RD&D-PROGRAMME 92 SUPPLEMENT

TREATMENT AND FINAL DISPOSAL OF NUCLEAR WASTE

SUPPLEMENT TO THE 1992 PROGRAMME IN RESPONSE TO THE GOVERNMENT DECISION OF DECEMBER 16, 1993

August 1994

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Treatment and final disposal of nuclear waste

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FOREWORD

The Act on Nuclear Activities (SFS 1984:3) prescribes in Section 12 that a programme shall be prepared for the comprehensive research and development and other measures that are required to safely handle and finally dispose of the radioactive waste from the nuclear power plants. The responsibility lies primarily with the owners of the nuclear power plants. These owners have commissioned SKB to prepare the prescribed programme.

A third such programme was submitted in September 1992 to SKI (the Swedish Nuclear Power Inspectorate). After broad review and commentary, analysis and recommendations from SKI and KASAM (the Swedish National Council for Nuclear Waste), the Government considered and accepted the programme in December 1993, subject to certain requirements on supplementation and clarification of the programme on a number of important points.

The present report presents the stipulated supplementary account. In response to comments received from the reviewing bodies, SKB has chosen to provide a relatively detailed account of the planned work in certain sections. The document is based on SKB's RD&D-Programme 92, where the necessary background for the information presented here is given.

Stockholm, August 1994

SWEDISH NUCLEAR FUEL AND WASTE MANAGEMENT COMPANY

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SUMMARY

BACKGROUND

In RD&D-Programme 92, SKB gave an account of its – and thereby the concerned power industry's – planning for deep disposal of the long-lived radioactive waste, including the spent nuclear fuel, that arises in connection with the operation of the Swedish nuclear power plants:

> The goal is to begin deposition in a deep repository of a small portion (5-10%) of the spent nuclear fuel in 2008, in compliance with all environmental and safety requirements. For this an encapsulation plant and a deep repository are required. Furthermore, additions to the existing transportation system are needed to ship the encapsulated fuel from the encapsulation plant to the deep repository. The basic scheme is encapsulation in copper canisters and deep disposal in accordance with the KBS 3 concept or a closely-related optimized version at a depth of about 500 m in the crystalline bedrock. The encapsulation plant shall be built as an extension of CLAB. The deep repository shall be built on a suitable site in Sweden that both enables the stringent safety requirements to be met and allows the necessary work to be carried out in consensus with the concerned municipality and the local populace. The safety and radiation protection aspects will be thoroughly penetrated and satisfactorily accounted for before a decision on essential binding measures is taken.

The main strategy described in RD&D-Programme 92 has been accepted in all essential respects by the regulatory authorities and the Government.

The regulatory authorities also level criticism at certain unclear points in the programme. With reference to this criticism, the Government decision stipulates that a supplementary account be submitted to SKI as follows:

SKB shall supplement RD&D-Programme 92 by describing

- the criteria and methods that can form a basis for selection of sites suitable for a final repository,
- *a programme for description of the specifications for the design of an encapsulation plant and final repository,*
- *a programme for the safety assessments which SKB intends to prepare,*
- *an analysis of how different measures and decisions influence later decisions within the final repository programme.*

The recommendations made by SKI and KASAM in their statements of comment should be taken into consideration in the supplementary account to the RD&D-Programme.

SKB sees this supplementary account as a natural step in the continued planning of the measures required to implement the approved main alternative. A number of important consequential decisions regarding environmental impact assessments, siting, safety reporting, investments, permits under various laws etc. must be made on the way up to completed final disposal. Background information of varying scope is required for these decisions and will be provided by the work now begun. Naturally, such information can also occasion re-evaluation and changes in the chosen main alternative and thereby also affect the schedule.

Some fundamental premises presented in RD&D-Programme 92 are that:

- in SKB's judgement, the current level of knowledge makes it possible to proceed from research and development to implementation,
- the need for further information on geological conditions is chiefly site-related,
- project-oriented work with clear goals is necessary to maintain the level of quality in the work.

The following report first presents an analysis of different measures and decisions in response to the last point in the Government's stipulations on a supplementary account. The reason is that such an analysis provides an overview of the entire process, while the other points deal with more specific programmes.

ANALYSIS OF DIFFERENT MEASURES AND DECISIONS

The requirement for *"an analysis of how different measures and decisions influence later decisions within the final repository programme"* concerns both overall measures and more short-term measures within the decided programme. The overall measures are discussed in this section, while the more short-term measures come under consideration in the specific programmes. Construction of an encapsulation plant and a deep repository, encapsulation of spent fuel and deposition of encapsulated fuel in the deep repository embrace a large number of measures regarding which decisions are made step by step. Figure 1 shows a general logic diagram over the most important major steps in the process. Measures that concern the deep repository embrace a time span of sixty years or more from the start of feasibility studies up to completed closure of the repository.

Decisions regarding different measures always entail certain commitments in different respects. In this context it may be purely physical commitments, i.e. the measure entails changing the physical state or properties of the waste in a way that makes it difficult or impossible to return to previous states or to choose an alternative path later on. It may also be that a decision on a certain measure ties up large resources, which in turn means that switching to an alternative path is more difficult due to a lack of resources.

In the plan presented by SKB, physical measures that directly affect the waste will not be carried out until encapsulation has begun after the necessary development, design and construction work has been carried out and the necessary permits have been obtained from the authorities. This will not occur until 2007 at the earliest. However, large resources will be committed earlier – especially when the construction work for the encapsulation plant is begun and when detailed characterization starts for the deep repository.

In the initial construction stage for the deep repository, approximately 10% of the spent fuel will be deposited. This will be followed by thorough evaluation and a new permit will be required to continue along the same path. SKB's judgement is, as was asserted in RD&D-Programme 92, that the deep repository will be expanded to full scale.

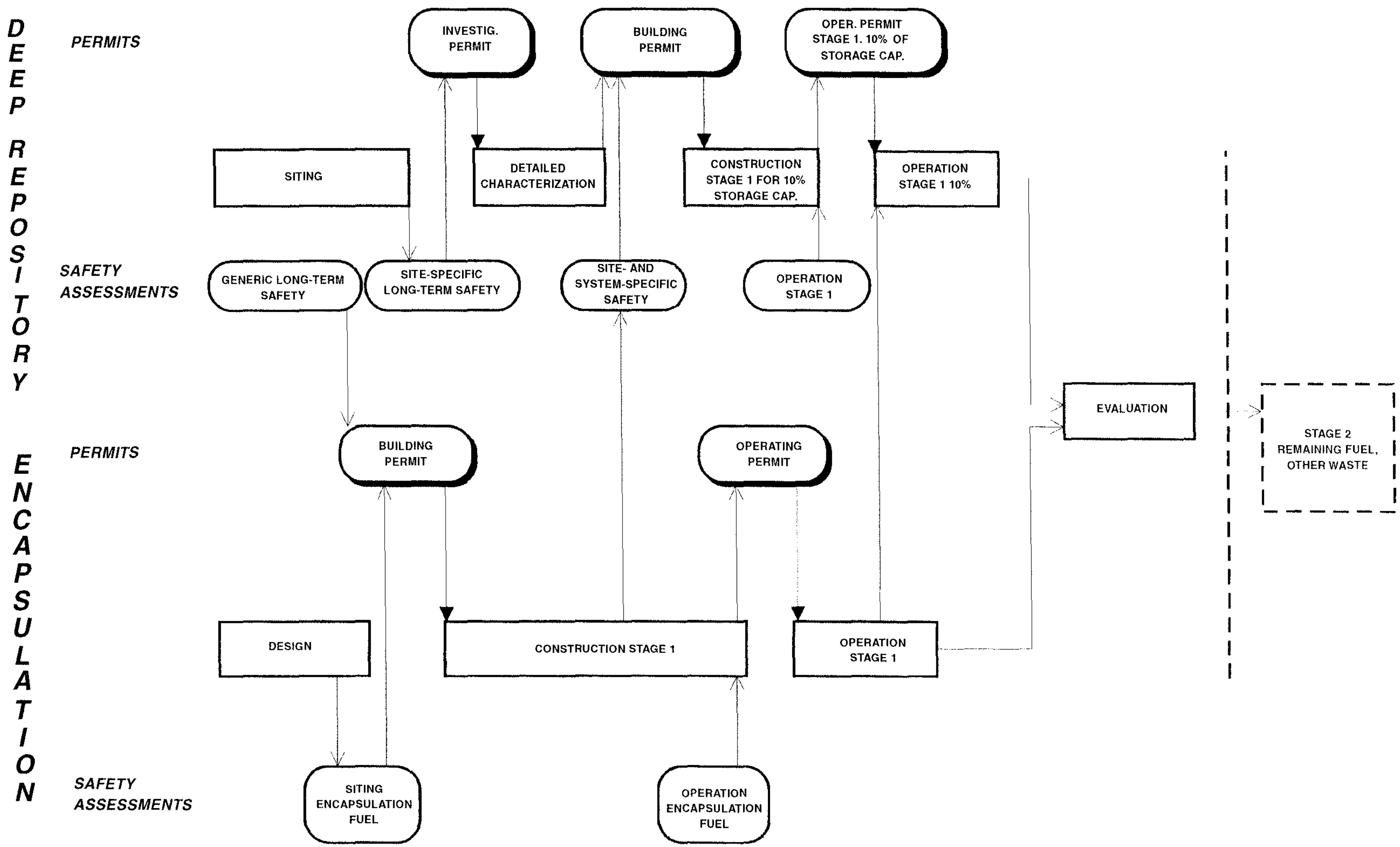

***Figure 1.** Logic diagram of the major steps in the deep repository programme, along with necessary safety assessments and permits under the Act Concerning Conservation of Natural Resources (NRL) and the Act on Nuclear Activities (KTL). The upper half of the figure concerns siting, construction and operation of a deep repository, while the lower half concerns the equivalent steps for an encapsulation plant. For each plant the diagram shows main activities (middle row), important decisions and permits (top row) and planned major safety assessments (bottom row).*

The approximately 400 fuel canisters that are deposited can, however, be retrieved if this should be deemed desirable. The cost of such retrieval is estimated at SEK 600 million. The investments that will then have been made in the encapsulation plant and in the deep repository are considerable – a total of about SEK 5,000 million, of which SEK 4,000 million will be invested prior to the first encapsulation of nuclear fuel.

One reason for retrieval could be, for example, that (international) technological developments in the field have led to a situation where other handling and/or treatment methods for the spent fuel are found to be very attractive. Another possible reason could be that it has been decided not to continue on the selected site.

The option of interrupting the deposition work and retrieving deposited waste will exist throughout the construction and operating periods for the deep repository, but naturally at progressively increasing costs. Before the repository is closed and sealed, it can be kept under surveillance for as long as desired.

Information on the repository will be filed and the site of the repository will be marked in an appropriate fashion. Even after closure of the repository, this information will make it technically possible for a long period of time to retrieve the waste, if desired. After closure, each generation will have to decide what kind of surveillance and monitoring they wish to have on the site.

An important principle for the encapsulation and deep repository projects is that each new step shall be based on an adequate body of technical data. Regulatory authorities, municipalities and other concerned bodies shall be given sufficient time to review the material thoroughly before making important decisions. At the same time, it must be borne in mind that it is important to keep the process moving forward at a certain pace, not least for the quality of the work. SKB believes that fifteen years is sufficient to complete the first construction stage in the deep repository programme. The necessary facilities are of neither such a size nor such a complexity that more time is needed.

Another important aspect is the interaction between supportive research, development, design and construction of the planned facilities. The development work within the framework of RD&D-Programme 92 is therefore being planned with the needs of the encapsulation and deep repository projects in mind. An example is the Äspö Hard Rock Laboratory (HRL), where the first phase with geological investigations and construction will be concluded during 1995. It is yielding important material for the design of site investigations and later detailed characterization for the deep repository. The next phase of experiments and investigations at Äspö will similarly yield material for safety assessments and for the final design of the deep repository and its barrier systems.

CRITERIA AND METHODS FOR SITE SELECTION

Criteria for siting

Of greatest importance for siting of the deep repository is to choose a site where the safety-related conditions are very good. Since the mid-1970s, SKB has carried out extensive study site investigations and other studies of geological conditions at depth in the Swedish bedrock. Furthermore, SKB and other organizations have conducted a number of detailed safety assessments for final disposal in the environment existing in the Swedish bedrock. Considerable knowledge also exists from siting and construction of underground rock facilities for mines, power plants, oil storage and defence purposes in most parts of the country. Based on this knowledge and experience, many municipalities are judged to have sites with very good conditions from a safety viewpoint. It is therefore reasonable and realistic to start with municipalities who actively wish to participate or otherwise show an interest and investigate the prospects for siting of a deep repository there. The possibilities in municipalities that already have nuclear activities will also be examined. Among municipalities with good safety conditions and with an expressed interest in a deep repository, siting will proceed on the basis of the results of a closer assessment of safety and environmental impact, transportation situation, experience of industrial activity and existing infrastructure in other respects.

This means that the organization of the siting work is based on a conviction that it is necessary and possible to find a site that meets high environmental and safety standards at the same time as a local understanding for the establishment of a deep repository is sought. This approach is well in agreement with the intentions underlying the applicable legislation in, for example, the Act Concerning Conservation of Natural Resources and the Act on Nuclear Activities. It also complies closely with the recommendations issued by the Nordic countries' radiation protection and safety authorities. The existing Swedish system with interim storage in CLAB also provides ample time and opportunity to consider the possibilities for executing deep disposal in collaboration.

Siting factors and criteria

Siting of the deep repository must take place in consideration of a number of factors (data, properties, conditions). The criteria which these factors must fulfil (or be evaluated against) for a deep repository site can be grouped under the following headings:

Safety	Siting factors of importance for the long-term safety of the deep repository.
Technology	Siting factors of importance for the construction, performance and safe operation of the deep repository.
Land and environment	Siting factors of importance for land use and general environmental impact.
Societal aspects	Siting factors connected to political considerations and community impact.

Fulfilment of the safety requirements is of primary importance, as already pointed out. Certain of the construction-related requirements are closely linked to safety. The most important requirements in this respect concern:

- the chemical environment in the rock for canister, bentonite and fuel;
- the mechanical stability of the rock;
- conditions for transport of corrodants and radionuclides in the rock;
- the risk of future intrusion, mainly for utilization of natural resources in the bedrock.

In an initial siting phase, the availability of data on the bedrock in areas judged to be of interest for siting is very limited. Many factors that are important for assessing long-term safety and construction-related aspects can only be clarified after comprehensive investigations on the site. Until then it is necessary to rely on general knowledge as a basis for selection of study sites. Since surveying general land and environmental factors as well as societal aspects is simpler to do at an early phase, these siting factors can be clarified more completely to begin with.

Key questions in the initial siting phase are:

- Which sites have particularly good chances of meeting the requirements with regard to safety, technology, land and environment as well as societal aspects?
- Which of these sites offer good opportunities for later carrying out a reliable characterization of, above all, the important environmental and safety factors?
- How can these sites be identified based on existing material?

The following conditions are thereby particularly favourable for the selection of study sites:

- A common rock type without interest for other utilization of natural resources.
- A large site with few major fracture zones.
- Few opposing land-use and environmental interests.

Secondarily, the following conditions are also favourable:

- Local positive interest.
- Availability of necessary infrastructure. Good means of transportation.

In the initial siting phase, i.e. without data from field investigations, the evaluation of the geoscientific material is focused on identifying unsuitable or unfavourable conditions based on publicly available information. Conditions that should be avoided are firstly:

- abnormal (for Swedish bedrock) groundwater chemistry;
- highly heterogeneous and difficult-to-interpret bedrock;
- known deformation zones and postglacial faults;
- pronounced discharge areas for groundwater;
- rock types that might be of interest for prospecting.

In subsequent phases (during execution of site investigations and, eventually, also detailed characterization — see below) efforts are directed at firstly clarifying the conditions that will prevail for the repository as a whole, secondly for the different repository parts, and finally for the individual canister positions. The following conditions are particularly favourable:

- reducing groundwater chemistry;
- normal (for Swedish bedrock) groundwater chemistry in other respects;
- homogeneous and easy-to-interpret bedrock;
- few fracture zones and low to moderate fracture density;
- low groundwater discharge;
- normal (for Swedish bedrock) rock stresses, strength properties and thermal conductivity.

Conditions which can lead to a site being abandoned in a site investigation and/or detailed characterization phase are above all:

- extreme groundwater chemistry, e.g. oxidizing groundwater;
- valuable ores or minerals in the repository area;

- several closely-spaced water-bearing fracture zones;
- extreme rock-mechanical properties.

Siting studies

The purpose of the siting studies is to gather all the background information that is needed to be able to select a site and obtain permission for detailed characterization. For this, SKB is carrying out or plans to carry out:

> **General studies** that provide a general background and general conditions. They cover the entire country or major regions. A collected account is planned for 1995. An overview and exemplification of the material that exists now within the general studies is provided in Appendix A.
>
> **Feasibility studies** that examine the prospects for a deep repository in potentially suitable and interested municipalities. The general land and environmental factors and the societal aspects are scrutinized in the feasibility studies. Judgements of siting factors for safety and technology are based on general knowledge and data. A feasibility study results in a judgement regarding if and where sites exist with good potential from both a geoscientific and planning viewpoint. It also provides a basis for judgements of impact on local industry and the local community. Two feasibility studies are currently being carried out. SKB plans to conduct feasibility studies for 5-10 municipalities.
>
> **Site investigations** primarily comprise geoscientific surveys from the ground surface and in boreholes of a specific site. The safety-related and technical siting factors are clarified as far as possible. Some further investigation of local land and environmental factors in particular is also done. The purpose is to gather material to permit a preliminary determination of whether it is possible on the site to build a deep repository that can meet all environmental and safety requirements. Selection of sites is made based on a combined assessment of the results of feasibility studies and general studies. The results of the general studies will be reported before the first site is selected so that this site can be placed in its regional and national context. The results of all feasibility studies will have been reported before the second site is selected.
>
> A site investigation is carried out in a number of stages. If it is found in the initial stages that a site has characteristics that would have a negative impact on the safety of a deep repository, the investigation is naturally interrupted and an alternative site chosen. The results of a complete site investigation are compiled in a site-specific environmental impact assessment (EIA), including an assessment of long-term safety.

When two complete site investigations have been carried out, all relevant material from the siting work is compiled in an application for permission to carry out detailed characterization on one of the two sites. The reasons for the choice of site are described, along with all background material in the form of data, analyses, surveys, appraisals and judgements.

Public insight, local collaboration and EIA process

An extensive programme for collaboration and information is required throughout the siting process. It embraces the municipal, county and regulatory authorities as well as the local inhabitants, local non-governmental organizations, concerned neighbouring municipalities and the general public. Regular information will also be furnished to scientists and other qualified experts with a particular interest in the field of nuclear waste.

In conjunction with the start of the site investigations, a local safety committee or similar body should, in SKB's opinion, be established in concerned municipalities and be given resources to follow the work in a qualified way.

It is essential that clear forms be established at an early stage for producing an environmental impact assessment (EIA process). For the siting of the deep repository, this should be done before site investigations are begun in a municipality. Principles must thereby be stipulated for how the process is to be organized and documented. Important parties are above all those in whose jurisdiction the facility may be built (the municipality), those who will build and operate the facility (SKB), the regulatory authorities and the county administrative board.

Concerned municipalities should be given resources to follow and participate in the siting work in a qualified way. It is important that clear forms be established for such support, for example via funds from the waste reserves administered by SKI. It is also important to establish forms at an early stage for scientific/technical support to concerned municipalities from the regulatory authorities for safety and radiation protection.

PROGRAMME FOR DESCRIPTION OF DESIGN SPECIFICATIONS

The design specifications are described for each step in the design process. The specifications are determined gradually as different kinds of material become available. The major facilities are designed in layout steps. In its work, SKB follows the design model that has been developed during the past two decades and applied with good results in, for example, the power industry for important civil engineering projects.

The geometric layout of the deep repository for spent nuclear fuel is being planned by and large in accordance with the KBS-3 concept. This consists of a number of deposition tunnels in the bottom of which holes are bored for placement of canisters with spent nuclear fuel and surrounding bentonite buffer. The deposition tunnels are interconnected by tunnels for transport and communication, which are also connected to a central service area and ramp/shaft to the ground surface. The exact placement of the deposition tunnels and deposition holes is adapted to local rock conditions. The repository depth is about 500 m in the normal case, but local adaptation will take place within the range 400 to 700 m.

The deep repository is planned to be constructed in two stages. The first stage is estimated to accommodate about 10% of the total quantity of spent fuel. The second stage includes deposition of the remaining quantity of spent fuel and other long-lived waste. Parts of the construction work for the deep repository will be commenced at the start of detailed characterization.

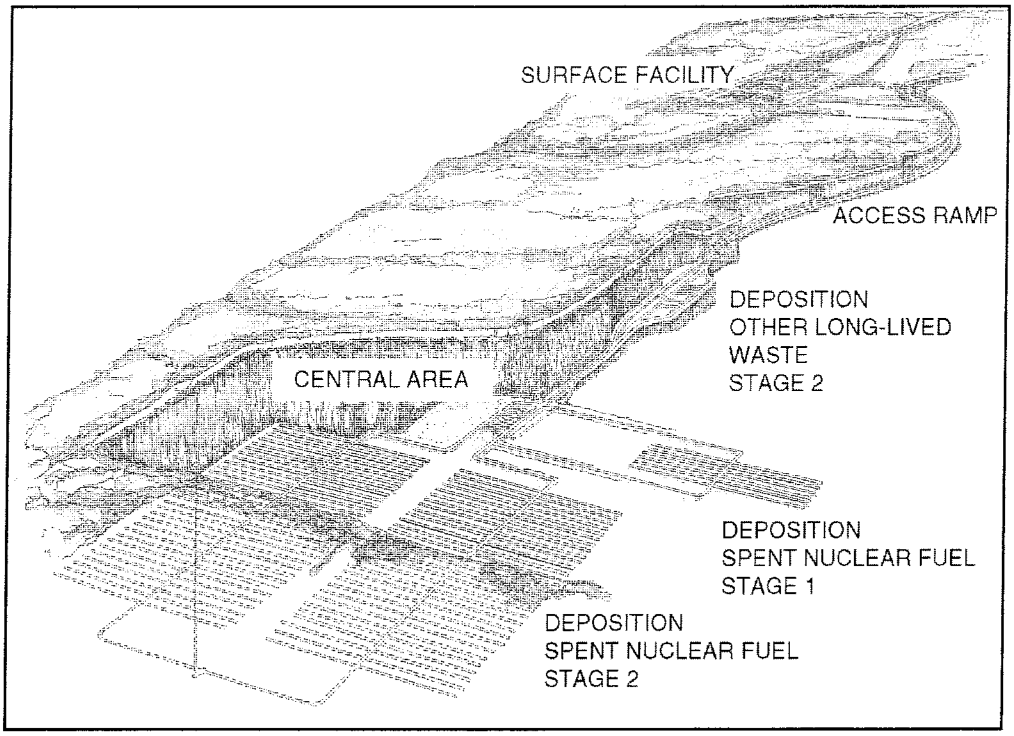

Figure 2. *Schematic drawing of the deep repository.*

Figure 2 shows a schematic drawing of the deep repository's different areas: surface facility, access ramp, central area under ground, deposition areas 1 and 2 for encapsulated spent nuclear fuel and deposition area for other waste.

In the design process, known technology or known methods will be adapted to the special conditions and requirements of the deep repository. A number of methods that will be used will be based on know-how obtained from ongoing R&D programmes. Important technology areas for the deep repository are:

- Construction method for tunnels and rock caverns, including boring of deposition holes.
- Grouting for sealing of water inflow.
- Compaction of bentonite blocks.
- Deposition procedure.
- Options for retrieval.
- Backfilling and closure.

The first two areas will be of importance already during the detailed characterization phase, while the others will not be applied until operating phase 1. The activities within supportive R&D and at the Äspö HRL are aimed at carrying out the necessary work in time for rational application during detailed characterization and during the first construction phase of the deep repository. Full-scale tests with certain special mechanical equipment, e.g. machines for compaction of bentonite blocks, are not planned to be done until during construction of the deep repository.

Before the spent fuel is placed in the deep repository it will be encapsulated in a durable canister. The most important requirement on the canister is that it shall remain intact for a very long time in the environment that will prevail in the deep repository. Accordingly it shall have a high corrosion resistance in the groundwater present in the rock and have a capacity to withstand by the mechanical stresses to which it is subjected in the deep repository.

The canister is planned to be constructed with an inner cylinder of steel, which provides mechanical strength, and an outer shell of copper, which provides corrosion resistance. Copper corrodes very slowly in the oxygen-free groundwater found at depth in Swedish bedrock. Completed studies show that the canister will probably remain intact for millions of years, providing a considerable margin of safety.

To determine dimensions for tunnels, deposition holes and radiation shields and requirements on mechanical equipment in the deep repository, the dimensions and properties of the canister must be known. Important parameters are weight, overall dimensions and maximum radiation level. These data need to be determined before the detailed investigation is begun.

Encapsulation is planned to take place in a new encapsulation plant connected to CLAB. There the fuel will be received from CLAB's storage pools and placed in the canister after being checked and dried. Before the lid on the inner steel container is put on, the air in the canister will be replaced with inert gas and the void filled with e.g. boron glass beads. Then the copper canister will be sealed with a copper lid fastened by means of electron beam welding. Very stringent requirements are made on the leaktightness of this weld and the capability to test this leaktightness. In designing the encapsulation plant, great emphasis will be placed on radiation protection for the personnel and the environment. This means, for example, that the actual encapsulation procedure will be performed by remote control from heavily radiation-shielded compartments called "hot cells". A large part of the handling of canisters will also be done by remote control. Experience from CLAB and SFR, as well as from various foreign facilities, will be drawn upon.

The work of fuel encapsulation is divided in the programme into canister design, sealing method and plant design.

Key issues for canister design are: functional requirements, material selection and tests for both copper and steel components, sizing of canister and steel components, inserts and possible backfilling in canister, detailed design of the lid with regard to lifting and non-destructive testing, and fabrication and inspection methods.

To meet the high requirements on sealing of the copper canister, a method for sealing by means of electron beam welding to industrial scale is currently being developed, along with methods for non-destructive testing. The latter will be used to verify that the seal meets the specified requirements.

The work on development of the sealing method includes the following steps: development and testing of inspection methods, trial welding of lids on copper cylinders, welding of prototype canisters and manufacture of prototype plant for testing of welding equipment and welding chamber before they are incorporated into the plant.

PROGRAMME FOR SAFETY ASSESSMENTS

SKB intends to give an account of safety and radiation protection matters for both the operating phase and the post-closure phase at all important decision occasions. This will be done

- in the form of (preliminary or final) safety reports (PSR/FSR) for the operational activities;
  - in the encapsulation plant,

- in connection with transports and
- in the deep repository, as well as

- in the form of safety reports on integrated assessments of the performance of the passive storage of the deep repository after deposition and closure.

The evaluation of operational safety at waste facilities can be done in all essential respects using the same methodology as is used for other nuclear facilities. It is therefore not discussed further here.

In the present programme for coming long-term safety assessments, the organization of the work and the methodology for performance and safety assessments for a deep repository are presented.

The programme during the coming sex-year period aims at producing:

- assessments for sizing and designing the repository with respect to safety;
- a suitable structure for how the integrated safety assessment is to be presented;
- a safety report on the long-term performance of the repository based on generic geologic information and preliminary site data prior to construction of the encapsulation plant, and a safety report (PSR) for the encapsulation plant;
- a safety report on the long-term performance of the repository based on data from site investigations prior to detailed characterization for the deep repository and a general safety report (PSR) for the operation of the deep repository.

The continued assessment work for subsequent safety reports will be carried out in basically the same way as for those mentioned above, but with progressively more detailed background data.

Regardless of whether the assessments constitute performance assessments of barriers or sub-systems, or whether they are safety assessments of the total performance of the entire disposal system, the work is carried out as follows:

- Definition of the purpose of the assessment.
- Definition of given assumptions for the assessment.
- Clarification of the conditions for which the system is to be assessed (scenarios).
- Clarification of the processes that are essential to the performance of the system.
- Definition of calculation models for quantifying the performance of the system.
- Quantification of the performance of the system and essential changes in performance.
- Discussion of uncertainties and of the validity of the assessment with respect to its purpose.

The programme describes how the studies of barriers and sub-systems are compiled into integrated safety assessments, and how uncertainties and validity will be handled.

1 BACKGROUND

In RD&D-Programme 92, SKB gave an account of its – and thereby the concerned power industry's – planning for deep disposal of the long-lived radioactive waste, including the spent nuclear fuel, that arises in connection with the operation of the Swedish nuclear power plants. The planning is based on a decision by SKB's board of directors to begin the design process and the other work that is needed to be able to apply for permission to carry out an initial stage in the construction of the facilities required for deep disposal about fifteen years from now. SKB's (and the concerned power industry's) decision entails the following, in brief:

> The goal is to begin deposition in a deep repository of a small portion (5-10%) of the spent nuclear fuel in 2008, in compliance with all environmental and safety requirements. For this an encapsulation plant and a deep repository are needed. Furthermore, additions to the existing transportation system are needed to ship the encapsulated fuel from the encapsulation plant to the deep repository. The basic scheme is encapsulation in copper canisters that hold a maximum of 12 BWR or 4 PWR fuel assemblies, maximum. The preferred alternative is a copper canister with an inner steel container, and the reserve alternative is a lead-filled copper canister. Deep disposal is intended to be carried out in accordance with the KBS-3 concept or a closely-related optimized version at a depth of about 500 m in crystalline rock. The encapsulation plant will be built as an extension of CLAB. The deep repository will be built on a suitable site in Sweden that both enables stringent safety requirements to be met and allows the necessary work to be carried out in harmony with the concerned municipality and the local population. Safety and radiation protection matters will be thoroughly explored and satisfactorily accounted for before a decision on essential binding measures is taken.

At the same time as the work with this main task is carried out, SKB will follow and, to a limited extent, support R&D on alternative lines of development, most of which is being conducted in other countries. This main strategy of SKB's programme, which was presented in detail in RD&D-Programme 92, is in harmony with the provisions of the Act on Nuclear Activities /1-2/ regarding a comprehensive programme. The preamble to this legislation /1-3/ states:

"that no commitment shall be made to a given handling or disposal method until sufficient knowledge has been obtained to recognize and evaluate all existing safety and radiation protection problems. If a new and better method emerges during the ongoing research work, it should be chosen instead."

The main strategy described in RD&D-Programme 92 has been accepted in all essential respects by the regulatory authorities and the Government.

SKI states that:

- *...RD&D-Programme 92 meets the basic requirements that are made on a programme for research and development in accordance with Section 12 of the Act on Nuclear Activities with respect to goals, breadth and depth.*

- *SKI can accept that the continued RD&D measures should be primarily focused on a method of the KBS-3 type. ... A KBS-3-like repository should also be able to be designed so that it can offer a reasonable balance between abandonability, retrievability and inaccessibility of the fissile material.*
- *SKI believes it is a good strategy to construct the deep repository in stages ...*

KASAM states that:

- *KASAM recommends that SKB focus its RD&D activities during the period 1993-1998 on a demonstration-scale deposition of fuel with the option of retrieval as an initial stage in the final disposal of the spent nuclear fuel,*
- *that this stage should comprise 5-10% of the total estimated quantity of fuel from the Swedish reactor programme, and*
- *that KBS-3 is a reasonable choice for the demonstration deposition.*

In a decision of 16 December 1993, the Government states regarding SKB's RD&D-Programme 92 that:

- *The Government finds in agreement with SKI that RD&D-programme complies with the stipulations set forth in Section 12 of the Act on Nuclear Activities.*
- *The Government notes that ... the work of depositing spent nuclear fuel and nuclear waste in a deep repository is planned to be carried out in two phases, namely demonstration deposition and final disposal.*
- *The Government finds in agreement with SKI and KASAM that the revision of the programme has considerable advantages, even though the long-term properties of the final repository cannot be demonstrated. The Government would especially like to emphasize that even if the KBS-3 method should be a reasonable choice for demonstration deposition, SKB should not commit itself to any specific handling and disposal method before a coherent and thorough analysis of associated safety and radiation protection aspects has been presented.*

The regulatory authorities also level criticism at certain unclear points in the programme. With reference to this criticism, the Government decision stipulates that a supplementary account be submitted to SKI as follows:

SKB shall supplement RD&D-Programme 92 by describing

- *the criteria and methods that can form a basis for selection of sites suitable for a final repository,*
- *a programme for description of the specifications for the design of an encapsulation plant and final repository,*
- *a programme for the safety assessments which SKB intends to prepare,*
- *an analysis of how different measures and decisions influence later decisions within the final repository programme.*

The recommendations made by SKI and KASAM in their statements of comment should be taken into consideration in the supplementary account to the RD&D-Programme.

SKB sees this supplementary account as a natural step in the continued planning of the measures required to implement the approved main alternative. A number of important consequential decisions regarding environmental impact assessments, siting, safety reporting, investments, permits under various laws etc. must be made to accomplish this. Background information of varying scope is required for these decisions and will be provided by the work now begun. Naturally, such information can also occasion re-evaluation and changes in the chosen strategy.

1.1 OUTLINE OF THE SUPPLEMENTARY ACCOUNT

The supplementary account to RD&D-Programme 92 requested by the Government has been compiled in this report. First certain general premises for the work and the decision process are described. Then *an analysis of how different measures and decisions influence later decisions within the final repository programme* is presented. The reason for starting with this analysis is that this provides an overall picture of the entire process. Then it is possible to describe in a clearer and more structured fashion the different parts of the process that are referred to in the first three points in the Government's stipulations on a supplementary account. These three points are then covered in sequential order.

2 GENERAL PREMISES AND DECISION PROCESS

Few areas have been studied as thoroughly as nuclear waste management. The scientific work is being pursued in close international contact and collaboration between responsible organizations and public authorities. Thorough evaluations have been carried out of e g technical aspects and options.

One result is that a broad consensus exists that deep geological disposal is a very good way to deal with the waste in a safe manner in a long-term perspective. Such disposal combines a relatively simple technology with great flexibility as regards pre-existing conditions. Solid and proven knowledge exists regarding the fundamental questions. There is therefore good reason for an initial stage of the disposal to be carried out now. Obviously, other fundamental concepts in terms of technology etc. can also lead to other good solutions with their own advantages. Even if the chosen strategy for the Swedish programme is good, one must naturally be open to improvements in this area, as in all other areas of technology.

Some fundamental premises presented in RD&D-Programme 92 are that:

- in SKB's judgement, the current level of knowledge makes it possible to proceed from research and development to implementation,
- the need for further information on geological conditions is chiefly site-related,
- project-oriented work with clear goals is necessary to maintain the level of quality in the work.

Against this background a schedule was presented in RD&D-Programme 92, which shows the earliest dates by which different measures can be carried out. The schedule includes both activities for which SKB can control the time required, and activities where the time required will largely be determined by outside factors. The clearest example of the latter is the local decision process in the different steps connected with the siting of the encapsulation plant and deep repository.

The schedule is divided into different steps with decision occasions between them. Before a new step is begun, an assessment is made of whether sufficient knowledge and information exists. The step-by-step decision process thus provides opportunity for revision of strategy and schedule at each step. The schedule in RD&D-Programme 92 shall thus be regarded as a guide for planning of the work for the next few years and not as an immutable timetable. Room must be allowed for revising the schedule gradually as new information emerges.

At the same time, the work must be pursued in an efficient manner towards established goals. This means that the focus of the work must be progressively narrowed towards the alternatives that are judged to have the best potential for being able to be realized and lead to the goal – safe final disposal. Successive choices of strategy will be made at different levels. In this respect the work does not differ from ordinary design activities. As is explained in chapter 5, design methods are therefore employed in the work which have long been established within industry.

The main strategy chosen in RD&D-Programme 92 was that the spent fuel is to be encapsulated in a canister of copper and steel and that the canister shall be deposited in a deep repository designed in accordance with KBS-3 or a similar optimized design. It was further chosen as the main strategy that the encapsulation plant is to be built adjacent to CLAB and that the deep repository is to be constructed in stages. The background is SKB's judgement that it is possible in this way to achieve a safe encapsulation and final disposal of the spent nuclear fuel at a reasonable cost /2-1/. The choices do not, however, mean that other alternatives, such as a lead-filled copper canister, have been ruled out, but merely that they are not being studied further at the present time. In the event it later turns out that SKB's judgement has been incorrect, it is always possible to resume studies of rejected alternatives. This might then naturally also affect the schedule for the continued work.

In a similar manner, a number of choices will have to be made in the future. In the case of the canister, for example, a design and a fabrication method will have to be chosen, as well as a sealing method and an inspection method. Several of the choices are dependent on each other and may have to be made in a single context. The choices will be based on analyses of various kinds. With some simplification, the process can be described in the following manner:

- the design requirements are formulated;
- alternative solutions are studied with respect to safety, economics, need for development work and risks;
- a main alternative is selected;
- if several alternatives lie close to each other, or if uncertainties exist in the design requirements or with regard to development work it is natural to continue studying several alternatives;
- if the alternatives differ widely with regard to cost or need for development work, but uncertainties exist regarding the design requirements, the design requirements should be clarified before a final choice is made;
- the choice is documented.

In order for this process to proceed smoothly, it is essential that the quality of the background data is good and that the grounds for the choice are documented clearly. Furthermore, it is important that information on rejected alternatives be preserved. In this way it is possible to make a judgement at a later point as to whether the premises are still valid or whether additional information necessitates that a different choice be made.

It is naturally important that sufficient information be available to make an educated choice. There are no general rules; how much is sufficient must be determined from case to case. The uncertainties in the decision base must be weighed against the risks entailed by the choice in terms of costs and schedule.

Important and imminent interim goals in the work are the coming applications for permits to build an encapsulation plant for spent fuel and to carry out detailed characterization for the deep repository. SKB's proposals for the site and design of the facilities will be presented in these applications. The applications will be supported by environmental impact assessments and safety assessments. A body of documentation on SKB's choices at various steps will exist as background to the applications.

As the focus of the work narrows, the knowledge base for the safety assessment will be progressively improved, firstly via measurements and observations that relate directly to the encapsulation and deep disposal operations, and secondly via continued supportive R&D. In this way, progressive detailing will be achieved as regards, for example, the composition and quantity of the waste, the properties of the canisters and site-specific data on the repository site.

This is particularly clear for the deep repository, which will undergo several extensive safety assessments spread out over a long period of time – about 60 years – with progressively more detailed site data. The early safety assessments will necessarily have to be based on preliminary assumptions regarding the site and on estimates of waste quantity and composition. When the fuel is encapsulated, it will be possible to measure quantity and burnup with relatively high precision, which also provides fairly accurate data on composition. As increasingly detailed site investigations are performed, knowledge regarding the site will be improved, and when the time comes to deposit the waste, detailed data will be available on the site and the design of the repository. Finally, when the repository is to be closed, data will be available from several decades of observations on and around the site of the repository. Safety assessments will be carried out in the different steps, and in connection with the permit application review the authorities will consider whether the data and the safety assessments have achieved a degree of maturity that is sufficient for the next stage of the work. Table 2-1 provides a rough overview of the gradually increasing degree of data precision:

Table 2-1. Overview of gradually increasing data precision.

Safety assessment prior to	Waste data	Site data – deep repository
Construction encapsulation	Estimated	Preliminary data
Detailed characterization	Estimated	Boreholes data
Construction deep repos.	Estimated	Detailed char. data
Initial deposition	Measured + est.	Detailed constr. data
Evaluation	Measured	Detailed constr. data
Closure	Measured	Several years of observ.

3 ANALYSIS OF DIFFERENT MEASURES AND DECISIONS

The requirement for "*an analysis of how different measures and decisions influence later decisions within the final repository programme*" concerns both overall measures and more short-term measures within the decided programme. The overall measures and the decisions are discussed in this chapter in the longer time perspective from the 1990s until the repository has been sealed in the middle of the next century or later.

In the shorter time perspective up to the initial canister deposition, the requested analysis is an integral part of the supplementary programme that is requested concerning design specifications and safety assessments and is presented in these sections.

Questions that are discussed here include:

- logic diagram of measures and decisions;
- degree of commitment in different stages and remaining degrees of freedom;
- retrievability after the demonstration phase, decisions regarding this, option to change method;
- costs for retrieval and change of method.

3.1 OVERVIEW OF MEASURES AND DECISIONS

Construction of an encapsulation plant and a deep repository and deposition of encapsulated fuel in the deep repository include a large number of measures that are decided on step-by-step. Figure 3-1 shows a general logic diagram of the most important major steps in the process. Measures that concern the deep repository span a time of about sixty years or longer from start of feasibility studies to completed closure of a fully expanded repository.

The following steps are distinguished for the **deep repository**:

- **Siting**, which takes place in two steps where the first step encompasses feasibility studies and general studies and the second step site investigations. The latter are primarily carried out on two sites that are chosen on the basis of the feasibility and general studies. See further chapter 4.
- **Detailed characterization** of one site. This requires a permit under the Act Concerning Conservation of Natural Resources (NRL) /3-1/. The work entails that construction work in rock is carried out to some extent. See further chapters 4 and 5.
- **Construction stage 1**, which concerns construction for deposition of approximately 10% of the spent nuclear fuel from the Swedish programme. The surface facility and necessary underground deposition chambers are built during this stage. At the same time, the necessary equipment for deposition of encapsulated fuel and associated activities is manufactured, delivered and tested. See further chapter 5.
- **Operation stage 1**, which comprises deposition of encapsulated spent nuclear fuel, about 10% of the quantity produced by the Swedish nuclear power plants up to 2010, i.e. about 800 tonnes (uranium) or about 400 canisters.

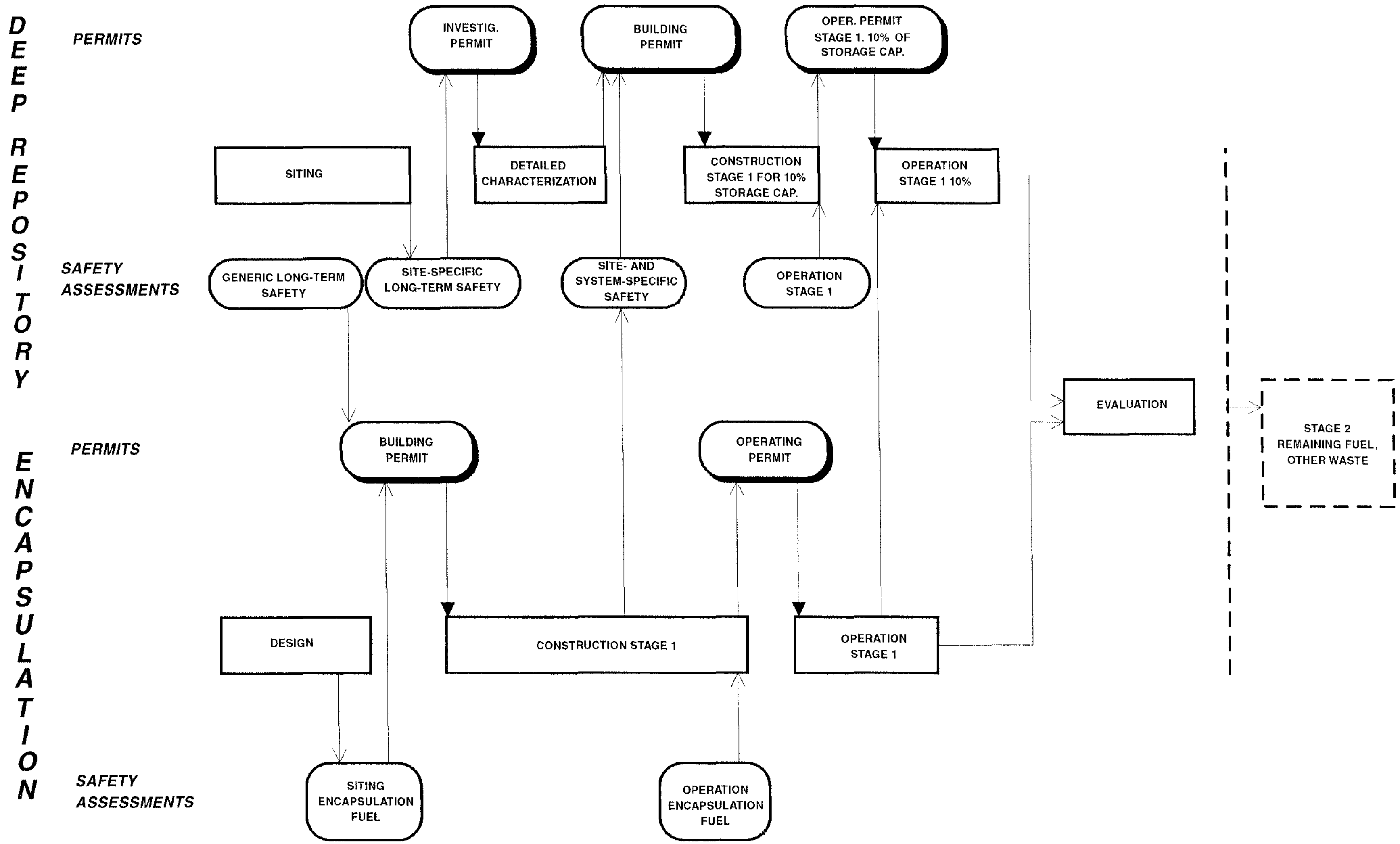

Figure 3-1. Logic diagram of the major steps in the deep repository programme, along with necessary safety assessments and permits under the Act Concerning Conservation of Natural Resources (NRL) and the Act on Nuclear Activities (KTL). The upper half of the figure concerns siting, construction and operation of a deep repository, while the lower half concerns the equivalent steps for an encapsulation plant. For each plant the diagram shows main activities (middle row), important decisions and permits (top row) and planned major safety assessments (bottom row).

- **Evaluation** (of Operation stage 1). If this turns out favourably for continued deposition of the remaining quantity of spent fuel and other long-lived waste, an application will be made for the necessary permits for construction and operation stage 2.
- **Construction and operation stage 2**, which comprises deposition chambers for all remaining spent nuclear fuel and all other long-lived waste. The work includes rock work, construction work and delivery and trial operation of equipment for the parts of the deep repository not included in stage 1. To the extent warranted by experience from operation and evaluation, the design of the facility and equipment is modified. The remaining waste is deposited during operation stage 2. This stage is the most long-lasting stage in the entire chain.
- **Supervised storage in the deep repository** for as long as desired. **Closure** of the deep repository. This activity is not indicated in the logic diagram.

The following steps are distinguished for the **encapsulation plant**:

- **Design** of the plant including decision on canister design and execution of the necessary final development work. Design is carried out in several phases with a gradually increasing degree of detailing up to applications for permits under NRL and KTL, which are planned to be submitted simultaneously. Required supporting documentation consists of an environmental impact assessment (EIA), including a preliminary safety report for the actual encapsulation plant and an initial safety assessment of the long-term safety of a deep repository with encapsulated spent fuel. See further chapter 5.
- **Construction stage 1**, which comprises detailed design and construction of the plant for encapsulation of spent nuclear fuel plus inactive trial operation of this plant. See further chapter 5.
- **Operation stage 1**, which comprises active trial operation and encapsulation of about 10% of the spent nuclear fuel.
- **Evaluation.** Coincides with evaluation of the initial stage of deep disposal as described above.
- **Construction and operation stage 2**, which comprises addition of a section for encapsulation of other long-lived waste (mainly core components) and encapsulation of remaining spent nuclear fuel and other long-lived waste.
- Possible **decommissioning** of the plant and deposition of resulting decommissioning waste — not indicated in the logic diagram.

3.2 HOW DO MEASURES AFFECT LATER DECISIONS – "COMMITMENTS"?

Decisions regarding different measures always entail certain commitments in different respects. In this context it may be purely physical commitments, i.e. the measure entails changing the physical state or properties of the waste in a way that makes it difficult or impossible to return to previous states or to choose an alternative path later on. It may also be that a decision on a certain measure ties up large resources, which in turn means that switching to an alternative path is more difficult due to a lack of resources.

In the plan presented by SKB, physical measures that directly affect the waste will not be carried out until encapsulation has begun after the necessary development, design and construction work has been carried out and the necessary permits have been obtained from the authorities. This will not occur until 2007 at the earliest. However, large resources will be committed earlier – especially when the construction work for the encapsulation plant is begun and when detailed characterization starts for the deep repository.

Table 3-1 provides a summary overview of measures that are planned and the commitments and the resource consumption that they lead to. The measures are given in chronological order in the table and tie in with the steps shown in Figure 3-1 and in section 3.1 above. Resource commitment increases with each stage as shown in Figure 3-2.

Table 3-1. Overview of measures, commitments, resource consumption and required formal permits.

Item	Measure	Commitments	Resources SEK mill.	Permits
1	Siting	No major	500	Landowners
2	Detailed characterization	Deep repository site	900	NRL + (KTL)
3	Design encapsulation plant	Canister design Siting encaps. plant	300	None
4	Construction 1 encaps.	Encaps. process	1300	NRL + KTL
5	Construction 1 deep rep.	Design deep rep.	2300	KTL + (NRL)
6	Operation 1 encaps.	Encaps. fuel	400	auth. KTL, SSL
7	Operation 1 deep rep.	Depos. canisters	300	auth. KTL, SSL
8	Evaluation		300	
9	Constr.+oper. stage 2	Waste deposited	9000	KTL, auth. KTL, SSL
10	Closure	Final disposal	1000	KTL

Abbreviations:

NRL = Act Concerning Conservation of Natural Resources
KTL = Act on Nuclear Activities
SSL = Radiation Protection Act
auth. = permit from regulatory authority
encaps. = encapsulation
rep. = repository
constr. = construction
oper. = operation

Note: Estimation of resources based on PLAN 94 /3-2/; no contingency allowances included here.

The various steps are discussed in the following.

Siting (1):

- The purpose of this work is to gather sufficient material as a basis for selecting a suitable site for a deep repository.

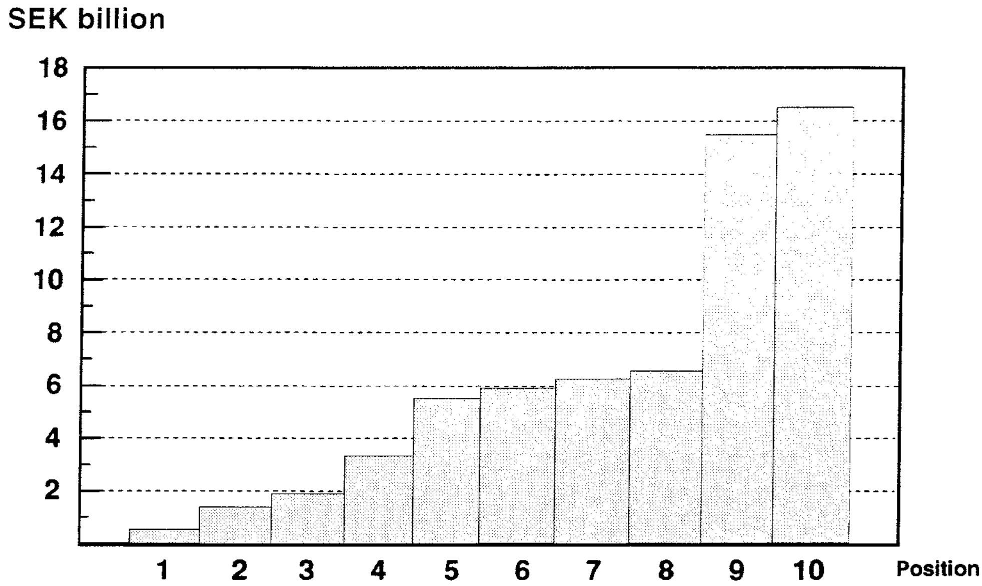

Figure 3-2. *Accumulated resource commitment (SEK billion) for main activities (steps) in Table 3-1.*

- The work in itself does not entail any actual technical commitment for the future.
- Resource consumption is estimated at about SEK 500 million for general and feasibility studies, site investigations and preparation of safety assessments and EIAs.
- The final results from the step serve as a basis for a site-related safety assessment, which will constitute an important part of the application for a permit to conduct detailed characterization on one of the sites. This safety assessment will be carried out in two phases, the first of which will be based on preliminary or generic site data and will serve as a supporting document for an application for permission to start construction of the encapsulation plant.
- The formal permission that is required is merely an agreement with concerned landowners to carry out the necessary drillings and investigations. In some cases, permits are required from the local building committee or environment and health protection administration.
- Any decision to interrupt the work after a completed site investigation at a given locality means that resources have been consumed but has no technical consequences.

Detailed characterization (2):

- The purpose of this work is to investigate the rock on a site in detail by means of tunnelling and/or shaft sinking and thereby finally determine whether the site is suitable or not.
- At the same time, design of the deep repository and of necessary equipment for it is continued.
- The detailed characterization provides a basis for compiling a detailed site-specific safety assessment. This consists mainly of an assessment of the long-term safety of the repository, but also a preliminary description of its operating safety. It in turn

serves as a supporting document for an application for a permit under the Act on Nuclear Activities (KTL) to build the first stage of a deep repository.

- If the work is successful, the site for the deep repository is determined. The work also entails a certain commitment to the layout of a future deep repository, especially in terms of the depth of the repository. The depth chosen for the repository on the selected site should in any case not be substantially less than the depth of the facility established during the detailed characterization work.

- The layout of the detailed characterization is also dependent to some extent on the planned layout of the deep repository. The design goal is, however, to adapt the repository as more data becomes available so that an optimal utilization of the selected rock is achieved.

- The scope of the characterization work is dependent on the conditions on the specific site. The nature of the activities coincides more or less with the activities performed at the Äspö HRL during the period 1990 — 1994. Resource consumption is estimated at SEK 900 million and time consumption at about 4 years, including simultaneous design.

- A permit under the Act Concerning Conservation of Natural Resources is required for execution of detailed characterization.

- Any decision to interrupt the work on a site after a completed detailed characterization means that resources have been consumed and that the site must be restored to its original state to as great an extent as possible, but otherwise has no technical consequences for the spent nuclear fuel.

Construction stage 1 for the deep repository (5):

- The work entails construction of a surface facility for handling of canisters and preparation of materials needed in connection with deposition, plus excavation of an underground facility for deposition of approximately 400 canisters. In connection with the construction work, collection of data on the site continues.

- The siting of the deep repository is definitely decided as far as stage 1 is concerned.

- Repository depth and layout are determined for stage 1 of the deep repository, as are the technology for handling of the canisters in conjunction with deposition and the prerequisites for a subsequent retrieval of the canisters.

- Resource consumption is estimated at about SEK 2,300 million over the course of about 4 years (includes design and owner costs but not infrastructure investments for transportation, the latter of which are highly dependent on the siting and can in unfavourable cases amount to considerable sums).

- A (final) safety report for the deep repository is compiled based on all available data and on the final design. This report covers both safety and radiation protection in conjunction with handling and operation, and long-term safety after closure. It will serve as a supporting document for an application for an operating permit from the regulatory authorities.

- A Government permit under the Act on Nuclear Activities is required for the execution of this construction stage.

Design of encapsulation plant (3):

- The work entails testing of technology for canister sealing, selection of detailed canister design, selection of technology and design of encapsulation plant.
- The work does not entail a strong technical commitment.
- Resource consumption is estimated at about SEK 300 million.
- In conjunction with plant design, preliminary safety assessments are compiled both for the encapsulation plant as such and for deep disposal of the canisters (see also siting above).
- No formal permits are required from the regulatory authorities for execution of plant design.
- Any decision to interrupt the work after design of the encapsulation plant entails that siting and detailed characterization for the deep repository can continue, but that design and construction of the deep repository cannot be executed.

Construction stage 1 for the encapsulation plant (4):

- The work entails construction of the encapsulation plant for encapsulation of spent fuel plus inactive trial operation of the plant.
- Siting of the plant is determined before the step begins. The work also entails that the detailed design of the canister and the encapsulation process for deposition stage 1 is finally determined.
- Resource consumption is estimated at about SEK 1,300 million over the course of about 9 years. The reason for the long time is above all that an extensive inactive trial operation is foreseen in view of the fact that this will be the first plant of its kind.
- A final safety report for the operation of the plant is compiled based on, among other things, experience from trial operation. This will serve as a supporting document for an application for an operating permit from the regulatory authorities.
- Permits under the Act Concerning Conservation of Natural Resources and the Act on Nuclear Activities are required for the execution of this construction stage.

Operation stage 1 for the encapsulation plant (6):

- Up to 800 tonnes (uranium) of spent fuel is encapsulated.
- If the main alternative — copper canister with inner steel container — is chosen, the canisters can be opened on a later occasion and the fuel assemblies retrieved. If the lead-filled copper canister should be chosen, any future opening of the canisters will be more difficult, and it cannot be assumed that the fuel assemblies will be intact.
- The canisters are placed in a temporary store at the encapsulation plant from which they are then sent to the deep repository as its capacity to receive canisters permits.
- Resource consumption is estimated at SEK 400 million over a 3-4 year period.
- A final permit from the authorities under the Act on Nuclear Activities and the Radiation Protection Act is required for start of operation.

Operation stage 1 for the deep repository (7):

- About 400 canisters are retrievably deposited over a 3-4 year period. A few canisters are provided with special monitoring instruments, which may be removed at a later point.
- Deposition in itself does not entail any further technical commitment. In the event it is decided to interrupt the deposition after stage 1, the canisters can be retrieved.
- Resource consumption is estimated at SEK 300 million, including sealing of deposition tunnels.

Evaluation (8):

- Results and experience from construction and operation of the encapsulation plant and the first stage of the deep repository are evaluated. Similarly, experience from parallel R&D on alternative handling and final disposal methods, as well as from other countries' similar programmes, is evaluated.
- The evaluation results in a decision either to continue along the chosen path or to do something else. SKB's judgement is, as was asserted in RD&D-Programme 92, that the deep repository will be expanded to full scale.
- In the event of a decision to continue, a safety report is compiled that has been revised in the light of the experience gained. This report will serve as a supporting document for an application for permits under the Act on Nuclear Activities and other laws to continue expansion of the deep repository to full scale and construction of supplementary parts of the encapsulation plant.
- In the event of a decision to interrupt the activity, either the deposited canisters will have to be retrieved and taken to an interim storage facility, or the repository will have to be closed, possibly after a period of surveillance.

Construction and operation stage 2 (9):

- The construction work in the encapsulation plant includes above all the parts of the plant that will be treating other long-lived waste. Excavation of the deep repository is expected to be able to be carried out in steps in parallel with the deposition of waste. The aim should be to maintain as steady a level of occupation with rock excavation work as possible.
- This stage entails final conditioning and deposition of all waste, including remaining spent nuclear fuel.
- Resource consumption is estimated at about SEK 190 million per year for encapsulation etc. and about SEK 250 million per year for deposition in the deep repository. Altogether this amounts to about SEK 9,000 million over the course of more than 20 years, including construction work, operation and backfilling of deposition tunnels.
- A decision may be made to retrieve the waste at any time during this period.

Closure of the deep repository; decommissioning of the encapsulation plant etc. (10):

- The work entails sealing and closure of the deep repository after all long-lived waste, including decommissioning waste from CLAB and the encapsulation plant, has been deposited.
- Closure can also take place in steps where surveillance is gradually reduced. A part of the surveillance can be a final inspection of previously deposited and possibly instrumented canisters that are once again deposited before the final step of closure. At closure, final filing of relevant information on the waste and the repository and necessary appropriate marking of the repository will also take place.
- Resource consumption is estimated at about SEK 1000 million.
- After closure of the deep repository, no continued surveillance is required in order for the repository to be safe. Such surveillance is possible, however, as is retrieval of the waste if this should be deemed desirable.

3.3 OPTION TO RETRIEVE THE WASTE AFTER THE FIRST CONSTRUCTION STAGE

Only about 10% of the spent fuel will be deposited in the first stage for the deep repository. This will be followed by thorough evaluation and a new permit will be required to continue along the same path.

The approximately 400 fuel canisters that have been deposited can be retrieved if this should be deemed desirable. The cost of such retrieval is estimated at SEK 600 million. The investments that will then have been made in the encapsulation plant and in the deep repository are considerable – a total of about SEK 5,000 million, of which SEK 4,000 million will be invested prior to the first encapsulation of nuclear fuel.

One reason for retrieval could be, for example, that (international) technological progress in the field has led to a situation where other handling and/or treatment methods for the spent fuel are found to be very attractive. Another possible reason could be that it has been decided not to continue on the selected site.

Naturally, the costs of possible alternative handling of the spent fuel cannot be estimated today. They will be heavily dependent upon which technology is developed and how well this development succeeds. Theoretically, all conceivable paths lie open. Depending on the final choice of canister design, however, it will be more or less difficult to take out the fuel assemblies for alternative treatment. The copper/steel canister is simpler in this respect than other studied alternatives.

It is deemed that the deep repository will be able to be used and will in fact be needed for final disposal of long-lived waste from alternative treatment of the spent fuel and from other activities. Similarly, it is judged that essential parts of the encapsulation plant will be able to be used for other encapsulation if this should prove desirable.

SKB's judgement, as already noted, is that it will be decided to expand the deep repository to full scale.

4 CRITERIA AND METHODS THAT CAN FORM A BASIS FOR SELECTION OF SITES SUITABLE FOR A DEEP REPOSITORY

In its decision on RD&D-Programme 92, the Government says:

"The Government notes that SKB has, in relation to the account given in R&D-Programme 89, changed the method for selection of sites suitable for a final repository. The Government shares the opinion expressed by both SKI and KASAM that RD&D-Programme 92 does not make it clear according to which methods or criteria the selection process will be conducted.

"In the opinion of the Government, good public insight is desirable in the selection process. SKB should furnish information on its work in this respect to SKI, SSI, KASAM, the National Board of Housing, Building and Planning and concerned county administrative boards and local authorities."

In view of the above, the Government has stipulated in its decision that:

"SKB shall supplement RD&D-Programme 92 by describing

- *the criteria and methods that can form a basis for selection of sites suitable for a final repository."*

This chapter contains such a description.

4.1 PREMISES FOR THE SITING WORK

Of greatest importance for siting of the deep repository is to choose a site where the safety-related conditions are very good. Since the mid-1970s, SKB has carried out extensive study site investigations and other studies of geological conditions at depth in the Swedish bedrock. Very extensive studies have particularly been conducted in the Stripa Mine and are currently being conducted in the Äspö HRL. Furthermore, SKB and other organizations have conducted a number of detailed safety assessments for final disposal in the environment existing in the Swedish bedrock. Based on this material, many municipalities are judged to have sites with very good conditions from a safety viewpoint. Considerable knowledge also exists from siting and construction of underground rock facilities for mining, power generation, oil storage and defence purposes in most parts of Sweden. From a rock excavation viewpoint, the technology for constructing a deep repository can be compared to well-established technology for mining, and the same hydrogeological issues are also encountered in connection with oil and gas storage. What distinguishes the deep repository from other rock facilities is the high demands that are made on detailed knowledge of the properties of the rock in order to permit the long-term safety aspects to be analyzed. In this respect, SKB's investigations of study sites etc. have yielded new, essential knowledge. SKB's conclusion from this general experience of rock facilities and its own specific research is that considerable potential exists for finding repository areas with excellent conditions for isolating the radioactive material.

Against this background, it is therefore reasonable and realistic to start with municipalities who actively wish to participate or otherwise show an interest and investigate the prospects for siting of a deep repository there. The possibilities in municipalities that already have nuclear activities will also be examined. Among municipalities with good safety conditions and with an expressed interest in a deep repository, siting will proceed on the basis of the results of a closer assessment of safety and environmental impact, transportation situation, experience of industrial activity and existing infrastructure in other respects.

As a basis for the coming site selection, SKB is compiling general studies of the entire country and will carry out feasibility studies in a number (5-10) of municipalities. Furthermore, it was stipulated in RD&D-Programme 92 that site investigations shall be carried out on at least two sites. Based on the results of the site investigations, one of them is then selected for detailed characterization.

The formal process of review of SKB's choice of site should take place before a detailed characterization is begun. There are strong reasons for this. Under the Act on Nuclear Activities, it is SKB's responsibility to gather the necessary background data for site selection. Before society's comprehensive review of the site selection takes place, SKB should therefore have collected sufficient data so that SKB can have a well-grounded and clear idea of which site they intend to propose. For this it is necessary that the surveys and investigations that are included in general studies, feasibility studies and site investigations have been carried out.

Further extensive knowledge of a site is obtained by means of a detailed characterization. Nevertheless, it would be impractical to wait for a detailed characterization to be carried out as well prior to review of the choice of site. A detailed characterization entails such extensive preparations and investments on a site that a comprehensive review should take place before it begins. This view is also expressed in the Government decision on R&D-Programme 89, where it was noted that SKB's site proposal will be scrutinized "in connection with SKB's application for a permit for detailed characterization...". The Government's decision regarding RD&D-Programme 92 entails no change in this respect.

The outline of the application and the scope of the scrutiny in conjunction with SKB's choice of site for detailed characterization need to be discussed further between SKB, the concerned authorities and municipalities, and the Government. The scrutiny can be expected to include all the background material that is then available pertaining to planned detailed characterization, construction and operation of the repository, and long-term safety. However, exactly what the application shall formally comprise at this point, and under which laws and in what order it should be reviewed, are points that need to be clarified. SKB intends to return on this matter and initiate a discussion with the concerned authorities in the autumn of 1994.

It is evident from what has been said above that SKB's siting strategy is based on the conviction that it is possible to find a site that meets stringent environmental and safety requirements at the same time as a local understanding for the establishment of the deep repository is sought. This strategy has been questioned by a number of reviewing bodies the review of RD&D-Programme 92 and in the current debate sparked by the feasibility studies that are now being conducted in Storuman and Malå. Fears have been expressed that the need for jobs rather than the need to fulfil the safety criteria is steering the siting work. There are also those who say that the best approach would be to systematically survey perhaps several hundred possible sites to start with and gradually narrow the choice down to find the best site. According to this view, establishment should then take place even if the municipality in question and the local population oppose the deep repository.

In the discussion of the siting process, criticism has also been levelled at the freedom with which SKB can itself choose to conduct the siting studies up to the time a site is selected for detailed characterization. A stronger control or presence on the part of the regulatory authorities and policymakers in the initial phase of the siting process has been advocated.

SKB has carefully followed and taken part in the debate related briefly above. The discussion and the work being pursued in connection with the feasibility studies currently being conducted have provided valuable experience. The following conclusions have been drawn from the discussion and the experience gained since RD&D-Programme 92 was written.

- There is a broad support in society and in the law for a serious and conscientious attempt to find a solution that meets both the safety criteria and the desire for local acceptance. The existing Swedish system with interim storage in CLAB makes it possible to consider thoroughly and without undue haste the options for carrying out deep disposal in collaboration and consultation with all stakeholders and in compliance with stringent environmental and safety requirements. It is therefore not defensible to plan the siting process based on the premise that it will be necessary in the end to force a siting on a locality.

- It is important, in view of the clear producer responsibility imposed on the power industry by the Act on Nuclear Activities, that SKB should have an opportunity to take the initiatives and conduct the studies they deem necessary. A detailed regulation of the siting work is not desirable, and a more comprehensive scrutiny should be deferred until SKB has a complete body of information for selecting a site for detailed characterization.

- It is urgent that the siting process up to choice of site for detailed characterization be clarified as regards, for example:

  - previously mentioned unclear points as to how the process of review prior to detailed characterization shall be conducted;
  - clarification of siting factors and criteria;
  - grounds for choice of municipalities for feasibility studies;
  - grounds for choice of areas for site investigations, and
  - the need to strengthen the municipalities' role and resources at the start of the siting process, i.e. during feasibility studies and site investigations.

The present supplementary account of siting criteria and methods for site selection should contribute to better clarity regarding the siting process.

The fact that a couple of concrete feasibility studies have been initiated has helped to clarify the required strengthening of the municipalities' role and resources. The problem must be solved by the state and SKB supports the view that municipalities where feasibility studies are conducted should be given funds for participation, scrutiny and information in connection with the feasibility studies. It is also important to establish at an early stage forms for offering scientific and technical support to concerned municipalities from the regulatory authorities for safety and radiation protection.

Finally, it is important that good forms be established for preparing environmental impact assessments, which shall serve as a basis for decisions on the site of the deep repository. This question lies beyond the scope of the requested supplementary account. However, it can be noted that preparatory work has already been initiated by both SKB and the concerned authorities. SKB's impression from discussions with municipalities, authorities and others is that a fundamental consensus and constructive will exists to do a broad and open job with the environmental impact assessments so that the factual basis for the siting decision will be as solid as possible.

The main features of the EIA process should be determined before site investigations are commenced in a municipality. Principles must thereby be stipulated for how the process is to be organized and documented. Important stakeholders are above all those in whose jurisdiction the facility may be built (the municipality), those who will build and operate the facility (SKB), the regulatory authorities and the county administrative board.

4.2 SITING FACTORS AND CRITERIA

In 1993, the Nordic radiation protection and nuclear safety authorities published the report "Disposal of High Level Radioactive Waste, Consideration of some Basic Criteria" /4-1/. The document describes the fundamental requirements for disposal of high-level waste, with an emphasis on the long-term safety aspects in a deep geological repository. In so doing they have taken into account recommendations and viewpoints published by the International Commission on Radiological Protection (ICRP), the Nuclear Energy Agency in the OECD (NEA) and the International Atomic Energy Agency (IAEA) (references in /4-1/).

According to the report, siting factors (= data, properties, conditions) can be divided into three main groups: The geological medium, environmental factors and societal (social and political) factors. SKB employs a classification that covers in the three main groups in the radiation protection and nuclear safety authorities' classification, but also ties in more strongly with the functional requirements on the deep repository:

Safety	Siting factors of importance for the long-term safety of the deep repository.
Technology	Siting factors of importance for the construction, performance and safe operation of the deep repository.
Land and environment	Siting factors of importance for land use and general environmental impact
Societal aspects	Siting factors connected to political considerations and community impact.

4.2.1 General aspects

There are fundamental requirements that must be met by a deep repository. They primarily have to do with long-term safety and other environmental impact. These requirements are set forth in laws and regulations issued by the authorities. The question of whether or not the requirements are met for a deep repository on a specific site is determined by the authorities when they review the safety assessments and environmental impact assessments presented by SKB. Regardless of how the site has been selected, it is the results of such broad and in-depth assessments of safety and environmental impact which ultimately decide whether the deep repository may be built on the site in question.

A comprehensive assessment of, above all, long-term safety requires access to site-specific data on the bedrock conditions on the site. Such data can only be obtained by means of extensive investigations on sites which must be selected on the basis of incomplete information. This distinguishes siting of underground facilities in general and a deep repository in particular from other industrial sitings (surface facilities) where knowledge of all important factors is relatively easily accessible. This in turn affects the strategy and organization of the siting work and the way of working with siting criteria. In its statement of comment /4-2/ on RD&D-Programme 92, the Swedish Nuclear Power Inspectorate, SKI, made the following comment in this context:

"SKI would, on the other hand, like to emphasize that it is not meaningful to rank sites for the purpose of finding the best site. Several important properties, chiefly with regard to the local groundwater flow and the retardation capacity of the rock, can presumably not be determined without extensive investigations. SKI therefore realizes that SKB must base its siting on an incomplete body of information. This means that SKB must be flexible in its evaluation of different sites. Coming site investigations and detailed characterization of a given site may necessitate abandonment of the site. The longer SKB has investigated a site, the greater the commitment to it is. It is therefore important that SKB reject as early as possible sites with poor prospects for guaranteeing safe final disposal."

SKB shares SKI's opinion, and with reference to the above line of reasoning SKB has chosen to work with siting factors and criteria in the following way:

- Identification of fundamental safety requirements on a deep repository.
- Identification of generally favourable conditions for the possibility of siting and building a safe deep repository.
- Identification of disqualifying factors for the possibility of siting and building a safe deep repository.

Based on the fundamental safety requirements and favourable versus unfavourable conditions, siting factors have in turn been identified. At each step of the siting studies, knowledge of the siting factors is ascertained. The results are used as guidance for the continued work. Areas deemed unable to fulfil the requirements ("poor prognosis") are excluded from continued studies. More detailed siting studies are done for areas with favourable conditions in some important respect.

The degree of precision in the survey of siting factors varies widely, depending on the scale on which the studies are done. A deep repository will occupy an area of around 1 km^2. The possibility of determining siting factors on different scales must be seen against this background. A limited number of factors can be surveyed on the Sweden scale (general studies) to exclude certain areas. As a rule, however, it is not until studies are conducted on a scale equivalent to a study area of 100 x 100 km^2 or smaller (feasibility studies) that the geographic variation for different siting factors can be determined with such resolution that it provides guidance in site selection. Furthermore, many of the properties of the bedrock that are essential for the safety of a deep repository can vary by several orders of magnitude even over short distances. Generalizations on large scales must therefore be made with great caution or avoided. Finally, it is important to note that detailed criteria for e.g. the properties of the bedrock

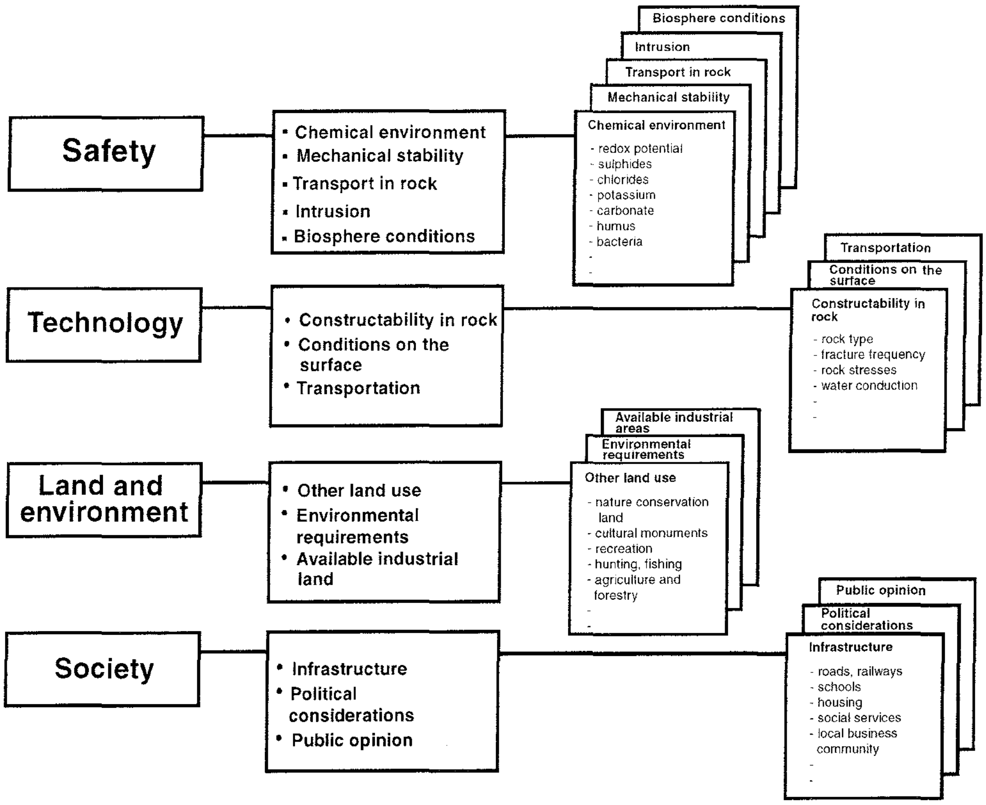

Figure 4-1. Structure for discussion of siting factors and criteria.

on a site cannot be considered isolated from the geometric configuration of the deep repository on the site. An important principle is to optimize the layout of the facility, both above and under ground, to the conditions prevailing on the particular site. The requirements on environmental protection and safety will determine how the facility is adapted to the properties of the site, for example the relative positions of the surface and underground facilities, the geometry and depth of the repository and the locations of the deposition positions.

The fundamental requirements on a deep repository site, for a repository of the KBS-3 type, are described in the following sections. Siting factors and criteria are discussed. A general structure for the siting factors is shown in Figure 4-1. The main emphasis is placed on requirements that have to do with long-term safety, since these are the most important ones. Requirements that have to do with technology or with land use and environment are also dealt with. Even though these requirements are also important and must be met, they are not specific to a deep repository but of the same type as for most major industrial facilities. Finally, the requirements that can be made on siting of the deep repository from a societal viewpoint are discussed. These are important in practice, since the deep repository will be a unique facility and its siting arouses much debate. The discussion of siting factors and criteria concludes with a discussion of their practical application in different steps of the siting process (section 4.2.6).

4.2.2 Safety

The fundamental safety principle for the deep disposal system planned by SKB is to completely contain and isolate the spent nuclear fuel in tightly sealed canisters deposited at a depth of about 500 metres on the selected repository site. This isolation shall be achieved and preserved over very long periods of time so that the radioactive materials decay inside the canister and cannot be released. This means that the most important safety-related function of the rock is to guarantee stable chemical and mechanical conditions for the engineered barriers over a long period of time.

The safety strategy for a deep repository is based on the multiple-barrier principle. This means that safety must not be solely dependent on the engineered barriers' functioning as planned. Another important safety-related function of the bedrock on a deep repository site is to retain the radionuclides or retard their transport if the engineered barriers should be damaged.

Finally, it is in principle favourable to have biosphere conditions that ensure that only very small quantities of any radioactive materials that are released will ever reach man.

Table 4-1 summarizes the safety functions and the siting factors that are linked to them.

Table 4-1 shows that for the sake of long-term safety, the following factors must be taken into consideration when selecting a site:

- chemical environment in the rock for canister, bentonite and fuel;
- mechanical stability of the rock;

Table 4-1. Safety functions related to the site characteristics at a deep repository. Level 1 provides complete isolation of the waste. Level 2 counteracts release and transport of radionuclides if there are any damaged canisters. Level 3 contributes to low individual doses if the safety functions on levels 1 and 2 should fail to perform fully satisfactorily.

	Safety function	Related site factors
Required:		
Level 1	Ensure long-term stable conditions for canister and bentonite clay so waste is isolated	– chemical environment for bentonite and canister; – mechanical stability of rock; – transport in rock of corrodants; – risk of future intrusion.
Level 2	Ensure low dissolution of exposed fuel and slow transport of released radionuclides through the rock	– chemical environment for fuel; – transport in rock or radionuclides.
Desirable:		
Level 3	Ensure favourable discharge area conditions	– biosphere conditions.

- conditions for transport of corrodants and radionuclides in the rock;
- risk of future intrusion, i.e. mainly conceivable utilization of natural resources in the bedrock;
- groundwater discharge areas and biosphere conditions.

Criteria for each of the above factors are presented and discussed in the following. A structuring is thereby also made of underlying factors and conditions. The following criteria for the siting factors are defined chiefly in qualitative terms and in relation to what is considered normal for Swedish crystalline rock. Prior to the site investigations, SKB will clarify suitable parameter intervals and couplings between different factors where necessary.

Chemical environment

Long-term stable chemical reducing conditions shall prevail in the groundwater in the selected rock regime. The groundwater must have properties that contribute to:

- *preservation of the properties of the bentonite;*
- *low corrosion rate for the canister material;*
- *low dissolution rate of the fuel (uranium dioxide);*
- *low mobility and good sorption properties for the radionuclides.*

Measurements of groundwater composition at different depths will be performed in the site investigations. Calculations of canister corrosion and changes in the bentonite and the possibility of fuel dissolution shall be included in the safety assessment.

A schematic classification of chemistry-related siting factors is shown in Table 4-2.

A detailed analysis of these factors is made in the performance and safety assessments that are carried out during the course of the siting work. In general terms, however, the following evaluation can be made.

Table 4-2. Siting factors: chemical environment.

Groundwater impact on			Transport calculation
Canister	**Bentonite**	**Fuel**	**Sorption of radionuclides**
– redox buffering	– calcium	– redox pot.	– humus
– sulphides	– potassium	– pH	– bacteria
– chlorides	– chlorides	– carbonate	– colloids
– bacteria	– sulphates		– mineralogy
			– geogas

Favourable factors are "normal" conditions in deep groundwaters, i.e.:

- pH 6-9,
- reducing conditions,
- reasonable salinities,
- reasonable concentrations of humic and fulvic acids.

Unfavourable factors are:

- presence of oxygen,
- extreme pH,
- extremely low or high salinity,
- high concentrations of humic and fulvic acids,
- high concentrations of sulphate-reducing bacteria,
- high concentration of total organic carbon (TOC),
- high concentrations of nitrogen compounds.

By and large, geohydrochemical conditions on most sites are expected to be favourable. At a depth of 100-1,000 metres with reducing conditions in rock of granitic composition and mineralogy, the situation will scarcely deviate more from site to site than it varies within one and the same site.

Mechanical stability

The repository shall be situated in parts of the rock that do not consist of zones of fractured rock in which future significant fault movements could possibly be released.

Site-specific analyses of the possibility and effect of future rock movements shall be included in the safety assessment.

Table 4-3 shows a breakdown into underlying factors and conditions that may be of importance for mechanical stability.

Table 4-3. Siting factors: mechanical stability.

Geology structure	Mechanical parameters	Processes
– rock type distribution – fracture geometry – zones, lineaments	– rock stresses – properties of intact rock – properties of fractures and zones	– plate tectonics – glaciation, deglaciation – aseismic forces – seismicity – induced disturbances

Based on SKB's previous study site investigations and separate studies of basic rock types, it is not possible to identify any obvious overall advantages for any special type of crystalline rock. Highly heterogeneous areas should be critically examined on more detailed map scales.

Persistent lineaments should be avoided. This includes areas adjacent to large deformation zones and postglacial faults.

The displacements that can take place over geological time spans in different types of structures (fractures, fracture zones) are related to the extent ("size") of the structures. Studies of these relationships provide essential knowledge on what sizes and properties of structures should be avoided when determining the placement and geometric configuration of the repository.

Predictions of future glaciations and deglaciations provide a basis for calculations of future load situations at a repository.

The significance of earthquakes at the magnitudes and depths at which they occur in Sweden today is generally negligible. However, an increased frequency of near-surface quakes within a specific area should occasion deeper studies on more detailed scales.

In summary, the following evaluations can be made:

Favourable conditions are:

- rock stresses and thermal conductivity properties that are normal for Swedish bedrock;
- homogeneous and easily interpreted bedrock;
- availability of rock blocks with few fracture zones and low fracture frequency surrounded by distinct zones of weakness.

Unfavourable conditions are:

- anomalous rock stress conditions or strength properties;
- highly heterogeneous and difficult-to-interpret bedrock;
- nearness to known deformation zones and postglacial faults.

Ability of rock to limit transport

The rock shall constitute a safety barrier by sorbing and retaining any released radionuclides so that their transport through the rock will be slow.

An analysis of radionuclide transport from the repository to the biosphere, based on site-specific data, shall be included in the safety assessment.

Factors that have to do with the transport of solutes with the groundwater are summarized in Table 4-4.

Since the groundwater is in practice the only dispersal pathway for radioactive materials from the repository, all conditions having to do with the transport of solutes with the groundwater are of potential importance.

The overall safety-related factors are:

- The groundwater flow at repository level (of importance for canister life, the release rate for the radioactive materials and possibly for the dissolution of the fuel).
- The travel time for solutes from the repository to the biosphere.

Table 4-4. Siting factors: Ability of rock to limit transport.

Groundwater flow, advection	Diffusion	Sorption
– hydraulic conductivity – hydraulic gradient – storage coefficient – flow porosity – fracture pattern	– fracture pattern – microporosity	– mineralogy – groundwater chemistry

The travel time is influenced by the following factors:

- The size and distribution of the groundwater flow, which is in turn dependent on the transmissivity (permeability), flow porosity and fracture pattern of the rock as well as the gradient (the driving force).
- The transport distance (flow path) from waste to biosphere.
- Diffusion to stagnant water and to micropores in the rock.
- Chemical reactions, sorption – ion exchange, surface complexation, precipitation, filtration, organic complexes, colloids.

The fracture structure of the rock is also an important factor for retardation of radionuclide transport. A high surface/volume ratio in the fractures is favourable, especially in combination with a strong chemical sorption capacity of the rock.

A site-specific evaluation of the rock's ability to limit transport cannot not be done until a site investigation has been carried out.

In summary, however, the following general evaluation can be made:

Favourable conditions are:

- low groundwater discharge and long flow paths to the biosphere;
- high surface/volume ratio in water-bearing fractures;
- strong chemical sorption capacity along the groundwater's transport pathways in the rock.

Unfavourable conditions are:

- highly heterogeneous and difficult-to-interpret bedrock;
- several closely-spaced water-bearing fracture zones with rapid transport pathways up towards the surface.

Intrusion

A repository should not be located so close to valuable or potentially valuable natural resources that a future exploitation of these resources would entail damage to the repository's barrier system.

The risks of future intrusion in or at the repository, and the consequences for the repository's barrier system, shall be analyzed in the safety assessment.

Future generations shall be able to exploit natural resources without special risks due to nearness to the repository, regardless of whether the existence of the repository is known or not at that time. Besides direct drilling in the repository area, it may be necessary to guard against large groundwater drawdowns in connection with future mining activities in nearby areas. For this reason, valuable mineral deposits (metals and industrial minerals) should be avoided.

The risk of intrusion can be evaluated by means of an inventory of ore- and mineral-bearing rocks of interest for exploitation. The inventory can be performed with maps showing ore deposits, active mining and mineral rights and rocks of interest for prospecting.

Regions that are found on the Sweden scale to possess potential natural resources in the bedrock do not have to be excluded in their entirety from consideration for siting. But the conditions must be surveyed and thoroughly investigated on a more detailed scale.

Discharge area conditions

Conditions (dilution, salt/freshwater, accumulation, enrichment...) in possible discharge areas for deep groundwater in the biosphere should be taken into account in a comprehensive assessment and comparison between different sites.

Calculation of the dose to the critical group for the first 10,000 years for different biosphere scenarios shall be included in the safety assessment.

Groundwater discharge from a repository can take place to:

- springs,
- lakes and streams,
- wetlands,
- brackish water,
- seawater.

In addition, groundwater can be discharged into the "biosphere" via wells in soil or rock.

Generally, however, it is desirable that dilution be as great as possible. As a rule, the greatest dilution is achieved by a siting on the coast or under the sea. However, since the principle of the deep repository is based on total containment of the radioactive materials, factors that contribute to this are of greater importance than those that favour dilution.

4.2.3 Technology

The siting of the deep repository must take into account the technical solutions that are available for transportation and for design of the facilities. Both construction and operation of the deep repository can be done for the most part with known technology. Special methods and equipment are being developed for special needs, e.g. emplacement of the canister in the deposition hole.

As a rule the technical solutions are flexible and can be adapted to varying site conditions and bedrock characteristics. This means that evaluations of different technical factors for alternative site choices could be made in economic terms. This will also be done at a point when specific data are available for different possible alternatives. In this account, technical factors are discussed solely in terms of general qualitative aspects.

The fundamental requirements can be formulated as follows:

The site of the deep repository shall offer the following:

- *Bedrock conditions that permit construction of stable shafts, tunnels and rock caverns so that the safety requirements during construction and operation are met.*
- *Good options for carrying out all transports to the site and all activities in the deep repository facility in a safe manner.*

A subdivision can be made into the following factors:

- transportation,
- conditions on the surface,
- constructability in rock.

Transportation

All transports to the site shall be able to be made in compliance with applicable rules and regulations.

An analysis of safety and environmental and radiation protection in connection with transportation shall be included in the environmental impact assessment. If new road or railway construction is necessary, an analysis of the effects on the environment shall be included in the environmental impact assessment (EIA).

There are basically three different alternatives for the location of the deep repository from a transportation viewpoint:

- The deep repository is located very close to the encapsulation plant at CLAB and can be reached via a private road.
- The deep repository is located on the coast near a pre-existing harbour.
- The deep repository is located inland, necessitating overland transport.

Depending on the location of the site of the deep repository, it may also be necessary to build a new road or railway along part of the route. The costs of shipping the waste will be dependent on where the deep repository is sited.

The various transportation aspects must be weighed in when making a decision on the siting of the deep repository. The requirement that transportation shall take place safely can as a rule always be met, with the aid of appropriate technology and the necessary investments. The costs can vary widely from site to site, however.

The following general evaluation can be made:

It is favourable if

- for the most part existing infrastructure for transportation by sea and overland can be used.

It is unfavourable if

- extensive new investments are required and if new harbours, roads or railways conflict with other important land-use interests (environmental protection, nature conservation, etc.).

Conditions on the surface

The surface facilities shall be designed and equipped in such a manner that requirements on public safety, occupational safety, radiation protection and environmental protection are met.

An analysis of the safety and environmental aspects of the surface facility shall be included in the environmental impact assessment (EIA).

The surface facilities are responsible for reception of all goods, plus buffer storage and transloading before the material is transported down under ground. The industrial site, when completed, will comprise an area of about 300 x 600 metres, in addition to which a possible dumping site for rock spoils will cover about 300 x 400 metres.

The soil on the site of the surface facilities must possess sufficient bearing capacity. The distance to the underground repository areas shall be reasonable.

It is advantageous if an existing industrial site can be utilized. The same also applies to nearness to suitable infrastructure such as public transport, railway, social services, etc.

Constructability in rock

The parts of the bedrock where shafts, access tunnels, transport tunnels, deposition tunnels etc. are planned shall possess such properties that the work can be carried out in a safe manner using known technology.

An analysis of constructability shall be carried out in each phase of the siting work. Design/construction of the facility, investigations and safety assessments shall be done in close coordination and iteratively from the time the site investigations are commenced until the facility is operable.

Factors which determine the constructability of an area are rock type, fracture frequency, locations and characters of fracture zones, hydraulic conductivity, sizes and orientations of rock stresses and mechanical properties of the repository bedrock. These factors can vary considerably in the rock as a construction material. A high degree of exposure (many outcrops), simple and homogeneous bedrock conditions and a regular system of fractures and fracture zones provide increased certainty in predictions of constructability.

In an international comparison, Sweden exhibits good geological conditions for rock construction. Long and extensive experience exists from siting and construction of different types of underground rock facilities. Hundreds of facilities for mining, power generation, oil storage and defence purposes provide a good picture of possibilities and variation from construction in different parts of the Swedish bedrock. Experience has revealed nothing to indicate that a particular area on a regional scale is particularly unsuitable. Suitability is more tied to local conditions. The fact that good technical prospects exist for different geological conditions is also demonstrated by the fact that deep repositories are being planned and evaluated for such widely differing formations as clay, salt, tuff, shale and granites all over the world.

A basic prerequisite is rock of high strength that permits the construction of stable rock caverns. The crystalline basement rock that is found in most parts of Sweden fulfils this prerequisite with ample margin. The rock types found in the Swedish mountain range and the sedimentary formations found in the province of Skåne and on the islands of Öland and Gotland, on the other hand, have generally poorer and more variable construction-related properties.

4.2.4 Land and environment

Site selection and design of the facilities shall be done so that conflicts with opposing interests are minimized. Consideration shall thereby be given to nature, environment, cultural monuments, recreation, hunting, fishing, other outdoor activities, important natural resources, agriculture and forestry, existing and planned land use. Facilities and transport routes shall blend in smoothly with the terrain.

To comply with the requirements laid down in the environmental legislation on a comprehensive environmental impact assessment of civil engineering projects, the facility's environmental impact must be weighed against the specific environmental conditions in the area already during the siting process.

In brief, the requirements can be formulated as follows:

The site for the deep repository shall have

- *few opposing interests for land use;*
- *good prospects for being able to build and operate the facilities in compliance with all environmental protection requirements.*

About 6% of all land in Sweden has been set aside as nature conservation areas. There may be no land development within these areas. If the concept is broadened to include all areas considered to be of national interest for nature conservation today, almost 22% of Sweden consists of such areas. Even if it is possible to obtain development permits in several of the latter areas, special reasons must exist in order for the deep repository to be sited there. This also applies to typical agricultural areas.

In connection with studies on a more local scale, the counties' nature conservation plans and the municipalities' comprehensive plans will be important. The latter contain plans for land and water use and building development and indicate where areas of national interest are situated within the boundaries of the municipality.

Areas with planned industrial land can be particularly interesting.

4.2.5 Societal aspects

Socio-economic consideration are important for both site selection and design of the facilities on the selected site. Establishment and operation of a deep repository will have different impacts on the locality and the region. These include e.g. impact on employment, the local business community and local services. Politically and in terms of public opinion, siting is a sensitive issue. Experience in both Sweden and other countries shows that strong feelings and opinions can be triggered. Opposition to industrial sitings in general are not unusual in modern society.

Siting of a deep repository shall be carried out so that

- *Investigation activities in different stages, construction and commissioning and operation, are firmly rooted in a democratic decision process.*
- *Social and socio-economic consequences are taken into account.*

Surveys of socio-economic, business and labour market aspects are carried out in the feasibility studies of different municipalities and are deepened and updated during the course of the siting work at the localities being considered. Measures that can reinforce positive effects and prevent negative effects of a deep repository siting are identified and analyzed.

4.2.6 Application of factors and criteria in siting studies

The factors and criteria that are discussed in preceding sections must be taken into account in an overall assessment of a chosen site. Many factors that are important for thoroughly assessing long-term safety and construction-related aspects can only be clarified after comprehensive investigations on the site. Until then it is necessary to rely on general knowledge as a basis for selection of study sites. Since the survey of general land-use and environmental factors as well as societal aspects is simpler to do at an early phase, these siting factors can be clarified more completely to begin with.

Key questions in the initial siting phase are:

- Which sites have particularly good chances of meeting the requirements with regard to safety, technology, land and environment as well as societal aspects?
- Which of these sites offer good opportunities for later carrying out a reliable characterization of, above all, the important environmental and safety factors?
- How can these sites be identified based on existing material?

The following conditions are thereby primarily favourable (give a "good prognosis") for the selection of study sites:

- A common rock type without interest for other utilization of natural resources. This gives good prospects for obtaining a good understanding of safety-related bedrock conditions and it reduces the risk that the area will be of interest for other use in the future.
- A large site with few major fracture zones. This provides extra flexibility in connection with coming investigations and improves the prospects of being able to construct a repository with room for the necessary number of canister positions in sound rock with a high level of safety.
- Few opposing land-use and environmental interests. Good prospects for adapting the facilities so that the environmental requirements are met in a satisfactory fashion.

Secondarily, the following conditions are also favourable:

- Local positive interest.
- Availability of necessary infrastructure and good means of transportation via existing harbours, railways or roads. Limited need for new investments in road or rail.

In the initial siting phase (general studies, feasibility studies), i.e. without data from field investigations, the evaluation of the geoscientific material is focused on identifying unsuitable or unfavourable conditions based on publicly available information. Conditions that should be avoided are firstly:

- abnormal (for Swedish bedrock) groundwater chemistry;
- highly heterogeneous and difficult-to-interpret bedrock;
- known deformation zones and postglacial faults;
- pronounced discharge areas for groundwater;
- rock types that might be of interest for prospecting.

In subsequent phases (during execution of site investigations and, eventually, also detailed characterization — see below), efforts are directed at firstly clarifying the conditions that will prevail for the repository as a whole, secondly for the different repository parts, and finally for the individual canister positions. The following conditions are particularly favourable:

- reducing groundwater chemistry;
- normal (for Swedish bedrock) groundwater chemistry in other respects;
- homogeneous and easy-to-interpret bedrock;
- few fracture zones and low to moderate fracture density;
- low groundwater discharge;
- normal (for Swedish bedrock) rock stresses, strength properties and thermal conductivity.

Conditions which can lead to a site being abandoned in a site investigation and/or detailed characterization phase are above all:

- extreme groundwater chemistry, e.g. oxidizing groundwater;
- valuable ores or minerals in the repository area;
- several closely-spaced water-bearing fracture zones;
- extreme rock-mechanical properties.

4.3 SITING STUDIES

The process, or method, which SKB is employing to site the deep repository was described in RD&D-Programme 92. Many reviewing bodies expressed viewpoints. Criticism was levelled mainly at the fact that SKB was not considered to have fully clarified how they plan to execute the step-by-step siting process. This lack of clarity was considered mainly to have applied to the initial siting studies: general studies, feasibility studies and site investigations. Questions were asked as to which investigations are included in each phase, what must be finished before the next phase is begun and on what grounds the selection is made of municipalities for feasibility studies and areas for site investigations.

This section describes the siting work up to the choice of site for detailed characterization.

4.3.1 General outline of the siting work

The purpose of the siting work is to obtain all the data necessary to be able choose a site and obtain a permit to commence detailed characterization. The guiding principles in the siting work include:

- The necessity that the site that is finally chosen must offer very good prospects for fulfilling the environmental and safety requirements.
- The necessity of seeking from the beginning an open dialogue, collaboration and interest at the localities that may be of interest.
- The need for a broad body of background material that can be used to place a site in its national, regional and local context.
- The need for a gradual narrowing of the focus of the work to areas and sites that can meet the requirements that are made with respect to safety, technology, land and environment, and societal aspects.
- The view (in e.g. the government decisions on both R&D-Programme 89 and RD&D-Programme 92) that "good public insight" is desirable.

Figure 4-2 shows a schematic illustration of the main components in the siting work. These are:

General studies that shall provide a general background and the general conditions.

Feasibility studies that shall examine the prospects for a deep repository in potentially suitable and interested municipalities.

Site investigations that shall yield site-specific data for safety assessments and environmental impact assessments for sites in areas deemed to be of interest in the feasibility studies and in the light of the general studies.

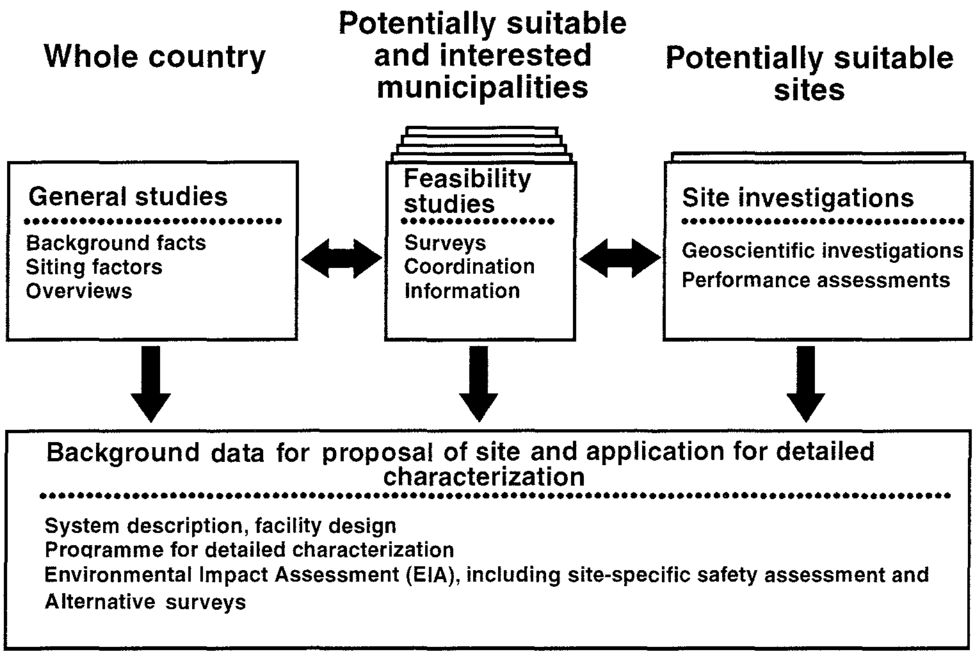

Figure 4-2. Main components in the siting work.

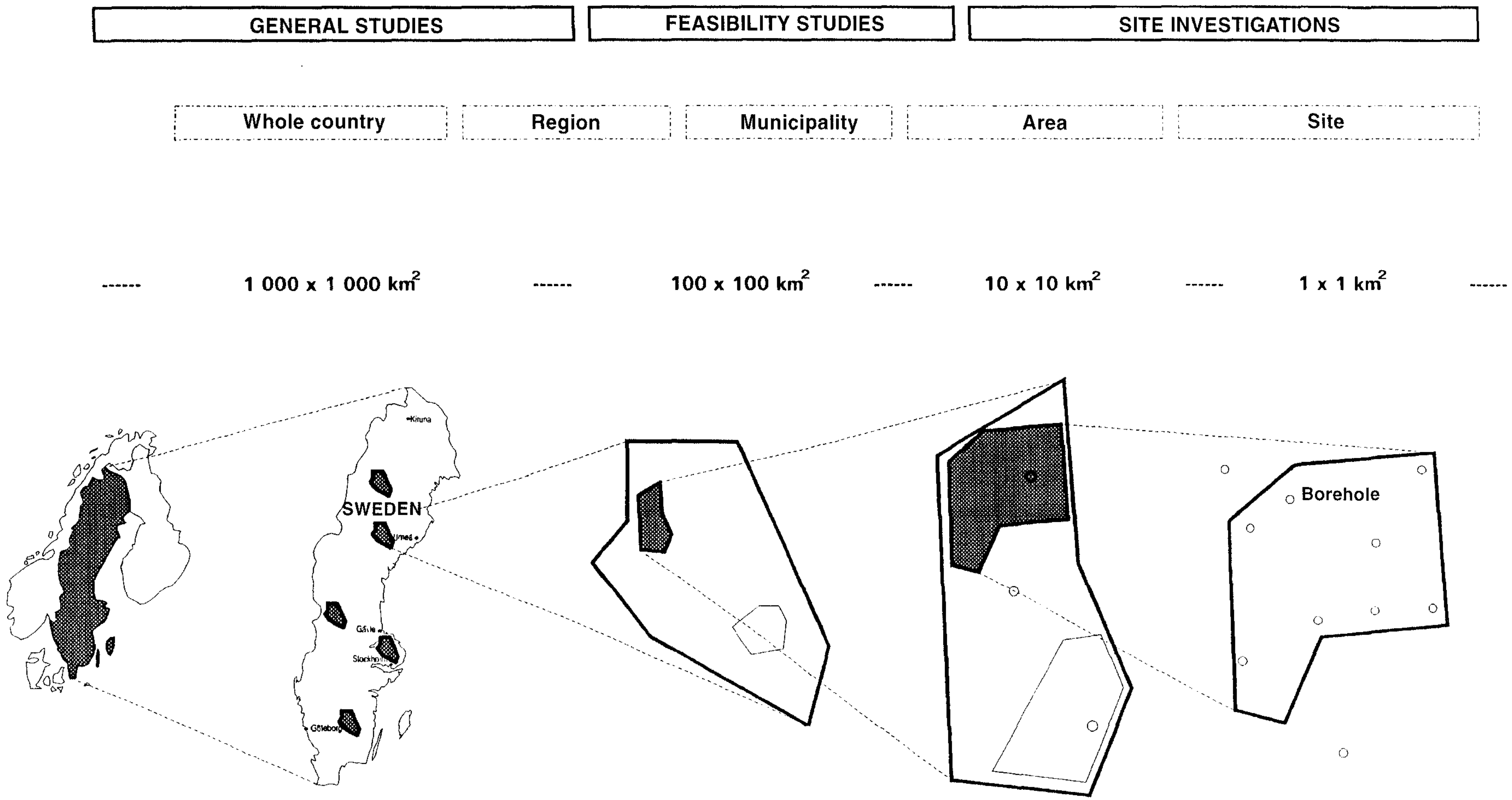

Figure 4-3. *Schematic illustration of the map scale for general studies, feasibility studies and site investigations. The scale (and thereby the degree of detail) changes at each stage by approximately one order of magnitude in each dimension. The "municipalities" shown in the map of Sweden are fictitious.*

The work with general studies, feasibility studies and site investigations can be said to entail a survey and description of siting factors on different scales. Figure 4-3 shows a schematic illustration of the variation in scale that is used in the collection of data for the siting work. A small number of factors can be described on a general scale, but most can better be determined in feasibility studies or in the site investigations.

The results can be used to make judgements of the siting factors enumerated in section 4.2 and thereby of:

- What areas may be unsuitable, suitable or particularly interesting on different scales.
- What must be particularly considered and investigated in continued more detailed studies.

An overview of formal requirements on permits, criteria for execution and expected results of general studies, feasibility studies and site investigations is provided in Table 4-5.

Figure 4-4 shows yet another illustration of how the work is planned to be conducted. A through H represent examples of municipalities where there is an interest in feasibility studies. Before these are begun, SKB confirms preliminarily — based for example on the material gathered from the general studies — that there is good reason to conduct a feasibility study, i.e. that good conditions may exist for siting of a deep repository. In the example, E represents a case where the finding is negative and no feasibility study is begun. In practice, this means that after SKB's initial assessment, the municipal leadership is informed and the matter is written off by both SKB and the municipality. In other cases in the figure, feasibility studies are carried out with surveys, evaluation and supplementary studies. After completion of the feasibility study, and if both SKB and the municipality are positive to a continuation, site investigations may be commenced. These are first carried out in an introductory phase (see more detailed description in section 4.3.4) which can confirm or disqualify the area as a candidate site. At least two complete site investigations are planned to be carried out before all material is finally evaluated and compiled for review in an application for a permit to conduct detailed characterization of a site.

A collective account is compiled of the general studies before the first site investigation is begun. The results of all feasibility studies shall have been reported before investigations on the other candidate site are commenced.

4.3.2 General studies

In the general studies, comprehensive background material on geological, technical, environment-related and societal conditions is compiled. The studies include, among other things:

- General facility description and general background data for future environmental impact assessments. /4-3, 4-4/
- General survey of transportation system, including transshipment in harbour and transport by road or rail. /4-5/
- Compilations of geographically related information on a national and/or regional scale concerning bedrock, topography, nature conservation areas, mineral deposits, major regional fracture zones, earthquake frequencies, etc.
- Surveys, analyses and forecasts of e.g. effects of glaciation on the bedrock and on seismotectonic conditions for different parts of the Swedish bedrock.

Table 4-5. Summary of requirements for and results of general studies, feasibility studies, site investigations and detailed characterization.

	GENERAL STUDIES	FEASIBILITY STUDIES	SITE INVESTIGATION	DETAILED CHARACTERIZATION
Formal permit requirements	None	None	Permit from landowner	Permit under NRL etc.
Criteria for execution	Executed for the whole country	Initial preliminary judgement based on existing material indicates that there may be areas with good conditions. Municipality not negative.	Potentially good conditions according to feasibility study. Field data (borehole measurements) needed for greater certainty. Municipality not negative.	Permit under NRL entailing that the municipality is positive.
Principal activity	Investigations and data compilations on national scale	Investigations and data compilations on regional, municipal and local scale. Collaboration and information.	Drillings, measurements, safety assessments, environmental impact assessment. Continued collaboration and information.	Construction of tunnel and/or shaft. Detailed investigations of rock at repository depth. Updated safety assessment and environmental impact assessment. Continued collaboration and information.
Required resources and time	About SEK 10 million	SEK 1-10 million per study 1-2 years	About SEK 100 million per study 2-3 years	About SEK 500 million 4-5 years.
Type of results	Background material, national and regional overviews	Municipality- (and in part region-) specific analysis of safety-related technical, land- and environment-related and societal premises	Area-specific data and investigations Site-specific EIA, including safety assessment, preliminary site-specific layout	Detailed data on planned repository site down in the rock. EIA including safety assessment.
Use	In determining whether feasibility study is appropriate. Background information for selection of candidate sites and for judgement of proposal for site for detailed characterization	Identification of areas with potentially good conditions. Basis for SKB's and the municipality's stance on a site investigation	Basis for selection of site for detailed characterization and for permit application	Basis for decision to build the deep repository.

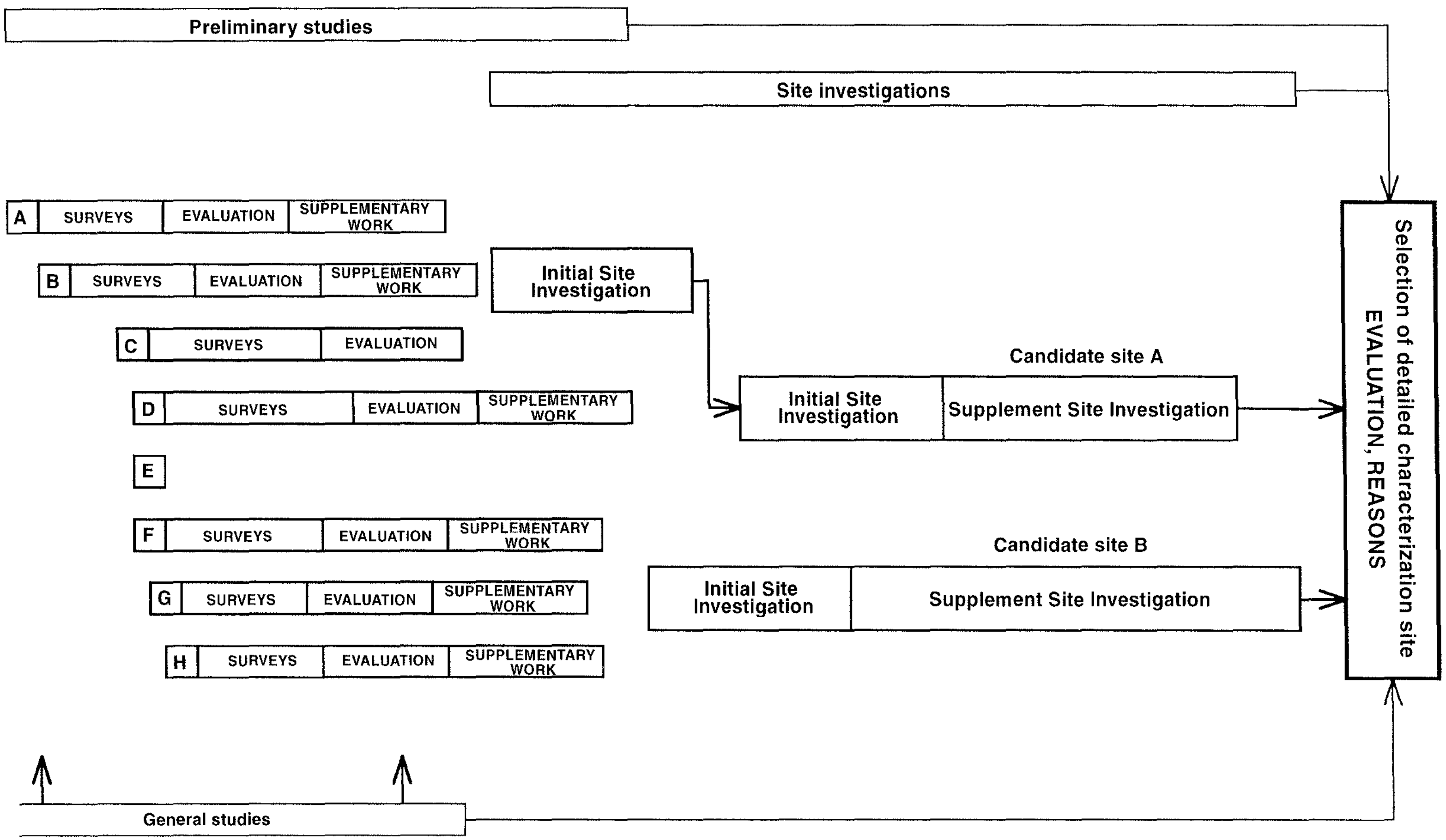

Figure 4-4. *Example of how the work of collecting background information for siting may be pursued. A through H represent municipalities where a feasibility study is considered. Site investigations are begun in two municipalities (B and G), one of which is completed while the other is interrupted. Another site investigation is then begun and completed in another municipality (D) before all material is compiled prior to consideration of proposals for a site for detailed characterization.*

The general studies constitute background facts for the municipality- or site-specific investigations that need to be done. With the aid of the general studies it will be possible to place the relevant sites in their national and regional contexts. Information is entered and stored in SKB's GIS system, which now comprises one of Sweden's largest databases of this type. The general studies will also provide a picture of different areas in the country which are, for different reasons, less suitable for siting of a deep repository. They cannot, on the other hand, provide any specific guidance in the work of finding suitable sites. This requires studies on a more detailed scale and a dialogue with, among others, concerned local and regional politicians and population.

The general studies, supplemented with more regional and local overviews, provide SKB with internal data at an early stage for making judgements of whether municipalities are suitable for feasibility studies.

SKB plans to compile a collective account of the general studies by 1995. An overview and exemplification of the material that exists now within the general studies is provided in Appendix A.

4.3.3 Feasibility studies

A feasibility study examines the prospects for a deep repository within a municipality. The studies are based principally on existing material. The following questions are dealt with:

- What are the general prospects for siting of a deep repository in the municipality?
- Within which parts of the municipality might there be suitable sites for a deep repository, considering geoscientific and societal aspects?
- How can the deep repository be designed with respect to local conditions?
- How can transportation be arranged?
- What are the important environmental and safety issues?
- What are the possible consequences (positive and negative) for the environment, the local economy, tourism and other enterprise within the municipality and the region?

No formal permits are required to carry out a feasibility study. However, in practice the feasibility studies are conducted in collaboration between SKB and the municipality in question. This means that the municipality must not be negative to conducting such a study.

A feasibility shall provide a broad body of facts for decisions by both the municipality and SKB. Both parties can then decide whether they are interested in conducting a site investigation. The same facts are made available to all stakeholders, who thereby have an opportunity to present viewpoints long before any decisions need to be taken on the siting of the deep repository.

SKB intends to conduct feasibility studies in municipalities that are interested in such studies and where SKB believes there are good prospects that the safety-related requirements on the bedrock can be met in some part of the municipality. The possibilities in municipalities that already have nuclear activities should also be examined. Feasibility studies of specific municipalities, together with general studies of the entire country, are judged to be able to provide the necessary background data and the breadth of alternatives that are required to identify suitable sites for site investigations. SKB believes that a reasonable number can be between 5 and 10 feasibility studies of municipalities in different parts of the country.

The scope of feasibility studies may vary considerably between different municipalities, depending on available data and local premises. The availability of data differs primarily when it comes to the geological level of knowledge. Possible experience of nuclear activities can influence the scope and thrust of the socio-economic investigations and the public relations activities.

Regardless of the state of knowledge at the start of the feasibility study, a feasibility study is performed mainly on the basis of existing material. There may however be specific questions that need to be answered by means of field studies, which may include some geological surveying. However, deep boreholes that go down to or can affect the undisturbed conditions at repository depth are not included in a feasibility study, but rather belong to a site investigation.

The scope of the investigations concerning societal aspects is determined largely by the wishes of the municipality. This is particularly true of the socio-economic surveys.

Two feasibility studies are currently in progress in the municipalities of Storuman and Malå. A complete picture of both the structure and the preliminary results of a feasibility study is provided by a situation report on the feasibility study in Storuman /4-6./ A list of the reports produced in the feasibility study in Storuman is given in Appendix B.

4.3.4 Site investigations

Site investigations consist primarily of geoscientific surveys of a specific site from the ground surface and in boreholes. The purpose is to gather material to permit a preliminary determination of whether it is possible to build a deep repository on the site that can meet all environmental and safety requirements. The results of the site investigation work are compiled in a site-specific environmental impact assessment (EIA), including an assessment of long-term safety.

The site investigations entail collection and analysis of field data. The work is done step by step and iteratively in interaction between investigations, performance assessments and constructability analyses (design).

The selection of candidate sites for site investigations will be made on the basis of a combined analysis of the results of general and feasibility studies, taking into account the siting factors described above. Two fundamental requirements and guiding factors in the analysis are that available data on the bedrock indicates a high potential that a site investigation will succeed in finding good conditions for the construction of a safe deep repository and that the municipality where the site is located is interested in having a site investigation carried out.

If the areas identified in the feasibility studies do not have any deep boreholes, considerable uncertainty will exist regarding conditions at repository depth. The site investigation must therefore begin with an initial phase to verify that the site actually possesses the potential for a deep repository that the feasibility study has indicated. Such an initial phase will include a geographic survey and geophysical measurements plus a few deep boreholes with associated borehole measurements. If conditions thereby prove to be unfavourable, the investigations will be moved to another area in the same or in another municipality.

Should the initial studies indicate favourable conditions, the investigations will be broadened to complete site investigations. The investigations will be conducted in accordance with a detailed investigation programme, which will be presented before the initial site investigations start.

The programme is based on experience from Stripa, Äspö, study sites, etc.

The site investigations aim at providing sufficient specific data to carry out the necessary performance and safety assessments before selection of a site for detailed characterization is made.

When two complete site investigations have been carried out, all relevant material from the siting work is compiled in an application for permission to carry out detailed characterization on one of the two sites. The reasons for the choice of site are presented, along with all background material in the form of data, analyses, investigations, arguments for and against and judgements.

4.4 PUBLIC INSIGHT AND LOCAL COLLABORATION

The Government and other policymakers have on several occasions expressed their view that "good public insight" is desirable in the siting work. SKB shares this opinion. Contacts with regulatory authorities, concerned municipalities and the public are therefore a vital part of the siting work. Regular meetings are held with concerned authorities and the investigation results are published as they become available. Regular information will also be furnished to scientists and other qualified experts with a special interest in the field of nuclear waste.

The feasibility studies offer very extensive opportunities for collaboration and information activities which, besides the municipality, county administrative board and regulatory authorities, also embrace local inhabitants, local non-governmental organizations, concerned neighbouring municipalities and the general public. This is a central and resource-demanding part of the siting work. As an example, a number of the meetings for collaboration and information that have been held during the feasibility study work in Storuman from project start up to and including a situation report are presented in Appendix C.

People's viewpoints and conceptions regarding the final disposal of radioactive waste are often anxiety-charged. SKB's ambition is to take up all questions in an open dialogue and carry out investigations and establishment with as broad collaboration as possible.

As soon as feasibility studies begin, the municipalities concerned need access to resources for their own initiatives. Such resources must cover the municipality's costs for information and collaboration during the course of the feasibility study. They must also cover the costs of obtaining independent opinions on the results of the feasibility study.

In conjunction with the start of the site investigations, a local safety committee or similar body should, in SKB's opinion, be established in concerned municipalities and be given resources to follow the work in a qualified way.

It is essential that clear forms be established at an early stage for producing an environmental impact assessment (EIA process). For the siting of the deep repository, this should be done before site investigations are begun in a municipality. Principles must thereby be stipulated for how the process is to be organized and documented. Important parties are above all those in whose jurisdiction the facility may be built (the municipality), those who will build and operate the facility (SKB), the regulatory authorities and the county administrative board.

Concerned municipalities should be given resources to follow and participate in the siting work in a qualified way. It is important that clear forms be established for such support, for example via funds from the waste reserves administered by SKB. It is also important to establish forms at an early stage for scientific/technical support to concerned municipalities from the regulatory authorities for safety and radiation protection.

5 PROGRAMME FOR DESCRIPTION OF DESIGN SPECIFICATIONS

The second point in the Government decision regarding a supplementary account to RD&D-Programme 92 has to do with:

- *a programme for description of the specifications for the design of an encapsulation plant and final repository.*

Description of the design specifications is done for each step in the design process. The specifications are finalized as various background data become available.

In their statements of opinion on RD&D-Programme 92, SKI and KASAM have expressed a desire for supplementary accounts regarding the methodology for the work of developing and designing the necessary components and systems for guaranteeing the long-term performance of the deep repository. Examples are questions such as choice of copper grade, method of canister fabrication, method of canister sealing, design of encapsulation plant, design of deep repository, rock excavation technology, preparation and application of bentonite and long-term material properties of canister material and bentonite. These and other questions will be dealt with in the development and design process.

The planned work for formulating and finalizing the most important specifications for the deep repository and the encapsulation plant is described in general terms in this chapter. Since both of these facilities will be dependent on the results of important ongoing and planned development work, the programmes take up this work as well.

5.1 THE DESIGN PROCESS

Major facilities are designed in phases. In its work, SKB follows the design model that has been developed during the past two decades and applied with good results in, for example, the power industry for important engineering projects. The work within each phase is based on interim decisions that precede that particular phase, as illustrated in Figure 5-1.

Phase E – Conceptual design

Project start. The project is defined with respect to the function, size and scope of the facility. A project organization is created. Alternative designs of systems and building parts are studied. An initial complete layout (E) is drawn up for the facility.

Phase D – Basic design

Preliminary principal data are compiled based on the required functions, basic technical solutions and overall requirements on the design of the facility. The systems are described so that a performance and safety assessment can be carried out as a basis for the preliminary safety report. A plant layout (layout D) based on preliminary information regarding systems, rock cavern and building structure is described.

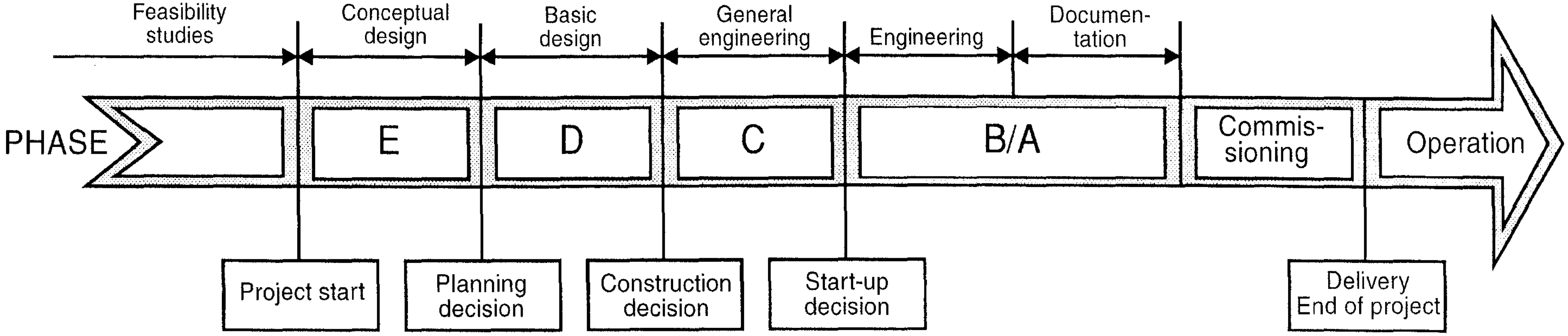

Figure 5-1. *Schematic illustration of the design process.*

Phase C – General engineering

Decision in principle to undertake construction. Specifications for purchase of certain equipment. The system designs are worked up into procurement specifications and specifications for construction documents. Layout C based on these specifications is presented.

Phase B – Engineering

Plans and budget are finalized. Requires that the necessary permits have been obtained. Establishment on the building site. The systems are described based on information from the selected supplier. Final principal documents for the rock and construction work is prepared and preparation of working plans is commenced.

Phase A – Documentation

Rock and construction work is carried out. Technical documentation is compiled.

5.2 DEEP REPOSITORY

5.2.1 Different areas of the deep repository

The general layout of the deep repository for spent nuclear fuel is being planned in accordance with the KBS-3 concept. This consists of a number of deposition tunnels in the bottom of which holes are bored for placement of canisters with spent nuclear fuel and surrounding bentonite buffer. The deposition tunnels are interconnected by tunnels for transport and communications, which are also connected to a central service area and ramp/shaft for communication with the ground surface. The exact placement of the deposition tunnels and deposition holes is adapted to local rock conditions. The repository depth is about 500 m in the normal case, but local adaptation will take place within the range 400 to 700 m.

A schematic drawing of the different parts of the repository is shown in Figure 5-2. The different areas are marked in the figure as follow:

- Surface facility.
- Access ramp.
- Central area under ground.
- Area for deposition of spent nuclear fuel, stage 1.
- Area for deposition of spent nuclear fuel, stage 2.
- Area for deposition of other, long-lived waste, stage 2.
-

The access ramp in the figure is one example of three different alternatives:

- Ramp with surface facility horizontally offset in relation to the central area under ground (Figure 5-2).
- Spiral ramp with surface facility straight above the central area.
- Shaft.

The final choice of ramp or shaft and the location of the different parts of the repository in relation to each other and to the surface facility is dependent on the conditions on the selected site. The geometric layout of the repository can now therefore only be sketched on the basis of general assumptions. Once a site has been investigated and site-specific design work has been carried out, the procedure described below for investigations, design and construction is used.

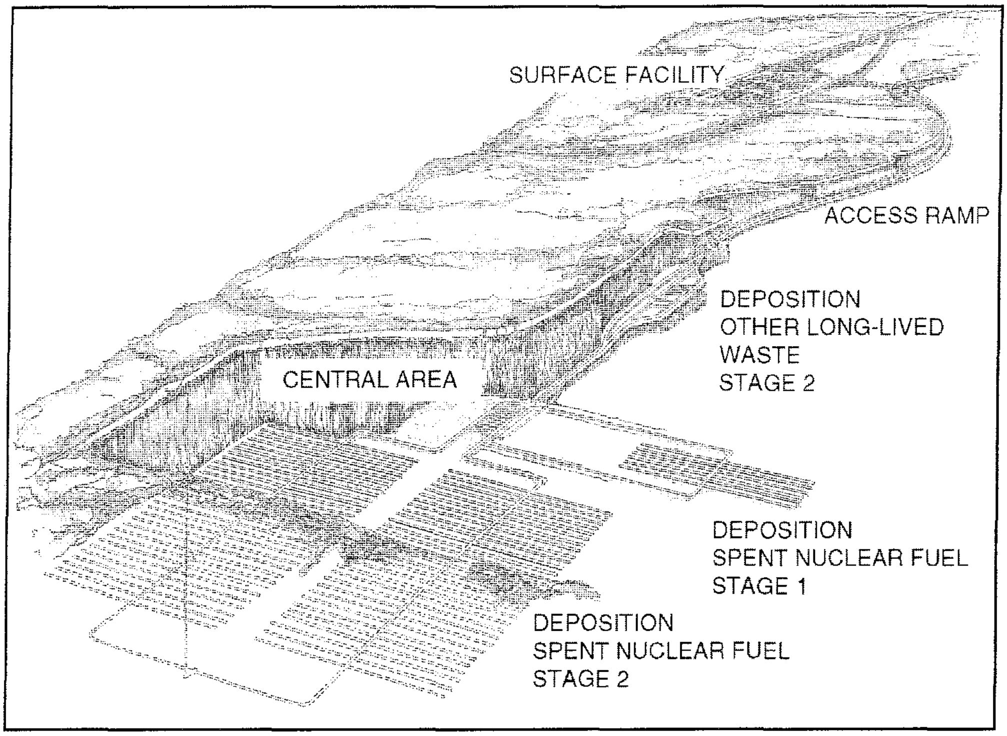

Figure 5-2. *Schematic drawing of deep repository.*

5.2.2 Construction stages

A planning and construction of the deep repository in two stages is presented in RD&D-Programme 92. The first stage aims at demonstrating and verifying the disposal method and is estimated to include about 10% of the total quantity of spent fuel. The second stage comprises deposition of the remaining quantity of spent fuel (about 90%) and other long-lived waste.

The programme for siting of the deep repository is described in chapter 4. Parts of the construction work for the deep repository are commenced in conjunction with the execution of detailed characterization.

The scope of the different construction stages that follow the siting phase is illustrated schematically in Figure 5-3.

Detailed characterization

The purpose of detailed characterization is described in chapter 4.

Detailed characterization includes the following construction activities (Figure 5-2):

Above ground

- Establishment of construction site including building of necessary roads and installation of electricity and water supplies.
- Erection of provisional construction quarters such as office barracks, rest cabins, canteen, information premises, field workshops and building stores.
- Establishment of dumping area for rock spoils.

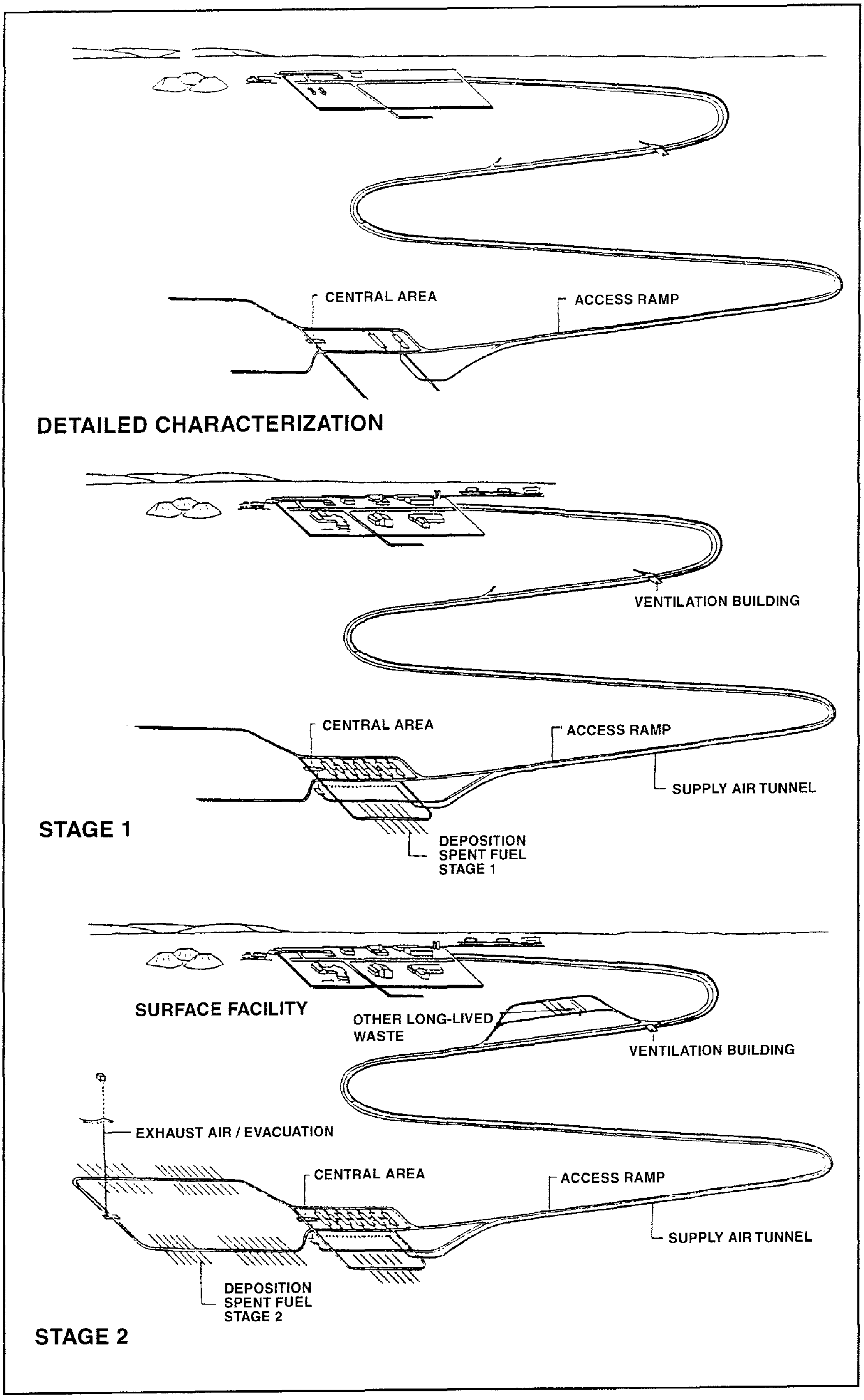

__Figure 5-3.__ Example of scope of different construction stages.

- Construction of necessary parts of ventilation building for supply air to the underground facility.

Under ground

- Construction (excavation) of ramp plus transport and investigation tunnels at repository level.
- Construction of perhaps one tunnel in each planned deposition area.
- Installation of service systems (ventilation, electricity, drainage, telecommunications, lighting, etc.) plus construction of necessary spaces for these systems.

Miscellaneous

Besides the aforementioned building activities, extensive investigations of the bedrock in the potential repository area are carried out during the detailed characterization stage. These investigations provide a basis for detailed assessments of the repository's safety and performance, and for continued detailed planning of the construction of the repository.

The stage also includes writing and submitting an application for a permit to construct deposition area 1. The supporting material for this application includes a preliminary safety report for the operating and disposal phases.

Construction stage 1

In this stage, virtually the entire surface facility is built above ground, while only the central area and deposition area 1 are built under ground. The activities include:

Above ground

- The ground work is carried out for the required operating area with associated road system and possible railway station. At the same time, the necessary road and rail links are built from the existing rail line.
- Erection of buildings for the different activities.
- Continued construction of dump for excavated rock spoils.

Under ground

- Construction of rock cavern in the central area and tunnels in deposition area 1.
- Construction of supplementary auxiliary and service systems.

Miscellaneous

After concluded construction and installation, try operation of the whole facility, including all handling and transport equipment, is carried out and a final safety report is compiled for the operating phase.

Operation stage 1

After try operation has been approved and an operating permit has been obtained, deposition of canisters with spent fuel begins and continues until deposition area 1 has been filled.

Evaluation

After operation stage 1, a programme is carried out for evaluation of experience. Based on this an application is made for a permit to build the remaining deposition areas.

Construction stage 2

The remaining parts of the facility are built. Deposition tunnels are expanded as deposition proceeds during Operation Stage 2. Rock caverns for other long-lived waste is excavated at a suitable time with a view towards other construction activities etc.

Operation stage 2

Remaining waste is deposited.

Closure/(supervised storage)

The shutdown phase includes a period of supervised storage, after which the closure and site restoration work is carried out.

5.2.3 Plan for design work

The process of designing the deep repository will proceed in the different phases that are described in general terms in section 5.1.

Today the first design phase – Phase E – has been worked through in a so-called "Facility description" for the entire deep repository /5-1/. This is an initial compilation of specifications and requirements with exemplifications of how they can be met. Since the site of the deep repository is not known, it has only been possible to use general data, based on representative values obtained from SKB's study areas.

In as much as the construction process will proceed in stages, some staggering of the design phases for different parts of the deep repository will be done in the continued design process. Figure 5-4 shows a plan for the design work.

During the current 6-year period, 1993 – 1998, all of Phase D is planned to be carried out and Phase C may possibly be commenced for the parts of the deep repository included in the detailed characterization stage, i.e. parts of the industrial area above ground, the access ramp/shaft and parts of the deposition and central areas under ground.

Phase D for the entire deep repository

The goal of Phase D is to describe the entire deep repository in site-specific compilations as a basis both for further activities and for the safety assessment and an application for a permit for detailed characterization on the selected site.

The most important background material during the phase is principal data on the waste, construction and deposition methods and requirements on service systems. An important prerequisite for Phase D is furthermore that site-specific data are available, and thus that the site investigations have gotten under way. Essential information for the design work from these site investigations are:

- Presence of major discontinuities, their extent, thickness and hydraulic conductivity.
- Properties of the bedrock from construction and stability viewpoints.
- Thermal parameters of the bedrock.

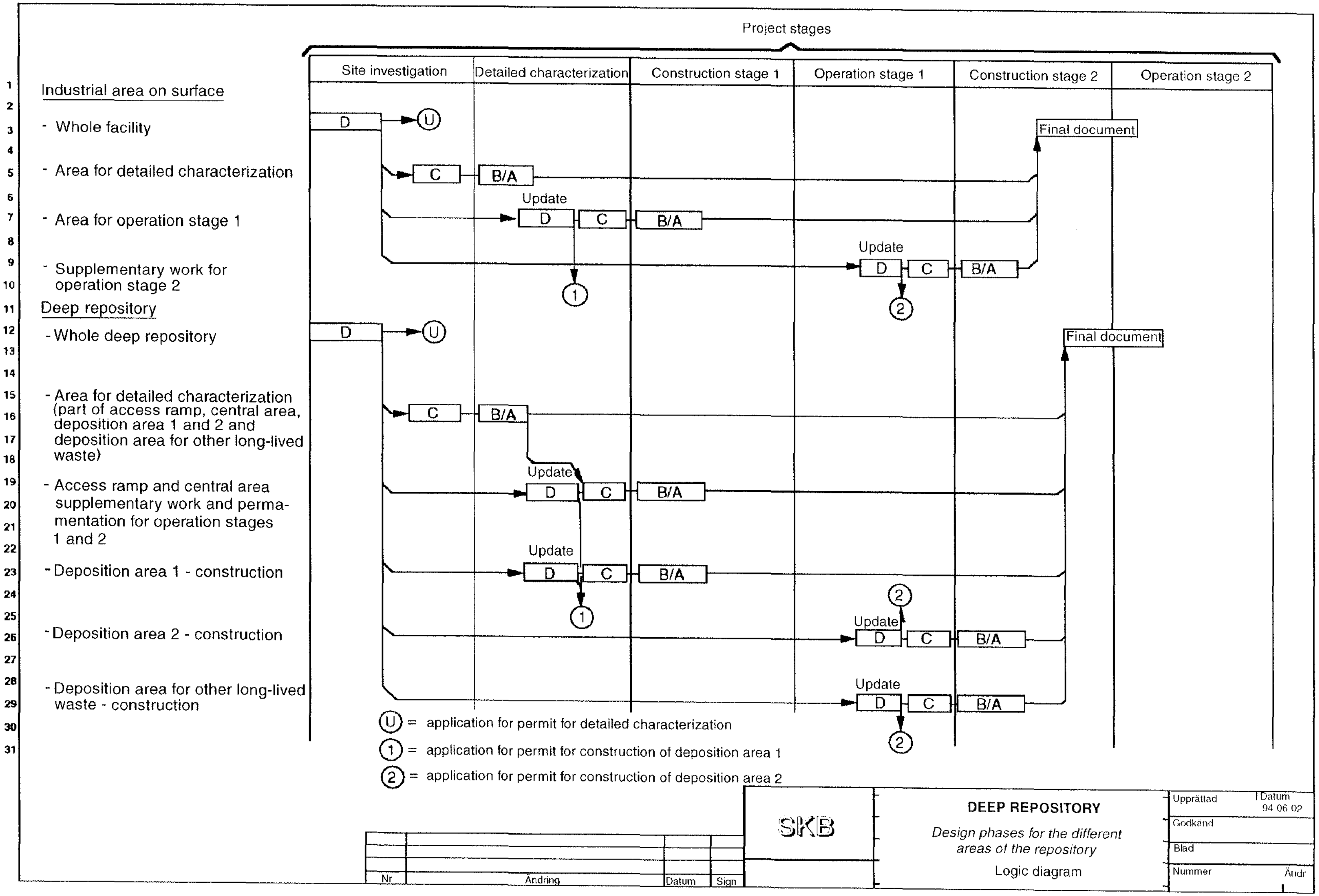

Figure 5-4. *Project plan for the deep repository.*

Phase D is divided into two stages so that initial results can be reported early with preliminary data. This serves as a basis for the first evaluations of performance and safety in the entire repository. Continued site investigations then provide additional knowledge regarding the area's geological and rock-related properties, which is utilized in the final compilation of Layout D.

The key issues that are special in Phase D for a deep repository are discussed in the following. Couplings to research and development work are described in section 5.2.4.

Above-ground facilities

- Transportation system consisting of possible rail-road transport of containers with encapsulated spent fuel and other long-lived waste plus transportation system down under ground and on the repository level.
- Technology for compaction of bentonite blocks.
- Methods for treatment of backfill material for tunnels.

Access ramp/shaft

- The repository depth will be determined early in the project, since the choice affects all design activities for the underground parts. The choice depends above all on safety and constructability with regard to local conditions. However, some flexibility will be provided for adjusting depth on the basis of the results of detailed characterization.
- Placement of access ramp/shaft – choice of ramp or shaft.
- Transportation system in ramp/shaft.

In the ramp case, different systems will be evaluated in operation for transport of the transport containers down to the repository. The gradient of the ramp is an important parameter.

The shaft alternative is being studied as regards hoist equipment for similar transports. In Germany, a full-scale demonstration is being conducted of down-transport in a shaft of packages with the same weight as the planned transport containers.

- Ramp, shaft and tunnel layout is determined on the basis of their need for detailed characterization and space needs for driving and later permanent operation.
- Construction methods for ramp/shaft.
- Conditions for backfilling, closure and plugging.

Central area under ground

- The size of the central area where all services, parking of vehicles, distribution of ventilation, electricity and freshwater, collection of drainage water etc. are gathered is determined by the scope of the entire underground operation. Complete information will thus not be available until the end of the design phase.
- Backfilling, closure and plugging are assessed simultaneously for the central area and the access system.

Deposition areas 1 and 2 for spent fuel

- Optimization of the design of the repository with regard to local conditions etc.

- Placement of deposition areas, transport tunnels and evacuation system (shaft and tunnels) with reference to the structure of the bedrock and results of analysis of constructability and safety after closure.
- Design of deposition tunnels including dimensions and quality of backfill material (bentonite and sand or equivalent).
- Design of deposition holes including dimensions and bentonite quality.
- Positioning and spacing of canisters with respect to the temperature in the bedrock, the thermal properties of the rock and thermal load per canister. The dimensions of the canister shall be given.
- Basic method for deposition and handling of bentonite blocks, canister, filling of the hole and backfilling and closure of deposition tunnels with regard to e.g. requirements on radiological occupational safety and the safety of the deep repository after closure. Preliminary design of handling equipment for canisters, bentonite blocks etc.
- Basic method for retrieval during deposition and after closure.
- Basic method for construction of tunnels and deposition holes.

Deposition area for other long-lived waste

The design and construction of this area are based above all on experience from SFR. The considerable differences that exist are the nature of the material and the greater depth at which deposition takes place in the deep repository. These differences are considered and evaluated as a basis for modification of the SFR technology.

Phase C – general

Phase C is the last phase in the design process where the system design specifications are affected. The results shall serve as a basis for investment decisions on construction and for contract procurements.

The construction decision prior to Phase C entails considerable commitments to methods, machines, designs and layouts. Phase C for the deep repository falls at different times for the different repository parts, as shown by Figure 5-4. The design work prior to **detailed characterization** and prior to **construction of stage 1** is discussed below.

Phase C prior to detailed characterization

Surface facilities, access ramp/shaft and parts of the deposition areas and the central area under ground which are included in the detailed characterization stage (see Figure 5-2) are begun first.

The work is based on the results of Phase D and additional information from the site investigations in the form of data from more detailed investigations in the locations for the access ramp/shaft, the ventilation duct and the central area, and information on the layout of the tunnels on the deep repository level.

The design of the rock caverns may be determined earlier than the actual placement of the rock caverns. Some decisions entail limitations on the flexibility of the size of machines, transport units and service systems.

Phase C prior to construction of stage 1

Above ground, virtually the entire facility is involved since very few of the required functions can be built with a lower capacity for operation stage 1 compared with what is required in operation stage 2.

Under ground, only a limited area is involved compared with the entire deep repository. However, complete technology development and design of the necessary machines are required, since operation is to be conducted in the manner prescribed for the entire programme of encapsulated spent fuel.

The construction decision is made jointly for the surface facilities, augmentation of access ramp/shaft and central area as well as for deposition area 1. In conjunction with the construction decision, the deposition method and the method for backfilling of the deposition tunnels for deposition area 1 are determined. Furthermore, construction methods are determined (mechanized tunnelling and/or drill/blast).

Detailed characterization provides supplementary and detailed information on the rock's construction-related properties. This information is utilized for detailed placement of deposition tunnels and holes.

5.2.4 Special development issues

Findings from R&D and the Äspö HRL

The design activities include adapting known technology or known methods to the specifications and requirements of the deep repository. A number of methods that will be used are based on knowledge obtained in the ongoing R&D programme. When the knowledge is established, adaptation or scaling-up to application will take place gradually and as the design work progresses. Important technology areas for the deep repository are:

- Construction method for tunnels and rock caverns, including boring of deposition holes.
- Grouting for sealing against water inflow.
- Compaction of bentonite blocks.
- Deposition procedure.
- Options for retrieval.
- Backfilling and closure.

The first two areas will be of importance already during the detailed characterization phase, while the others will not be applied until operating phase 1. The activities within supportive R&D and at the Äspö HRL are aimed at carrying out the necessary work in time for rational application during detailed characterization and during the first construction phase of the deep repository.

The aforementioned topics are also of interest to foreign organizations who work with deep disposal in crystalline rock. Construction methods and grouting technology of interest to SKB are being studied and developed within underground construction the world over.

Construction methods in rock

In a deep repository, special demands are made on the possibility of describing the impact on the rock made by the construction of shaft, ramp, tunnels and deposition holes. The problem lies partly in understanding the relationships between excavation method and impact, and partly in developing and adapting equipment for mechanized excavation of tunnels, shaft boring, boring of deposition holes, etc.

Practical experience from mechanical excavation is being obtained from ongoing TBM tunnelling (TBM = full-face boring with a Tunnel Boring Machine) in the Äspö HRL, from recently conducted tests with boring of deposition holes in Finland in cooperation with TVO, and from planned boring of deposition holes in the Äspö HRL.

Fracture propagation after drill/blast and TBM tunnelling will be investigated in the international ZEDEX experiment at the Äspö HRL. Other activities have been going on for many years outside of SKB's programme to clarify the formation and propagation of fractures in rock.

Grouting technology for sealing of water inflow

Technology tested in conventional rock excavation works in most practical cases, but not in all. Two areas outside normal grouting activities being studied by SKB are sealing of large water-bearing zones at repository depth and sealing of fine fissures for restriction of water seepage during deposition. In both cases the work involves building on existing experience and know-how so that both the theoretical frame work and the practical application will be robust. Practical tests have been conducted at Stripa and at Äspö and supplementary tests can be conducted at the Äspö HRL.

Compaction of bentonite blocks

Ongoing activities are aimed at determining the parameters during compaction. Studies aimed at scaling up the compaction technology to full scale are being commenced during 1994. Ongoing R&D work on bentonite aims at presenting a compilation of material properties etc. of importance for its use as a buffer material by 1996 at the latest. This will enable data to be determined for the buffer, compaction tests to be planned and carried out, full-scale tests at Äspö to be planned and commenced, and development of suitable machinery to be carried out. Tests with the machinery are planned to be conducted in place in the deep repository.

Deposition procedure – options for retrieval

The deposition process has already been described in rough terms. What remains to be done is to design and develop equipment that is capable of executing emplacement of bentonite blocks and canisters in the prescribed manner as well as retrieval of the canister, if necessary.

After the deposition holes have been filled with buffer material and the deposition tunnels have been backfilled and the backfilled material has had time to homogenize, in order for the canisters to be retrieved it is first necessary that the backfill material be excavated, and second that the canisters be uncovered in the deposition holes so they can be gripped. Different items of mechanical equipment will probably be required for this. Methods are being analyzed first and then machine designs. A technically important question is how the canister is to be gripped and how it is to be taken out of the deposition hole to radiation-shielded transport containers. The needs for model and prototype testing must be clarified. The plan for the development work follows the plan for the development of the deposition equipment as closely as possible and is assumed to be carried out simultaneously.

Backfilling and closure

Backfilling and closure of the deposition tunnels are primarily being studied. Different materials are being considered today, such as bentonite and sand in various mixtures and grades. Beyond this, two principles are being held open: block compaction versus in-situ compaction. Equipment needs to be developed and experiments performed for the methods that are being further studied.

Alternatively, in certain cases backfilling with either crushed rock or natural glacial till can provide the desired function. Use of these materials is more a question of safety after closure. The technology for emplacement and compaction is known.

Plugs for closure and sealing against water transport comprise important components whose design need to be adapted to the particular conditions on each site. Practical tests have been carried out at Stripa and are being planned at Grimsel in Switzerland and URL in Canada. Through cooperation agreements, SKB has access to the results of these tests. Certain design parameters are general, and these can be determined through experiments in e.g. the Äspö HRL. Such tests can be conducted even after the construction work for the deep repository has been commenced. Long-term tests can be conducted throughout the deposition phase and in connection with the deep repository.

5.3 ENCAPSULATION

5.3.1 Canister and encapsulation process

Before the spent fuel is placed in the deep repository it will be encapsulated in a durable canister. The most important requirement on the canister is that it shall remain intact for a very long time in the environment that will prevail in the deep repository. Accordingly it shall not corrode apart in the groundwater present in the rock or be broken apart by the mechanical stresses to which it is subjected in the deep repository.

To achieve this it is proposed that the canister be made with an inner container of steel, to provide mechanical strength, and an outer shell of copper, to provide corrosion protection (Figure 5-5). Copper corrodes very slowly in the oxygen-free groundwater found at depth in Swedish bedrock. Completed studies show that the canister will probably remain intact for millions of years, providing a considerable margin of safety.

Previously other designs of the canister have also been studied, e.g. a homogeneous copper canister, where encapsulation is accomplished by means of hot isostatic pressing, or a copper canister where the void around the fuel is filled with lead /5-2/. However, both of these alternatives require that encapsulation take place at high temperature, which can be avoided with the copper/steel canister. This consideration has been crucial for the choice, since the three canister types are equivalent in terms of long-term performance. The lead-filled canister is, however, being retained as a reserve alternative.

Encapsulation is planned to take place in a new encapsulation plant connected to CLAB. There the fuel will be received from CLAB's storage pools and placed in the canister after being checked and dried. Before the lid on the inner steel container is put on, the air in the canister will be replaced with inert gas and the void filled with e.g. boron glass beads. Then the copper canister will be sealed by welding-on of a copper lid. Very stringent requirements are made on the leaktightness of this weld and the capability to test this leaktightness. Electron beam welding is planned to be used to make this seal.

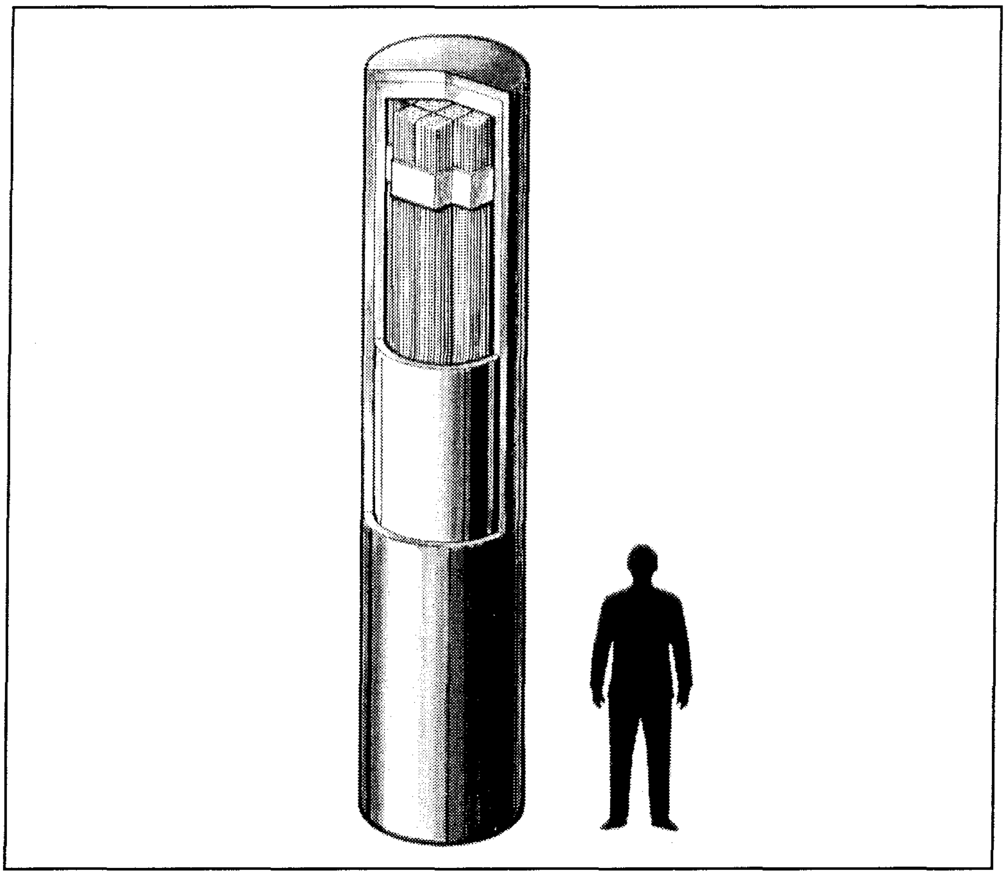

Figure 5-5. Copper canister with inner steel container for spent nuclear fuel.

The necessary transports will take place in containers of a type similar to those used today for shipments of spent fuel from the nuclear power plants to CLAB.

In designing the encapsulation plant, great emphasis will be placed on radiation protection for the personnel and the environment. This means, for example, that the actual encapsulation procedure will be performed by remote control from heavily radiation-shielded compartments called "hot cells". A large part of the handling of canisters will also be done by remote control. Experience from CLAB and SFR, as well as from various foreign facilities, will be drawn upon.

In a later phase, other long-lived waste will also be treated in the encapsulation plant. Examples of such waste are core components, e.g. control rods, and other reactor internals that have become activated by neutron bombardment during operation of the reactors. These components are planned to be embedded in concrete. (This part of the encapsulation project is not described in the following).

5.3.2 Plan for the design work

The process of designing the encapsulation plant follows the guidelines for step-by-step design described in section 5.1.

What is planned to be done in the different phases is described in general terms below – see Figure 5-6. A more detailed description of the planned work with canister design, sealing method and plant design is given in the following chapters.

PROGRAMME FOR DESCRIPTION OF DESIGN SPECIFICATIONS FOR ENCAPSULATION PLANT

Period up to start of construction work

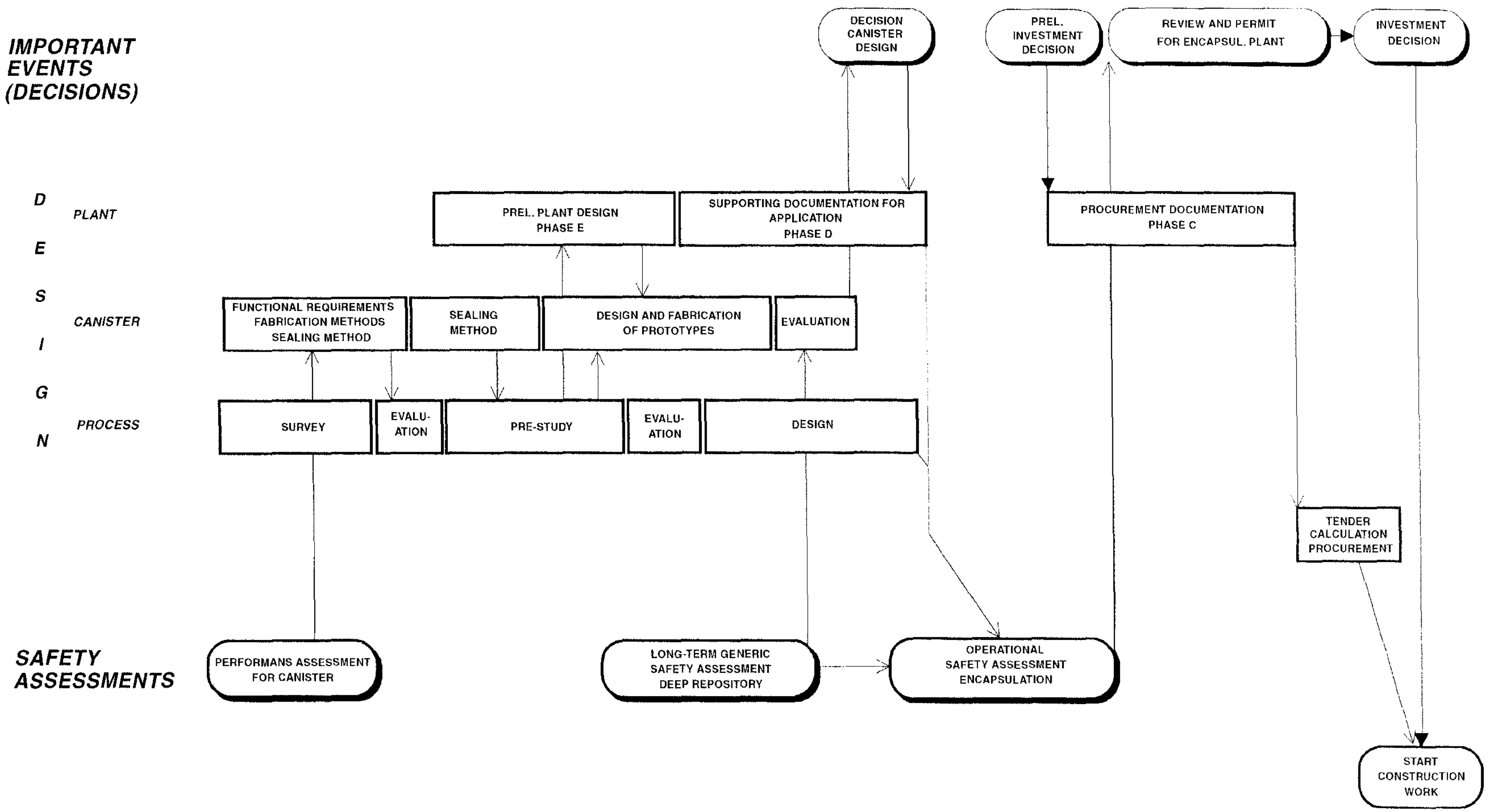

Figure 5-6. Logic diagram for design of encapsulation plant.

Phase E – Conceptual design

Plant design

- In this phase the alternative studies for the encapsulation process are concluded. A preliminary plant description and preliminary system descriptions for the main systems are prepared.

Canister design

- Compilation of functional requirements.
- Material selection and tests are carried out for both copper and steel components.
- Sizing of copper and steel components.
- Description of contents of canister.
- Detailed design of canister lid with regard to requirements on lifting during handling in the plant and performance of quality inspection.
- Fabrication and inspection methods are examined and evaluated.

Sealing method

- The sealing method employing electron beam welding is tested on full-sized copper lids.

Miscellaneous

- Preliminary design of transport container for encapsulated fuel.

Phase D – Basic design

Plant design

- In this phase the systems are studied and optimized. A plant description and system descriptions are written as a basis for the preliminary safety report.
- Methods for changing the atmosphere in the canister and filling are tested if deemed necessary.

Canister design

- Supplementary material tests are conducted as needed.
- Fabrication and inspection methods for the canister are tested on full scale.
- Fabrication is carried out and evaluated for some canisters.
- Premises for series fabrication of canisters are investigated.
- Decision on canister design.

Sealing method

- The sealing method is tested on canisters.
- Inspection methods are tested and developed.
- Supplementary tests are carried out as needed.

Miscellaneous

An environmental impact statement including a preliminary safety report is compiled in support of an application for a permit under the Act Concerning the Management of Natural Resources and the Act on Nuclear Activities for the encapsulation plant.

Phase C – General engineering

Plant design

- Drawings and descriptions are prepared for procurement of the construction work and the various systems.

Canister design

- The design of the canister is determined.
- The necessary agreements on series production are prepared with suppliers.

Sealing method

- A pilot plant for welding is built and tested for subsequent incorporation in the plant.

Phase B – Engineering

Plant design

- The detailed plant design is determined on the basis of documentation from suppliers of the different system parts. Working documents for the construction work are prepared.

Canister design

- Trial fabrication is carried out at suppliers.

Sealing method

- The pilot plant is built and trial weldings are carried out.

Phase A – Documentation

Plant design

- Relational documents are drawn up and final system descriptions are written as a basis for commissioning and a final safety report (FSR).

Canister design

- The results of trial fabrication are reported.

Sealing method

- The results of trial welding in the pilot plant are reported.

Miscellaneous

- A final safety report is drawn up in support of an application for an operating permit.

5.3.3 Canister design

The work of designing the canister is planned to take place in the following steps.

Compilation of functional requirements [Phase E]

The canister shall be designed so that it:

- remains intact and leaktight for the necessary time in the deep repository,
- can be fabricated and sealed in a reliable manner,
- can be handled in a safe manner during fabrication, transport and deposition,
- gives a limited thermal load in the deep repository, and
- has the necessary margin to criticality in all phases.

This means that the canister shall meet functional requirements on:

- Resistance to external and internal corrosion.
- Strength against external stress.
- Radiation shielding to prevent radiolysis.
- Limited thermal load.
- Criticality-proof geometry (including fill material).

The functional requirements are compiled as a basis for the final choice of canister design.

Material selection and tests [Phases E+D]

Properties that are essential for long-term safety shall be taken into account in the selection of material grades and methods for fabrication, sealing and inspection.

This work can be divided into the following main parts:

- Specifications for the copper material.
- Tests of material properties for different copper grades.
- Studies of stress corrosion cracking in copper.
- Specifications for the steel material.
- Possible verifying tests of steel material.

Finally, a compilation and evaluation is done of possible material choices for the canister.

Sizing [Phase E]

This part of the work consists of the following main parts:

- Determination of the number of fuel assemblies the canister shall contain with regard to maximum thermal load on the bentonite and expected residual heat in the fuel at the time of deposition
- Determination of the inside cross-sectional area and length with regard to the number of fuel assemblies, and

- Sizing of wall thicknesses for steel and copper with regard to the functional requirements.

Contents of canister [Phase E]

This work includes design of necessary inserts or guides for the fuel assemblies in the canister.

The risk of criticality in the canister is investigated, and if necessary the void is planned to be filled with suitable material.

Detailed design of lid [Phase E]

The steel lid is designed in detail with regard to the requirements that are made on lifting and welding of this lid plus possible additional requirements from the encapsulation process.

The copper lid is designed in detail with regard to the requirements that are made on lifting the lid and possibly the entire canister and for execution and inspection of the sealing weld.

Fabrication and inspection methods [Phases E+D]

A compilation is made of suitable methods for fabrication and inspection of canisters. Method testing is carried out for evaluation of quality and costs.

Premises for series production of canisters are investigated.

Fabrication of test canisters [Phase D]

Fabrication of test canisters is planned to be carried out in several stages. These will be used for testing of the sealing method and later for inactive trial operation of the encapsulation plant.

Reserve alternative [Phase D]

The previously studied design of the copper canister with fill of molten lead around the fuel assemblies comprises a reserve alternative to the copper canister with inner steel container. In the event the results of the development work during the next few years show that this canister does not meet the requirements made, the work with the lead-filled canister can be resumed. This will affect the schedule for the encapsulation plant, but the size of the effect depends on when such a decision is made.

The plan is to finalize the design of the copper canister during the work with layout D.

5.3.4 Sealing method

In order to meet the stringent requirements on sealing of the copper canister, a method is being developed for sealing by means of the electron beam welding method. Methods for non-destructive testing that can be used for verification of the fact that the sealing method meets the requirements will also be developed.

The work with development of the sealing method is planned to proceed in the following stages.

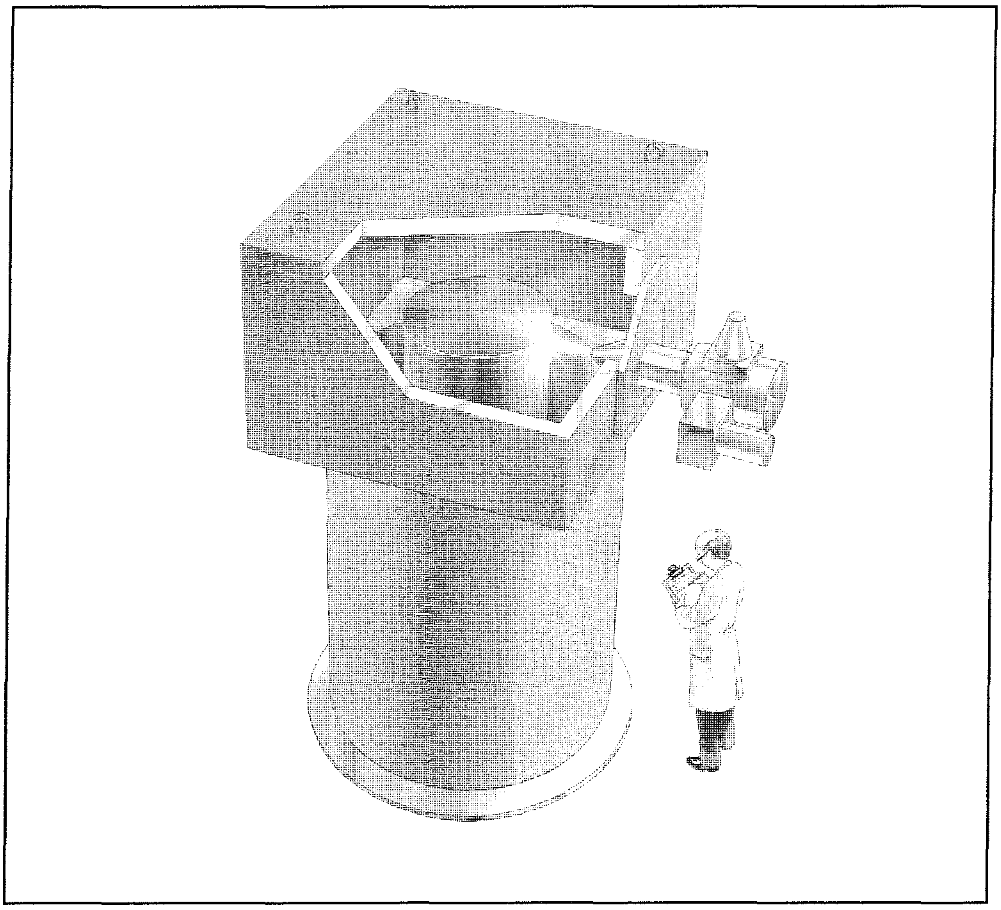

Figure 5-7. Electron beam welding of copper lid on copper cylinder.

Development of electron beam welding method [Phase E]

The work of technology development has been going on for about 10 years, and during 1993 it has come so far that the equipment is producing the desired results /5-3/. The important parameters for control of the results have been determined by means of variation studies in connection with trial weldings, and there is a good basis for the execution of trial weldings of lids on copper cylinders.

Development of inspection methods [Phases E+D]

To guarantee satisfactory integrity of the canister, rigorous in-process inspection of the metal containers and post-sealing inspection of the canister shall be carried out. Methods for these inspections shall be determined and, if necessary, developed simultaneously with establishment of methods for fabrication and sealing of the canister.

Trial welding of lids on copper cylinders [Phase E]

A welding chamber has been built for trial welding of lids on copper cylinders (Figure 5-7). The first trial series was carried out during 1994. These trials are performed on copper cylinders with full diameter and wall thickness, but with half the length (about 2.5 m). This is sufficient for these trials with regard to studies of heat dispersion from the weld area in the copper cylinder. Experience from this trial series will then serve as a basis for continued work with verification of the electron beam welding method.

Welding of test canisters [Phase D]

When the first full-length copper cylinders have been trial-fabricated, trial weldings of copper lids are planned to be carried out on these cylinders (which then also have an inner steel container). These will be the first prototype canisters.

Prototype plant [Phase C]

After completed trial welding series and after a building permit has been obtained, a prototype plant will be built for trials of the welding equipment and the welding chamber before they are incorporated into the plant.

5.3.5 Encapsulation plant

The encapsulation plant shall be designed and built mainly to house the encapsulation process. Furthermore, it shall later be possible to add a process line for treatment of core components. In designing the plant, special consideration shall be given to matters related to operation and maintenance as well as industrial and radiological safety.

The functional parts planned to be included in the plant, besides the actual encapsulation process, are:

- treatment of core components,
- areas for materials handling,
- service systems,
- areas for operating staff,
- areas for maintenance activities.

The encapsulation process shall be designed to deliver flawless fuel-packed canisters to the deep repository. In designing the process, special attention shall be given to matters related to industrial and radiological safety.

The work of designing a suitable process for encapsulation of the fuel can be divided into functional parts where different technical solutions will be considered. The following steps are planned to be included in the process (see Figure 5-8).

The fuel is **transported** to the encapsulation plant via the fuel elevator in CLAB.

Before the fuel is taken to encapsulation it must be identified, sorted and measured.

In a **handling cell for fuel** the fuel is dried and undergoes the steps that are required up to placement in a canister. Final safeguard control takes place here.

In this part of the plant, where the fuel is handled freely, there is a risk of radioactivity escaping. The compartment is built with radiation-shielding walls and special requirements on airtightness and ventilation. This type of compartment is usually termed a "hot cell".

Other encapsulation functions are planned to be located at separate work stations.

Transport of the canisters inside the plant takes place in a channel that connects the handling cell and the various work stations. During transport the canister is sealed so that radioactivity cannot escape from the fuel.

From the handling cell, the canister is taken to a **filling station** where the atmosphere in the canister is replaced and packing of the fuel assemblies is done if required. This work station is also designed as a hot cell in view of the fact that the canister is not yet sealed. Finally, the steel lid is fitted and sealed by welding.

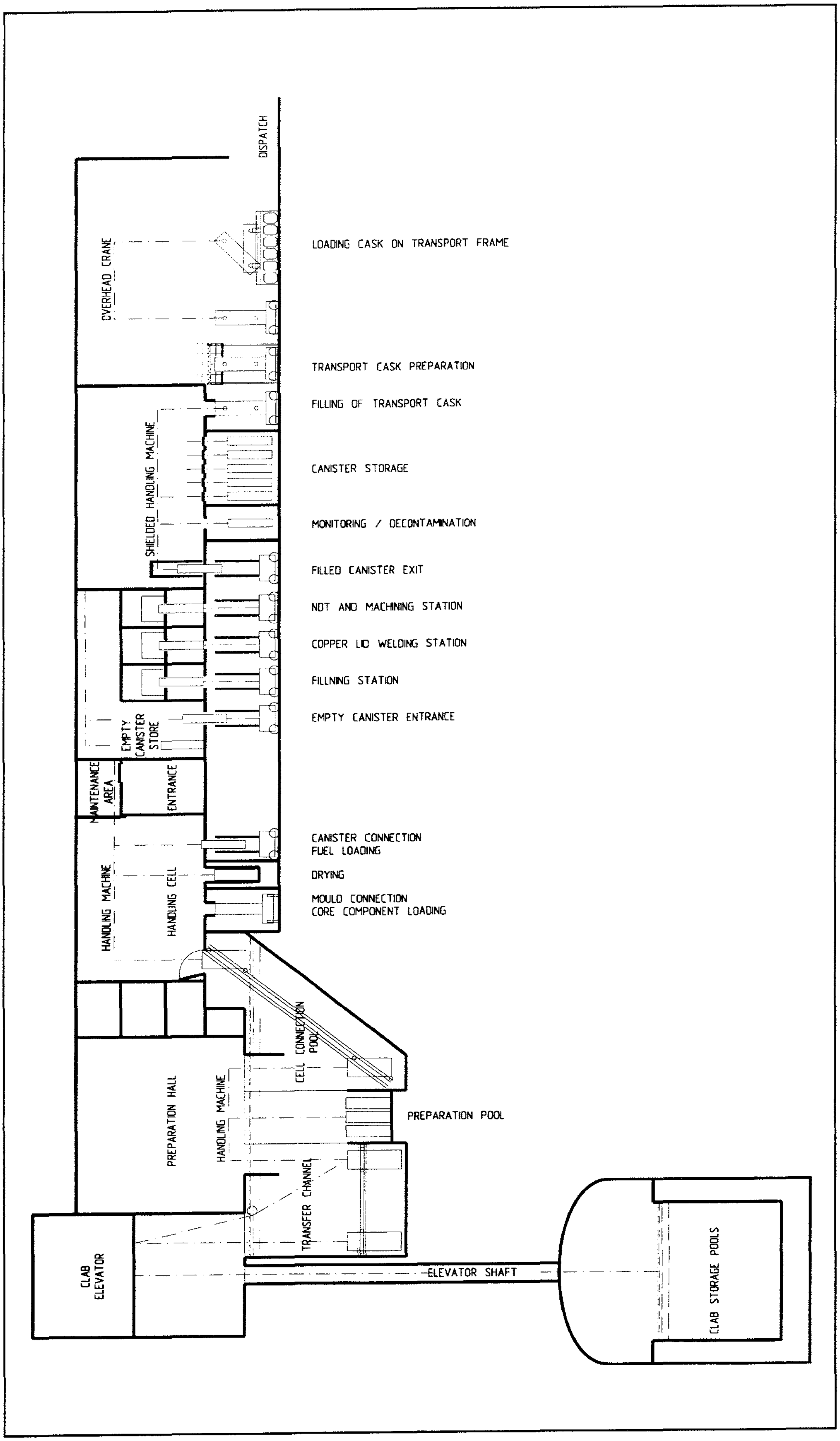

Figure 5-8. *Encapsulation plant – flow layout.*

In a **sealing station** the copper canister is sealed by electron beam welding in a vacuum chamber.

An **inspection and machining station** contains equipment for inspection of the lid weld and machining of the weld area on the canister.

The plant is also designed in such a way that defectively sealed canisters can be rectified. This is preferably done by removing the lid in the machining station, after which the canister is returned to the sealing station and provided with a new lid. If this is not possible, the canister is returned to the handling cell and emptied of its fuel, which is placed in a new canister.

After weld inspection the canister is brought into a **decontamination station** where a routine check of surface contamination is planned and the outside of the canister can be decontaminated.

After sealing, a final recording and documentation of data for each individual canister takes place.

Before the canister is taken to the deep repository it is placed in a **buffer store**.

5.3.5 Safety assessments

Matters relating to the radiological safety of the encapsulation plant during operation are analyzed and reported in two steps.

- Preliminary safety report, PSR

The safety of the plant is described based on the design work carried out during 1994-96. The level then achieved is termed layout D. The report shall describe safety-related matters for the handling process, especially possible accidents and their consequences. Emissions via cooling water and ventilation air are expected to be very small and will presumably be contained within existing limits for the CLAB facility.

- Final safety report, FSR

Safety is described for the finished plant. The background documentation for the report consists of the plant description and final system descriptions, layout A.

Results of inactive trial operation with fabrication of a number of canisters are reported as a complement to the FSR for regulatory review of operating permit applications under KTL.

Matters relating to the long-term performance of the canister are dealt with in the safety assessment for the deep repository. See chapter 6.

5.4 QUALITY ASSURANCE

The overall goal of quality assurance in the deep repository and encapsulation projects conforms to "SKB's guidelines for quality assurance work".

The goals of the quality work in the projects are to ensure that:

- the project work is efficient with clear descriptions of goals and of responsibilities and powers within the organization;
- information on the progress of the project is disseminated to all concerned;

- the documentation that is prepared during the licensing, design and construction process is correct, clear and available for scrutiny; and that
- the demands of the authorities on quality assurance in conjunction with the permit applications are met.

6 PROGRAMME FOR SAFETY ASSESSMENTS

Regarding the third point in the Government's stipulations on a supplementary account – a programme for the safety assessments which SKB intends to prepare – the Government's view is given in a number of matters relating to this point:

- *that the methods for safety assessments should be further developed, particularly as regards how different uncertainties are to be described and weighed together;*
- *that a strategy should be developed for checking the validity of the models (validation), based on the requirements made by the safety assessment;*
- *that there is a need for a holistic view of radiation protection matters. SKB should be able to give an account of safety and radiation protection matters for both the operating phase and the post-closure phase.*

The Government also stipulates that the recommendations made by SKI and KASAM should be taken into consideration in the supplementary account.

6.1 GENERAL

6.1.1 Safety reports

Nuclear activities must be carried out in a safe manner. Assessment of the safety of the activity is done with the aid of assessments of the performance of the plant with regard to safety and radiation protection. In the case of radioactive waste, safety must be shown both for operation including treatment, storage, transport and deposition, and for the passive post-closure phase after the repository has been sealed.

Methods for safety assessment of systems in active operation have been developed and are being constantly refined within e.g. the nuclear power industry. Evaluation of safety during operation of waste facilities can be performed in essentially the same manner as equivalent evaluation for other nuclear facilities and is therefore not dealt with here.

The link between operating safety and long-term safety consists of the quality of the engineered barriers that are built up and of the probability and scope of possible fabrication defects.

As the design process and site investigations proceed, SKB will gradually determine the design of different engineered safety barriers and the repository's layout and location in the bedrock, cf. chapter 5. This presupposes a continuous evaluation of the performance of the repository and the barriers and their importance for long-term safety.

Important decisions within the programme will be based on comprehensive safety assessments. These will serve as an important basis for SKB's decisions and for the regulatory review of permissibility under different laws. SKB foresees that the following occasions are of such a crucial character that they will be supported by comprehensive safety assessments and applications for permits under relevant laws (see Figure 3-1 in chapter 3):

- Encapsulation plant, application for permit for
  - siting and construction,
  - operation, stage 1,
- Deep repository stage 1, application for permit for
  - detailed geoscientific characterization,
  - siting and construction,
  - operation.
- Evaluation of experience from stage 1.
- Deep repository and encapsulation plant, stage 2, application for permit for
  - construction,
  - operation,
  - closure.

When applying for these permits, SKB will give an account of safety and radiation protection matters for both the operating phase and the post-closure phase in safety reports. Under current schedules, the first reports will be submitted as supporting material for the siting application etc. for the encapsulation plant and for the application for a permit to conduct detailed site characterization for the deep repository.

The background material for assessments of long-term safety will gradually increase as increasingly extensive investigations and possibly construction proceed. Prior to each decision, an evaluation will be made as to whether the background material and safety assessments have reached a sufficient degree of maturity and yielded adequate results for the next step in the work.

In the case of site-specific data in particular, the information will be limited in the early assessments. The safety assessments in this phase must be based on information from surface-based investigations and boreholes, and on hypothetical repository layouts. This information can be revised in coming phases.

6.1.2 Scope and delimitations of the programme

This is a programme for SKB's safety assessments of the passive post-closure period. The programme defines the logical sequence of the work and the methodology for performance and safety assessments, i.e. the methodology in producing

- safety-related background material as a basis for a step-wise design of the repository's engineered barriers and of the repository's emplacement on different candidate sites;
- a suitable structure for the presentation of long-term radiological safety in future safety reports;
- a safety report in support of applications for different permits for construction of the encapsulation plant;
- a safety report in support of an application for a permit for detailed characterization for the deep repository.

The programme description has been focused on the compilation of the two safety reports that are due next, i.e. up to and including application for a permit for detailed geoscientific characterization on a candidate site. The methodology and work procedure in subsequent safety assessments will be roughly similar. The endeavour is that the same report structure shall be retained in all reports to simplify identification of new information and comparisons with previous reports. Some modification of the structure of the report with regard to experience and specific questions may be needed, however. Figure 6-1 shows the site- and system-specific information that is intended to serve as a basis for the two first safety reports, cf. also chap. 5.

The goals of the work with the safety assessments are presented in section 6.2. The work procedure and methodology for carrying out performance and safety assessments is then presented in section 6.3. The way in which checking and reporting of uncertainties and validity in safety assessments will be carried out, planned allocation of efforts during different work phases, and grounds for prioritizing among these efforts are discussed in section 6.4. A discussion of the time requirements for carrying out integrated safety assessments is held in 6.5.

6.2 GOALS

The capability of a deep repository to keep the radioactive materials isolated from nature and human beings over a long period of time, and to keep the radiation dose in the surroundings well below given limits, is evaluated with the aid of performance and safety assessments.

These assessments shall, during the initial phases:

- evaluate the performance and interaction of the engineered barriers to provide an understanding of the safety issues and provide a basis for system design, material selection and sizing of the repository system;
- evaluate site-specific conditions of importance for safety to provide a basis for continued site characterization and emplacement of the repository in the area, and for designing the deep repository;
- provide background data for safety reports prior to important decisions and for permit applications for the encapsulation plant and deep repository.

A template is developed for the structure and contents of the safety reports. This template intended to be utilized for all coming reports on long-term safety. The report template will be presented during 1995. Safety reports shall constitute supporting documents for applications for permits to site and build the encapsulation plant and to carry out detailed characterization for a deep repository. The reports shall provide the "coherent and thorough analysis of safety and radiation protection matters" which the Government wants SKB to present before making a commitment to a specific handling and disposal method, and will cover both operating safety and long-term safety.

The safety report prior to the permit application for the encapsulation plant shall

- describe the safety of a scheme for the deep disposal of spent nuclear fuel which utilizes the chosen canister design and methods for fabrication and inspection. The analyses will be based on an assumed repository design and layout and on generic data for Swedish bedrock;
- describe and discuss any design- or site-specific factors that could exist in certain realistic siting alternatives and that are of such a character that the suitability of the canister for safe final disposal could be called into question.

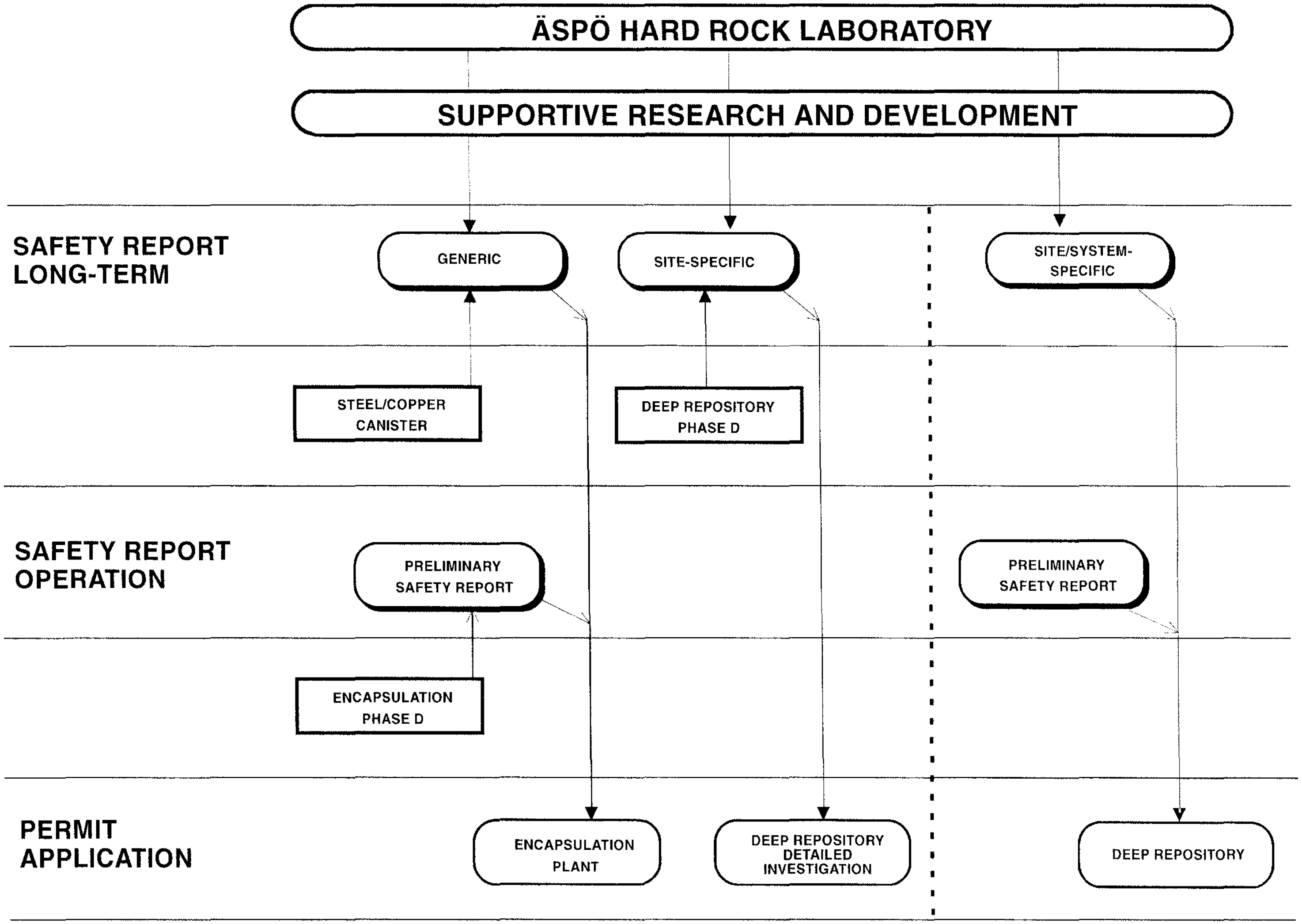

Figure 6-1. *Logic diagram of upcoming safety assessments for deep disposal of spent nuclear fuel.*

A similar report prior to the permit application for **detailed geoscientific characterization** for a deep repository shall

- describe the potential of the two candidate sites and show an acceptable level of safety for a deep repository for spent nuclear fuel and other long-lived nuclear waste;
- describe and discuss any site-specific factors that are of such a character that they could cause the suitability of the site to be called into question.

The safety reports during later phases shall demonstrate that, with the chosen repository design on the chosen site, the radioactive waste can be handled and disposed of in a safe manner.

6.3 EXECUTION OF THE WORK

6.3.1 General

Acceptance criteria and safety goals for a deep repository have been discussed in the publication "Disposal of High Level Waste, Consideration of Some Basic Criteria", 1993 /6-1/. Together with international recommendations, it is intended to serve as a basis for the framing of national criteria. SKB will take into account the guidelines in these documents, previously issued regulations for similar activities, and announced provisions on scope and content.

In a phase where system development and site selection are in progress, periodic evaluations of safety and performance, as well as variation analyses, are needed as a basis for the detailed design and sizing of the systems. Similar evaluations are needed to arrange the repository in such a way that the site's natural barriers against radionuclide dispersal are utilized effectively. Such periodic analyses of suitable barriers or sub-systems under typical environmental conditions are termed **performance assessments** here.

In order to obtain a comprehensive picture of the overall performance of the system, the performance assessments must be combined to embrace the entire disposal system and compared with the safety goals. These integrated assessments are termed **safety assessments**.

The safety assessments are based on the understanding of the performance of the system that has been obtained from the performance assessments or from previous safety assessments. They are focused on elucidating effects of the total repository on man and his surroundings, and on how different designs and sizes influence the repository's integrated safety. Performance and safety assessments also serve as a basis for determining the priorities of supplementary R&D efforts for deepening of knowledge and experiments.

Regardless of whether assessments are performed for sub-systems or for the total disposal system, they are based on an assessment methodology that includes (see Figure 6-2):

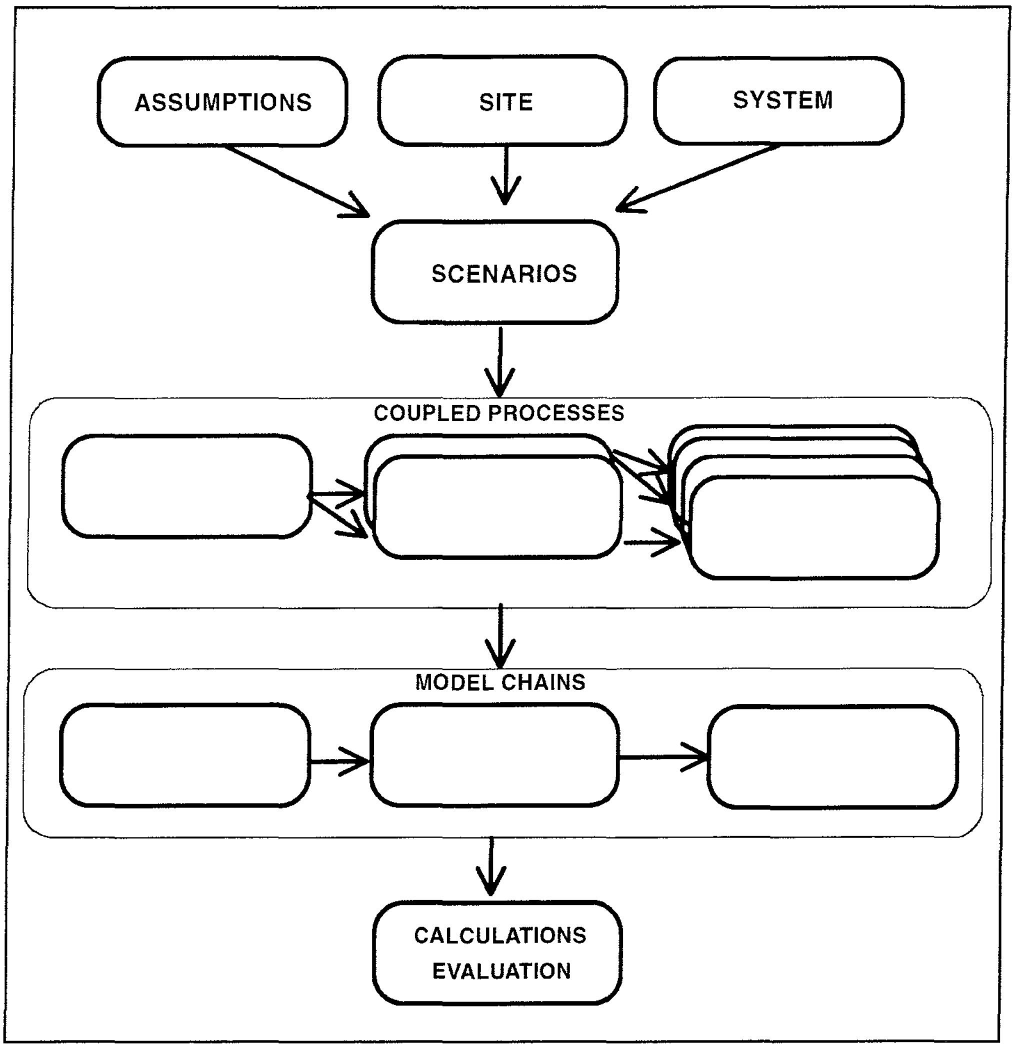

Figure 6-2. *Schematic procedure for safety assessment.*

- Definition of the purpose of the assessment.
- Definition of given assumptions for the assessment, i.e. types and quantities of radioactive waste, the repository system and its dimensions and the location and surroundings of the repository.
- Clarification of both the probable and the less probable or improbable conditions for which the system/facility is to be analyzed (scenarios).
- Clarification of the time-dependent processes which are essential for the intended performance of the system/facility in different scenarios.
- Definition of calculation models for quantifying the performance of the system and the couplings between the models.
- Quantification of the performance of the system/facility and essential changes in performance.
- Discussion of the uncertainties in the assessments and evaluation of the adequacy of the assessment with respect to its purpose.

Many decisions regarding the direction of the work etc. during the development of a repository system must be made in the face of considerable uncertainty. The assessment work shall therefore try not only to quantify the performance of the repository, but also to clarify the uncertainties in the assessment and what influence these uncertainties have on the conclusions.

Analysis of the uncertainties in the assessment, and of confidence in the adequacy of the assessment for its purpose, is an activity that cannot in practice be separated from the other assessment work. To clarify the work procedure and principles for how this validation work is intended to be pursued, however, the account of how the safety assessments are to be conducted has been divided into two sections. In the continuation of this section 6.3 below, an account is given of the logical steps from broad performance studies up to a safety report. A more detailed explication is presented in section 6.4 with a focus on the validation work, divided into sub-steps as per figure 6-2, where different types of uncertainties are brought into the assessment.

6.3.2 Performance assessments

At present, assessments are being conducted of the performance of the copper/steel canister in a KBS-3-like repository environment. The assessments consist of a run-through of reasonable scenarios, an examination of the processes of interaction that occur in the repository, and an assessment of how they affect the ability of the canister to isolate the waste from the groundwater. Furthermore, assessments are being carried out of how radionuclides could be released to the flowing groundwater if the isolation is broken. Calculations are being performed for a large number of variations.

In a similar manner, variants of the system design are being analyzed to obtain data for sizing of other engineered barriers in the near field and tunnel system. If the choice of any parameter in the design of the near field is heavily dependent on the properties of the surrounding rock, this parameter should as a rule not be determined before the necessary site-specific data are available. In such cases the limits within which data for the parameter can be permitted to vary are investigated.

Performance assessments with varying assumptions are a part of the ongoing system development and overall design of a deep repository. These assessments can in turn specify or change the premises for the further studies. The performance assessments are being conducted in parallel with further development of data sets and calculation models. R&D efforts are being focused on areas where data sets and understanding need to be broadened.

Site-specific performance assessments of the natural barriers cannot begin until candidate sites have been selected for investigation. When this has been done, performance assessments must be carried out taking into account the results of

- site characterization
- evaluation of how the site can best be utilized for a deep repository
- evaluation of the properties of the site relating to emplacement of a safe repository
- evaluation of constructability on the site.

Site characterization provides data for a geological model of the site containing important structures and characteristic data for them. Based on this structural model, the groundwater movements in the area will be modelled. The structure and groundwater conditions affect the placement of the various repository sections in the area. This in turn constitutes the foundation for continued work on site characterization.

The numerical coupling of linked calculations is done primarily with the aid of the PROPER system /6-2/. Both stochastic and deterministic calculation models will be used.

The variation analyses during this phase are gradually broadened so that they also take into account unexpected or unusual features, events or processes (FEPs) which can occur and influence the normal course of events. This provides an initial rough screening of which FEPs need to be quantified by means of more detailed calculations. These initiating FEPs then serve as the starting point for defining scenarios containing all known coupled or logically interlinked processes which are associated with the initiating event in the chosen surroundings.

A systematic review and examination of how FEPs affect the repository is a part of the performance assessments. Specific variation analyses where certain functions or barriers are disregarded in order to illustrate the isolating or retarding capacity of other barriers may be carried out even if they are not deemed to be physically possible.

The performance assessments also entail a test of the adequacy of the available databases, as well as of the feasibility of quantifying the changes of the repository sections with time via calculations. The primary choice of how different processes are to be conceptualized in calculation models is made and tested during this phase. The supporting material, which in a later phase makes it possible to check the validity of the safety assessment with regard to planned decisions, is built up by compiling uncertainty/confidence in the selected assumptions, databases and models etc. See further section 6.4 on validation. The results of the performance assessments serve as a basis for designing and executing integrated safety assessments. Completed work and results are reported in technical reports or work reports.

6.3.3 Selection of scenarios for the safety assessment

The start of a safety assessment means that the purpose of the assessment has been established, that the disposal system has been delimited in time and space, and that a general understanding exists of how the different repository parts interact and how the repository can be affected by different external events.

Based on, among other things, experience accumulated during previous performance assessments, a set of scenarios is selected that together shed light on

- the repository's probable performance during the period in question,
- natural events or less probable phenomena that could appreciably alter the performance of the repository,
- the impact of future human activities on the performance of the repository,
- errors or mistakes that can occur in the construction of the repository or the barriers and alter the performance of the repository.

As a basis for the selection of scenarios, the processes in the repository that are most essential to safety will be examined (the process system). The normal performance of the process system under expected future conditions (the normal scenario) sheds light on the probable development of the repository. A systematic examination of how different less probable and improbable external processes or events can affect the process system then provides the foundation for other scenarios.

An essential safety factor in the KBS-3 concept is the highly durable canister that isolates the canister from the groundwater. As long as it is intact, no radionuclides can be released. To judge the importance of other barriers to the total safety of the system, a specific scenario is therefore defined with such defects in fabrication that a few canisters have through holes in the copper shell, known as the scenario. So that it can be used as a central reference case, the scenario will otherwise be based on expected conditions, with certain simplifications. Variations around the scenario will be made to shed light on the importance of the simplifications made and conditions assumed.

If the performance assessments are to provide an adequate understanding for an integrated safety assessment, all important development paths must have been identified. This is checked with the aid of the methodology utilized to define the process system and how the processes are affected by changed assumptions, and with the aid of historical/geological evidence and scientific experience.

6.3.4 Integration to a safety assessment

The selection of a set of scenarios comprises the start of an integrated evaluation of the overall performance of the deep repository.

An integrated safety assessment shall, based on

- the system boundaries in time and space,
- possible connections between the subsystems of the repository system,
- data and knowledge regarding the components and their interaction,

calculate the integrated performance of the repository and its consequential impact on the surrounding environment and provide an assessment of the safety of the repository taking into account included uncertainties. The degree of detail in the assessment, as in the performance assessments, is heavily influenced by the phase during which the assessment is carried out and by the purpose of the safety assessment.

The schematic procedure for carrying out a safety assessment is illustrated in Figure 6-2.

Scenario selection entails that the relationships between the parts and constituent components of the system are examined and that developments relevant to safety are defined. Then the essential processes have to be expressed in mathematical models, and the models joined to form coupled calculation chains to quantify the safety of the system.

The choice of input data, model parameters and model interfaces is checked to ensure mutual consistency and uniformity.

As far as is possible, the calculations shall quantify the future development of the repository and be expressed in performance indexes that can be related as directly as possible to safety goals and acceptance criteria. Performance indexes can be chosen differently depending on the purpose of the assessment and the phase in which the assessment is carried out. The composite results comprise the safety-related basis for the planned decision.

During the safety assessments, the variation and uncertainty analyses that have served as a basis for the evaluation of the potential performance of the different barriers will change into sensitivity analyses, where light is shed on the dependence of the calculation results on uncertainties or changes in different system parts, barriers or parameters.

Uncertainties of various kinds can be brought into the analyses at all stages of the safety assessment. Checking of validity and adequacy is discussed in section 6.4.

The safety assessments shall be carried out and documented in a traceable fashion in accordance with an established quality assurance programme.

6.3.5 Safety report

To facilitate follow-up of how the safety assessments develop in terms of breadth and depth as the project progresses, a template for safety reporting will be established. This can also simplify both presentation and review.

An initial presentation of the report template will take place in 1995. The template is being made as a synopsis of a safety report where each section begins with a paragraph that goes through the intentions and contents of the section. In the report template, parts that are independent of specific site data and detailed design (for example the section on waste quantities and kinds, or the section on safety goals and acceptance criteria) can be presented with a degree of detail close to that required for the formal reviews. For sections with a strong coupling to the site or the planning phase, accounts from previous assessments will illustrate work methodology and questions.

The ambition is that the account, in the form of the safety report, shall illustrate available analysis methods and approaches for safety assessments.

6.4 UNCERTAINTIES / VALIDITY

6.4.1 Purpose and strategy

The purpose of the validation work is to analyze and report the validity of the assessments, i.e. how well the assessment manages to describe reality. An important part of this is to clarify the uncertainties in the assessment and to evaluate whether the assessed safety of the repository is robust and conservative with respect to its uncertainties. The handling of uncertainties and the handling of validity in a safety report are thus very closely linked and are dealt with here simultaneously.

The validation work is carried out according to a systematic plan – validation strategy – which stipulates

- what is to be validated,
- in what phases different parts of the work are planned to be done,
- how the work is to be prioritized, and
- guidelines for how validity is to be reported.

A further testing of methods and technique for quantification of uncertainties and application of these methods in performance and safety assessments will be carried out.

As the work progresses, the way in which uncertainties are handled, and the perception of their importance, will be developed. The practical application of the strategy will be concretized in the analysis work, and with regard to the international cooperation taking place within the OECD/NEA.

6.4.2 What is to be validated? and when?

Due to the fact that all steps in the assessment procedure can bring uncertainties into the safety verdict, validity checking must cover the entire procedure and in practice be woven into all safety work.

The uncertainties can be of a varying nature. Some uncertainties are very difficult to quantify, for example the risk that we have an incorrect understanding of an essential process. Other uncertainties, such as the variability in geophysical parameters for the bedrock, can have a large spatial variation which can, however, be described by statistical means. Yet other uncertainties can be quantifiable with margins of error, for example the accuracy of certain measuring instruments. Even though different uncertainties are not easy to combine, all types of uncertainty should be reported and discussed.

The phases in the work where it is suitable to check and report uncertainty/validity are presented below.

Assumptions for the assessment

All assumptions for the assessment shall be documented. The general assumptions for the deep repository are basically established. Nevertheless, quantities and types of radioactive waste, including the uncertainties, are updated prior to each safety assessment. The design of the technical systems and the characteristics of the site are updated in conjunction with the various project stages for the encapsulation plant and the deep repository and in conjunction with the site investigations, see chap. 5.

The documentation will cover

- the waste (categories and quantities),
- the engineered barriers (materials, grade and dimensions),
- the site (primary data from the site investigation and derived structural model)

In principle, the uncertainty in all data shall be discussed and, where feasible, be quantified.

In particular, "uncertainties" in the analysis results stemming from the fact that certain sizing is being kept open for future optimization or site-specific adaptation shall be identified. The freedom in the choice of such a parameter and its importance to the analysis results shall be discussed separately.

Documentation and updating of the site follows the programme for site investigations and is a prerequisite for site-specific safety assessments. The alternative interpretations of the structure of the site that exist in different phases will be reported and discussed.

Routines for quality assurance and traceability will be established prior to the start of these investigations. Documentation of assumptions, as well as changes and/or gradual narrowing-down of parameters, shall be identifiable and be filed in accordance with established instructions.

Scenarios

The chronological development of the repository is identified in scenarios. These scenarios represent both the probable development and conceivable, possible and/or hypothetical developments. Similarly, they represent both normal (expected) conditions and disturbed or abnormal conditions. The set of scenarios finally selected, as well as the systematics of how it has been arrived at, are presented in conjunction with the integrated safety assessments.

The scenarios constitute the foundation of the model calculations of consequences and probability that are to be carried out. The adequacy of this set of scenarios for the intended purpose of the assessment is discussed and documented in the safety reports.

Processes

For each scenario, the processes that have an essential influence on the performance of the repository are identified. The influence of initiating events on the process system is examined and documented. The reasons for omitted processes, or simplifications in the description of the processes, are explained.

Conceptual modelling

The choice of how the processes are to be described with mathematical models is discussed and justified.

If conceptually different models are available to describe the same process and no clear discrimination can be made, the consequences of using the different models are evaluated and reported. Calculations with different alternative models make it possible to quantify the effect of different conceptualizations.

Calculation models

The mathematical calculation models that are utilized to assess the performance of the repository after closure are identified unambiguously (with version designation and with references to source code, manual, etc.). A specific "validation document" is written for each important calculation model. The document shall contain a discussion of

- intended area of application and limitations, if any,
- fundamental theory,
- conceptualization,
- mathematical modelling, simplifications and numerical approximation, and
- background data, including initial values, model parameters and boundary conditions.

The document should also describe important experience and applications, such as

- calibration/benchmarking,
- verification,
- supporting experiments and observations, including validation tests, if any.

The above documentation is produced in connection with the development/procurement of the models or when it is utilized in the performance and safety assessments. The documentation may have to be revised prior to new safety assessments. It is

SKB's ambition to try to arrive at a consensus in these matters so that such documents can be written and utilized in international cooperation.

Databases

The databases or model parameters to be used in the safety assessments shall be clearly identified with date and reference either in the calculation model's validity document as described above or in a separate document. The document shall describe the intended area of application, possible limitations in the use of the database, the manner in which the database has been selected, and how the uncertainties have been evaluated.

Documentation is produced in connection with the establishment of the database and each time it is revised. The database shall also contain calculated and/or estimated uncertainties.

Model couplings

Parts of the calculations in the safety assessment are carried out with several models linked in calculation chains. In such cases, special allowance must be made for the fact that the data in the different models may have been collected under different conditions.

The reliability of different models and their ability to describe actual conditions (validity) must be supplemented with a check of the interfaces between the models and of the fact that they are mutually compatible as regards model structure, background data and area of applicability.

Such checks can occasion supplementary variation analyses. The reasonableness of the results and their applicability to the decision to be made are discussed, see further section 6.4.4.

6.4.3 Prioritization

Checking and reporting of validity can sometimes be carried to a very high degree of detail, often probably without significantly improved results. In the interests of efficiency in the work, the validation strategy must allow for prioritization. The fundamental principle is that efforts shall be focused on areas with inadequate validity. Beyond this, the following grounds for prioritization will be observed:

- Allocate the efforts between different scenarios according to their risk (probability x consequence) and with regard to the potential hazardousness of the waste.
- Allocate the efforts between models and parameters in a given scenario according to the sensitivity of the performance index (dose/risk) to the uncertainty in the models/parameters in calculations of probable outcomes.
- Prioritize the efforts on parameters with the greatest relative uncertainty which cannot easily be limited.

Prioritization must be done with consideration given to where the efforts are judged to be capable of yielding a reasonable return.

As a consequence of the validation work, measures may have to be taken to strengthen validity in different parts of the assessment. This can be accomplished by

- defining free parameters;
- reducing the uncertainty in the databases;
- strengthening confidence in the utilized models by means of
  - new experiments,
  - further processing of previously conducted experiments, or
  - testing of the models against natural analogues.

Conversely, a reduction of efforts can be warranted by the fact that the uncertainties that have been introduced via models and data are small in relation to the natural variability.

6.4.4 Integration of uncertainties

For integrated safety assessments, it is also necessary to combine the evaluation of the uncertainty and validity of the various parts to an evaluation of the entire assessment.

The importance of different parameter distributions and numerical uncertainty can be presented with different techniques as uncertainty in the calculation results. Similarly, the sensitivity of the result to changes in model parameters in a parameter range immediately surrounding the calculation result can be evaluated. However, these methods only deal with certain aspects of the numerical uncertainties in the calculations. For example, chosen simplifications or over-conservative assumptions in the calculations can impair the interpretation of the true implications of the uncertainties. The uncertainty can also be influenced by the existence of unidentified correlations between the parameters.

When the more essential scenarios have been analyzed, a systematic examination of the sensitivity of the results to errors in different parameters or calculation steps is most likely the most powerful method for clarifying the integrated effect of quantifiable uncertainties. The underlying data may have to be strengthened with sensitivity analyses of certain parameters in hypothetical scenarios.

Other types of uncertainties are, however, of a more philosophical nature and are difficult to quantify, for example the possibility that we do not fully understand certain phenomena. The importance of such uncertainties can be elucidated to some extent by means of modellings where some barrier is completely neglected or certain processes are assumed to take an extremely unfavourable course. For the most part, however, such uncertainties must remain qualitative and be based on a judgement of how mature the scientific field is.

In the current phase of the development of the deep repository, the foremost value of uncertainty/validity assessments is the measure that is obtained of the strengths and weaknesses of the system. It is therefore deemed important for our understanding of the performance of the repository that different kinds of uncertainties existing in underlying data do not disappear in an attempt at fully integrating the uncertainties, but are reported separately.

As noted in section 6.1, at important decision-making points SKB intends to give an account of safety and radiation protection matters for both the operating phase and the post-closure phase. The possibility of making integrated evaluations of the reliability of the assessments and building up an overall picture of radiation protection for the different facilities included in the system and over different lengths of time will be discussed.

6.4.5 Reporting of validity

Owing to the recurrent nature of the safety assessments, the reporting of the validity of different input data and modelling tools will be done in the form of separate documents (see section 6.4.2). These will be revised at the same time as data and models are revised or supplemented.

In connection with the execution of safety assessments, these documents will have to be augmented according to how the data and the tools are utilized in the integrated assessment. This account comprises a part of the safety report's account of scenarios and associated model chains. This also applies to evaluations of the degree to which the assessment meets the demands on validity warranted by the expected decisions.

6.5 TIME REQUIREMENTS

The work of producing a safety report can, as explained above, be divided into four main elements:

- Performance assessments, more or less continuously ongoing and supported by specific R&D efforts.
- Scenario selection, including definition of the goals and delimitations of the safety assessment.
- Safety assessments with calculations of the total performance of the repository, resulting effects in the surrounding environment and the sensitivity of these effects to uncertainties in the analysis.
- Reporting of results.

The need for safety assessments in SKB's programme is illustrated in the logic diagram in Figure 6-1. The time required to carry out a safety assessment, from the start of the work of defining a comprehensive set of scenarios until the final safety report is finished, can vary widely. It is affected by the purpose of the safety assessment, the degree of detail in analyses allowed by the underlying data, and the scope of previously done performance assessments.

Just over a year is judged to be necessary for the safety report prior to an application for a permit for the encapsulation plant.

The time required to compile a safety report in support of a permit application for detailed geoscientific characterization is estimated to be about 2 years, owing to the fact that the safety assessment is supposed to cover two sites. This safety assessment is carried out in two stages, where the first stage is based on preliminary or generic site data and shall serve as a basis for issuing a permit to commence construction of the encapsulation plant.

The time required for subsequent safety assessments is influenced to a high degree by the routines for review that are emerging and the issues identified in previous reviews as being essential.

7 REFERENCES

Chapter 1

1-1 SKB RD&D-Programme 92. Treatment and final disposal of nuclear waste. Programme for research, development, demonstration and other measures. Main report plus three background reports.
SKB September 1992

1-2 Act on Nuclear Activities.
SFS 1984:3. Amended SFS 1992:1536

1-3 Government Bill 1983/83:60. Ny lagstiftning på kärnenergiområdet.
(In Swedish only)

Chapter 2

2-1 Project on Alternative Systems Study (PASS). Final report.
SKB Technical Report TR 93-04, Stockholm, October 1992

Chapter 3

3-1 Act Concerning Conservation of Natural Resources.
SFS 1987:12. Amended SFS 1987:247, 1990:442, 1991:651, 1991:738, 1991:1164

3.2 SKB PLAN 94.
SKB June 1994

Chapter 4

4-1 Disposal of High Level Radioactive Waste – Consideration of Some Basic Criteria; The radiation protection and nuclear safety authorities in Denmark, Finland, Iceland, Norway and Sweden, 1993

4-2 SKIs utvärdering av SKBs FUD-program 92. Sammanfattning och slutsatser.
SKI Technical Report 93:13, March 1993

4-3 Kortfattad preliminär anläggningsbeskrivning. S Pettersson, C Svemar.
AR 44-93-008, SKB, November 1993

4-4 Preliminär beskrivning av miljökonsekvenserna av ett djupförvar för använt kärnbränsle och annat långlivat avfall.
SKB, 1994 (in progress)

4-5 Transportsystem för avfall och bulkmaterial till djupförvar. P Lindeman, Saltech.
TPM 93-4471-01, SKB, November 1993

4-6 Förstudie Storuman. Sammanfattning av hittills utfört arbete.
PR 44-94-025, SKB, June 1994

Chapter 5

5-1 See 4-1

5-2 See 2-1

5-3 The application of high power non-vacuum EB welding for encapsulation of nuclear waste at reduced pressure. – Summary Report.
Inkapsling, PR 94-01, SKB, January 1994

Chapter 6

6-1 See 4-1

6-2 PROPER MONITOR USERs MANUAL, Version 3.1.
SKB, Stockholm, 1993

GENERAL STUDIES AND SKB'S GEOGRAPHIC INFORMATION SYSTEM – BRIEF SITUATION REPORT

The purposes of the investigations and compilations being performed in the general studies are to:

- In a general fashion (on a national scale), shed light on conditions of interest for determining which parts of the country are unsuitable, interesting or suitable for siting a deep repository.
- Yield data for determining SKB's interest in feasibility studies in different regions or municipalities.
- Provide indications of what must particularly be taken into account and studied in connection with continued more detailed studies within suitable or particularly interesting areas.
- Yield data for putting coming site selection in its national and regional context.

For the above purposes, SKB compiles geoscientific and socio-economic data and conditions in a nationwide database. These data can be handled, summarized and presented in a geographic information system – GIS. A large number of general studies of a geoscientific character have previously been carried out. In the following, a brief overview of the contents of SKB's database is given, along with an idea of previously conducted and ongoing general studies. A collective account of the results of the general studies is planned for 1995.

Geographic Information System (GIS)

There is a need in the siting work to be able to retrieve and present prevailing conditions quickly and clearly. This requires access to geographic (often cartographic) information on geology, natural resources, land use, land ownership, infrastructure etc. To enable any kind of concrete work to be done, this type of information must first be made accessible. This can be a problem, as the information is often kept in various archives, often has a varying format, seldom has the desired coverage and is of varying resolution, age and quality.

Geographic thematic information is handled by SKB in its own Geographic Information System (GIS). This is a computer-based aid and tool for handling geographic information. It is used and will be used by SKB on various scales during the siting work for storage, presentation and analysis of such data. Table A-1 provides a list of commercially available information that has been acquired for SKB's GIS.

GIS provides tools that permit analysis and presentation of conditions for siting of the deep repository. However, high demands are made on checking of basic data and structuring of the analysis work.

GIS processing does not necessarily mean that entire analyses have to be run in GIS. A useful method is to have GIS process well defined questions and then link them together with results from manual analysis activities. In this way, the human ability to critically control and validate an analysis is combined with GIS' capacity to uncritically perform large and comprehensive processing runs.

Table A-1. Information layers in SKB's GIS. (Local databases that have been entered into GIS in conjunction with the feasibility studies are not included in the list.)

Nationwide GIS databases

INFRASTRUCTURE
Urban areas
Administrative limits
Plan details
Power lines
Shooting range
Environmentally hazardous activity
Churches

PHYSICAL GEOGRAPHY DATA
Coast
Islands
Lakes
Watercourses

GEOLOGICAL DATA
Bedrock geology
Soil types
Mining and mineral rights
Industrial minerals and rock types
Marine limit and dammed ice lakes
Bedrock and tectonics of the continental shelf
Earthquakes
Ore deposits
Crystalline rock provinces and sedimentary bedrock
Major lineaments
Major deformation zones
Current land uplift

HYDROGEOLOGICAL DATA
Groundwater resources in soil
Groundwater resources in rock
SGU's well archive

CHEMICAL DATA
Groundwater composition – chloride and pH
Soil geochemistry
Glacial till geochemistry

PHYSICAL DATA
Aeromagnetic data
Gravitational data

NATURAL RESOURCE DATA
Nature conservation areas of national interest
Outdoor recreation areas of national interest
Wetland areas, protected
Wetland areas, unprotected
CW areas
Virgin forest areas
National park plan
Physical geography regions
National parks
Nature reserves
Nature conservation areas
Animal sanctuaries
Natural monuments
Natural landmarks
Forest service reserves
Private reserves

LAND USE DATA
Land use and type of ownership

SOCIO-ECONOMIC DATA
Population statistics

LANDOWNER DATA
Large landowners in Sweden

TRANSPORT DATA
Roads – red map
Railways – red map

COAST DEVELOPMENT DATA
Marine limit
Baltic Ice Lake
Ancylus Lake
Littorina Sea
Yoldia Sea

ALTITUDE DATA
Altitude data, 500 metres

Examples of information layers

To illustrate what SKB's GIS database contains, Figures A-1 to A-4 show some examples of information layers pertaining to geological and societal siting factors. A brief description is given for the different information layers, including their importance for siting a deep repository.

Presence of sedimentary bedrock

Sedimentary superimposed or overthrust rock types are found in Skåne, Öland and Gotland, some areas in Närke, Västergötland and Östergötland, and the Swedish mountain range. These areas are not of interest for siting of a deep repository at the present time.

The reason is that the Swedish programme and repository concept is oriented towards siting a repository in an area where the crystalline rock is exposed on the surface or is covered by a thin layer of soil. Various investigation methods have been devised over a long period of time to identify and investigate geological structures in such an environment.

As pointed out by the former National Board for Spent Nuclear Fuel in its review of R&D-Programme 89, the repository could be sited in crystalline rock under areas covered by sedimentary rock deposits that are not too thick.

Such a siting might have both advantages and disadvantages. Since crystalline rock areas without sedimentary cover are deemed to be capable of providing adequate safety, there is no reason to actively seek out sediment-covered areas as repository sites.

However, if opportunities present themselves during the course of the siting work for studies of sites with good prospects in sediment-covered crystalline rock, SKB does not exclude such an alternative.

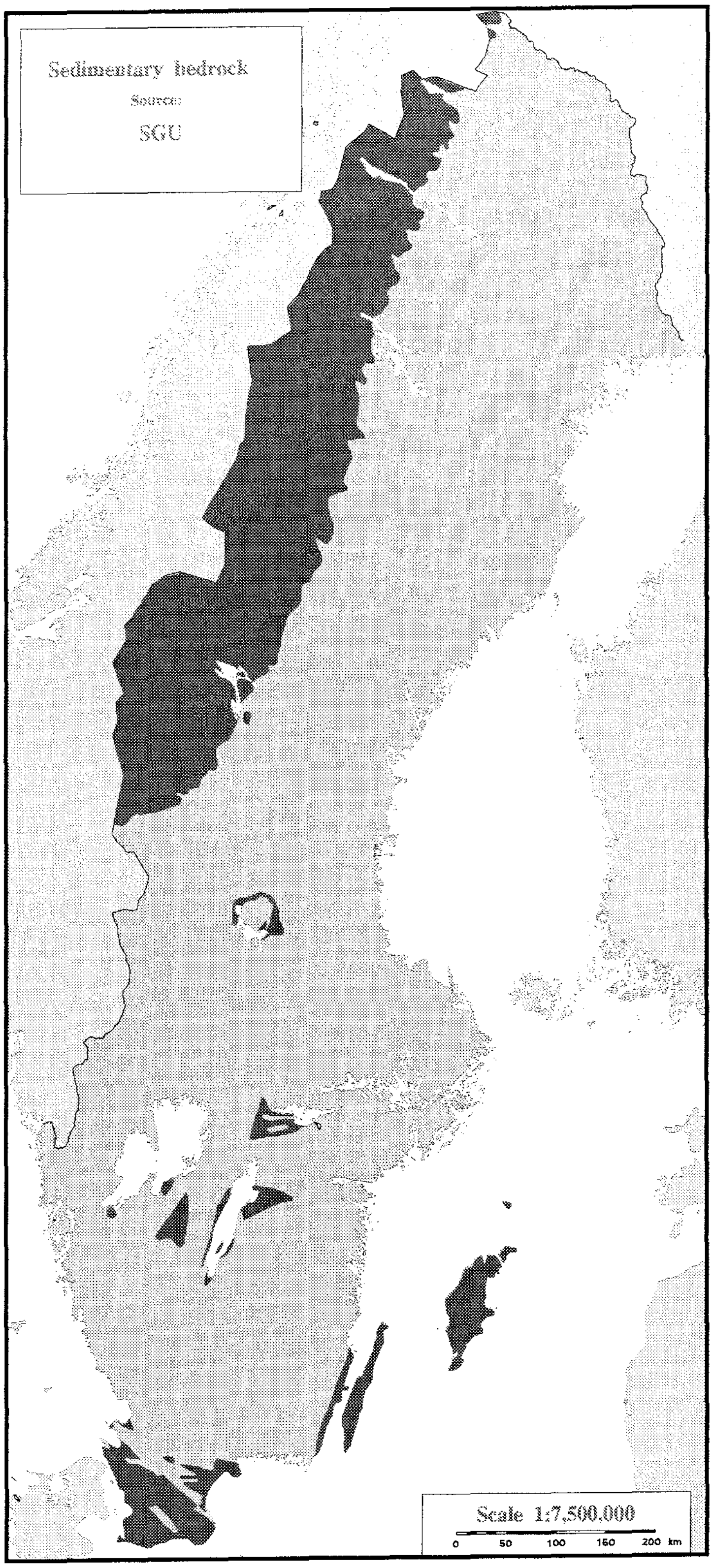

Figure A-1. Areas with sedimentary bedrock including mountain range.

Presence of large fracture zones

Swedish crystalline rock is penetrated by large fracture zones. These zones form networks that could be reactivated under new stresses in a geological time perspective. They are found on all scales from local, with a length of a few hundred metres, to regional, with a length of 500 km or more.

Mapping of fracture zones is carried out on different scales during all phases of the siting work. Figure A-2 shows a map where two information layers in SKB's GIS database have been juxtaposed. The information has been interpreted by the Geological Survey of Sweden (SGU).

The first information layer consists of major deformation zones where extensive rock movements have occurred during geological history. The second information layer consists of a compilation of topographically visible lineaments, 30 km or longer, based on the Central Office of the National Land Survey's relief map of Sweden. Experience shows that pronounced lineaments indicate fracture zones in the underlying bedrock.

The fact that certain areas on the map have few lineaments / deformation zones may be a result of interpretation difficulties due to thick soil layers or the absence of modern geological mapping.

Aside from the fact that fracture zones constitute mechanical planes of weakness in the bedrock, they can be hydraulically conductive and constitute discharge areas for groundwater. For these reasons, the repository should not be sited in direct connection with such zones.

Figure A-2. Major lineaments and deformation zones in Swedish crystalline rock.

Presence of valuable minerals

Valuable minerals or other natural resources associated with the bedrock vary between different parts of the country. Figure A-3 shows a map produced by SGU, Swedish Geological Survey, of ore deposits in Sweden. The map includes mines that have been in operation during the past 80 years and known reserves and deposits not exploited. Altogether the material includes 451 deposits (the map does not show all deposits in ore-rich areas).

SKB's GIS database also contains all of Sweden's exploration and processing concessions (claims and staked claims in a concession), which gives a somewhat fuller picture of where prospecting interest exists in the country. The database also contains deposits of industrial minerals and rock types.

Areas with potential for future mining should be avoided when siting a deep repository. This is mainly because of the risk of future inadvertent intrusion in the repository when searching for ore. The map indicates where this factor must particularly be taken into account. However, the bedrock is so heterogeneous that ore-free bedrock can only be distinguished from potentially ore-containing bedrock by studies on a regional or local scale.

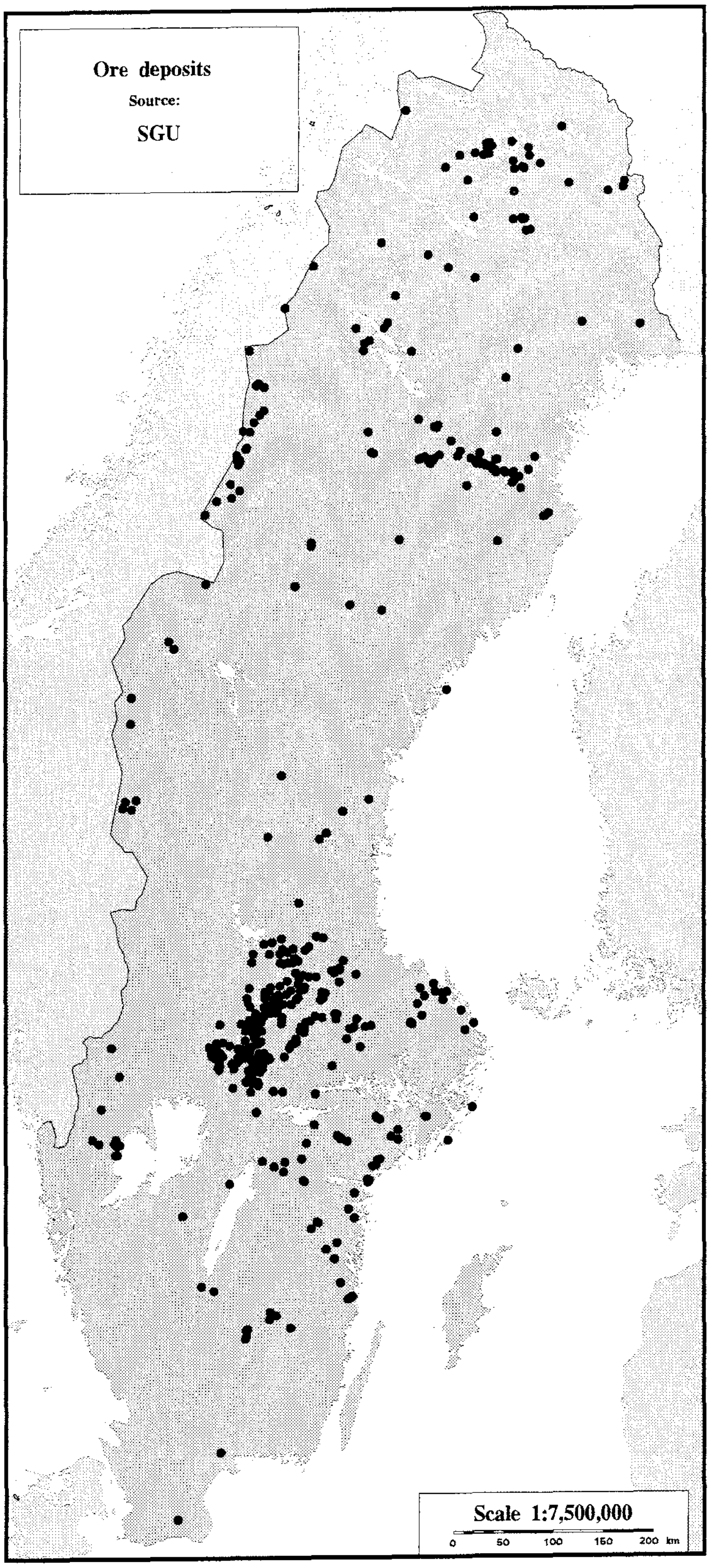

Figure A-3. *Known ore deposits in Sweden.*

Presence of nature conservation areas

Approximately 6% of all land in Sweden has been set aside as nature conservation areas, Figure A-4. No exploitation may take place within these areas. If all areas currently considered to be of national interest for nature conservation are included, they cover nearly 22% of Sweden's surface area. Even though it is possible to obtain exploitation permits in many of the latter areas, special reasons must exist if the deep repository is to be sited there. This also applies to typical agricultural areas.

The Act Concerning the Management of Natural Resources mentions certain limited coastal, mountain and river areas where direct guidelines are given for land use that must be observed when siting a deep repository.

In studies on a more local scale, the counties' nature conservation plans and the municipalities' comprehensive plans will be important. The latter present plans for land and water use, building development and where areas of national interest are situated within the boundaries of the municipality.

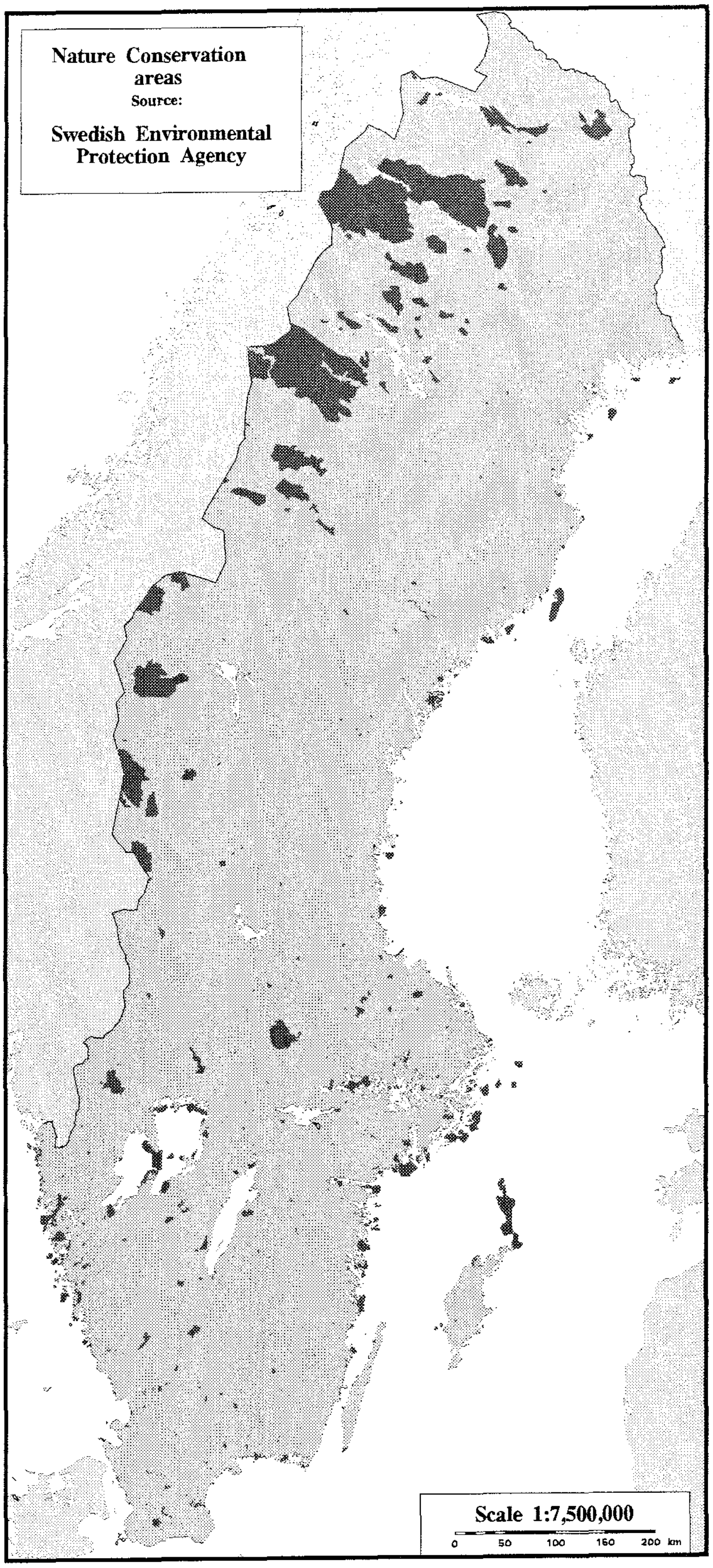

Figure A-4. Nature conservation areas.

Examples of geological general studies

In the general studies, a comprehensive body of background material is compiled on geological and societal conditions that can be of interest in connection with siting of a deep repository. Some of the material consists of studies and analyses of different geoscientific questions. These studies have been published continuously as a part of the research and development work which SKB has been conducting since the late 1970s. Examples of such background material included in the general studies are listed in Table A-2.

Table A-2. Examples of background material included in the general studies. (Reports with Swedish titles are available in Swedish only.)

Report	Comments
The gravity field in Fennoscandia and postglacial crustal movements. KBS TR 17, 1977 A Bjerhammar	The report deals with tectonic and isostatic movements based on gravimetric measurements.
Studies of neotectonic activities in central and northern Sweden, review of aerial photos and geophysical interpretation of recent faults. KBS TR 19, 1977 R Lagerbäck, H Henkel	The report deals with postglacial structures and reactivation in a regional perspective.
Tectonic analysis of southern Sweden, Lake Vättern – Northern Skåne. KBS TR 20, 1977 K Röshoff, E Lagerlund	The report deals with lineament interpretations and neotectonics within the region.
Earthquakes of Sweden 1891–1957, 1963 –1972. KBS TR 21, 1977 O Kulhànek, R Wahlström	The report deals with seismic data in a national perspective.
The Blekinge coastal gneiss, Geology and hydrogeology. KBS TR 25, 1977 I Larsson et al.	The report deals with structure-geological units and their relation to groundwater occurrence for the region.
Seismotectonic risk modelling for nuclear waste disposal in the Swedish bedrock. KBS TR 51, 1977 F Ringdal et al.	The report deals with general geotectonic risks related to earthquakes and creep movements in Sweden.

Report	Comments
Stress measurements in Scandinavian bedrock – premises, results and interpretation. KBS TR 64, 1977 S G A Bergman	Rock stress measurements in a three-dimensional perspective are discussed.
Groundwater chemistry at depth in granites and gneisses. KBS TR 88, 1978 G Jacks	The report deals in general terms with groundwater chemistry in Swedish crystalline rock.
Hydrochemical investigations in crystalline bedrock in relation to existing hydraulic conditions. Experience from the SKB test sites in Sweden. SKB TR 85-11, 1985 J Smellie et al.	The report is a compilation of the comprehensive hydrochemical work carried out on SKB's study sites during the period 1982-1984.
A preliminary structural analysis of the pattern of post-glacial fault in northern Sweden. SKB TR 86-20, 1986 C Talbot	The report deals with the kinetics of postglacial faults.
Geological maps and cross-sections of Southern Sweden. SKB TR 87-24, 1987 K-A Kornfält et al.	Compilation of regional map material.
Earthquake measurements in southern Sweden, Oct 1, 1986 – Mar 31, 1987. SKB TR 87-27, 1987 R Slunga et al.	Regional compilation of earthquakes.
Swedish hard rock laboratory first evaluation of preinvestigations 1986-87 and target area characterization. SKB TR 88-16, 1988 G Gustafson et al.	Compilation of geoscientific premises for the Äspö project in a regional perspective.
Characterization of the morphology, basement rock and tectonics in Sweden. SKB TR 89-03, 1989 K Röshoff	Compilation of morphological terrain types in Sweden.

Report	Comments
Earthquake mechanisms in Northern Sweden Oct 1987 – Apr 1988. SKB TR 89-28, 1989 R Slunga	Regional compilation of earthquakes.
Interdisciplinary study of post-glacial faulting in the Lansjärv area Northern Sweden 1986 – 1988. SKB TR 89-31 G Bäckbom et al.	Summary of studies in the Lansjärv region.
Characterization of humic substances from deep groundwaters in granitic bedrock in Sweden. SKB TR 90-29, 1990 C Pettersson et al.	The report deals with the presence of fulvic acids in groundwaters from a number of study sites in Sweden.
The earthquakes of the Baltic Shield. SKB TR 90-30, 1990 R Slunga	Analysis of 200 earthquakes, ML 0.6-4.5, with emphasis on depth of focus, of focus dynamic outcrop parameters and fault plane.
SKB/TVO Ice age scenario. SKB TR 91-32, 1991 K Ahlbom et al.	Scope of hypothetical future glaciations.
Gideå study site. Scope of activities and main results. SKB TR 91-51, 1991. K Ahlbom et al.	Main report on Gideå study site.
Fjällveden study site. Scope of activities and main results. SKB TR 91-52, 1991 K Ahlbom et al.	Main report on Fjällveden study site.
Sternö study site. Scope of activities and main results. SKB TR 92-02, 1992 K Ahlbom et al.	Main report on Sternö study site.
Kamlunge study site. Scope of activities and main results. SKB TR 92-15, 1992 K Ahlbom et al.	Main report on Kamlunge study site.

Report	Comments
The Protogine Zone. Geology and mobility during the last 1.5 Ga. SKB TR 92-21, 1992 P Andreasson et al.	The report summarizes the Protogine Zone's geological and geophysical functions.
Klipperås study site. Scope of activities and main results. SKB TR 92-22, 1992 K Ahlbom et al.	Main report on Klipperås study site.
Bedrock stability in Southeastern Sweden. Evidence from fracturing in the Ordovician limestones of Northern Öland. SKB TR 92-23, 1992 A G Milnes & D Gee	Regional stability in the bedrock is reported on the basis of a fracture mapping.
Geologiska miljöer och faktorer sett i olika skalor att beakta vid planering av ett slutförvar för använt kärnbränsle. (In Swedish) SKB PR 44-92-101, 1992 Å Brunn et al.	The report includes nationwide maps of crystalline rock provinces, ore deposits, active mining and mineral rights, lineament interpretation and major deformation zones.
Gabbro as a host rock for a nuclear waste repository. SKB TR 92-25, 1992 K Ahlbom et al.	The report describes the location of gabbro formations in Sweden and the advantages and disadvantages of siting a deep repository in basic rock.
The Äspö Hard Rock Laboratory: Final evaluation of the hydrogeochemical pre-investigations in relation to existing geologic and hydraulic conditions. SKB TR 92-31, 1992 J Smellie & M Laaksoharju	The report compiles and interprets all hydrochemical analyses in the introductory phase of the Äspö project.
Finnsjön study site. Scope of activities and main results. SKB TR 92-33, 1992 K Ahlbom et al.	Main report on the Finnsjön study site.
Climatic changes and uplift patterns – past, present and future. SKB TR 92-38, 1992 S Björk & N-O Svensson	The report describes the climate changes of the past 2.5 million years and their effects in a global and Scandinavian perspective.

Report	Comments
Post-glacial faulting in the Lansjärv area, Northern Sweden. SKB TR 93-11, 1993 R Stanfors et al. participation.	The report summarizes the second programme phase in the Lansjärv project, including comments from the 1991 excursion with international
A review of the seismotectonics of Sweden. SKB TR 93-13, 1993 R Muir Wood	The report deals with seismological aspects of tectonics in the Baltic Shield in a historical perspective.
Simulation of the European ice sheet through the last glacial cycle and prediction of future glaciation. SKB TR 93-14, 1993 G S Boulton & A Payne	The report presents the results and the structure of a coupled, time-dependent glaciation model which allows simulation of hydrogeological, thermal and rock-mechanical regional effects.
Tectonic regimes in the Baltic Shield during the last 1200 Ma – A review. SKB TR 94-05, 1994 S-Å Larsson & E-L Tullborg	The report summarizes the geological history of Scandinavia with an emphasis on plate tectonic movements and probable rock stress directions.
A reconstruction of the tectonic history of Fennoscandia based on observations at the boundary areas. SKB TR 94-XX, 1994 (in draft form) R Muir Wood	The report deals with the past 100 million years in detail based on geophysical interpretations in the sedimentary basins surrounding the Baltic Shield. The interpretation is based on the large body of material from oil and gas prospecting that exists mainly in the North Sea.
Databas för bergspänningsmätningar. (In Swedish). SKB AR (in progress), 1994 C Ljunggren	An updated compilation of all available rock stress measurements in Sweden.
Sammanställning av jordbävningar och undersökning av fokaldjup. (In Swedish) SKB AR (in progress), 1994 R Wahlström	Databases in GIS format including reporting. The report deals with all available data in Fennoscandia. Special emphasis on superficial earthquakes.
Storumans kommun i ett regional-geologiskt sammanhang. (In Swedish) SKB PR 44-94-003, 1994 T Eliasson & T Lundqvist	The report is part of the background material for the feasibility study of Storuman.

Report	Comments
Tectonic framework of the Hanö Bay area, southern Baltic Sea SKB TR 94-09, 1994 K O Wannäs, T Flodén	The bedrock tectonics of Hanö Bay have been interpreted via seismic reflection methods.

PUBLISHED REPORTS FROM THE STORUMAN FEASIBILITY STUDY

(All in Swedish only)

Published	Title
Report describing the scope and organization of the feasibility study	
Oct -93	Organisation och arbetsplan samt geografisk avgränsning, K Ahlbom, SKB (PR 44-93-008)
Reports describing the geoscientific situation in the municipality	
Dec -93	Beskrivning till jordartskarta över Storumanområdet, K Johansson, G Ransed och L Rodhe, SGU (PR 44-94-004)
Jan -94	Storumans kommun, geohydrologisk beskrivning, G Nyberg, S Jönsson, Geosigma AB (PR 44-94-005)
Feb -94	Storumans kommun i ett regionalgeologiskt sammanhang, T Eliasson, T Lundqvist, SGU (PR 44-94-003)
Feb -94	Juktans pumpkraftverk. Sammanställning av geologisk och hydrologisk information, K-L Axelsson, L Hansen, T Olsson, Golder Associates AB (PR 44-94-007)
Feb -94	Malmer och mineral inom Storumans kommun, H Lindroos, Mirab AB (PR 44-94-008)
Apr -94	Vattenkemiska förhållanden, R Jönsson, V Nõmtak, VBB/VIAK (PR 44-94-006)
Apr -94	Beskrivning till berggrundskarta över urberget i Storumans kommun, H Lindroos, Mirab AB (PR 44-94-009)
Apr -94	Geofysisk dokumentation och tolkning, H Isaksson, R Johansson, GeoVista AB och SGU (PR 44-94-010)
Apr -94	Bergbyggnadstekniska erfarenheter i regionalt och lokalt perspektiv, B Leijon, Conterra AB (PR 44-94-011)

Published	Title

Report describing the societal situation in the municipality

June -94	Samhällsplanering och markanvändning, E Setzman, Vattenfall Energisystem AB (PR 44-94-016). (Under tryckning).

Report describing the environmental consequences of a deep repository in the municipality

June -94	Miljöaspekter på förläggning av ett djupförvar för använt kärnbränsle och annat långlivat avfall i Storumans kommun, N Kjellbert och S Johansson, SKB och ÅF-Energikonsult AB (PR 44-94-017). (Under tryckning).

Report describing possible means and routes of transportation to the municipality of Storuman

June -94	Transportmöjligheter till ett djupförvar i Storumans kommun, P Lindemalm, Saltech AB (PR 44-94-012). (Under tryckning).

Report describing possible facility design and manpower during construction and operation of a deep repository

Nov -93	Kortfattad preliminär anläggningsbeskrivning, S Pettersson, C Svemar, SKB (AR 44-93-008)

Reports discussing socio-economic consequences of a deep repository in the municipality of Storuman

Feb -94	Turism och kärnavfall i Storumans kommun, Christina Olsson, Handelshögskolan i Umeå (PR 44-94-013)
May -94	Socioekonomiska konsekvenser av ett djupförvar för använt kärnbränsle i Storumans kommun, Einar Holm (red), Umeå Universitet (PR 44-94-019)
May -94	Storuman inför tusenårsskiftet – ett omvärldsperspektiv, C Fredriksson, EuroFutures AB (PR 44-94-020)
May -94	Referenser från större anläggningsprojekt, L Welander, Vattenfall Energisystem AB (PR 44-94-021)

Published	Title
	Report summarizing all investigations through June 1994
June-94	Lägesrapport. Sammanfattning av hittills utfört arbete. SKB (PR 44-94-025)

COLLABORATION AND INFORMATION RELATING TO THE FEASIBILITY STUDY IN STORUMAN

(October 1992 – August 1994)

Time	Activity
October 1992	• Letter from SKB with general information on RD&D-Programme 92 and the siting work to all municipalities in Sweden.
November 1992	• Storuman municipality contacts SKB, which leads to an information meeting with the Municipal Executive Board's working committee.
January 1993	• Study trip to SFR and CLAB. Participants from political parties, various organizations and associations. • Political parties are informed.
February 1993	• SKB's exhibition trailer spends a week visiting the municipality (approx. 700 visitors). • Information meeting for the Municipal Council. • Information to the County Council.
March-April 1993	• Representative from SKB is on hand at the municipal office in Storuman and in Tärnaby one day a week.
March 1993	• Approx. 10 evening meetings with local associations. • Toll-free telephone line (020 number) installed.
April 1993	• The question of whether to invite SKB to carry out a feasibility study is tabled in the Municipal Council. • Debate on national radio.
May-June 1993	• Information meetings are held at five different locations in the municipality, SSI and SKI participate (approx. 80 people participated). • The Inland Fair — SKB's stand is visited by approx. 600 people.
May 1993	• Information to the 10-municipality group in Västerbotten County (all inland municipalities in the county).
June 1993	• Decision by Municipal Council on feasibility study. • Sigyn visits 3 Norrland ports – 13,700 visitors.

Time	Activity
September 1993	• Reference group established by municipality. • Feasibility study's investigative work begins. • Hiring of person to head local office.
October 1993	• Reference group meeting. • Local office established. • Association meetings.
November 1993	• Open house at the local office. • Letter to the transit municipalities regarding transports. • Mailing to all households with general information on the feasibility study and its structure.
December 1993	• Reference group meeting. • Association meetings. • Information to the Environmental Office, the Fire Protection Office and the Department of Real Estate, Streets and Traffic in Umeå Municipality.
January 1994	• Reference group's study trip to SFR and CLAB. • Association meetings. • Information to the Municipal Executive Board in Skellefteå. • Public evening meeting on the transports in Skelleftehamn (SKB, SKI, SSI and Greenpeace participated). • Information to the Environmental Office, the Department of Real Estate, Streets and Traffic and the Rescue Service in Skellefteå Municipality.
February 1994	• Seminar on "Radiation and radiation protection" (Representatives from SSI and Vattenfall). The reference group during the day, the public in the evening (110 participants). • The Field Biologists in the region are informed. • Association meetings in certain neighbouring municipalities.
March 1994	• School information. • Municipal Executive Board and Municipal Council – letters concerning the debate on the feasibility study. • Debate programme on regional television – "Radiant times". • Geoscience Day with Open House at the local office. • Panel debate held in the town. Attended by about 300 people. • Folk high school is informed. • Reference group meeting. • Information to Municipal Executive Board in Umeå.

Time	Activity
April 1994	• Seminar on encapsulation, encapsulation plant and transportation. Reference group during the day, public in the evening. • 10-municipality group is informed. • AMU (county employment training commission) receives information. • Association of Local Authorities is informed during a trip to Tärnaby.
May 1994	• Mailing to all households including situation report. • Participation in seminar arranged by the association Young and Proud and the Municipality of Storuman. • Seminar on geoscientific matters for the reference group and the public. • Health Care Fair in Umeå. SKB participates with exhibition. • Inland Fair in Vilhelmina. SKB participates with exhibition.
June 1994	• Seminar on socio-economic consequences for the reference group and the public. • Presentation of summary situation report to Municipal Council. • Reference group meeting. • Mailing to all households with summary of results of all investigations. • Sigyn tour to five Norrland ports.
August 1994	• Reference group meeting. • Presentation of summary situation report to invited representatives of the municipalities in the county. (Arranged by the Association of Local Authorities.)

Opinion formation has been intensive ever since the municipality contacted SKB to discuss a feasibility study. The debate has been reflected in the regional media in special reports, news items, debate articles and letters to the editor. The national media have also had some coverage of the issue. All in all, some 1,000 media items on the subject have been run during the period from January 1994 to June 1994.