn up for the applications in 2009. This material will also be classified.

7.3 Physical protection for the transportation system

The physical protection requirement only applies to shipments of spent fuel, but is in principle also applied to shipments of other radioactive waste.

The physical protection in the transportation system is designed to:

- prevent theft and removal of transport casks,
- prevent intentional sabotage of transport casks that could lead to activity releases.

The system consists of a combination of engineering and other measures that both physically protect the spent fuel and permit rapid detection and alarm should anything abnormal occur. The content of these measures is also classified.

8 Environmental risk analysis

An initial environmental risk analysis regarding non-radiological consequences was carried out in 2006 /Andersson et al. 2006/. As in previous studies, groundwater lowering in conjunction with the construction of the final repository was judged to constitute a risk. A groundwater lowering may affect wells and animal and plant life. A hydrogeological study is currently being conducted, which will provide a more detailed picture of the groundwater conditions in affected areas and what the environmental consequences of a groundwater lowering might be, as well as loss prevention measures.

According to the environmental risk analysis, a large portion of other identified risks involve spills of oil or diesel fuel, mainly on land. Generally, the risks mainly occur during the construction phase and do not differ from the risks associated with any large construction project. These risks can be minimized with a good organization and established procedures, and spills can be cleaned up as needed. Something that has a relatively high probability of occurring and cannot be easily cleaned up is damaged trucks or road tankers that leak oil. The magnitude of the damage this causes depends on where it occurs (near sources of water, sensitive fauna etc) and possibly also when.

An update of the environmental risk analysis will be performed prior to the applications in 2009. Then the design work will have proceeded further and the layout and location of the facilities will have been more precisely determined. Additional risk scenarios, for example fire, will be analyzed in the update.

9 Working environment

All studies, all planning and documentation of work environment management take place within the framework of designing the encapsulation plant and the final repository. By "systematic work environment management" in the regulations is meant the employer's efforts to investigate, execute and follow up the activity in such a way that ill health and accidents at work are prevented and a satisfactory working environment is achieved. A written working environment policy and written procedures describing how the work environment is managed shall be provided.

The regulations for the construction and civil engineering work state that a working environment plan shall be prepared. The underground working environment is characterized by noise, dust, gases (e.g. radon), damp, darkness and confined spaces. According to the provisions for rock work, the need for ventilation and the design of the ventilation system shall be planned and documented before the work is begun. There shall also be a written plan of action regarding what to do in the event of an accident. The plan of action will comprise a part of the working environment plan.

Responsibility for management of the work environment on different construction sites rests with the owner, in this case SKB. Coordination of the work is usually entrusted to one of the major contractors.

The design work is also governed by laws and regulations that lie within the area of responsibility of the Swedish Rescue Services Agency. These kinds of matters, as well as working environment matters, are not included in the applications, but preliminary versions of all documentation will exist when the applications are submitted in 2009.

10 References

ALARA, 2006. Utredning av tekniker och metoder för reduktion av radioaktiva utsläpp från centralt mellanlager för använt kärnbränsle (Clab) och planerad inkapslingsanläggning för använt kärnbränsle, Simpevarp, Oskarshamns kommun. ALARA engineering report 06-0008R, Revision 1.

Andersson J, Herly L, Pettersson L, 2006. Miljöriskanalys för inkapslingsanläggning och slutförvar. SKB P-06-108, Svensk Kärnbränslehantering AB.

Broman U, Dybeck P, Ekendahl A-M, 2005. Transport av inkapslat bränsle. SKB R-05-65, Svensk Kärnbränslehantering AB.

Ekendahl A-M, Pettersson S, 1998. Säkerheten vid transport av inkapslat bränsle. SKB R-98-14, Svensk Kärnbränslehantering AB.

SAR for Clab. Clab Säkerhetsrapport. OKG report 8/A1. (Internal report)

SKB, 1992. SKB 91. Final disposal of spent nuclear fuel. Importance of the bedrock for safety. Svensk Kärnbränslehantering AB.

SKB, 1995. SR 95 – Template for safety reports with descriptive example. Svensk Kärnbränslehantering AB.

SKB, 1999. SR 97, Main Report Volumes I and II. Svensk Kärnbränslehantering AB.

SKB, 2000. Integrated account of method, site selection and programme prior to the site investigation phase. SKB TR-01-03, Svensk Kärnbränslehantering AB.

SKB, 2005. Säkerhetsrapport för transportsystemet. D-05-02, Svensk Kärnbränslehantering AB.

SKB, 2006a. Long-term safety for KBS-3 repositories at Forsmark and Laxemar – a first evaluation. Main report of the SR-Can project. SKB TR-06-09, Svensk Kärnbränslehantering AB.

SKB, 2006b. Ansökan om tillstånd enligt kärntekniklagen. Inkapslingsanläggning och centralt mellanlager för använt kärnbränsle, vid Simpevarp i Oskarshamns kommun. Miljökonsekvens-beskrivning (MKB). Svensk Kärnbränslehantering AB. October 2006.

SKB, 2006c. Ansökan om tillstånd enligt kärntekniklagen. Inkapslingsanläggning och centralt mellanlager för använt kärnbränsle, vid Simpevarp i Oskarshamns kommun. Bilaga F. Preliminär säkerhetsredovisning. Svensk Kärnbränslehantering AB. November 2006.

SKBF/KBS, 1983. Final storage of spent nuclear fuel – KBS-3. Parts I–IV. Svensk Kärnbränsleförsörjning AB.

SSI, 2005. Personalstrålskydd inom kärnkraftsindustrin under 2004. Swedish Radiation Protection Authority, SSI report 2005:12.

The references that are not available on SKB's website, *www.skb.se*, can be obtained on request.