Technical Report

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Feasibility Studies – Östhammar, Nyköping, Oskarshamn, Tierp, Hultsfred and Älvkarleby

Summary Report

Svensk Kärnbränslehantering AB

June 2001

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Preface

Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company), SKB, has carried out feasibility studies on a municipal scale as a part of the siting programme for the deep repository for spent nuclear fuel. Final reports describing the results of the six feasibility studies in Östhammar, Nyköping, Oskarshamn, Tierp, Älvkarleby and Hultsfred were submitted during the autumn and winter of 2000/2001. With this as a basis, the siting work can now proceed to the next phase – site investigations. In this stage, investigations that include test drilling will be conducted on at least two sites.

In December 2000, SKB published the report "Integrated account of method, site selection and programme prior to the site investigation phase," in which SKB stipulates where they want to conduct site investigations and how they will be carried out. The report is being reviewed by the Swedish Nuclear Power Inspectorate during the first half of 2001. Before the site investigations can be initiated, the go-ahead is required from the national safety authorities, the Government, and concerned municipalities and landowners. SKB projects that the it will be possible to commence the site investigations in 2002.

This report comprises an English summary of the final reports from the six feasibility studies. The report summarizes the most important results and conclusions from the different feasibility studies. All six final reports are available in their entirety in Swedish.

Contents

1 Introduction

A deep repository is planned to be built at a depth of around 500 metres in the bedrock as a part of the Swedish system for management of radioactive waste. A total of approximately 4,000 canisters of spent nuclear fuel will be emplaced in the repository, surrounded by a number of barriers designed to prevent the escape of radioactivity. The siting work for the deep repository is a step-by-step process that mainly comprises general siting studies, feasibility studies in 5–10 municipalities and at least two site investigations. Once a site has been selected for the deep repository, detailed characterization will be performed on the site and construction of the repository will be commenced. In conjunction with initial operation, when approximately 10% of the canisters are deposited, an evaluation will be performed. If the outcome of this evaluation is favourable, the rest of the canisters will be deposited, after which the repository can be closed and sealed. Siting, construction, operation and closure of the deep repository are expected to take on the order of 50 years.

1.1 Waste system

The deep disposal concept and its implementation conform to the fundamental ethical principles formulated by KASAM (Swedish National Council for Nuclear Waste) back in 1987 /1-1/: "*A final repository should be designed so that it makes inspection and intervention unnecessary, but not impossible.*" These ethical values are well in line with the values that have guided the development of the system SKB plans for management and disposal of the Swedish nuclear waste. In the current Swedish and international debate regarding the ethical aspects of the nuclear waste issue, attention has been focused on the question of how an equitable distribution of risks, burdens and resources can be achieved between the generation active now and future generations. SKB's stance is that today's generation should not expose future generations to greater risks than we would accept ourselves. The generation that enjoys the benefits of the nuclear power also bears full responsibility for creating a disposal system that is safe in both the short and the long term.

It is therefore urgent that we take action today – when the knowledge, technology and resources are available – to comply with the requirement in the Nuclear Activities Act stating: "*The holder of a licence for nuclear activities shall be responsible for ensuring that all measures are taken that are required for ensuring the safe handling and final storage of nuclear waste arising in the activities.*" The obligation to future generations also entails that we may not take action today which blocks future possibilities that may be created by new knowledge and technological progress. Freedom of action is therefore as important a legacy to leave to future generations as reduced burdens and risks. SKB's strategy for solving the nuclear waste problem in accordance with the above principle is to design and build a repository, based on present-day know-how and technology, which offers such a level of radiological safety that neither man nor the environment will be harmed, now or in the future. At the same time the deep repository must be designed to permit retrieval of the waste, giving future generations the option of using possible future technology to render the waste harmless or use it as a resource.

SKB's main strategy is that the spent fuel will be encapsulated and then disposed of in a deep repository at a depth of approximately 500 metres in accordance with the so-called KBS-3 method. This main strategy has been accepted by the safety authorities and the

Government. Continuous work is also under way on alternative disposal concepts /1-2/, and even though the feasibility study describes conditions of importance for a KBS-3 repository, the results are for the most part also applicable in an assessment of the siting prospects for other types of rock repositories. It can also be mentioned that some form of final disposal will be needed even if a method such as transmutation should become reality. The work with the deep repository will therefore be essential even with such a technology.

Figure 1-1 shows an overview of the different components in the Swedish system for management of radioactive waste. The radioactive waste from the nuclear power programme varies in both form and activity content, ranging from virtually inactive trash to highly radioactive spent nuclear fuel.

Different waste types require different management, and the design of the system is based on the following basic principles:

- Short-lived waste is disposed of as soon as possible after arising.
- Spent fuel is kept in an interim storage facility for about 30 years before being encapsulated and emplaced in a deep repository.
- Long-lived LILW (low- and intermediate-level waste) is emplaced in a special disposal chamber, which may be situated adjacent to the deep repository for spent nuclear fuel or elsewhere.

The most recent calculations of the quantities of different waste types produced in the Swedish nuclear power programme assume 25 or 40 years of operation of all twelve nuclear power reactors /1-3/. Based on these calculations, the number of spent fuel canisters will be about 4,000 (about 3,100 for 25 years of operation, about 4,500 for 40 years). However, the twelve reactors may have different operating lives. After the three-party agreement on the phase-out of nuclear power, it may be reasonable to assume that some reactors will be operated for a longer time than until 2010 (the previously phase-out deadline), while others will be shut down earlier.

The quantity of long-lived LILW is estimated at about 25,000 cubic metres, and the quantity of operational and decommissioning waste at about 220,000 cubic metres.

The management system as it looks today (see Figure 1-1) is the result of gradual development and expansion over a twenty-year period. In simplified terms, the division of roles has been (and is) that the nuclear power industry – through SKB (Swedish Nuclear Fuel and Waste Management Company) – is responsible for and carries out the work, the regulatory authorities review and oversee, while the Government issues key decisions and guidelines. This role division has been established by the Riksdag (the Swedish Parliament) in the Nuclear Activities Act.

Two waste facilities have been put into operation. The Final Repository for Radioactive Operational Waste (SFR) is situated beneath the seabed outside the Forsmark Nuclear Power Plant in Uppland County, north of Stockholm. Short-lived low- and intermediate-level operational waste from the NPPs is disposed of here, along with waste from hospitals, research and industry, and in a later stage decommissioning waste from the decommissioning of the NPPs. The spent fuel is taken from the nuclear power plants to the Central Interim Storage Facility for Spent Nuclear Fuel (CLAB) situated at the Oskarshamn NPP. During the approximately 30 years the spent fuel is stored in CLAB's water pools, its activity content declines by about 90%. Both SFR and CLAB are built in the bedrock.

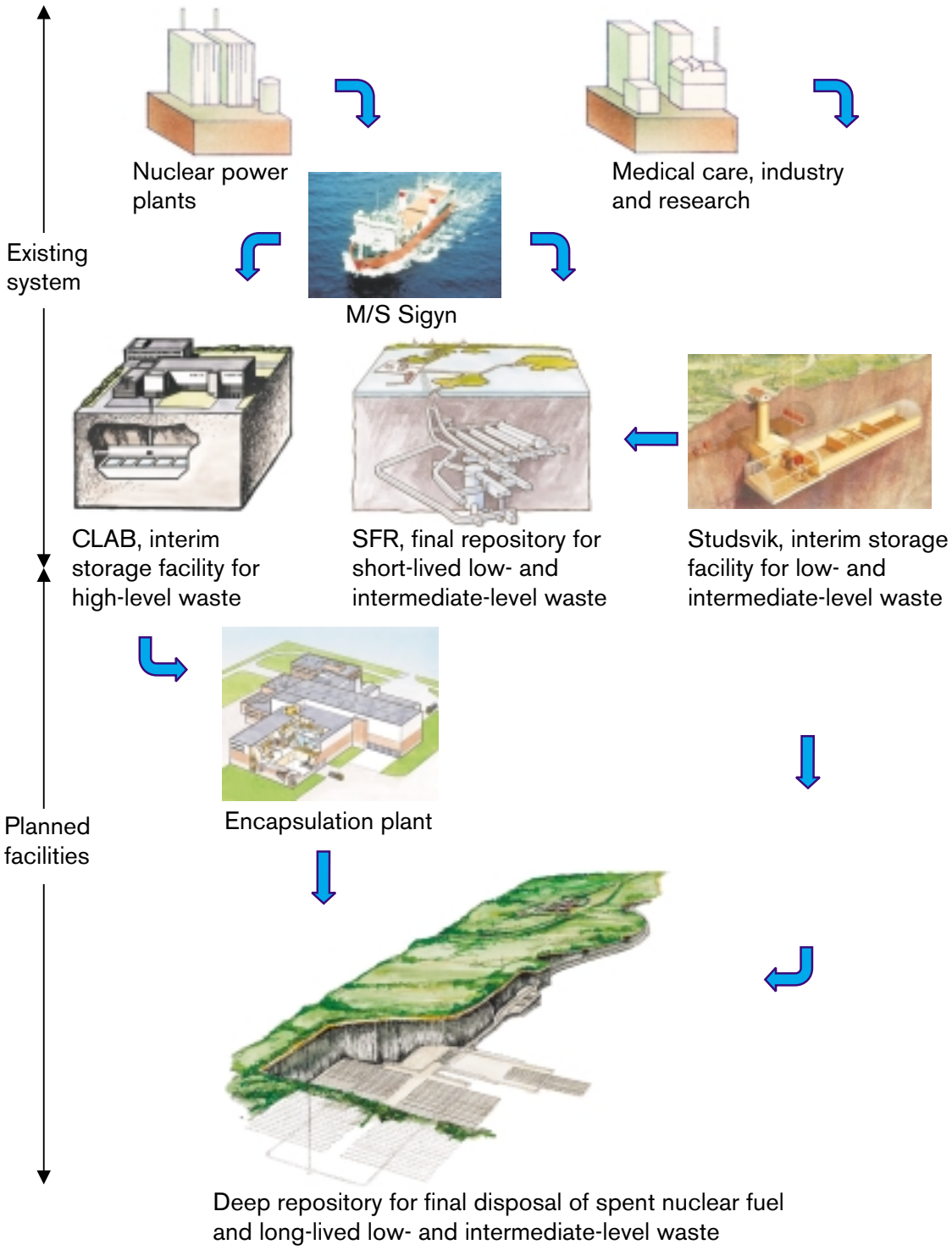

Figure 1-1. *Facilities in the Swedish waste management system.*

In addition to these facilities, a transportation system has been developed and put into service for transportation of the different waste types from the NPPs and Studsvik to the waste facilities.

The following facilities remain to be built before the system planned by SKB is complete:

- An encapsulation plant for spent nuclear fuel.
- A deep repository for encapsulated spent fuel.
- A final repository for long-lived LILW.

The following also remains to be done: Modification of the transportation system for shipments to the deep repository, construction of a factory for canister fabrication, certain additions to SFR and the ongoing expansion of CLAB.

In accordance with the main alternative, the encapsulation plant will be built directly adjacent to CLAB. Design and development work is currently under way, including testing of methods for canister fabrication. The Canister Laboratory in Oskarshamn is a centre for development of encapsulation technology and training of personnel for the encapsulation plant.

The siting process for the deep repository for spent nuclear fuel is under way and is described in section 1.4. The development and design work for the deep repository has been under way for a long time.

According to the plans, long-lived LILW will be disposed of at a depth of some hundred metres in the bedrock. The main alternatives are a co-siting with the deep repository for spent nuclear fuel or with SFR, but the possibility of siting somewhere else will also be studied. The current siting process is aimed at finding a site where it is possible to build a safe deep repository for encapsulated spent nuclear fuel. The process is therefore currently aimed solely at an application for a permit to site and build the deep repository for spent nuclear fuel. An application for siting and construction of the final repository for long-lived LILW will be handled as a separate process that will not begin until after 2025. However, the possibility of locating the final repository for long-lived LILW on the same site as the deep repository for spent nuclear fuel will be studied within the framework of the ongoing siting studies for the deep repository.

1.2 Deep repository

Figure 1-2 shows the main features of the planned design of the deep repository, while Figure 1-3 shows the principles for achieving safe disposal. In its design, the deep repository resembles an industry with plants both above and under ground. The underground portions are located at a depth of about 500 metres and consist for the most part of horizontal tunnel systems. The tunnel systems consist mainly of deposition areas. There is a smaller area for initial operation (approximately 400 canisters) and larger areas for regular operation (approximately 3,600 canisters). If the final repository for long-lived LILW is built adjacent to the deep repository, a small area for this waste will be added.

The purpose of deep disposal is to isolate the spent fuel so that it cannot harm man or the environment, now or in the future. In the KBS-3 method, safe long-term disposal is achieved by means of a number of barriers that prevent radionuclides from escaping:

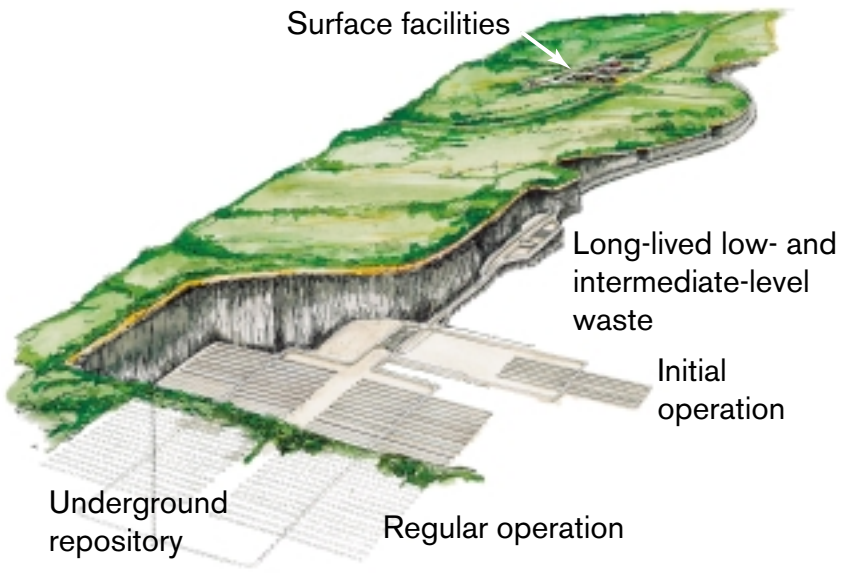

Figure 1-2. *Schematic drawing of the deep repository.*

- The fuel is chemically very stable and poorly soluble in water. This greatly restricts the dissolution and transport of radioactive substances from the repository, even if a canister was to be damaged.
- The fuel is placed in corrosion-resistant copper canisters. They are five metres long and have an iron insert for mechanical strength.
- The canisters are deposited in holes bored in the floor of the tunnel and embedded in a special clay, bentonite, which protects against rock movements and restricts groundwater movements in the repository.
- The crystalline bedrock provides a stable environment for these barriers and constitutes in itself an extra protective barrier.

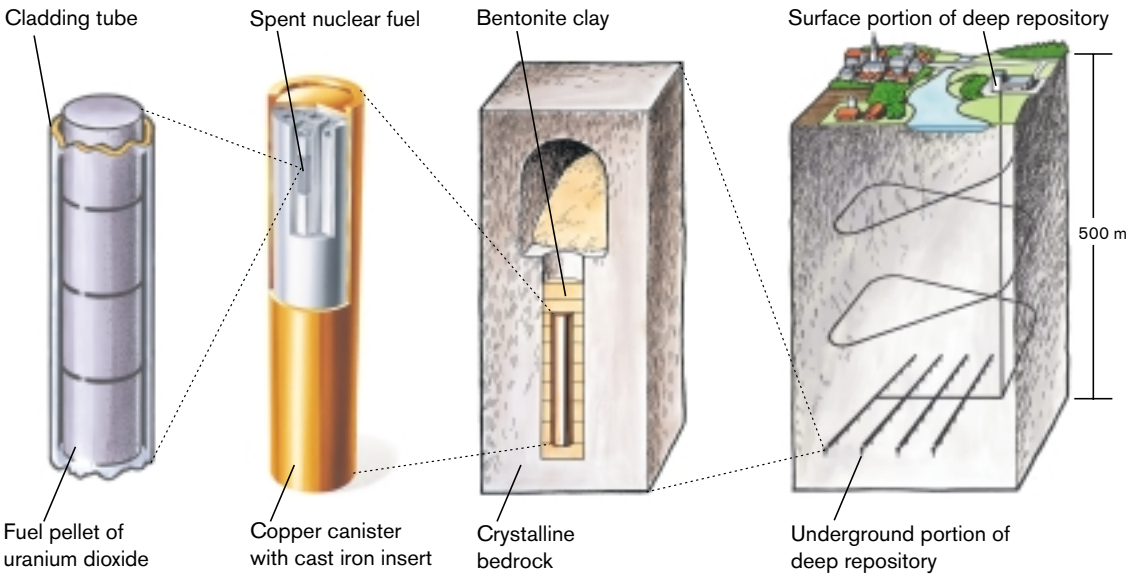

Figure 1-3. *Protective barriers in the deep repository.*

1.3 Different stages of the deep disposal programme

Siting, construction and operation of the deep repository is a process that proceeds in stages. As is evident from Figure 1-4, SKB must apply for permits prior to the various stages. These are:

Stage 1. Siting.

Stage 2. Detailed characterization and construction.

Stage 3. Initial operation and evaluation.

Stage 4. Regular operation.

Stage 5. Closure and long-term supervision.

The timetable for execution of the deep repository project is shown in Figure 1-4. The speed with which the siting process progresses is, however, dependent on technical as well as societal and political factors, of which the latter two in particular are difficult to predict. In general, the greatest uncertainties in terms of time are in the initial stage. For a more detailed discussion of the timetable, see RD&D-Programme 98 /1-2/. Main activities within each stage are discussed below.

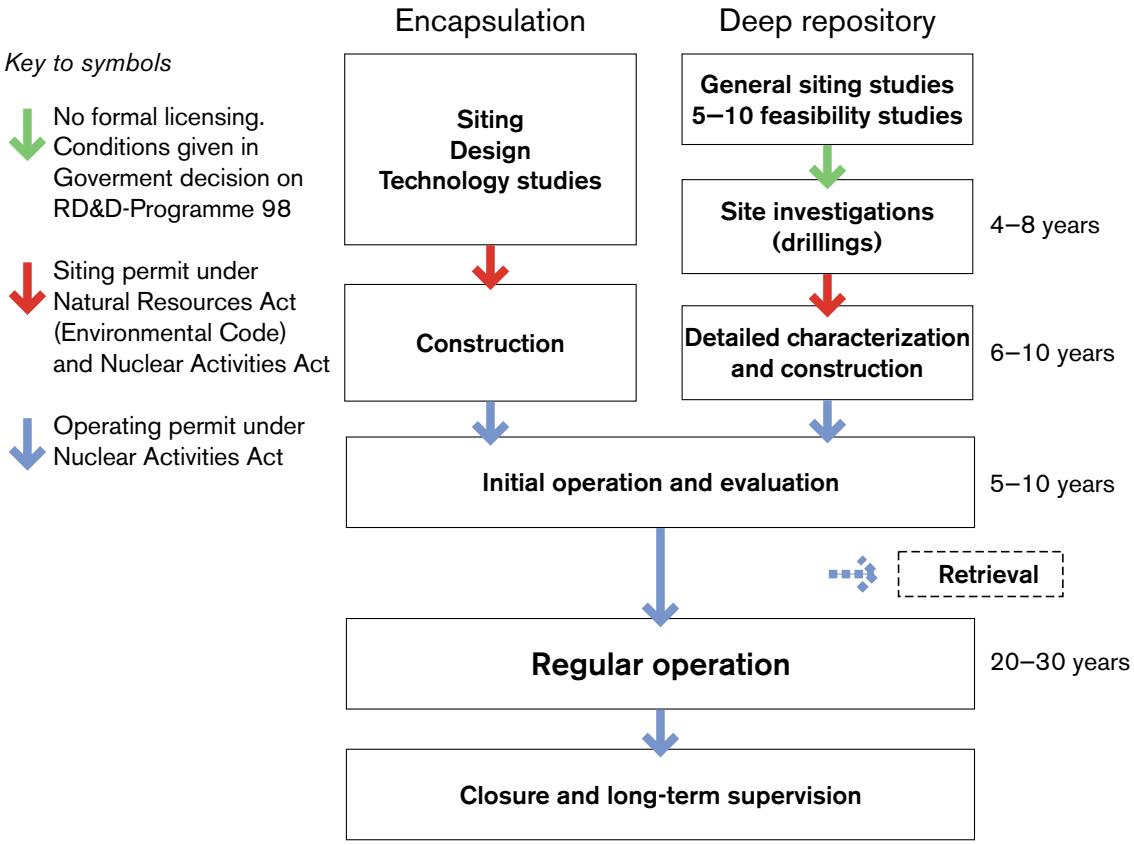

Figure 1-4. *Timetable for the deep repository project.*

Stage 1. Siting

The siting work involves assembling the background material that is needed to select a site for the deep repository. The background material consists of general siting studies of the entire country, feasibility studies in eight municipalities, of which six comprise the selection pool for continued studies, plus site investigations in at least two municipalities. According to the plans, site investigations cannot be commenced until 2002 at the earliest and will take an estimated 4–8 years to conduct.

At the same time, work proceeds on facility design and layout, performance and safety assessments, and environmental impact assessments/statements (EIAs/EISs) and consultations. The stage concludes with compilation of supporting material for a siting application to the Government pursuant to the Environmental Code, and an application for a permit to construct the deep repository under the Nuclear Activities Act. Consultations and environmental impact assessments and statements are discussed in section 2.4, while a more exhaustive description of the activities during the siting stage is given in section 1.4.

Stage 2. Detailed characterization and construction

This stage involves design and construction of the deep repository's underground and surface facilities with appurtenant equipment and machinery. The rock volumes to be utilized are investigated progressively, mainly from boreholes and tunnels down to repository depth. On the surface, the deep repository's industrial facility with service roads and rail spurs are built. The work of building the deep repository is continuously overseen by the Swedish Nuclear Power Inspectorate (SKI) and the Swedish Radiation Protection Institute (SSI), based on the siting permit's regulations for the different steps in the process. The stage is concluded with trial operation without radioactive material and application for a licence under the Nuclear Activities Act for initial operation.

Stage 3. Initial operation and evaluation

Approximately 10% of the total number of around 4,000 canisters are deposited during initial operation. A thorough evaluation of the entire system is also conducted in conjunction with initial operation. This enables the lessons learned from, and technical advances that have occurred during, this initial operation to be put to use. It is also possible to retrieve the deposited canisters at this time.

Provided that the evaluation of initial operation has a favourable outcome and it is decided to proceed, an application is submitted for a licence for regular operation under the Nuclear Activities Act.

Stage 4. Regular operation

During regular operation, the remaining 3,600 canisters of spent nuclear fuel are deposited in the deep repository. Long-lived LILW may also be deposited in a special deposition area during this stage.

During both initial and regular operation, deposition of canisters in prepared tunnels takes place at the same time as new tunnels are excavated. Repository construction therefore proceeds throughout the operating period.

Stage 5. Closure and long-term supervision

After canister deposition is concluded, the repository can either be kept open for some time or closed and sealed immediately. Before repository closure, a permit for this must be applied for under the Nuclear Activities Act. At closure, the underground facility is backfilled and plugged, after which the surface facility can be demolished or used for other activities. Even if a decision for closure is taken immediately after concluded operation, the initially deposited canisters, as well as the surrounding rock volume, have been under surveillance for several decades. The experience gained from this should come in handy when a decision on closure of the repository is to be made. The questions of possible future surveillance of the repository and/or the repository site, and how available information is to be preserved, are decided by the generation active at that time.

1.4 Siting work

1.4.1 Premises

The purpose of the siting work is to collect whatever background material is needed to select a site for the deep repository and to enable a permit to commence detailed characterization on this site to be granted.

Siting of the deep repository is a key issue for the Swedish nuclear waste programme, and the siting work is both controversial and complex. Technology, and above all safety, are central issues, but siting is also influenced by community planning, politics and public opinion. Experience from other industrial establishments – such as nuclear power plants, CLAB and SFR – is a valuable asset in the siting work, but no previous project is comparable in all respects with the deep repository.

Siting of the deep repository is dependent on a number of safety-related, technical, environmental and societal factors. The criteria and factors that guide the work are further discussed in Chapter 3. The most important is to choose a site with excellent safety-related prospects.

The programme for siting of the deep repository which SKB has prepared is presented in detail in the supplement to RD&D-Programme 92 /1-4/. The programme is based on e.g. prolonged and comprehensive scientific studies and investigations, the purpose of which has been to accumulate general knowledge concerning the Swedish crystalline basement and those conditions that could influence the performance of a deep repository. The studies started at the end of the 1970s and have been going on continuously since then. In addition, general experience has been gained from the siting, construction and operation of other rock facilities.

Much of the background work has consisted of SKB's own investigations of rock conditions at depth in Swedish crystalline bedrock. The investigations have included thorough mapping of the crystalline basement at a number of places in the country (the so-called study site programme), research in the Stripa Mine, and the work in conjunction with the establishment of the Äspö Hard Rock Laboratory (HRL). SKB and other organizations have also conducted extensive safety assessments for a deep repository in Swedish crystalline bedrock /1-5/.

Important general results from these studies are:

- There are good prospects of finding sites in Swedish crystalline basement with conditions that are suitable for a deep repository.

- Suitable bedrock is not limited to any particular part of the country or geological province within the crystalline basement. The most important factor is instead local conditions.

It is against this background that SKB considers it reasonable and realistic to approach municipalities that a) may have good geological conditions for a deep repository /1-6/ and b) are interested in collaborating in the siting process. The existing Swedish system with interim storage in CLAB also makes it practically possible for SKB to thoroughly examine the possibilities of carrying out siting and subsequent deep disposal in collaboration with potentially suitable municipalities.

1.4.2 General siting studies, feasibility studies and site investigations

The background material that is needed to select a site for the deep repository is obtained in general siting studies, feasibility studies and site investigations. These studies are performed on different scales and in parallel. For example, there are county-specific general siting studies for the whole country except Gotland. Feasibility studies have been done in eight municipalities, and holes have been drilled down to a depth of 700–800 metres in the bedrock at some ten or so places in the country. In addition there is the Äspö HRL with its underground experiments. An exchange of knowledge and experience between studies on different scales has taken place continuously.

General siting studies

General siting studies is the general heading for large-scale background studies of the general prospects for the siting of a deep repository based above all on safety-related and environmental factors. The geological studies are concerned with the crystalline basement in general, the country as a whole and large regions. In the general siting studies, databases of various factors of interest from a siting viewpoint are compiled on a national scale. The results are published continuously, mainly in the form of technical reports.

In the spring of 1995, SKB conducted a general compilation of the prospects for a deep repository in five municipalities with nuclear facilities: Varberg, Kävlinge, Oskarshamn, Östhammar and Nyköping /1-7/. A collective account, General Siting Study 95 /1-6/, was presented in conjunction with RD&D-Programme 95 /1-8/. This account has since been augmented by county-specific general siting studies for all counties (except Gotland). The results of the county studies of Kalmar, Södermanland and Uppsala counties were reported during 1998 /1-9 – 1-14/. SKB has also examined the advantages and disadvantages of siting the deep repository in northern versus southern Sweden, as well as aspects of a siting on the coast versus in the interior /1-15/.

Feasibility studies

The possibilities of siting a deep repository within a given municipality are explored in a feasibility study. The studies are based primarily on existing material. Important questions that are dealt with are:

- What are the general prospects for siting of a deep repository in the municipality?
- Within what parts of the municipality might bedrock exist that is particularly favourable with respect to the long-term safety of a deep repository?
- What are the technical prospects for building a deep repository in the municipality and how can transport be arranged?
- What are the prospects from a land and environmental viewpoint?

- What are the possible consequences (positive and negative) for population, environment and social development in the municipality and the region?

SKB does not need any formal permits to conduct a feasibility study. In practice, however, it is necessary for SKB to agree with the municipality in question on a programme and how it is to be carried out.

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

The purpose of the feasibility study is thus to investigate whether the necessary prerequisites exist for siting a deep repository in the municipality and to provide background material for a decision on whether to continue the investigations. Questions regarding the principles of final disposal, the advantages and disadvantages of the chosen concept, and the methods for evaluating long-term safety, are dealt with in other contexts and are not examined in the feasibility study. It is, on the other hand, possible to bring up these questions in the dialogue that is conducted with all stakeholders in connection with a feasibility study. It is also important to note that the results of a feasibility study do not permit any far-reaching conclusions to be drawn regarding long-term safety. This is because data on the bedrock conditions at depth on a particular site are generally not available at this early stage. Such data are necessary for a holistic assessment of safety.

SKB's siting programme includes eight feasibility studies, which has been deemed reasonable to ensure the availability of a sufficiently broad body of data for decisions at later stages of the siting programme.

The current situation as regards the execution of feasibility studies is indicated in Figure 1-5. Final reports on the feasibility studies in Storuman and Malå were published in 1995 and 1996, respectively /1-16, 1-17/. The results showed that there may be good prospects for a deep repository in these municipalities. Municipal referendums have, however, said no to continued investigations. This means that the municipalities will not participate in the continued siting process. The data collected in Storuman and Malå will, however, continue to be an asset as comparison material.

During the period 1997 to 2000, preliminary final reports were presented for the other feasibility study municipalities, which are: Östhammar, Nyköping, Oskarshamn, Tierp, Älvkarleby and Hultsfred. The different municipalities have been given an opportunity to review and comment on the preliminary final reports. During the review and commentary period, SKB has carried out supplementary investigations within the feasibility studies. Final reports on all of these feasibility studies have been submitted during the autumn and winter of 2000/2001 /1-18 – 1-23/. Some other municipalities in Sweden have considered feasibility studies at various points but refrained.

Site investigations

Based on the results of general siting studies and feasibility studies, SKB plans to select at least two sites for site investigations. These investigations take 4–8 years, and it is estimated they can be commenced no sooner than 2002. The investigations involve detailed mapping of rock conditions on the site. Extensive investigations are conducted in boreholes drilled to repository depth or even deeper. The site-specific data that are obtained

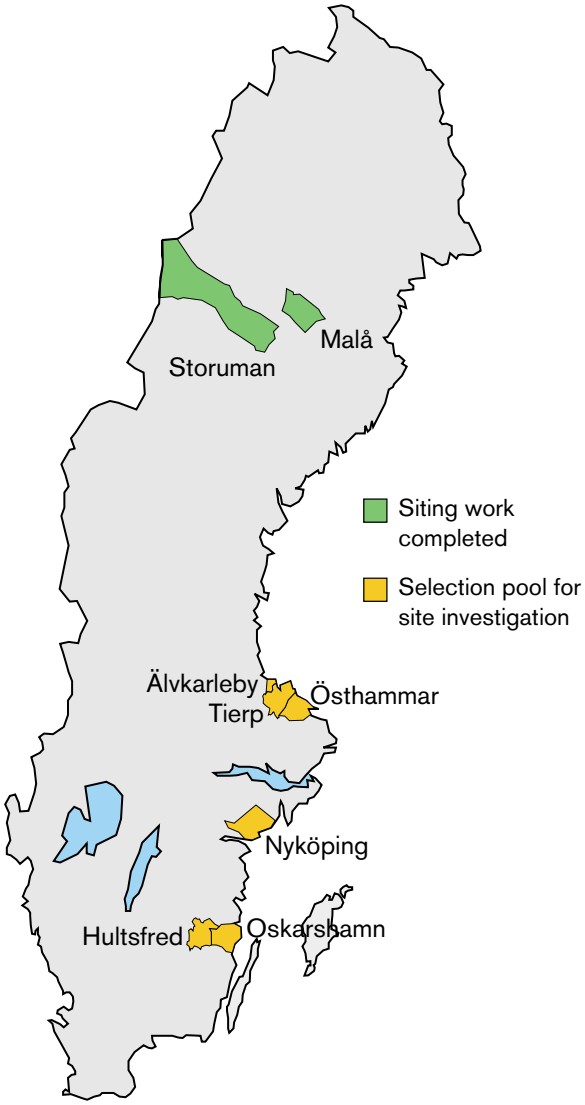

Figure 1-5. *Current situation regarding feasibility studies in different municipalities.*

serve as a basis for proposals for a site-adapted layout of the deep repository and for comprehensive assessments of safety and performance. At the same time, the investigations started in the feasibility study of land-use, environmental and societal aspects of a siting on the site in question are pursued in greater depth.

The site investigations are supposed to provide all the information needed to propose a site for the deep repository and to prepare an application for a permit to commence detailed characterization on this site. An application to commence detailed characterization must include an environmental impact statement (EIS) based on an environmental impact assessment (EIA). The consultation process for environmental impact assessment is described in section 2.4.

The final examination of the application to build a deep repository is conducted by the Government pursuant to the Environmental Code and the Nuclear Activities Act. If the application is approved and the concerned municipality says yes to a siting, the siting process is completed.

1.5 Government decisions regarding the siting process

Every third year, SKB publishes a research, development and demonstration programme, RD&D programme, for management of the spent nuclear fuel and the nuclear waste. SKI, which conducts a broad further review, and KASAM submit statements of comment to the Government in which the viewpoints of regulatory authorities and experts are presented, after which the Government makes a decision on the RD&D programme. In the Government decisions made thus far on SKB's RD&D programmes, a number of clarifications have been made that have been of great importance for the continued siting work. Some of these are summarized in the following sections.

1.5.1 Supplement to RD&D-Programme 92

The Government's decision regarding SKB's supplementary account to RD&D-Programme 92 was announced in May 1995 /1-24/. The most important points bearing on the siting process can be summarized as follows:

- Applications for permits to build a deep repository *"should contain material that shows that site-specific feasibility studies have been conducted on between 5–10 sites in the country and that site investigations have been conducted on at least two sites"*.
- The factors and criteria which SKB stipulated as providing guidance for siting *"should, in the Government's opinion, be a point of departure for the continued siting work"*.
- An application for a permit to commence detailed characterization should, according to the Government, be examined in parallel under both the Environmental Code and the Nuclear Activities Act. Previous programmes predicted that this licensing procedure would be based on the Natural Resources Act (now the Environmental Code), to be supplemented by examination under the Nuclear Activities Act after a detailed characterization had been performed. The new decision thus gives added weight to the examination phase after the site investigations.
- The EIA process is said to be *"an important instrument in contacts with authorities, concerned municipalities and the public."* It is further said that *"The Government assumes that the county administrative board in the county affected by feasibility studies, site investigations or detailed characterization will assume coordinating responsibility for the contacts with municipal and national authorities that are needed for SKB to assemble material for an EIA"*.
- *"The municipalities affected by the site selection process should be given an opportunity to closely follow SKB's site selection studies."* Municipalities in which SKB conducts feasibility studies can therefore on request receive up to two million kronor per year for *"costs that enable the municipality to follow and judge and to furnish information in questions pertaining to final disposal of spent nuclear fuel and nuclear waste."* The Government instructs SKI to administer this, and specifies that the money is to be taken from the funds set aside for financing of the nuclear waste programme. It is further said that the concerned county administrative board should assume coordinating responsibility in this context as well.

1.5.2 RD&D-Programme 95

In its decision of December 1996 on SKB's RD&D-Programme 95, the Government concluded the following /1-25/:

- SKB should not commit to any specific management and disposal method before an integrated and thorough analysis of associated safety and radiation protection questions has been submitted. SKB should given an account here of how the principles for radiation protection and safety are practically applied in safety assessments, alternative solutions to the KBS-3 method, and the consequences if the deep repository is not built.
- SKB has described *"a good and flexible framework for future safety reports. However, the template needs to be further developed and concretized."* A safety assessment of the long-term safety of the final repository should *"be carried out before an application for a permit for erection of the planned encapsulation plant is submitted to the authorities, as well as before site investigations on two or more sites are commenced."*
- SKB's research is for the most part of high class in an international perspective. The continued research should *"take into account the requirements that will be made by a future regulatory review of the safety assessments."* SKB should in particular give an account of how supporting research and development ties in with the safety assessments, and how fundamental uncertainties will be handled.
- *"Before the site selection process can proceed to site investigations, concerned municipalities should have access to SKB's collective account of general siting studies, feasibility studies and whatever other background and comparison material"* SKB may wish to present. SKB should be able to stipulate criteria for evaluation of the sites and the factors which preclude further studies on a site, as well as the consequences of siting near the coast versus in the interior and the consequences of siting in southern versus northern Sweden.
- SKB should consult with SKI and SSI regarding the premises that should apply to the investigation work in site investigations.

1.5.3 RD&D-Programme 98

In its decision from January 2000 on SKB's RD&D-Programme 98 /1-26/, the Government stipulates a number of conditions, of which the most important points with a bearing on the continued siting process are presented below:

- The Government may *"stipulate the KBS-3 method as a planning prerequisite"* for SKB's choice of sites for site investigations. To do this, the Government needs background material in the form of a supplementary analysis of alternative system designs. *"The final examination of the choice of method is made in conjunction with an application for a permit under the Environmental Code and the Nuclear Activities Act to construct a final repository for spent nuclear fuel etc."*
- The Government observes in its decision that a complete body of material for the choice of method does not yet exist. *"Based on currently existing material, however, the Government judges...that some form of final disposal in the bedrock would seem to be the most appropriate solution."*

- Prior to the selection of sites for site investigations, SKB must submit a "*collective account of completed feasibility studies etc. and a clear programme for site investigations*" to clarify that SKB's choices are founded on a solid basis.
- When it comes to the timetables for the continued work which SKB presents in RD&D-Programme 98, i.e. that selection of sites for site investigations will take place during 2001 and that the investigations can then be commenced during 2002, the Government says that they "*assume that the company will, together with concerned municipalities, proceed in accordance with timetables which all those concerned find suitable.*"
- The reports which the Government stipulates in its decision that SKB must prepare shall be compiled "*in consultation with concerned municipalities, county administrative boards and authorities. An account of these consultations shall be submitted.*" The reports must be available by not later than the publication of RD&D-Programme 2001 (the deadline for the next RD&D programme in accordance with the Nuclear Activities Act), but can be submitted to the Government if they are ready earlier "*so that the necessary decisions can be made.*"

2 Feasibility studies

During the period 1995–1999, SKB initiated feasibility studies in the six municipalities Östhammar, Nyköping, Oskarshamn, Tierp, Hultsfred and Älvkarleby. SKB has had a project organization in each of the municipalities that has been responsible for the study work and for public relations in each municipality. The municipalities have had their own feasibility study organizations to handle contacts with SKB, the regulatory authorities and other parties, and to take charge of information and dialogue with the municipal inhabitants from its point of view. SKB's studies in the six municipalities within the fields of long-term safety, technology, land and environment, and society have been presented in sub-reports that have been compiled in a preliminary final report for each feasibility study. The municipality's statement of comment on the preliminary final report and SKB's supplementary studies have then led to a final report. Consultations and discussions have been held with the municipality, the county administration and concerned authorities. At a later stage, in conjunction with site investigations (if any), early and extended consultation in accordance with the provisions of the Environmental Code can be initiated with concerned parties.

2.1 Deliberations concerning feasibility studies

During the spring of 1995, SKB made a general overview of the siting prospects for a deep repository in five municipalities with nuclear installations /2-1/: Varberg, Kävlinge, Oskarshamn, Östhammar and Nyköping. The conclusion was that the existing body of geological material for Oskarshamn, Östhammar and Nyköping is extensive. The material was also judged to be well-suited as a basis for feasibility studies aimed at leading to a more detailed assessment of the particular municipality's geological prospects for construction of a deep repository. SKB therefore judged it to be of primary interest that feasibility studies be carried out in these municipalities. In the case of Varberg, it was found that a general uncertainty exists regarding the suitability of the bedrock for a deep repository, in part because modern geological maps are lacking for large parts of the municipality. SKB nevertheless considered it desirable that Varberg should be included in the selection pool so that a feasibility study could be conducted to determine its suitability. However, the municipality decided not to proceed with the matter. In the case of Kävlinge, SKB found that the geological and technical conditions are not suitable for a deep repository.

Based on the results of the general siting study, SKB informed the municipal executive boards in the municipalities of Östhammar, Nyköping and Oskarshamn of its interest in feasibility studies in the three municipalities. In response to this inquiry, the three municipalities said yes – Östhammar in 1995, Nyköping in 1995 and Oskarshamn in 1996 – to feasibility studies. The feasibility studies in Östhammar and Oskarshamn also led to the judgement that the neighbouring municipalities could have favourable bedrock, so they were contacted. As a result, Tierp Municipality agreed in 1998 to participate in a feasibility study, and Hultsfred and Älvkarleby municipalities made similar decisions in 1999.

2.2 Organization

2.2.1 SKB's project organization

Responsibility for the feasibility studies rests with SKB, who has conducted the work in each of the six municipalities in accordance with the project organization shown in Figure 2-1. A project manager has been in charge of the research work and of the public dialogue in the municipality. SKB has an information office in the municipality's principal town with locally employed public relations officers for contacts with the public. Within each of the fields long-term safety, technology, land and environment, and society, sub-project managers have assisted the project with their specialized knowledge. The sub-project managers have also coordinated the contributions of various experts from universities, colleges and consulting firms within the different fields.

2.2.2 Municipalities' feasibility study organizations

The municipalities have established their own feasibility study organizations, whose main task has been to handle contacts with SKB, the regulatory authorities and other parties, and to take charge of information and dialogue with the municipal inhabitants from its point of view. This work has involved the municipalities' political bodies, civil servants, and to varying degrees other local stakeholders and the general public. Somewhat different solutions have been chosen when it comes to work forms and organization. This may reflect differences in political circumstances, previous experience of nuclear activities, the established division of labour between politicians and civil servants, and, not least, the dates and timetables for the different feasibility studies. Since 1995, the municipalities can obtain financial assistance from the Nuclear Waste Fund (via SKI) for their activities in connection with the feasibility studies.

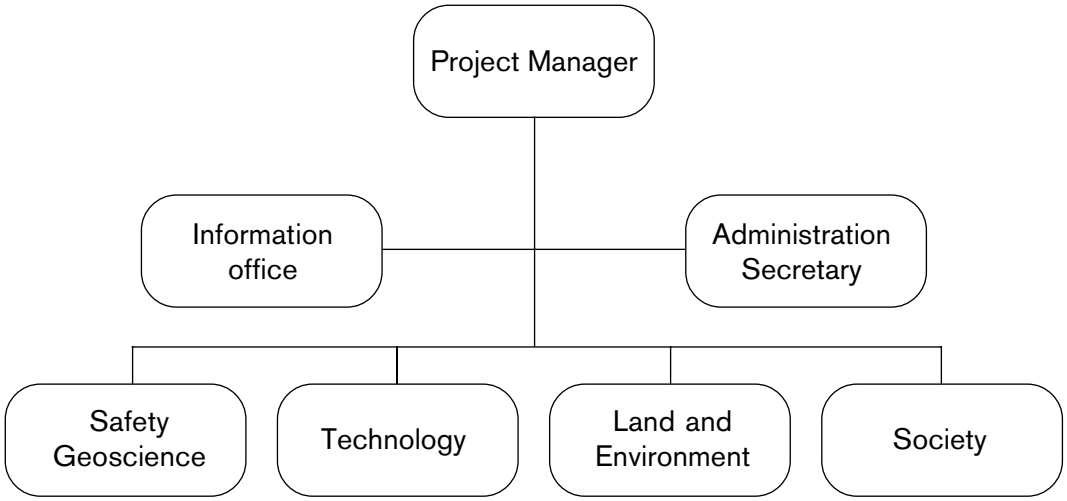

Figure 2-1. *Schematic diagram of SKB's project organization.*

2.3 Execution and documentation

SKB initiated each feasibility study by having the project manager, together with the topic supervisors, draw up a preliminary work plan describing in detail which topics would be dealt with and how the work would be executed and organized. The work plan was presented to the municipality, which was given an opportunity to offer viewpoints and request additions before it was published by SKB /2-2 – 2-7/.

The research work in the municipality resulted in interim reports, which were published as they were finished. Based on the results of the investigations, SKB published a preliminary final report for the feasibility study, which was submitted to the municipality, neighbouring municipalities, the county administrative board and other stakeholders for review and commentary. The municipality has compiled comments and viewpoints, and this material has, along with the municipality's own review, served as a basis for the municipal council's (in Nyköping the municipal executive board's) statement of comment on the preliminary final report.

In parallel with the municipality's review of the preliminary final report, SKB has carried out geological field checks in areas identified as interesting in the preliminary final report. Other supplementary studies have also been carried out in several of the municipalities. The preliminary final report, SKB's supplementary studies and the municipality's statement of comment have served as a basis for the final report for the feasibility study in the municipality.

All research within the feasibility studies has been conducted by independent experts who are themselves responsible for their reports, while SKB is responsible for the contents and conclusions of the final reports. The work with the interim reports has been carried out with full insight from the municipalities. Interim results have been presented and discussed continuously. In conjunction with the publication of the interim reports, the investigators have reported the results to the municipality's feasibility study organization and to the mass media. In parallel with the research work, regional consultations have taken place under the auspices of the concerned county administrative boards.

2.4 Consultation, dialogue and information

2.4.1 The consultation process

Maintaining a dialogue with the general public, organizations, regulatory authorities and politicians is an important part of the feasibility study work. SKB therefore has information offices in Östhammar, Nyköping, Oskarshamn, Tierp, Hultsfred and Skutskär to which the public can turn with questions and viewpoints. Meetings, debates, visits to schools and workplaces, study visits to SKB's facilities and similar activities are a part of SKB's efforts to reach out to the public and create a dialogue with those living in the municipality. Consultations have also taken place at the regional level with the county administrative board and at the national level during the feasibility study.

Applying for a permit to site the deep repository on a particular site entails the preparation of an environmental impact statement (EIS) describing the impact on the environment, both short- and long-term, which a deep repository is expected to lead to. Furthermore, the EIS shall include a description of alternative disposal methods and sites, as well as a zero alternative. The zero alternative is usually defined as not doing anything and has often been described as the consequences of a prolonged (for hundreds of years) storage of the spent fuel in CLAB. It can be concluded that there is no long-term zero alternative for the nuclear waste, but that a permanent solution must be found sooner or later.

The EIS shall be preceded by a consultation procedure in accordance with the provisions of the Environmental Code. Early consultation shall be held with the county administrative board and with private individuals who are particularly affected by the planned activity. In the case of a nuclear installation, the early consultation is followed by extended consultation, which includes concerned authorities, municipalities, members of the general public and organizations. This extended consultation shall relate to the siting, scope, design and environmental impact of the activity or measure, as well as the content and design of the environmental impact statement. SKB believes that consultations in accordance with the provisions of the Environmental Code should be commenced at the beginning of the site investigations, since it is not until concrete sites have been found for a siting that specially affected members of the public can be identified. It is important that concerned parties agree early on the forms of the consultation procedure. Experience from the consultations during the feasibility study therefore form a valuable basis for continued work with consultations in accordance with the provisions of the Environmental Code and preparation of an EIS.

2.4.2 Local dialogue in the municipalities

SKB's position is that the siting work should take place in an open dialogue between SKB, the municipality, concerned authorities, interest organizations and the general public. A number of activities are therefore pursued within the feasibility study to discuss and provide information on the feasibility study and the underlying nuclear waste programme in its entirety.

SKB has information offices in the principal towns in the six municipalities. The information offices give the public an opportunity to engage in discussions with SKB's personnel. They also have the reports that have been produced in the feasibility study, other relevant reports, brochures, etc. Furthermore, there is an exhibition illustrating different parts of the planned final disposal method and the barriers that are designed to provide long-term isolation of the spent fuel from man and the environment.

Besides the activities at the information offices, representatives from SKB have participated in information meetings arranged by various organizations and associations or by SKB itself. The local information officers have also visited other communities in the municipality outside the principal town with an exhibition bus. SKB's transport ship M/S Sigyn has visited ports in or near the feasibility study municipalities with its exhibition, attracting large numbers of visitors. Numerous seminars have also been held on the ship. Moreover, various groups have been offered an opportunity to visit SKB's facilities in Oskarshamn (CLAB, the Äspö HRL, the Canister Laboratory), and study visits to SFR in Forsmark have been arranged for the residents of the feasibility study municipalities in Northern Uppland.

The municipalities have also conducted an active dialogue with their inhabitants. This has been done in different ways in the different municipalities. Examples of activities arranged by the municipalities are information meetings with inhabitants where various experts, representatives of regulatory authorities or opponents have participated. In some cases they have also started their own information offices, organized study circles, mailed information brochures to households, etc.

As a special effort on behalf of the three newest feasibility study municipalities – Hultsfred, Älvkarleby and Tierp – SKB arranged three seminars during the winter of 2000. The purpose was to give more information to elected officials, civil servants and other concerned persons. The seminars spanned over a broad field – from technology, legislation and EIA/EIS to the decision-making process for the deep repository. During the spring and autumn of 2000, SKB arranged joint seminars for all six feasibility study municipalities on ethics, waste management in Eastern Europe and the former Soviet Union, and the psychosocial effects of a deep repository.

2.4.3 Regional consultation at the county administrative boards

According to the Government's decision regarding SKB's supplement to RD&D-Programme 92, the county administrative boards in the counties affected by feasibility studies have a coordinating responsibility for contacts with municipal and national authorities. Important stakeholders are those who will host the facility (the municipality and nearby residents), the one who will run the facility (SKB), regulatory authorities and the county administrative board. The Government's decision that the municipality can obtain money from the Nuclear Waste Fund for these purposes makes it easier for the municipality to actively follow, evaluate and furnish information on the feasibility study.

In the counties where SKB has conducted feasibility studies (Uppsala, Södermanland and Kalmar), the county administrative boards have worked for a coordination of activities at the regional level. In Uppsala County, the consultation group has been progressively expanded as new feasibility study municipalities have been added in the county. In Södermanland County, a consultation group was established for the feasibility study in Nyköping. In Kalmar County there was already an EIA forum due to the fact that SKB had, in RD&D-Programme 92, named Simpevarp in Oskarshamn Municipality as a possible site for the encapsulation plant. When Oskarshamn Municipality said yes to a feasibility study, the already established EIA forum decided that the group's work should also include the feasibility study. EIA Dacke has followed the feasibility study work in Hultsfred Municipality at the regional level. The forms for the regional consultations, as well as which parties participate, vary. But in all cases the concerned municipalities, SKI, SSI, the Special Government Advisor and SKB are represented.

If the siting studies continue after the feasibility study, the consultation work is concretized and intensified with early and extended consultation in accordance with the provisions of the Environmental Code. Through the consultation during the feasibility study, the municipalities have acquired considerable knowledge in the matter and should therefore be able to look after their interests and contribute constructively to a stable and credible process. The site investigation entails that there is a designated site in the municipality, which means that nearby residents and landowners can be identified and these specially affected individuals can thereby participate in a consultation process in accordance with the provisions of the Environmental Code. Since transport to the deep repository is studied during the site investigations, the municipalities that may be affected by such transport will also participate in the consultations.

2.4.4 National collaboration

In May 1996 the Government appointed a National Coordinator in the nuclear waste field /2-8/. The Government found that there could be a need for a special coordination resource for those actors (municipalities, county administrative boards, safety authorities etc.) that have been involved in SKB's efforts to find a suitable site for final disposal of spent nuclear fuel and nuclear waste. The National Coordinator was supposed to promote coordination of those information and research activities deemed necessary by affected municipalities. He was thereby supposed to proposed forms for information exchange about management and disposal of spent nuclear fuel, and otherwise be prepared to coordinate contacts between the municipalities and county administrative boards affected by the studies.

A consultation forum – the National EIA Forum for Nuclear Waste – was formed in November 1997 as an informal consultation body and as a part of the activities of the National Coordinator. The main purpose of the National EIA Forum was to create a consensus on what questions should be dealt with in the EIA work and to provide an opportunity to deal with questions of general importance for the contents of an environmental impact statement /2-9/. Meetings of the National EIA Forum for Nuclear Waste were arranged 2–3 times a year. A public record were kept of the meetings, and the work in the National EIA Forum has been described in annual reports on the National Coordinator's activities, which have been submitted to the Government /2-10, 2-11/.

The National Coordinator's commission expired in June 1999. In conjunction with a decision on a new commission, the function was renamed "Special Advisor on Nuclear Waste" /2-12/and was thereby tied more closely to the Government Offices than before. The Special Advisor is supposed to follow the ongoing work of finding a site for the deep repository and assist the Government Offices with advice in dealing with matters pertaining to the nuclear waste field. The Special Advisor is also supposed to help convey the Government's views on issues pertaining to management and disposal of spent nuclear fuel to those affected by the siting process.

The Special Advisor on Nuclear Waste is supposed to promote coordination of educational and informational activities between concerned authorities, county administrative boards and municipalities and maintain close contact with the organizations that wish to participate in the siting process. This is done by participation in the consultations that take place on a regional level in concerned municipalities and by participation in the seminar activities that have been conducted in the feasibility study municipalities.

3 Factors and criteria for siting

The site that is chosen for a deep repository must satisfy a number of fundamental requirements. The possibilities of siting the deep repository in a municipality are investigated in a feasibility study. This is done primarily by compilations of existing material within the fields of safety, technology, land and environment, and society. The evaluation done in the feasibility study is mainly aimed at identifying and roughly evaluating areas deemed to be of special interest for further studies. It is not, however, possible at this stage to draw any far-reaching conclusions regarding the prospects for long-term safety, since the available information on the bedrock is mainly based on data from the ground surface. When all feasibility studies have been completed, a broad body of material is compiled and on the basis of this at least two sites are selected, in consultation with the concerned municipalities, for site investigations.

3.1 General

The siting work and how evaluation and site selection are carried out in different phases of the siting process are described in RD&D-Programme 98 /3-1/. This includes both selecting areas for site investigations after concluded feasibility studies, and deciding what is to be investigated in the site investigations and how this material is then to be evaluated prior to a siting decision. The fundamental requirements on the site for a deep repository are described in RD&D-Programme 92, Supplement /3-2/ and in the report "What requirements does the KBS-3 repository make on the host rock? Geoscientific suitability indicators and criteria for siting and site evaluation" /3-3/. This chapter summarizes these requirements and how to determine that the requirements are met on a specific site, with an emphasis on what is applicable in a feasibility study.

The fundamental requirements that must be satisfied by a deep repository mainly concern safety and environmental impact, requirements that are defined by laws and regulations. The question of whether the requirements for a deep repository are satisfied on a specific site is examined in conjunction with the authorities' review of the system and safety assessments and the environmental impact statement submitted by SKB as a basis for a decision on detailed characterization (see the timetable in Figure 1-4).

A holistic assessment of above all long-term safety requires access to data on bedrock conditions from a specific site. Such data can only be obtained by conducting extensive investigations on sites that must be selected based on incomplete data. This distinguishes the siting of underground facilities from above-ground industrial sitings, where knowledge of all important factors is relatively easily accessible.

The body of data available after the feasibility studies on conditions in the rock at the planned repository depth, about 500 metres, is thus very limited. However, this body of material is improved considerably by the site investigations, which include test drilling to a depth of 1,000 metres.

SKB published the safety assessment SR 97 /3-4/ in the autumn of 1999. It includes both revision of the technology for safety assessment and its application to three hypothetical cases with regard to geoscientific conditions on the repository site. SR 97 constitutes a basis for the continued work with safety assessments which will in turn serve as a basis for the evaluation of the sites included in the site investigations.

SR 97, together with other knowledge and experience from SKB's many years of research and development, also comprises an important basis for the work of establishing requirements, preferences and criteria for SKB's continued work with site selection and site investigations. During 1997, SKB initiated a project named "Siting factors and criteria for site evaluation" with the following main goals:

- Identify and quantify requirements and preferences regarding the rock's properties and conditions from the perspectives of long-term safety and technology,
- Propose criteria that can be used both to assess the fulfilment of requirements and preferences and, if possible, to compare sites after feasibility studies and during the site investigations.

The project stipulates what requirements are made on the rock, what conditions in the rock are advantageous (preferences) and how to judge whether requirements and preferences are satisfied (criteria). These requirements, preferences and criteria will be used in SKB's continued work both in the selection of sites for site investigations and in the execution of site investigations for evaluation of sites. In other words, the criteria must be able to be used to judge whether a site satisfies the stipulated requirements or not. It is not usually possible to specify exactly which values would be preferable or optimal for each investigated parameter, since these values are often interdependent and may be connected in a more or less obvious way. The long-term performance and safety of the deep repository must therefore always be evaluated by means of a safety assessment using data from the investigated site. The safety assessment provides a holistic assessment of the safety-related suitability of the area.

3.2 Siting factors

The siting factors that determine whether an area is suitable for siting of a deep repository can be ordered in the following main groups:

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

Figure 3-1 shows schematically that these four main groups contain numerous factors that determine the suitability of the site.

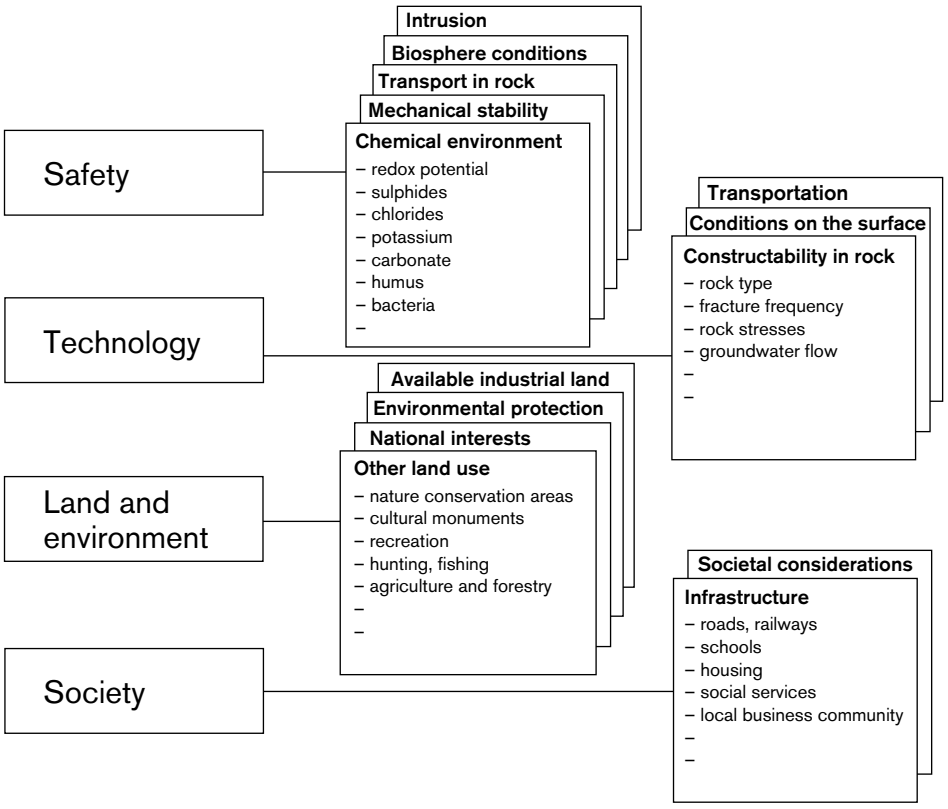

Figure 3-1. *Main groups and subgroups of siting factors.*

Some siting factors are absolute requirements which a site must satisfy or describe properties which rule out the possibility of building and operating a deep repository in a safe manner. This above all applies to properties of the bedrock that bear upon the safety of the repository. For example, the groundwater at repository level must be free from dissolved oxygen, and there may not be any ores or mineralizations on the site. Furthermore, according to the provisions of the Environmental Code there are certain areas that may not be utilized for nuclear installations, and the site of the deep repository may not, for example, be situated within a national park. These types of fundamental requirements can be stipulated as points of departure in the siting work.

Many of the siting factors are of the character favourable/unfavourable. Such factors are important in an overall assessment of a site, but are not sole determinants of the suitability of the site. This is true of many of the technology- and environment-related parameters, for example distance to existing transport routes, protected and valuable areas, and risks of disturbances in the natural environment. The importance of such factors is in many cases related to the possibilities of detailed adaptation of the layout to the characteristics of the site.

The requirements associated with the four main groups of siting factors in Figure 3-1 are briefly discussed in the following.

3.2.1 Safety

The fundamental safety principle for the deep disposal system planned by SKB is to completely contain and thereby isolate the spent nuclear fuel for such a long time that the quantity of radioactive substances decreases to such an extent that they no longer pose a risk to man or the environment. It is the requirement on isolation from the biosphere for very long timespans that underlies the choice of the bedrock as a disposal medium.

In order to put safety-related siting factors in context, it is necessary to briefly discuss some fundamental principles for the structure of the deep repository. For a more complete account, the reader is referred to RD&D-Programme 98 /3-1/ and the system analysis of the KBS-3 method /3-5/.

Figure 3-2 shows a schematic drawing of the most important components of the deep repository. The spent fuel is encapsulated in leaktight canisters, which are deposited at a depth of approximately 500 metres. The canisters prevent the fuel from coming into contact with groundwater and have an estimated life that exceeds with good margin the length of time the fuel must be isolated. The canister consists of an inner container (insert) of iron surrounded by an outer container (shell) of copper. The iron provides mechanical strength while the copper shell protects against corrosion.

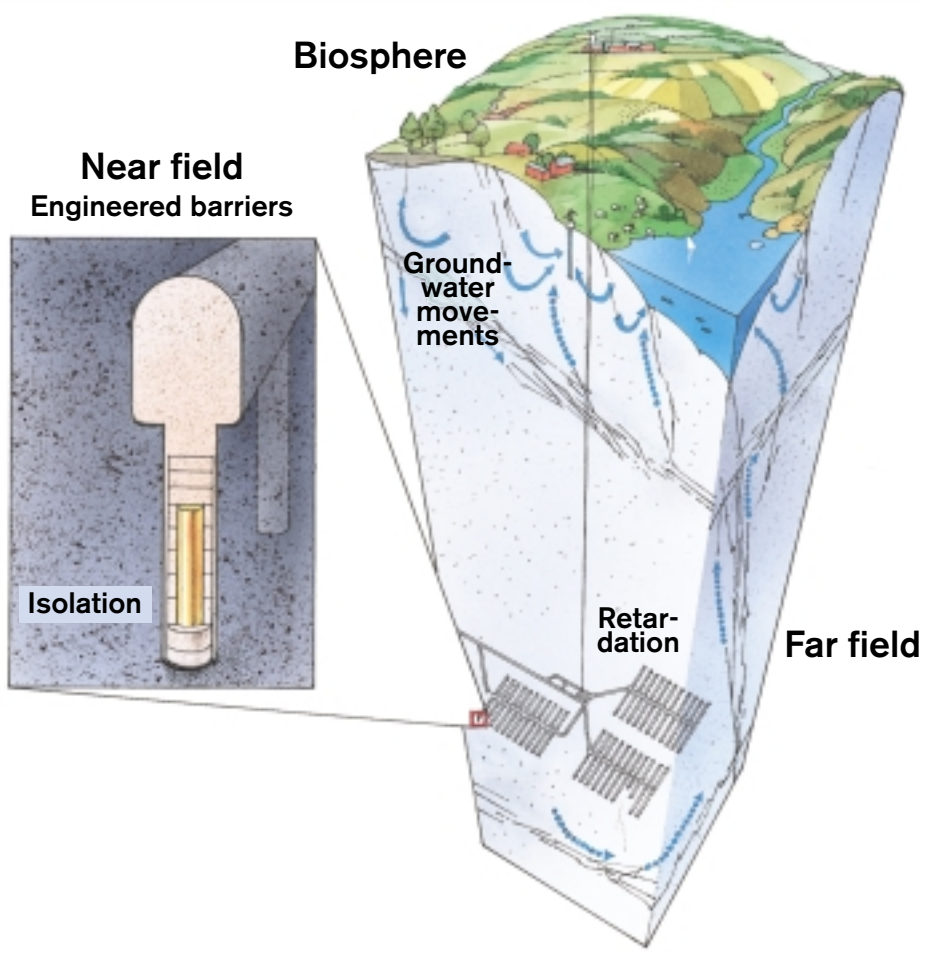

Figure 3-2. *The deep repository's most important safety functions.*

The basic design of the repository is based on the so-called multiple barrier principle, whereby if a canister should be damaged, other protective barriers remain. The fuel itself is extremely poorly soluble in water. Furthermore, the canister is surrounded by compacted bentonite clay that fills up the deposition space. The bentonite absorbs water, swells and forms a very watertight barrier that counteracts groundwater movements while providing mechanical protection for the canister. Finally, the rock on the selected site should have a good capacity to retain or retard radioactive substances so that they cannot reach the biosphere, if the chain of internal protective barriers should fail.

The canister and the bentonite comprise the near field's engineered barriers, whose main function is to isolate the fuel from its surroundings. The performance of these barriers is dependent on the chemical and mechanical conditions on the selected site. This means that the rock, besides constituting a protective barrier in itself, has another important safety-related function, namely providing a suitable environment for the engineered barriers over long timespans.

In summary, the rock has a dual function:

- To ensure a long-term stable chemical and mechanical environment that is suitable for the engineered barriers.
- To constitute an extra protective barrier in itself.

The following factors that must be taken into account in site selection derive from the main principles for achieving long-term safety, and the fundamental requirements on the rock that follow from them:

- Chemical environment for canister, bentonite clay and fuel.
- Mechanical stability of the rock.
- Conditions for transport of corrosive and radioactive substances in the rock.
- Risk of future intrusion, i.e. mainly possible utilization of natural resources in the bedrock.

3.2.2 Technology

When it comes to the requirements on the selected site with regard to construction and operation of the deep repository, it is possible to distinguish between factors relating to the surface facility, the underground facility and the transportation system. Site-specific information on surface factors and transportation can be obtained early, as can general information on underground factors. Detailed information on underground factors is obtained in conjunction with site investigations and detailed characterization.

Surface facility

All reception of goods, as well as interim storage and transshipment, takes place above ground. The surface facility must be designed and equipped so that requirements on safety, working environment, radiation protection and other environmental protection are satisfied. Nearness to infrastructure in the form of public transport, community services, etc. is an advantage. The requirements that are made on the bearing capacity of the ground are no different from those for other industrial activities.

Underground facility

The underground facility includes shaft, access tunnels, personnel and storage areas, transport tunnels, deposition areas, etc. Construction of these areas is to a great extent comparable to that of other rock excavations, for example mines. The operating environment will bear great similarities to that in SFR.

The rock where the facility is built must have such properties that the excavation work can be carried out with adequate safety and known technology. In international comparison, Swedish crystalline basement provides good conditions for rock construction. There is also large and well-established experience of siting and construction of rock facilities for various purposes in Sweden. This experience does not point towards any significant regional differences or indicate that any crystalline basement region should pose any particular difficulties. Any difficulties are more linked to local conditions.

The detailed building conditions on a site cannot be more precisely determined until investigation data from repository depth become available. Important factors include the strength properties of the rock, the locations and character of fracture zones, loads (rock stresses) and the water-bearing properties of the rock.

Transportation

Safe transport will be ensured by specially adapted technology and the necessary investments. The required technology is well known from the shipments of radioactive materials, including spent nuclear fuel, that have long been carried out in Sweden and abroad. It is favourable if existing infrastructure can be used to as great an extent as possible. If new harbours, roads or railways must be built, they may conflict with other important land-use interests.

3.2.3 Land and environment

Site selection and facility layout should be done so that conflicts with competing interests are limited. Consideration should be given in a broad sense to the natural and cultural environments. Factors to be taken into consideration are nature conservation, recreation, hunting, fishing and other outdoor activities, cultural monuments, important natural resources, agriculture and forestry. Facilities as well as transport and communication infrastructure should blend in with the terrain.

In summary, the site for the final repository should be:

- Selected and configured taking protected and valuable areas into consideration.
- Offer good conditions for constructing and operating the facilities and meeting environmental requirements.

3.2.4 Society

Societal aspects are important for both site selection and facility layout. Establishment and operation of a deep repository will affect the local community and the region in different ways. Perhaps the most noticeable effects are on employment, economic life and local services. Politically and in terms of public opinion, siting is a sensitive issue. Experience in both Sweden and other countries show that strong feelings and opinions can be aroused.

Siting of a deep repository should be carried out so that:

- Various stages of the investigation activities, construction, commissioning and operation have democratic support.
- Social and socioeconomic consequences are taken into consideration.

3.3 Siting criteria in a feasibility study

The siting factors that have been mentioned must all be taken into consideration in a holistic assessment of a selected site. The possibilities of obtaining the data needed for such an assessment are, as noted, different for different siting factors. Many of the geoscientific factors that can affect the long-term safety of the repository and the rock construction conditions can only be clarified by extensive investigations on a specific site. The feasibility study contains no such investigations, but is aimed primarily at compilation and analysis of existing data on a general scale (the entire municipality). The knowledge that can be obtained in a feasibility study on geoscientific conditions at repository depth is therefore incomplete.

In the feasibility study, efforts are focused on identifying and analyzing geoscientific conditions that may be favourable or unfavourable on the basis of generally available information. Conditions that should be avoided are:

- Rock types that are of interest for mineral extraction or other utilization.
- Highly heterogeneous or difficult-to-interpret bedrock.
- Known deformation zones or neotectonic (geologically recent) faults.
- Pronounced groundwater discharge areas.
- Groundwater chemistry that is abnormal for Swedish bedrock.

Site evaluation with respect to these factors can rule out larger or smaller areas from further studies. Important questions for the remaining areas are:

- Which areas may have particularly good prospects of satisfying requirements on safety, technology, land and environment, and societal aspects?
- Which of these areas offer good prospects of subsequently conducting a reliable survey of the important environmental and safety factors in particular?

Conditions that are particularly favourable with respect to the various siting factors are:

- An ordinary rock type of no interest for other utilization of natural resources. This reduces the risk that the area will be chosen for other use in the future.
- A large area with few major fracture zones. This provides extra flexibility in future investigations and increases the possibilities of being able to build a sufficiently large repository in good rock with high safety.
- A high proportion of exposed rock, simple and homogeneous bedrock conditions, and a regular system of fractures and fracture zones. This provides good opportunities for obtaining a good understanding at an early stage of bedrock conditions of importance for the prospects of safety and rock construction.
- Access to the necessary infrastructure and good transport options in the form of harbours, railways or roads. Limited need to make use of land for new roads or railways.

- Few competing land use and environmental interests. This provides wide options for modifying the facilities to comply with the environmental requirements.
- Local positive interest.

Based on these criteria, an evaluation is made in an endeavour to identify and roughly evaluate areas that may be of interest for further investigations and to see if there are concrete sites that may be of particular interest for the deep repository's surface facility.

All of the studies that have been conducted are aimed at contributing to the evaluation process described above.

3.4 Material as a basis for selection of areas for site investigations

At least two areas will be selected for site investigations. They must be located in different municipalities and have good prospects of satisfying stringent requirements on safety and environmental protection. Furthermore, the sites must be situated in municipalities which accept participation in further siting studies. The assessments on which the selection of site investigation areas will be based will in turn be based on selection pool material, comparison material and background material.

The selection pool material consists of the feasibility studies in the six municipalities that are participating in the siting process. The choice is made among the areas that have been identified in the feasibility studies as being of interest for further investigations.

The comparison material consists of, besides the selection pool material, compilations of siting conditions in other concrete areas. These may, for example, include the so-called study sites where SKB has previously conducted investigations, areas that have been identified in regional overviews and areas that have been studied and investigated in the Finnish site selection programme. The purpose of the comparison material is so that the choice of site investigation areas can be evaluated against a broad and varied group of other concretely described areas. Comparison material is compiled in a clear fashion and presented by SKB during the winter of 2000/2001.

The background material consists of general overviews or special studies, in particular of geoscientific questions that can be of importance in siting. The county-specific general siting studies form a part of the background material, as does General Siting Study 95 (see section 1.4). These describe large contiguous parts of the country that should not be considered and discuss a number of conditions that may be of importance in the evaluation of alternative sitings at different places in the country.

3.5 Programme for site investigation

Questions to be answered by a site investigation are what the bedrock conditions look like on the site in question, and what the prospects are for the long-term safety of the repository and for underground construction. Furthermore, studies should be made of how transport and facilities can be designed and what environmental impact a deep repository will have on the site in question.

SKB has prepared a programme for site investigations. This programme is general and independent of local conditions /3-6/. As mentioned previously, criteria are also formulated that can be used to determine whether a site satisfies the stipulated requirements and that also make it possible to compare sites in various respects. SKI and SSI will submit statements of comment on the site investigation programme and the siting criteria with assessments of whether the authorities are given opportunities to obtain the data that are required in a future application. Consultation will also take place with e.g. concerned municipalities. When sites have been selected for site investigations, SKB prepares site-specific programmes, based on the general programme, the authorities' comments on it, and viewpoints from the municipalities in question and local stakeholders.

4 Östhammar – summary evaluation

SKB's assessment from the feasibility study is that there are good prospects for further studies concerning the siting of a deep repository in Östhammar Municipality, Figure 4-1. The most interesting alternative is siting the deep repository's surface facility at SFR/Forsmark with the underground facility in the area between the Forsmark NPP and Kallrigafjärden bay. A siting at SFR means that the deep repository will not disturb a possible expansion of facilities for future energy production within the Forsmark area. Since both the deep repository and SFR will be operated for many years after shutdown of the last nuclear power reactor, synergy gains with SFR in the form of a shared harbour, workshops, offices, information activities, surveillance etcetera may exist even after closure of the last reactor. Another alternative judged to be interesting is a siting of the surface facility at Hargshamn with the underground facility in the geologically interesting area west of highway 76. If this alternative was to be considered, a deeper study would need to be done of whether such a siting is possible with reference to the protection provided in the Environmental Code for certain coastal and archipelago areas.

SKB's holistic assessment is that both alternatives offer good technical and societal prospects, at the same time as environmental impact is limited by the utilization of existing industrial areas for the surface facility and by avoidance of overland transport. Both alternatives are also judged to offer good prospects for a long-term safe disposal of the nuclear waste in the bedrock. Test drilling is required before this can be established, however.

Östhammar Municipality

The municipality of Östhammar has historically rested on three pillars: fishing/shipping, iron/steel and agriculture. Today it is dominated by two corporations: Sandvik Coromant AB with some 1,500 employees, and Forsmarks kraftgrupp AB with some 800 employees. Roughly 1,500 persons work in the agricultural sector.

There are several Wallonian ironworks of historical interest in the municipality. Together with the nuclear power plant and SFR in Forsmark, the ironworks are the most popular tourist destinations. The coastal and archipelago areas are also important tourist attractions.

Location
Coastal municipality in Uppsala County. Borders in the west on Tierp, in the southeast on Norrtälje and in the south on Uppsala.

Land area
2,790 km^2

Inhabitants
Approx. 21,600

Towns
Östhammar pop. 4,700, Gimo pop. 2,700, Alunda pop. 2,300, Österbybruk pop. 2,200, Öregrund pop. 1,600.

Transportation
A railway for goods transport passes through the southern part of the municipality. Highway 76 passes through the northern part of the municipality and county road 292 through the southern part. Harbour for heavy goods traffic in Hargshamn. Arlanda Airport is situated approximately 1.5 hours from Östhammar.

Land
Approximately 71% forest land, 14% arable land and pastureland, 15% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 22, Left Party 4, Moderates 9, Christian Democrats 2, Centre Party 8, Liberal Party 2, Green Party 2.

Feasibility study decision
June 1995 – 36 yes, 12 no.

Nuclear power-associated activities
- Forsmark NPP with three reactors, the oldest in operation since 1980.
- SFR (Final Repository for Radioactive Operational Waste) in operation since 1988.

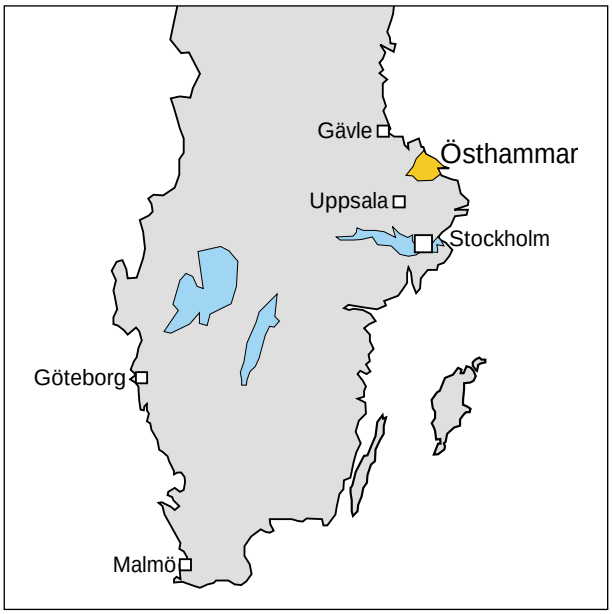

Figure 4-1. *Location of Östhammar Municipality.*

4.1 Siting prospects in Östhammar Municipality

4.1.1 Background

During the spring of 1995, SKB made a general study of the siting prospects for a deep repository in five municipalities with nuclear installations, among them Östhammar Municipality. The conclusion was that the municipality has such geological prospects that it was judged to be of interest for further studies. This, together with the knowledge and experience of nuclear activities and management of radioactive waste that exists in the municipality, have been the most important reasons that SKB has deemed it of interest to conduct a feasibility study regarding the possibilities of siting a deep repository in the municipality. The municipal council decided in June of the same year to consent to a feasibility study by SKB.

4.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. In a feasibility study, geological maps and other geoscientific material are compiled. This provides a general picture of where in the municipality bedrock with suitable properties may be located. However, knowledge of conditions at repository depth is needed for a reliable assessment of the long-term safety of a deep repository, which requires measurements in deep boreholes. Such borehole investigations are conducted in a site investigation and are not included in a feasibility study.

Bedrock conditions

Large parts of Östhammar Municipality, particularly the coastal region, have a relatively thin soil cover and a high proportion of bare rock, which facilitates geological mapping of the bedrock and thereby increases the prospects of predicting conditions at repository depth.

The material that has been obtained regarding conditions in the bedrock shows that the municipality is dominated by metagranitoids, normally called gneissic granites. Generally speaking, these rocks have good properties from a deep repository viewpoint. In certain areas, however, the gneissic granites are inhomogeneous with intercalations of e.g. amphibolite or pegmatite dykes. Other rock types are judged to be less favourable from a deep repository viewpoint.

The bedrock has been affected by plastic and brittle deformation. The plastic deformation has resulted in large-scale plastic shear zones, for example the Singö shear zone in the northeastern part of the municipality. The brittle deformation has given rise to large-scale faults and fracture zones. The scope of plastic shear zones is greater than normal for Swedish bedrock, while the occurrence of faults and fracture zones is deemed normal. Embedded in the plastic shear zones are so-called tectonic lenses, i.e. relatively large areas where the bedrock has been much less affected by plastic deformation.

Östhammar Municipality is situated in the northeasternmost spur of the ore province of Bergslagen, and mining has very old traditions, not least at the Dannemora orefield. Today there are no mines in operation in the municipality, but around one-third of the bedrock can be considered to have ore potential. In a longer time perspective, it is possible that ore prospecting may once again be of interest in these parts of the municipality.

In the feasibility study's geological survey, all parts of the municipality that exhibit potentially unsuitable conditions (certain rock types, heterogeneous bedrock, areas with ore potential, plastic deformation zones) have been dismissed as uninteresting for further studies. After areas protected by law, nearness to potential large-scale mining activities (Dannemora) and the size of possible investigation areas have also been taken into consideration, four areas remain, see Figure 4-2. Two of these, the Forsmark area and the Hargshamn area, have been deemed to be particularly interesting since both are situated near existing industrial ports. In the case of the Forsmark area, nearness to SFR and the Forsmark NPP is also a positive factor, since different nuclear activities there can be coordinated. Geological field checks were therefore performed in the Forsmark and Hargshamn areas in the supplementary phase of the feasibility study.

The relatively extensive field check at **Forsmark** shows that there is potentially suitable bedrock between the Forsmark NPP and Kallrigafjärden bay, see Figure 4-3. Here there is homogeneous bedrock with a low degree of deformation. The area is located within a tectonic lens whose main rock type is a red to greyish-red gneissic granite (metagranite). The fracture frequency is usually low (less than one fracture per metre) and the number of interpreted fracture zones within the lens is relatively small. These conditions presumably persist to repository depth or deeper. A nature reserve in the southeastern part of the area limits the available area to approximately ten square kilometres. The proportion of exposed rock varies within the area. The outcrops where field checks have been performed are widely spread, however, which means that the geological map can be regarded as reliable for a general assessment.

One possibility that should not be excluded is siting the deep repository beneath SFR. Experience from the construction of more than four kilometres of tunnels and rock caverns is very encouraging. A factor that militates against this alternative is, however, the nearness of the area to a wide plastic shear zone and a partially inhomogeneous bedrock.

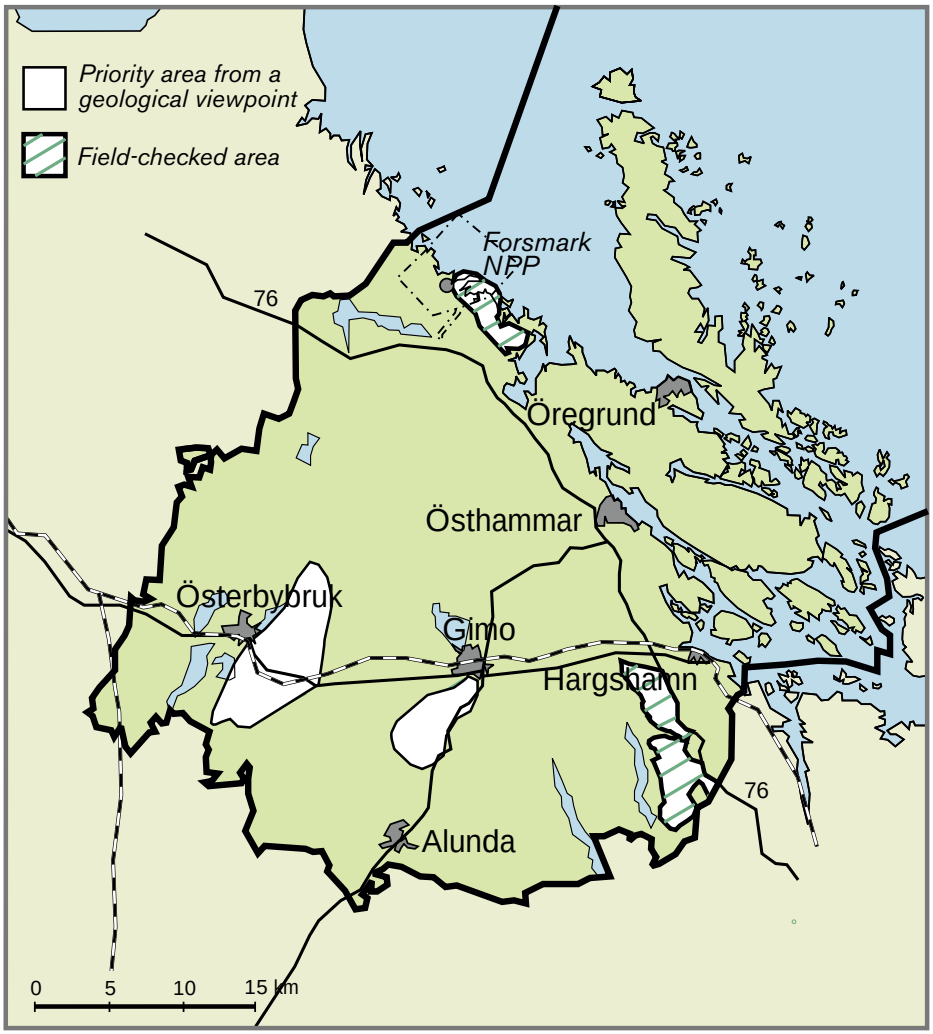

Figure 4-2. *Potentially suitable areas for a deep repository in Östhammar Municipality. Field checks have been performed in the area southeast of Forsmark and west of Hargshamn. These have confirmed that both areas are suitable for further studies from a geological viewpoint.*

The field check conducted west of **Hargshamn** has also confirmed the presence of potentially suitable bedrock with sufficient volume for a deep repository. The field check has not been as extensive as in the Forsmark area, however.

The Hargshamn area is situated in a tectonic lens. The main rock is a red, medium-to-coarse-grained, sometimes weakly foliated gneissic granite (metagranite). The field check indicates homogeneous bedrock with a low fracture frequency and otherwise suitable conditions. The gneissic granite in this area covers roughly 20 square kilometres, if only the bedrock west of highway 76 is assumed to be available and if areas with some nature conservancy interests are excluded. The area has been marked in Figure 4-4.

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for a deep repository. Investigations on different sites in the country show that the flow at repository depth is largely controlled by local variations in the hydraulic conductivity of the bedrock.

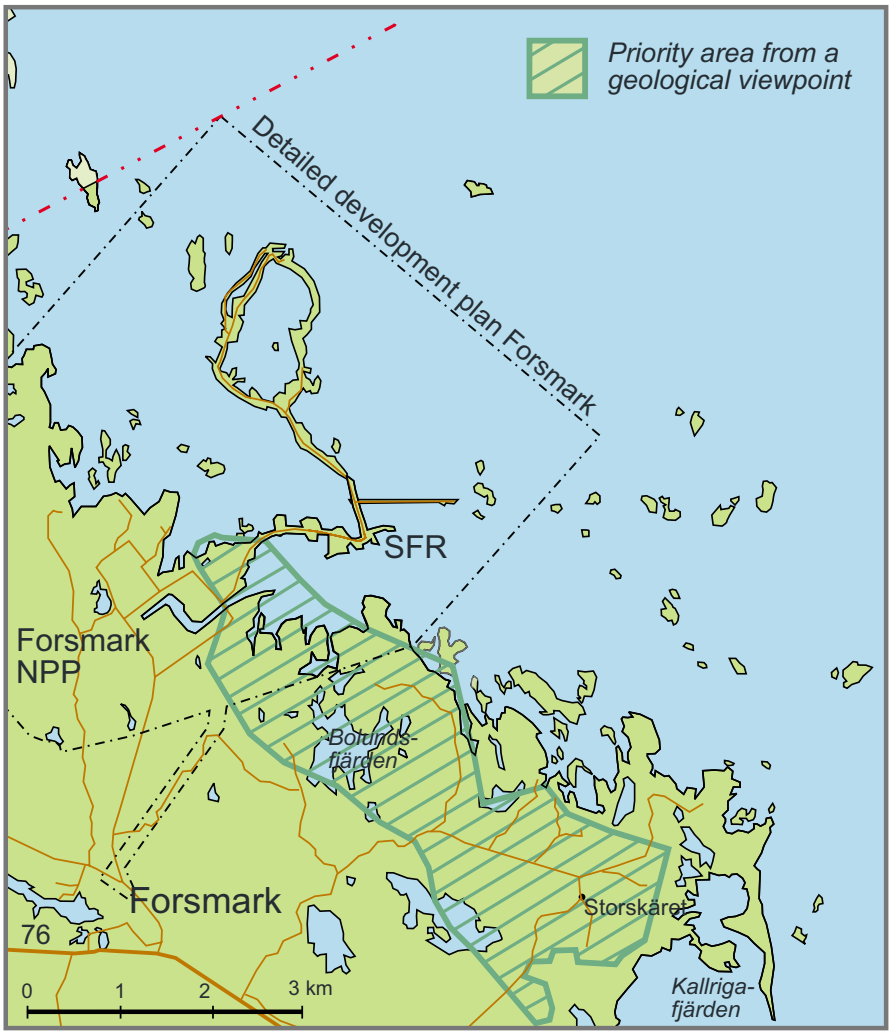

Figure 4-3. *Geologically suitable area for further studies between the Forsmark NPP and Kallrigafjärden. Only the part of the area located outside the Kallriga nature reserve is marked.*

The terrain in most of Östhammar Municipality is very flat, which provides little driving force (gradient) for groundwater flow. This generally contributes to slow groundwater flow and thereby low groundwater fluxes at great depth.

Data on the groundwater's flow conditions and chemical composition at repository depth are largely lacking in the municipality. Just west of the boundary between Östhammar and Tierp municipalities is the well-investigated Finnsjön area, however. Here, in addition to geological studies, extensive groundwater investigations have been carried out by SKB in boreholes down to greater depths than the planned repository depth. The most important conclusions from these investigations is that the hydraulic conductivity of the bedrock in the Finnsjön area is higher than in certain other areas SKB has investigated. Despite this, very low groundwater flows have been found under a wide, gently-dipping fracture zone encountered in a part of the investigation area at a depth of 100–295 metres. According to one interpretation, the gently-dipping zone may act as a "hydraulic cage" that restricts groundwater flux beneath the zone. Gently-dipping zones have also been encountered or indicated in SFR, at the Forsmark NPP and at Dannemora. They are presumably commonly occurring in the region.

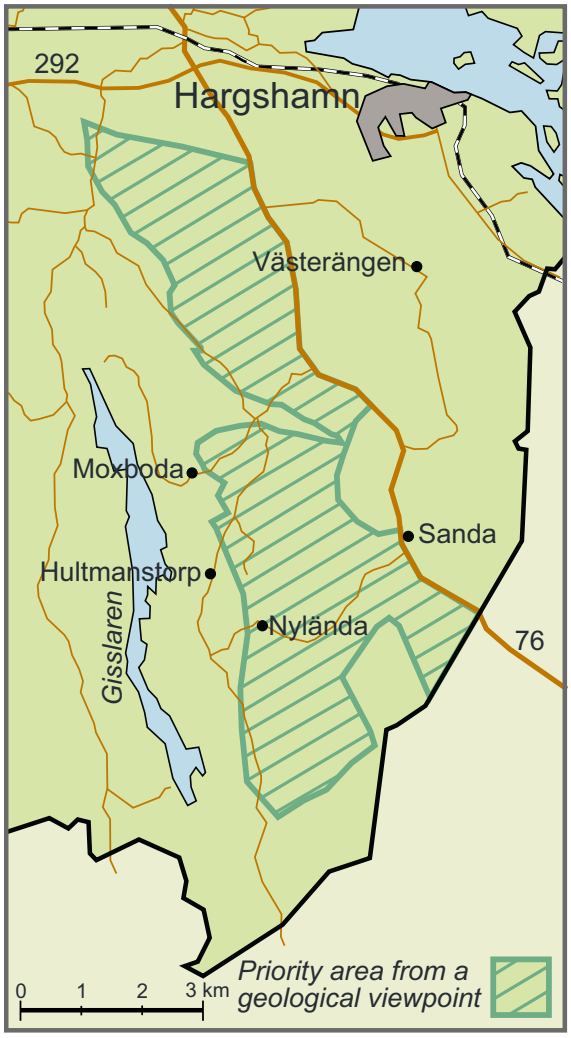

Figure 4-4. *Geologically suitable area for further studies west of Hargshamn. Only the part of the area that is not subject to special nature conservancy interests or the Environmental Code's protection of certain stretches of coast has been marked.*

Statistical analyses of well data from Östhammar Municipality indicate average or slightly lower water capacities in rock-drilled wells compared with the country as a whole. The range of variation between individual wells is great, however. Taken together, this indicates normal groundwater conditions in the upper portion of the bedrock. A comparison with Finnsjön data is not possible, since the wells are considerably shallower than the investigation boreholes at Finnsjön and spread out all over the municipality.

The chemical composition of the groundwater is also an important safety-related factor. Groundwater samples from rock-drilled wells in Östhammar municipality indicate a normal groundwater chemistry for Swedish bedrock, which entails a favourable chemical environment for a deep repository. One difference compared with average conditions in Swedish bedrock is that wells with elevated salinity occur more often than normal. Water samples from certain boreholes in the Finnsjön area show salinities that are slightly higher than today's Baltic Sea water. Salinity and concentrations of other substances are nevertheless well within the limits of what is acceptable from a deep repository standpoint. Samples from greater depths show groundwater that is free from dissolved oxygen, which is an important factor for the deep repository.

Overall assessment

SKB's overall assessment is that both the Forsmark and Hargshamn areas are of interest for further investigations from the geological and safety-related viewpoints. Data from deep boreholes are needed for a reliable assessment of the long-term safety of a deep repository on either of these sites.

4.1.3 Technology

The bedrock must have properties that make it possible to build and operate the underground facility with adequate safety and with known technology. In the case of the surface facility, nearness to existing infrastructure is an advantage. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Underground facility

The dominant rock types in the municipality are gneissic granites, which have been shown by experience to provide good conditions for rock construction. As in all crystalline basement settings, facility layout and construction methods must be adapted to the locations and character of existing fracture zones. In rock chambers at great depth, high rock stresses can generally cause stability problems during the construction and operating periods. Furthermore, the occurrence of radon in the facilities can entail special requirements on e.g. ventilation. Both the Forsmark and Hargshamn areas are judged to have normal construction-related properties for Swedish bedrock, but this must be checked by measurements in deep boreholes.

Data regarding hydraulic conductivity at repository depth in these areas are lacking. However, extensive experience is available from the shallower SFR facility, and this experience has not revealed any unusual or adverse circumstances for construction and operation. The occurrence of saline groundwater may entail a higher risk of corrosion of installations and equipment in the facility. This is not regarded as any great problem, but may entail special requirements on choice of materials and on maintenance during the operating period of the deep repository.

Surface facility

The deep repository's surface facility does not make any special demands on the bearing capacity of the ground or other ground conditions in comparison with other industry. From a technical viewpoint there are good possibilities for adapting the facility to the conditions that prevail on the site in question. Good transport services and nearness to other infrastructure are advantages, but are not requirements for an establishment.

In the event of a siting of the deep repository's surface facility at **Forsmark**, the main surface facility can be located adjacent to SFR's surface facility. This means that the deep repository will not disturb a future expansion of facilities for future energy production within the Forsmark area. Since both the deep repository and SFR will be operated for many years after shutdown of the last nuclear power reactor, synergy gains with SFR in the form of a shared harbour, workshops, offices, information activities, surveillance etcetera may exist even after closure of the last reactor.

SFR's surface facility is situated on a partially artificial peninsula next to the harbour at Forsmark. The deep repository's buildings could be accommodated on the site after moderate filling-out. A drawing of a possible layout of these facilities is shown in Figure 4-5. An rock spoil heap could be located on another site within the Forsmark NPP or in the water area near SFR. Rock spoils can also be removed by sea from the harbour in Forsmark or by overland transport.

The surface facility can be connected to the deep repository's underground facility southeast of the Forsmark NPP by a sloping tunnel. Since the tunnel will probably be short, only a few small buildings are needed for ventilation and evacuation above the repository. The elevator shaft with buildings for passenger transport can then probably be located inside or next to the detailed development plan area at the Forsmark NPP. If the repository is located at a greater distance from the Forsmark NPP, an elevator shaft will probably be needed above the repository for passenger transport.

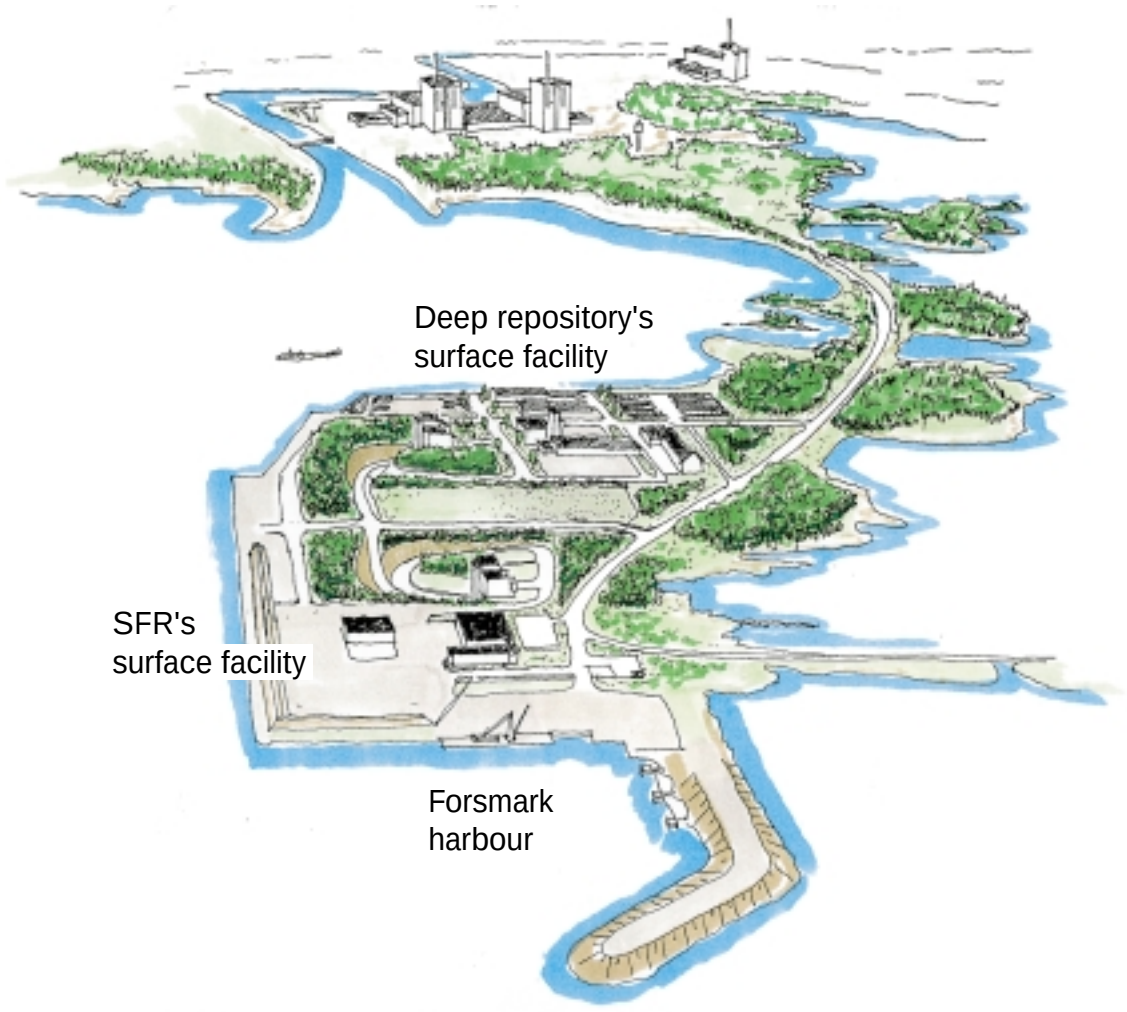

***Figure 4-5**. Possible layout of the deep repository's surface facility at SFR. The surface facility has been positioned between the existing buildings for SFR at the harbour and the Forsmark NPP.*

In **Hargshamn**, the municipality is preparing a large area next to the harbour which would also accommodate the deep repository's surface facility, in addition to new industry and expanded port activities. The facility could be located in such a way that other industrial activities and the port activities are not disturbed. In the same way as for Forsmark, the geologically interesting area west of Hargshamn can be reached by a tunnel from Hargshamn. Buildings for ventilation and an elevator shaft for passenger transport will probably be needed within the geologically interesting area.

Transportation

During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel will be transported. Hargshamn has a harbour with capacity to handle the deep repository's shipments of nuclear waste and backfill materials. Forsmark also has a harbour capable of receiving shipments of nuclear waste. However, some extensions, or transloading in another harbour to smaller ships, are needed for shipments of backfill materials. Alternatively, backfill materials can be received in Hargshamn and transported by highway to Forsmark. Both siting alternatives entail locating the deep repository's surface facility – and the tunnel mouth to the underground facility – near the harbour in Forsmark or Hargshamn. This means that no overland transport of nuclear waste on public roads is needed in either of the two alternatives.

Overall assessment

SKB's overall assessment is that both the Forsmark and the Hargshamn areas are probably suitable with respect to construction and operation of the deep repository's underground facility. However, factors such as rock stresses and locations and character of fracture zones should be given special attention in any further studies.

The deep repository's surface facility can be sited at Forsmark or Hargshamn. Both sites are situated on the coast with access to harbours with sufficient capacity for goods to the deep repository. The sites already have an extensive infrastructure, which means good opportunities for coordination with existing and other planned activities. The region offers good transport options.

4.1.4 Land and environment

Land and environment aspects are, in addition to safety, of great importance for the siting of the deep repository. Areas that both can offer good rock and have suitable land for an establishment of the surface facility within a reasonable distance are therefore of particular interest. The deep repository's surface facility represents the greatest intrusion in land and environment due to the area needed for its various functions. This is also where other environmental impact can be expected, such as noise, handling of rock spoils and transport activities. The fact that the surface and underground facilities can be displaced in relation to each other offers wide flexibility to adapt to local conditions and thereby to avoid areas worthy of protection.

During the investigation phases and prior to construction of a deep repository, deep drilling activities lead to some impact on the flora and fauna in the area above the planned underground facility. During construction and operation, some buildings may be needed directly above the underground facility, along with ventilation buildings along the tunnel connecting the surface and underground facilities.

Protected and valuable areas

Figure 4-6 shows areas with varying degrees of protection for nature conservancy, protection of cultural environments and outdoor recreation, as well as water protection areas. All the areas marked on the map are not to be considered off-limits for siting of a deep repository, but are intended more to illustrate where areas requiring special consideration are located. The most sensitive areas in the municipality, for example the Kallriga and Florarna nature reserves, are coloured red. These areas are not being considered for any of the deep repository's facilities. As is evident from the map, all of the municipality's coastal and archipelago area is valuable from a nature conservancy viewpoint.

Environmental impact

There are wide options for optimizing the location and layout of the deep repository's facilities and activities so that they have little environmental impact. Transport of spent nuclear fuel, backfill materials, rock spoils and personnel to and from the deep repository have an impact on the environment. Construction or rebuilding of transport routes can also lead to environmental impact that must be taken into consideration in an overall assessment of different siting alternatives.

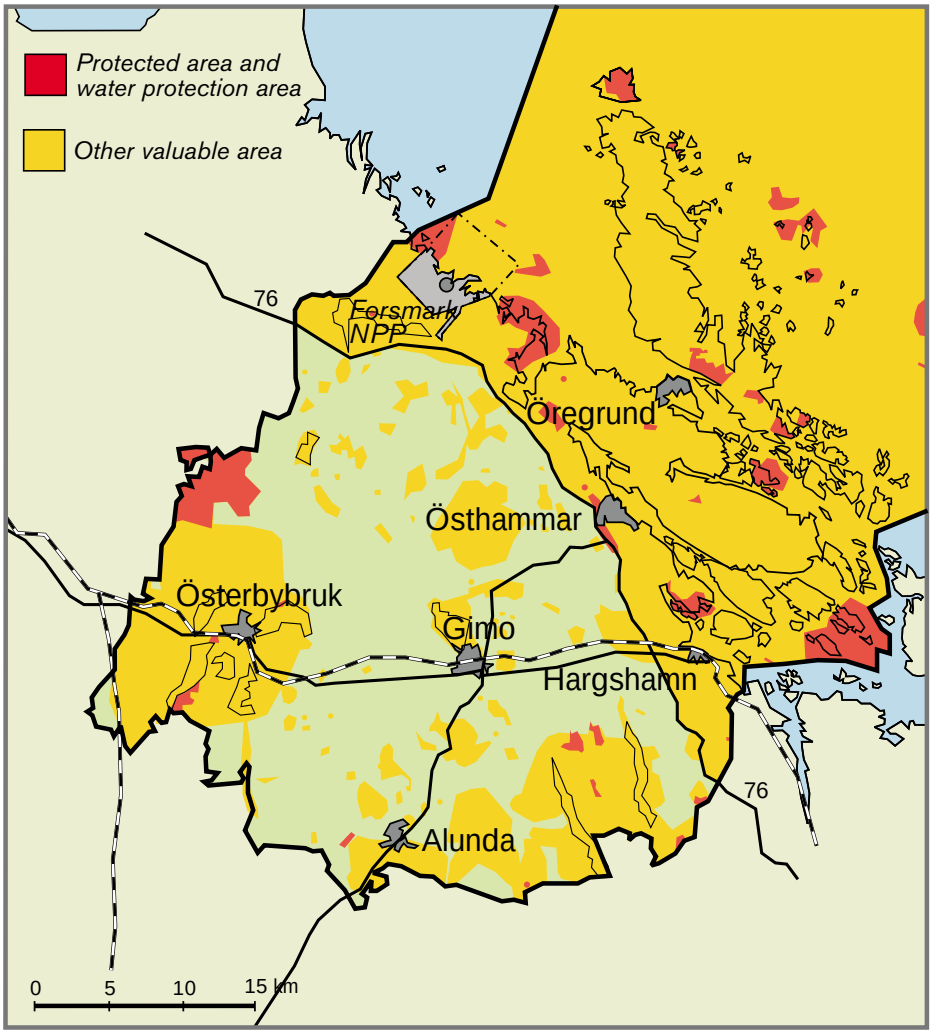

Figure 4-6. *Protected and valuable natural areas in Östhammar municipality.*

A siting at **Forsmark** would entail that the deep repository's surface facility is located within a detailed development plan area for nuclear activities. By situating the facility adjacent to SFR's harbour and surface buildings, all waste management can be gathered to one site and overland transport of nuclear waste will be very limited. The sensitive coastal location requires special consideration in designing buildings and other installations so that noise and other disturbances and impact on the landscape are limited. This particularly applies to rock spoil heaps.

The deep repository's underground facility would in this alternative be located in the geologically interesting area between the Forsmark NPP and Kallrigafjärden bay. The surface and underground facilities are connected by a tunnel. The geologically interesting area is of national interest for nature conservancy, and parts of the area have high natural values. Intensive forestry is conducted within the area. By using existing logging roads and otherwise planning the activities to limit disturbances, a site investigation can be conducted with respect for the area's natural values. If a repository was to be built in the area, some shafts for ventilation and evacuation would probably be needed. A building for passenger transport by elevator shaft to the underground facility may also be needed. It should be possible to locate these buildings by existing roads or other places where the natural values will not be disturbed. How the facilities and activities above and under ground can be designed to limit the environmental consequences will be studied in a site investigation and reported in an EIS.

In the **Hargshamn** siting alternative, the deep repository's surface facility is sited on the industrial land the municipality is preparing by the harbour. The underground facility is situated in the geologically interesting area west of Hargshamn and west of highway 76. The surface and underground portions are connected by a tunnel. Since this alternative also makes use of an existing industrial area by the harbour, the deep repository's facilities and activities can presumably be designed in such a way that the environmental impact is limited and acceptable in relation to the harbour's other activities.

The Environmental Code specifies coastal and archipelago areas where certain types of industry, such as nuclear activities, may not be established. According to the municipality's comprehensive plan, Hargshamn is located in such a coastal and archipelago area. An establishment of the surface facility in Hargshamn may therefore be prevented due to the provisions in the Environmental Code. If this alternative is realized, this question will have to be carefully considered. The geologically interesting area, and thereby the site of a possible repository, is located west of highway 76 and is therefore not affected by these provisions. If site investigations are conducted, however, an inventory of special nature conservancy interests and other interests needs to be done in the area in a similar manner as has been done for the Forsmark area.

Overall assessment

SKB's overall assessment is that there are good possibilities to optimize the siting and layout of the deep repository's surface and underground portions with consideration given to areas worthy of protection and to conduct the activities so that environmental impact is limited. Consideration must thereby also be given to surrounding areas with special protection values and to areas that may be affected by a tunnel between the surface and underground facilities.

4.1.5 Society

A deep repository affects socioeconomic conditions, both locally and regionally. Conditions that may be affected are, for example, the local business sector, employment, tourism and the hospitality industry. Forecasts of how a municipality may develop with or without a deep repository are naturally uncertain, not least in view of the long timespan (about 50 years) covered by the deep repository project, but they nevertheless give some idea of what a deep repository might entail for Östhammar Municipality.

Employment effects

The costs of investment and operation of the deep repository are estimated to amount to on the order of SEK 13 billion (prices in 2000), distributed over about 50 years. The average number of persons directly employed during the regular operation of the deep repository amounts to about 220. During the construction phase – about 5–6 years altogether – more persons will be employed at the facility. In addition, some 100 persons will be indirectly employed.

The municipality's economic life is dominated by two companies: Sandvik Coromant AB and Forsmarks Kraftgrupp AB. In addition there are small companies within many sectors that can contribute to a deep repository establishment, for example in the fields of metalworking, construction and engineering. The proximity of Stockholm and Uppsala means that the regional labour market is one of the largest in Sweden. This means that the recruitment prospects are good and that there is good access to subcontractors. Östhammar Municipality has no colleges, but there are several universities and colleges nearby. These factors, in combination with the nuclear activities already present in the municipality, make for good prospects for recruiting personnel, even for the limited number of positions that require specialized competence. There are also good opportunities for planning and offering custom-tailored training for the deep repository's needs once a siting has been decided on. When all of the above factors are weighed together, it is found that a deep repository would fit well into the area's existing industrial and labour market structure.

Tourism and hospitality industry

Östhammar Municipality has a relatively large hospitality industry. In the summertime there are many boat tourists, particularly in the Öregrund and Gräsö area. Other important attractions are Vallonbruken, Dannemora mines and the Forsmark NPP with SFR. There are approximately 4,000 vacation homes. Most of the tourists in Östhammar Municipality come from the Uppsala and Stockholm regions.

A deep repository could be a popular visitor destination in the municipality and thereby contribute further to the growth of the hospitality industry. An estimate of the number of visitors to a deep repository and the business travel that will be generated indicates something on the order of 5,000–10,000 visitors per year (equivalent to CLAB), according to the surveys that have been done. This would make an annual contribution to the local hospitality industry of around SEK 5–10 million. It can be assumed that international visits and other business visits will take place at other times of the year than the Swedish summer vacation, which would help to distribute the streams of visitors over the year.

Overall assessment

SKB's overall assessment is that Östhammar Municipality offers good societal prospects for building and operating a deep repository. Professional competencies for most of the jobs at the facility can be found within the region. The municipality's nearness to the Stockholm and Uppsala regions means that very good opportunities exist for meeting the deep repository's labour needs during both the construction and operating phases. The nuclear activities in Forsmark with the NPP and SFR contribute to a pool of knowledge and skills in the area of nuclear engineering in particular, but also with regard to siting, procurement, construction and operation of nuclear installations.

4.2 Holistic assessment from the feasibility study

SKB's holistic assessment is that there are good prospects for further studies concerning the siting of a deep repository in Östhammar Municipality. The most interesting alternative is siting the deep repository's surface facility next to SFR with the underground facility in the area between the Forsmark NPP and Kallrigafjärden bay. In this way the repository can be situated in suitable bedrock at the same time as the operating advantages of a co-siting with SFR and the Forsmark NPP can be exploited.

Another alternative deemed to be interesting is locating the surface facility at Hargshamn with the underground facility in the geologically interesting area west of highway 76. If this alternative is realized, a deeper study would need to be made of whether such a siting is possible with reference to the Environmental Code's provisions concerning protection of certain coastal and archipelago areas.

A compilation of the geological conditions in the municipality and experience from the investigations in the Finnsjön area and the construction of the facilities in Forsmark and SFR shows that in the event of a site investigation with test drilling, special attention should be devoted to the following questions:

- Importance of shear zones for long-term safety.
- Advantages and disadvantages of a deep repository in a tectonic lens.
- Occurrence and importance of steeply- and gently-dipping fracture zones.
- Risk of bedrock with ore potential at great depth.
- Occurrence and importance of high rock stresses.
- Hydraulic conductivity of the bedrock.
- Hydrochemical conditions.

SKB's holistic assessment is that both Forsmark and Hargshamn offer good technical prospects for a deep repository, at the same time as environmental impact can be limited by utilizing industrial areas for the surface facilities and avoiding overland transport. Both alternatives are also deemed to offer good prospects for a long-term-safe disposal of nuclear waste in the bedrock. Test drilling is nevertheless required before this can be established.

5 Nyköping – summary evaluation

There are probably good geological prospects for a deep repository in large parts of Nyköping Municipality, Figure 5-1. Two siting alternatives have been specially examined in the feasibility study: Skavsta/Fjällveden and Studsvik/Björksund. A large body of data is available for Fjällveden from previous test drilling that confirms the judgement of suitable bedrock.

If the repository is located in Björksund, the above-ground industrial facility can be located at Studsvik. Transport between the two can take place in an approximately seven kilometre long tunnel. Preliminarily, a similar technical solution is possible for a repository in Fjällveden, where a tunnel up to about fifteen kilometres long can depart from an industrial facility at Skavsta. Nuclear waste and backfill materials can be transported to Skavsta on a partially newly-laid railway from Oxelösund, but other transport solutions are possible between Oxelösund and Fjällveden.

Nyköping Municipality

The economic life of Nyköping Municipality has changed considerably during the past century. Industry has been replaced by services. Today the municipality has a broad economy characterized by a large public sector, a large private service sector and a small manufacturing sector. One large workplace is Studsvik with its companies in nuclear-related activities, with a total of 350 employees. Other large private employers are SAAB Automobile AB with some 375 employees and Thorsman & Co AB with some 225 employees.

The municipality is rich in cultural environments and historical monuments. Nyköping is one of the oldest cities in Sweden, and Nyköpingshus Castle has played a vital role in the country's history. There are many lakes in the interior of the municipality, such as Båven. The coastal and archipelago areas are important from a cultural and environmental viewpoint. The Nyköpingsån River, which discharges in the Baltic Sea via Stadsfjärden in Nyköping, is popular with anglers and canoeists.

Land area
1,420 km^2

Inhabitants
Approx. 49,000

Location
Coastal municipality in Södermanland County. The northern parts of the municipality border on the municipalities of Trosa, Södertälje and Gnesta, the western parts on the municipalities of Flen and Katrineholm, and the southern parts on the municipality of Norrköping. Oxelösund Municipality and the Baltic Sea are on the east.

Towns
Nyköping pop. 30,000, Stigtomta pop. 2,000, Svalsta pop. 1,000, Nävekvarn pop. 900, Tystberga pop. 900.

Transportation
Stockholm-Skavsta airport with both freight and passenger service. The E4 motorway passes through the municipality. Rail link with Stockholm and Norrköping/Linköping. A considerable part of the population commutes to Stockholm. Harbour for heavy goods traffic in Oxelösund.

Land
Approximately 52% forest land, 26% arable land and pastureland, 22% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 25, Left Party 6, Moderates 13, Christian Democrats 6, Centre Party 5, Liberal Party 3, Green Party 3.

Feasibility study decision
No decision in the municipal council.

Nuclear-related activities
Research facility at Studsvik, in operation since 1959.

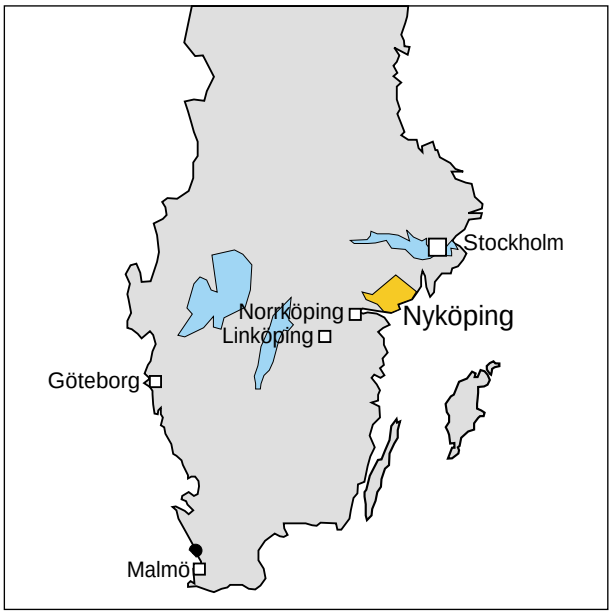

Figure 5-1. *Location of Nyköping Municipality.*

Several reviewing bodies have expressed environmental objections to an establishment in Studsvik/Björksund. Equivalent circulation for review and commentary has not been carried out for Skavsta/Fjällveden, so the situation is unclear. The question of overland transport needs to be clarified in further studies. Different technically suitable solutions must be proposed and evaluated based on their environmental consequences, and a more in-depth dialogue must be held with those who would be affected by the different alternatives.

5.1 Siting prospects in Nyköping Municipality

5.1.1 General

During the spring of 1995, SKB made a general study of the siting prospects for a deep repository in five municipalities with nuclear installations, among them Nyköping Municipality. The conclusion was drawn from this general siting study that there may be good geological siting prospects in the municipality and that the existing body of geological data is large. The material was also judged to be well-suited to serve as a basis for a feasibility study aimed at leading to a more accurate assessment of the municipality's geological prospects for hosting a deep repository.

Nyköping is a municipality in southeastern Södermanland between the two metropolitan regions of Stockholm and Norrköping/Linköping. The distance to Stockholm is 100 kilometres, to Norrköping 60 kilometres and to Linköping 100 kilometres. Both road and rail connections to these cities are very good. The municipality has a diversified economy with companies and competencies within many of the areas that would be in demand if a deep repository was established there.

The Studsvik facility has experience and knowledge of nuclear activities since the late 1950s. In other words, the municipality offers competence and experience in many sectors of relevance to the deep repository.

5.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. In the municipality of Nyköping, data are available from Fjällveden for assessing safety there. Such an assessment cannot be done for other parts of the municipality, since data are lacking on conditions at repository depth. Instead, general and preliminary assessments of the suitability of the bedrock for a repository are based on compilations and analyses of existing maps and other material. Field checks have been performed in the subareas which were singled out as being of interest in the feasibility study's preliminary final report.

Bedrock conditions

The municipality is dominated by two rock types: gneissic granites and sedimentary veined gneiss. Both of these rocks are judged to be generally favourable for a repository. The soil depth is generally moderate and the proportion of bare rock is relatively high, particularly near the coast. This facilitates geological mapping and increases the chances of making accurate assessments of conditions at repository depth. There are three orefields in the municipality: The Tunaberg, Marieberg and Förola fields. There is no known ore potential in other parts of the municipality that would entail restrictions in the siting possibilities.

The western and southwestern part of the municipality is characterized by lens-shaped rock blocks surrounded by large-scale plastic shear zones. A large number of fracture zones also occur in this part of the municipality. There are also several major zones of a similar character in the southeastern part of the municipality. The latter area is bounded by two regional faults with rich deposits of mylonites and crush breccias. The central and northern part of the municipality largely lacks plastic shear zones. Regional fracture zones occur here in a regular pattern that leaves room for relatively large blocks of intact rock in between.

In the feasibility study's geological survey, all parts of the municipality that exhibit potentially unsuitable conditions (certain rock types, heterogeneous bedrock, areas with ore potential, plastic deformation zones) have been dismissed as uninteresting for further studies. After this has been done, two areas which together cover approximately one-third of the area of the municipality remain: One area in the northern part of the municipality from Lake Båven down to the town of Nyköping, and one area in the south between Studsvik and the town of Nyköping.

An evaluation with regard to land and environment aspects was done in these two large geologically interesting areas in the preliminary final report. As a result of this evaluation, seven smaller subareas remained – four in the northern and three in the southern area. Field checks were done in these subareas in the supplementary phase of the feasibility study. Six subareas are still judged to have suitable bedrock for further studies, see Figure 5-2.

In the southern area, field checks have been done in the Björksund area, the Ekekulla area and the Svankäng area. The proportion of bare rock is very high in the entire area. The field check in the Björksund area showed that the frequency of fractures is low in the area. A five square kilometre area with porphyritic gneissic metagranite is judged to be particularly fracture-free and homogeneous. Within the Ekekulla area, the field check showed that the bedrock resembles that in Björksund, but that homogeneous conditions only exist within a three square kilometre area. The size of the homogeneous area is thereby on the borderline for what is acceptable as the basis of a site investigation, since

there is a greater risk that a small area will have to be abandoned if rock with inferior properties is encountered in test drilling. The Svankäng area is small (about 2.5 square kilometres) and has a bedrock which the field check has found to be thoroughly inhomogeneous. This area is therefore not of interest for further studies.

Field checks in the four subareas between the town of Nyköping and Lake Båven (see Figure 5-2) show that the proportion of exposed rock is high, that the bedrock is often homogeneous and fracture-poor and that the frequency of interpreted regional fracture zones is low. Several of the areas are also considerably larger than is needed for a deep repository (between 7 and 50 square kilometres). The positive geological assessment from the preliminary final report therefore remains valid for all four subareas. SKB's study site Fjällveden is located in the largest subarea, the Fjällveden-Tunsätter area. Data from a large number of boreholes down to a depth of 700 metres in Fjällveden were evaluated in the KBS-3 safety assessment. The conclusion from this assessment was that good geological and hydrological prospects exist for a repository in the area, but that supplementary investigations are required before this can be established.

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for a deep repository. Investigations on different sites in the country show that the groundwater flow at repository depth is largely controlled by local variations in the hydraulic conductivity of the bedrock.

Figure 5-2. *Geologically interesting areas for further investigations in Nyköping Municipality and the six subareas still considered to be of interest after field checks.*

The terrain in most of Nyköping Municipality is flat, which generally contributes to slow groundwater flow. Knowledge of groundwater conditions at great depth is only available from investigations in Fjällveden. Hydraulic conductivity at repository depth, about 500 metres, is generally very low there, both in most of the rock mass and in the fracture zones. An exception is steeply-dipping layers of gneissic granite, where it is higher. Data on the water-bearing capacity of the bedrock down to a depth of approximately 100 metres are available from a large number of rock-drilled wells spread over the whole municipality. These data show wide variation, with wells yielding both a lot of water and little water, regardless of the rock type or where in the municipality the well is located. On average, however, hydraulic conductivity is lower than the national average.

When it comes to the chemical composition of the groundwater, samples from holes drilled to repository depth in Fjällveden and from rock-drilled wells in the municipality show a composition that is normal for Swedish bedrock. Wells with saltwater intrusion occur at different places and regardless of the distance to the Baltic Sea. Samples from greater depths show groundwater that is free from dissolved oxygen, an important factor for the deep repository.

Overall assessment

SKB's overall assessment is that geological prospects exist for further investigations within six of the seven areas where field checks have been performed (see Figure 5-2). A possible exception is the Ekekulla area, where the size of the geologically interesting area is on the borderline for what is acceptable as the basis of a site investigation. The major fracture zones in the areas of interest that emerge on the feasibility study's investigation scale usually delimit bedrock blocks that are considerably larger than is needed for the deep repository. This indicates good possibilities to situate the repository in such a way as to avoid major fracture zones. In the Fjällveden area, where data are available from repository depth from SKB's previous investigations, conditions are deemed to be good for a deep repository. Among other things, hydraulic conductivity is low both in most of the rock mass and in fracture zones. Rock-drilled wells indicate that it is presumably possible to find equivalent conditions in other parts of the municipality. The chemical composition of the groundwater is deemed to be normal for Swedish bedrock, which is favourable for a deep repository.

5.1.3 Technology

The technical prospects for building and operating the deep repository apply to the facilities both above and under ground. The bedrock should have properties that make it possible to build and operate the repository's underground facility with adequate safety and known technology. As far as the above-ground activities are concerned, nearness to infrastructure and access to industrial land provide advantages. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Underground facility

The dominant rock types in the municipality are sedimentary veined gneiss and gneissic granite. Experience shows that these rock types offer good conditions for rock construction. The areas designated as interesting for further studies from a safety viewpoint, see Figure 5-2, are deemed to offer good conditions for construction and operation of the repository's underground facility. As in other crystalline basement settings, facility layout and construction methods must be adapted to the locations and character of existing fracture zones, since these zones often are characterized by poorer rock quality and

higher hydraulic conductivity than the surrounding rock. Furthermore, high rock stresses can generally cause stability problems in rock chambers. These factors are particularly important to take into consideration in possible further studies.

Surface facility

The surface operations do not make any special demands on the bearing capacity of the ground or other ground conditions in comparison with other industry. From a technical viewpoint there are good possibilities for adapting the facility to the conditions that prevail on the site in question. Good transport services and nearness to other infrastructure are considerable advantages, but are not requirements for an establishment.

Two concrete proposals for siting of the surface facility have been offered in the feasibility study: at Skavsta airport and adjacent to the nuclear installation at Studsvik.

Skavsta will be of interest if the repository is sited in the Fjällveden/Tunsätter area. Most of the above-ground activities can then be housed in a facility that is established within an operations area at Skavsta airport. Today the site is an undeveloped wooded area a few kilometres from the centre of the town, west of highway 53. The distance from Skavsta to a repository in Fjällveden is about 15 kilometres. Waste and backfill materials can be transported between them via a sloping tunnel, or by road or rail. To facilitate the personnel's daily commuting, among other things, a number of buildings will be established for offices, personnel quarters, information and visiting activities, and for shaft and ventilation on the site directly above the repository. These buildings are estimated to occupy an area of about 2–3 hectares. Passenger transport and certain utilities to the repository can then go via a shaft from this facility. In addition, one or more ventilation buildings may be built along a tunnel from Skavsta and in the peripheral areas of the repository.

Studsvik will be of interest if the repository is sited in the Björksund or Ekekulla area. Two possible sites for the above-ground industrial facility have been studied. Both are situated within the fenced-in nuclear area at Studsvik. One site has room for an operations area big enough for the entire operation with all its functions. The other can only accommodate parts of the operation, but a good total solution can nevertheless be achieved by housing certain functions in rock caverns adjacent to the existing rock cavern for waste disposal. A sloping tunnel is the alternative recommended to connect a facility at Studsvik with a repository in one of the aforementioned areas. The tunnel will be about seven kilometres long if the repository is sited at Björksund. It is suitable to build a number of buildings above the repository, in a similar manner as for the Skavsta alternative. In addition, one or more ventilation buildings are presumably needed along the tunnel route.

Transportation

During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel and visitors will be transported. Oxelösund has a harbour with capacity for the deep repository's needs. Studsvik also has a harbour capable of receiving shipments of nuclear waste, although some extensions, or transloading in another harbour to smaller ships, are needed for shipments of backfill materials. The region's major roads and railways are shown in Figure 5-2. There are two railways in the municipality with sufficient bearing capacity for the heavy waste transports. The main southern line runs from Norrköping through the municipality towards Vagnhärad. The former TGOJ railway originates in Oxelösund and leads via the town of Nyköping towards Flen. The roads in the municipality vary in standard. The two biggest roads with motorway capacity are E4, which runs through the municipality in a northeastly direction, and highway 52 between Oxelösund and the town of Nyköping.

The **Skavsta/Fjällveden** siting alternative assumes that Oxelösund is used as a receiving harbour for goods to the deep repository. Further transport to a facility at Skavsta can take place by rail or possibly road. The former TGOJ railway from Oxelösund towards Skavsta can be used for the rail alternative. A 4–5 kilometre long rail link then needs to be built from the existing railway to the facility. Most of that section will be built for the airport's need of connecting rail services. In this case, an approximately one-kilometre new railway is needed for the deep repository. The road standard between Oxelösund and the town of Nyköping is high, but the roads leading to Skavsta may need to be refurbished, in the event heavy goods are to be transported by road.

A siting at **Studsvik/Björksund** entails that transport casks of nuclear waste are shipped to the harbour in Studsvik, where they are carried by terminal vehicle within the area and then via tunnel. Bentonite clay can be imported on large ships to e.g. the harbour in Oxelösund for transloading to smaller ships that can be received at the harbour in Studsvik. The existing roads to Studsvik may need to be refurbished for the increased volume of daily transport of personnel and of goods in smaller volumes.

Overall assessment

SKB's overall assessment is that the areas that are considered of interest for further studies from the viewpoint of long-term safety can also provide a favourable environment with respect to construction and operation of the deep repository. The two siting alternatives that have been described are both judged to be fully feasible from a technical viewpoint. Important questions remain for Skavsta/Fjällveden as regards transport solutions, both for the section Oxelösund-Skavsta and for further transport to a repository in Fjällveden. The technical prospects for the Studsvik alternative have been better clarified, but uncertainties remain here as well.

5.1.4 Land and environment

Aside from safety, land and environment aspects are also of great importance for the siting of the deep repository. Areas that both can offer good rock and have suitable land within a reasonable distance for building the surface facility are therefore particularly interesting. The deep repository's surface facility represents the greatest intrusion in land and environment due to the area needed for its various functions. The fact that the surface and underground facilities can be displaced in relation to each other offers wide flexibility to adapt to local conditions and thereby to avoid areas worthy of protection.

During the investigation phases prior to construction of a deep repository, deep drilling activities lead to some impact on the flora and fauna above the planned underground facility. During construction and operation, some buildings may be needed directly above the underground facility, along with ventilation buildings along the tunnel connecting the surface and underground facilities.

Protected and valuable areas

Figure 5-3 shows areas with varying degrees of protection for nature conservancy, protection of cultural environments and outdoor recreation. The figure also shows where there are water protection areas and road or railway reserves. All the areas marked on the map are not to be considered off-limits for siting of a deep repository, but are intended more to illustrate where areas requiring special consideration are located. The most sensitive areas in the municipality – the coastal and archipelago area in the eastern part of the municipality, the Lake Båven area and the water protection areas at e.g. Stigtomta and Högåsen – are coloured red on the map. None of the deep repository's facilities will be located in these areas.

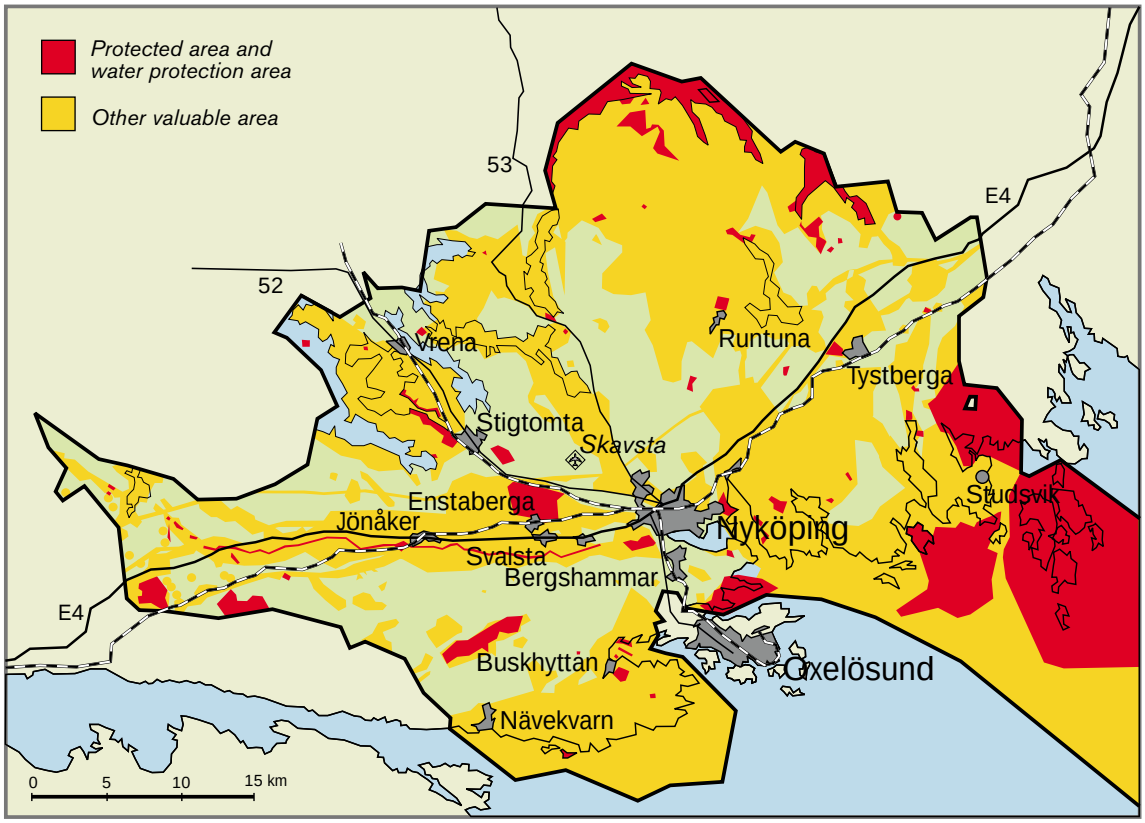

Figure 5-3. *Protected and valuable areas for nature conservancy, protection of cultural environments, outdoor recreation and water supply.*

The **Skavsta/Fjällveden** siting alternative entails that the above-ground activities are mainly housed in a facility adjacent to the existing airport. The repository and a number of buildings for offices, personnel quarters, information and visiting activities, as well as for shaft and ventilation, can be located in Fjällveden. There are judged to be wide options there for establishing the facilities in such a way that conflicts with other interests are avoided. A possible tunnel from Skavsta to a repository in Fjällveden must be routed so that areas worth protecting, such as along the valley of the Nyköpingsån River, are not affected.

A siting at **Studsvik/Björksund** would entail that most of the above-ground activities are housed within an existing nuclear installation. Such a siting must, however, take into account the nature reserves and national interests for nature conservancy, protection of cultural environments and outdoor recreation that surround Studsvik. A repository in the Björksund or Ekekulla area west and northwest of Studsvik will probably require a number of buildings on the site, in a similar manner as for the Skavsta/Fjällveden alternative. There are today wide options for positioning such a facility with respect to land and environmental interests. If the municipality's proposal for a new comprehensive plan is adopted, however, this would entail restrictions on certain types of facilities, including nuclear activities, within most of the geologically interesting Björksund area. This also applies to a smaller portion of the Ekekulla area.

Environmental impact

There are wide options for optimizing the location and layout of the deep repository's facilities to minimize their environmental impact. Transport of spent nuclear fuel, backfill materials, rock spoils and personnel to and from the deep repository have an impact on the environment. Construction or rebuilding of transport routes can also lead to environmental impact that must be taken into consideration in an overall assessment of different siting alternatives.

Overall assessment

SKB's overall assessment is that good possibilities exist to optimize the siting and layout of the deep repository's different parts with consideration given to areas worthy of protection and so that environmental impact is limited. Consideration must thereby also be given to surrounding areas with special protection values and to areas that may be affected by a tunnel between the surface and underground facilities. The municipality's ongoing planning work for coastal areas must also be taken into consideration in any further siting studies.

5.1.5 Society

A deep repository can affect socioeconomic conditions, both locally and regionally. There are a large number of aspects which, taken together, can provide a picture of what prospects Nyköping Municipality may have for an establishment of the deep repository. Conditions that may be affected to a greater or lesser extent by the project are, for example, the local business sector, employment, tourism and the hospitality industry. Forecasts of how a municipality may develop with or without a deep repository are naturally uncertain, not least in view of the long timespan (about 50 years) covered by the deep repository project, but they nevertheless give some idea of what a deep repository might entail for Nyköping Municipality.

Employment effects

The costs of investment and operation of the deep repository are estimated to amount to on the order of SEK 13 billion (prices in 2000), distributed over about 50 years. The average number of persons directly employed during the regular operation of the deep repository amounts to about 220. During the construction phase – about 5–6 years altogether – up to 600 persons will be employed at the facility. To this can be added indirect effects on employment.

Nyköping is a relatively large municipality with a diversified economy. The municipality is located near both Stockholm and Norrköping/Linköping and has very good transport services to these places. This facilitates commuting and recruitment. It also provides access to many subcontractors within a limited distance and makes it easy to recruit construction workers even during the most intensive construction phase. Know-how from metalworking, building and construction is available within the municipality. Nyköping Municipality has no institutions of higher learning, but this has not had any adverse effect on the level of education among the municipal inhabitants. There are a large number of universities and colleges in the near region. These factors, in combination with the nuclear activities already present in the municipality, make for good prospects for recruiting personnel, even for the limited number of positions that require specialized competence. There are also good opportunities for planning and offering custom-tailored training for the deep repository's needs once a siting has been decided on. When all of the above factors are weighed together, it is found that a deep repository would fit well into the area's existing industrial and labour market structure.

Tourism and hospitality industry

Nyköping is not a typical tourist municipality, but there are a number of important tourist attractions such as Nyköpingshus, castles, manor houses, medieval churches, and a large and relatively untouched archipelago. There are around 2,800 vacation homes, but it is transients and business travellers who account for most of the revenues in the hospitality industry.

A deep repository could be a popular visitor destination in the municipality and thereby contribute further to the growth of the hospitality industry. An estimate of the number of visitors to a deep repository and the business travel that will be generated indicates something on the order of 5,000–10,000 visitors per year (equivalent to CLAB), according to the surveys that have been done. This would make an annual contribution to the local hospitality industry of around SEK 5–10 million. It can be assumed that international visits and other business visits will take place at other times of the year than the Swedish summer vacation, which would help to distribute the streams of visitors over the year.

Public opinion

As far as public opinion in Nyköping Municipality towards the nuclear waste programme and SKB's activities is concerned, those opinion polls that have been conducted indicate that the majority have a positive attitude towards SKB and towards the possibility of achieving safe disposal of the spent nuclear fuel. However, there is also a strong opinion among several groups against the deep repository project and against a siting in Nyköping Municipality. A number of reviewing bodies, such as the county administrative board and the Swedish Society for Nature Conservation, have also proffered critical viewpoints on a siting in the Studsvik area, with reference to the areas worthy of protection that exist along the coast. The proposal to site the deep repository at Skavsta/Fjällveden has not undergone an equivalent review and commentary procedure, so the attitude towards this alternative is unclear.

Overall assessment

SKB's overall assessment is that Nyköping Municipality offers good societal prospects for building and operating a deep repository. Professional competencies for most of the jobs at the facility can be found within the region. The municipality's location between Stockholm and Norrköping/Linköping means that very good opportunities exist for meeting the deep repository's labour needs during both the construction and operating phases. More than 40 years of experience of nuclear activities in Studsvik contribute to a pool of knowledge and skills in the area of nuclear engineering in particular, but also with regard to siting, procurement, construction and operation of nuclear installations.

5.2 Holistic assessment from the feasibility study

SKB's holistic assessment is that there are good geological prospects for further studies concerning the siting of a deep repository in Nyköping Municipality. This is based on the positive experience obtained from test drilling in Fjällveden and the occurrence of areas with similar bedrock in several other parts of the central and northern part of the municipality.

Two siting alternatives have been specially studied. The first is Studsvik/Björksund. The deep repository's above-ground industrial facilities can then be situated for the most part within the nuclear installation in Studsvik, and a tunnel can connect the industrial portion with a repository in Björksund or Ekekulla. However, several reviewing bodies have expressed doubts about a siting in the Studsvik area. The municipality's ongoing planning work also contains indications that large parts of the Björksund and Ekekulla areas will in the future be subject to tougher restrictions on an establishment than is the case today.

The other alternative is Skavsta/Fjällveden. An inland location requires overland transport of nuclear waste and backfill materials to the facility and rock spoils away. The possibility of locating the industrial facility at the Skavsta airport has been specially studied in the feasibility study. Transport to the airport can take place by rail from Oxelösund. Further transport from Skavsta to Fjällveden can then go in a tunnel. It has not been determined whether this transportation system is acceptable to the municipality and other stakeholders. There may also be other possible system solutions, for example overland transport all the way from Oxelösund to Fjällveden. Such a transport solution will probably require extensive refurbishing and expansion of the road network.

SKB's conclusion is that the geological prerequisites for a repository probably exist in Fjällveden and in Björksund as well. Moreover, the technical prerequisites also exist for industrial establishment and transportation in Studsvik/Björksund and preliminarily in Skavsta/Fjällveden as well. Several reviewing bodies have expressed environmental objections to an establishment in Studsvik/Björksund. An equivalent review and commentary procedure has not been carried out for Skavsta/Fjällveden, so the situation there is unclear. If further studies are conducted in Nyköping Municipality, the data available from previous geological investigations in the Fjällveden area should be further analyzed to begin with. The question of overland transport needs to be clarified in further studies. Different technically suitable solutions must be proposed and evaluated based on their environmental consequences, and a more in-depth dialogue must be held with those who would be affected by the different alternatives.

6 Oskarshamn – summary evaluation

SKB's assessment from the feasibility study is that there are good prospects for further studies concerning the siting of a deep disposal system in Oskarshamn Municipality, Figure 6-1. The most interesting alternative is siting the deep repository at Simpevarp, adjacent to CLAB (the interim storage facility) and the planned encapsulation plant. The surface facility can then be located in the industrial area on the Simpevarp Peninsula. The bedrock in the Simpevarp area is judged to be potentially suitable for the underground facility, but investigations are required with drilling on and west of the Simpevarp Peninsula to determine this, and if so to pinpoint a suitable location and layout for the facility. Since a siting of the encapsulation plant adjacent to CLAB is SKB's main alternative, all spent fuel management would then be gathered around the Simpevarp Peninsula. This alternative offers good opportunities for coordination with the Oskarshamn NPP and CLAB, at the same time as it largely eliminates the need for nuclear waste transport.

Another alternative deemed to be of interest is a siting of the deep repository in the southern part of the municipality. Potentially suitable bedrock exists within an area south and southwest of the town of Oskarshamn. Oskarshamn's harbour is well-equipped to receive and handle goods for the deep repository. The surface facility can be located at Oskarshamn's harbour and/or at Storskogen, approximately three kilometres from the town of Oskarshamn.

Oskarshamn Municipality

Oskarshamn is a forest and industrial municipality on the coast of Småland. The municipality used to be dominated by shipbuilding, agricultural and forestry. Today, engineering and energy are the dominant industries. The largest private employers are Scania with 1,600 employees and OKG with 1,000 employ-ees at the Oskarshamn Nuclear Power Plant. SKB's facilities – CLAB, the Äspö HRL and the Canister Laboratory – employ some 170 persons.

Renowned tourist destinations are the Döderhultare Museum, the Simpevarp Peninsula with the NPP, CLAB and the Äspö HRL, and the Misterhult archipelago in the northern part of the municipality. The island of Blå Jungfrun (Blue Maiden) is a national park in Kalmarsund.

Location
Coastal municipality in Kalmar County. Borders in the north on the municipality of Västervik, in the south on the municipality of Mönsterås and on the inland side on the municipalities of Vimmerby, Hultsfred and Högsby.

Land area
1,047 km^2

Inhabitants
Approx. 26,500

Towns
Oskarshamn pop. 18,000, Figeholm pop. 1,000, Kristdala pop. 1,000, Påskallavik pop. 1,000.

Transportation
Airport with daily flights to Stockholm/Arlanda. Rail connections (passenger service) with Linköping and Kalmar. The E22 highway passes through the municipality in a north-south direction. Highway 23 leads westward towards Växjö. Oskarshamn has one of Sweden's biggest industrial ports with large exports of sawn timber products. Ferry service to Gotland.

Land
Approximately 75% forest land, 7% arable land and pastureland, 18% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 22, Left Party 10, Moderates 9, Christian Democrats 6, Centre Party 2, Liberal Party 1, Green Party 1.

Feasibility study decision
October 1996 – 38 yes, 5 no.

Nuclear-related activities
- Oskarshamn NPP with three reactors, the oldest in operation since 1974.
- CLAB (Central Interim Storage Facility for Spent Nuclear Fuel) in operation since 1985.
- Äspö HRL (research method development for the deep repository), completed 1995.
- Canister Laboratory (development of encapsula tion technology for the deep repository), in operation since 1998.

Figure 6-1. *Location of Oskarshamn Municipality.*

SKB's holistic assessment from the feasibility study is that good technical prospects exist for siting a deep repository in the municipality while taking both safety-related aspects and environmental interests into consideration.

6.1 Siting prospects in Oskarshamn Municipality

6.1.1 General

Oskarshamn Municipality occupies a special position in Sweden's nuclear power programme, since it is here the spent nuclear fuel is interim-stored and SKB's research laboratories are located. Oskarshamn is therefore affected by SKB's programme regardless of where in the country the deep repository and associated facilities are eventually sited. SKB has also stated in RD&D-Programme 92 that an encapsulation plant at CLAB is a main alternative. Against this background, it is of great value for the entire programme that the municipality has chosen to participate fully and actively in the ongoing siting process.

There are special opportunities and advantages in gathering all management of high-level waste in Sweden in one place. One obvious advantage is that all transport from the encapsulation plant to the deep repository is largely eliminated. However, this is only one of many aspects that must be weighed into the final assessment of siting alternatives for the deep repository system. The most important is that the areas that are selected for site investigations have good prospects of satisfying the safety and environmental requirements.

6.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. In a feasibility study, geological maps and other geoscientific materials are compiled. This provides a general picture of where in the municipality bedrock with suitable properties may be located. However, knowledge of

conditions at repository depth is needed for a reliable assessment of the long-term safety of a deep repository, which requires measurements in deep boreholes. Drilling of such boreholes is done in a site investigation but is not included in a feasibility study.

Bedrock conditions

The data that have been gathered on conditions in the bedrock show that the dominant rock type in Oskarshamn Municipality is Småland granite, which occurs in different variants. Large parts of the municipality, especially in the north and along the coast, have no or only a thin soil cover. This facilitates geological mapping and assessments of the conditions at depth. With the exception of a small area in the far north, there is no known ore potential that would entail restrictions in the siting possibilities. Nor has any information emerged to suggest anything other than favourable conditions with regard to the long-term stability of the bedrock. Among other things, the earthquake frequency is low and no major quakes have been recorded in historic time.

The system of shear and fracture zones that traverses the municipality at a level with Oskarshamn-Bockara should be avoided if the deep repository is sited in the municipality. Otherwise, fracture zones occur to an extent that is normal for Swedish bedrock, as far as can be judged. Fracture zones can adversely affect safety, in part because future bedrock movements cannot be excluded in certain zones, and in part because the fracture zones often have much higher hydraulic conductivity than the rest of the rock mass. The location and layout of the deep repository must therefore be adapted to the positions and properties of the zones. However, investigations on a larger scope and a more detailed scale than in the feasibility study are required for this purpose.

In the feasibility study's geological survey, all parts of the municipality with potentially unsuitable conditions (certain rock types, heterogeneous bedrock, plastic deformation zones, dominant fracture zones, areas with ore potential) have been dismissed as uninteresting for further studies. After this, approximately two-thirds of the municipality's land area remains (see Figure 6-2). The bedrock is homogeneous here, and existing fracture zones delimit bedrock blocks that are in many cases large enough to accommodate the deep repository. Two areas, the Simpevarp area and the southern part of the municipality, stand out as being particularly interesting. In these areas, the transport prospects are judged to be good, at the same time as there are good opportunities to observe environmental protection. In the case of the Simpevarp area, nearness to CLAB and the planned encapsulation plant is another positive factor. Geological field checks were therefore carried out during the supplementary phase of the feasibility study, both on and west of the Simpevarp Peninsula and in the southern part of the municipality (see Figure 6-2). The assessments that were made in the preliminary final report in June 1999 have largely been verified in the field checks.

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is regarded as an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for a deep repository. Investigations in Oskarshamn Municipality and on other sites show that local variations in the hydraulic conductivity of the bedrock can be considerable, even at repository depth. The main reason for this is that the frequency and character of fracture zones differs from place to place. The variations in hydraulic conductivity also cause the groundwater flow to vary within relatively wide limits.

Figure 6-2. *Potentially suitable areas for a deep repository in Oskarshamn Municipality. Field checks have been performed on the Simpevarp Peninsula and west of there, and in an area in the southern part of the municipality.*

Data on the hydraulic conductivity of the bedrock are available from SGU's (Geological Survey of Sweden) well archive, and from investigations in deep boreholes on several sites in the northeastern part of the municipality. The latter are above all taken from the Äspö HRL, and to a lesser extent from investigations at Laxemar, on Ävrö and in the Kråkemåla area. The most important conclusion from these data is that hydraulic conductivity varies locally within wide limits and that fracture zones account for most of the water flow. Data from the Äspö HRL indicate that the bedrock there has a higher hydraulic conductivity than many other areas in crystalline basement studied by SKB. A study was therefore conducted in the feasibility study's supplementary phase of the hydraulic conductivity of Småland granites in order to determine whether conditions on Äspö are representative of the municipality as a whole. The study was primarily based on analyses and evaluations of data from the aforementioned places, and on data from Klipperås in Nybro Municipality.

According to the study, there is nothing to suggest anything but that Småland granite is generally characterized by low hydraulic conductivity in rock blocks between fracture zones. As far as conditions on Äspö are concerned, it is judged that the occurrence of many fracture zones in a relatively limited area, together with the occurrence of dykes with fine-grained granite, may be a contributing cause to the fact that hydraulic conductivity there exhibited slightly higher values than in many other areas studied by SKB.

As far as the chemical composition of the groundwater is concerned, water samples from rock-drilled wells in the upper part of the bedrock and from sites in the municipality that have been investigated by deep boreholes show a composition that is normal for Swedish bedrock. Saline groundwater has been encountered at e.g. the Äspö HRL and can also be expected in near-coast locations in the rest of the municipality.

Overall assessment

SKB's overall assessment is that large parts of the municipality have a bedrock that is potentially favourable for a deep repository. Large parts of the two areas where field checks have been performed are considered of interest for further studies (see Figure 6-2). The major fracture zones that emerge on the feasibility study's investigation scale in the areas of interest border on bedrock blocks that often are considerably larger than the area of the deep repository. This provides wide opportunities to position the repository in such a way as to avoid these major zones. General conclusions from data on the hydraulic conductivity of the bedrock are that Småland granites, which dominate the bedrock in the municipality, are characterized by a normal hydraulic conductivity for Sweden, and that the fracture zones on various scales often exhibit much higher hydraulic conductivity than the rest of the rock mass. The local conditions at repository depth in areas of interest for further studies, on and west of the Simpevarp Peninsula and in the southern part of the municipality, must therefore be judged on the basis of data from repository depth on the site in question. According to the investigated samples, the chemical composition of the groundwater is normal for Swedish bedrock, which is regarded as favourable for a deep repository.

6.1.3 Technology

The bedrock must have properties that make it possible to build and operate the underground facility with adequate safety and with known technology. In the case of the surface facility, nearness to existing infrastructure is an advantage. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Underground facility

There are a number of hard rock facilities in the municipality where experience from construction and operation is positive. The Äspö HRL thereby occupies a special position, since the facility extends down to the planned repository depth and there is extensive documentation on it. Valuable experience has also been obtained from the facilities on the Simpevarp Peninsula (CLAB, cooling water tunnels, rock caverns), although these facilities are closer to the surface. Both the Äspö HRL and the facilities on the Simpevarp Peninsula have been built and operated as planned, and experience of rock excavation is generally positive.

The occurrence of radon in the bedrock can impose special requirements on e.g. ventilation of the facility. The Småland granites which dominate the bedrock in the municipality exhibit locally slightly elevated radium concentrations, and there are also areas with marked elevations. The salinities that have been encountered at repository depth in the coastal zone are not judged to adversely affect the long-term safety of the repository, but must be taken into account in design and construction.

In general, the repository should be adapted to local petrological conditions. It is, for example, important that it should be positioned and configured so that major fracture zones are completely avoided, and/or configured so that fracture zones in the excavated rock volume do not have an unacceptable influence on tunnel stability or water seepage. Configurations where the repository is laterally displaced in relation to the operations area on the surface entail that the access tunnel will probably have to pass through one or several major fracture zones. Both siting alternatives – the Simpevarp Peninsula and the southern part of the municipality – would involve tunnel passages through fracture zones of varying size. This is not regarded as a technical obstacle, but may require more or less extensive measures to ensure the stability of the tunnel and to prevent or reduce groundwater seepage. The latter is important with respect to both construction and operation, and possible environmental effects on the surface above the tunnel. The bedrock under the inlet that comprises the harbour entrance at Oskarshamn's harbour is suspected of being heavily affected by deformations. The tunnel should therefore not be routed under the inlet.

Surface facility

The deep repository's surface facility makes roughly the same demands on the bearing capacity of the ground and other ground conditions as other industry. From a technical viewpoint there are good possibilities for adapting the facility to the conditions that prevail on the site in question. During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel and visitors will be transported, mainly locally.

On the **Simpevarp Peninsula**, two locations in the nuclear power plant's industrial area have been identified for the deep repository's surface facility, one near the tunnel mouth to the Äspö HRL and the other adjacent to CLAB and the planned encapsulation plant. On the former place, all functions could be gathered in one and the same area. Rock spoils can be dumped north of the industrial area. On the latter place, there is room for the tunnel mouth to the deep repository's underground facility immediately adjacent to CLAB and the planned encapsulation plant, which means that the transport distance for nuclear waste on the surface from the encapsulation plant will be very short. The facility's other functions can in this case be located in an operations area above the underground facility's central area within the geologically interesting area west of the Simpevarp Peninsula.

In the **southern part of the municipality** as well, two locations have been identified for the underground facility: Oskarshamn's harbour and Storskogen. A siting in the harbour area provides access to the city's infrastructure, with nearby connections for utilities. At present (autumn 2000) there is no site in the harbour area that would accommodate the entire surface facility. An interesting possibility would therefore be to build a harbour terminal for goods reception and a tunnel mouth leading down to the underground facility in the harbour area. Other functions could thereby be located in Storskogen or in an operations area directly above the deep repository's underground facility.

The studied site at Storskogen is situated approximately three kilometres southwest of the town of Oskarshamn, just north of a municipal waste management plant. The site consists of slightly hilly forest land without any residential development. All surface facility functions can be gathered on the site. Alternatively, functions that cannot be accommodated in, or are deemed unsuitable to site in, the harbour area can be located

here. The detailed layout, and a possible division of functions between the harbour and Storskogen, will be dependent on the location of the underground facility and the availability of land on each site. If a site investigation is conducted in the southern part of the municipality, the possibility of dividing functions and transport between the two sites needs to be further explored. The studies should then be aimed at finding an environmentally favourable solution while ensuring that the facility can be built and operated in an efficient manner and with a good working environment.

Transportation

During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel will be transported. There are two harbours in the municipality that can be used for transport: Oskarshamn and Simpevarp. There is a railway with sufficient bearing capacity for the heavy waste transports from the town of Oskarshamn westward. The roads in the municipality vary in standard. The only big roads are European highway E22 along the coast and highway 23 leading west from the town of Oskarshamn. However, all roads in the municipality require rebuilding or reinforcement to a greater or lesser extent to carry heavy waste transports.

In the event the surface facility is situated in Simpevarp, nuclear waste would only have to be transported within the nuclear installation. Simpevarp's harbour does not at present have sufficient capacity for large ships carrying backfill materials. Certain extensions of the harbour are therefore required to receive backfill materials. Alternatively, bentonite can be transloaded to smaller ships in another harbour or be carried by road from e.g. Oskarshamn's harbour.

Oskarshamn's harbour has sufficient capacity for the deep repository's shipments of nuclear waste and backfill materials. If the deep repository is sited in the southern part of the municipality, further transport of heavy goods, including nuclear waste, can take place in a tunnel from the harbour area to the underground facility. Alternatively, these goods can be transported by rail or possibly by road, but this would require heavy transports to be routed through the town of Oskarshamn.

Overall assessment

SKB's overall assessment is that both the Simpevarp area and the southern part of the municipality are probably suitable with respect to construction and operation of the deep repository's underground facility. However, factors such as rock stresses and locations and character of fracture zones should be given special attention in any further studies.

The deep repository's surface facility can be sited at Simpevarp or Oskarshamn's harbour/Storskogen in the southern part of the municipality. Both alternatives provide good opportunities for coordination with existing and other planned activities. The Simpevarp alternative provides special advantages as regards both possibilities for coordination and the elimination of the need for nuclear waste transport. In the southern part of the municipality, Oskarshamn's harbour has sufficient capacity for all the deep repository's transport needs. There are good road and rail connections in the southern part of the municipality, and in the east is highway E22, which is of high standard.

6.1.4 Land and environment

Land and environment aspects are, in addition to safety, of great importance for the siting of the deep repository. Areas that both can offer good rock and have suitable land for an establishment of the surface facility within a reasonable distance are therefore of particular interest. The deep repository's surface facility represents the greatest intrusion in land and environment due to the area (approx. 30 hectares maximum) needed for its various functions. This is also where the greatest environmental consequences can be expected, for example due to noise, handling of rock spoils and transport activities. The fact that the surface and underground facilities can be displaced in relation to each other offers wide flexibility to adapt to local conditions and thereby to avoid areas worthy of protection and sensitive environments.

During the investigation phases and prior to construction of a deep repository, deep drilling activities lead to some impact on the flora and fauna above the planned underground facility. During the construction and operation of the facility, some buildings may be needed directly above the underground facility, along with ventilation buildings along the tunnel connecting the surface and underground facilities.

Protected and valuable areas

Figure 6-3 shows areas with varying degrees of protection for nature conservancy, protection of cultural environments and outdoor recreation. The figure also shows the location of water protection areas. All the areas marked on the map are not to be considered off-limits for siting of a deep repository, but are intended more to illustrate where areas requiring special consideration are located. The most sensitive areas in the municipality – for example the Misterhult archipelago, wildlife sanctuaries and water protection areas – are coloured red. The deep repository's facilities will not be located in any of these areas.

Development is limited along the municipality's coastline, according to provisions in Chapter 4 of the Environmental Code. Simpevarp is special in this respect, since the area is already used for nuclear activities, which means it is possible to locate certain types of industrial activities in the area, for example the deep repository. The restrictions that exist along the coast on establishing nuclear installations must also be taken into account in the case of the deep repository's underground portion. However, it remains to establish what these restrictions entail in detail in terms of restrictions on establishing the deep repository's underground portion. West of the Simpevarp Peninsula, inside the coastal area, are large areas with good options for siting the deep repository's underground facility and any necessary ventilation buildings without infringing on areas marked in Figure 6-3. In the southern part of the municipality as well, there are good options for siting the deep repository while taking into account areas worthy of protection. Development is also restricted there along the coast, however. South of the railway, west of the town of Oskarshamn, are areas worthy of protection for e.g. outdoor recreation that must be taken into consideration.

Environmental impact

There are wide options for optimizing the location and layout of the deep repository's facilities and activities so that they have little environmental impact. It is therefore mainly transportation to the deep repository and construction or rebuilding of transport routes that cause impact on the environment. Historically, there have been numerous environment-impacting activities in the harbour area in Oskarshamn, such as copper manufacture. As a result, both soil and sediment in the harbour area are contaminated with high metal concentrations. This must be taken into consideration and appropriate measures taken in connection with both technical studies and possible establishments in the area.

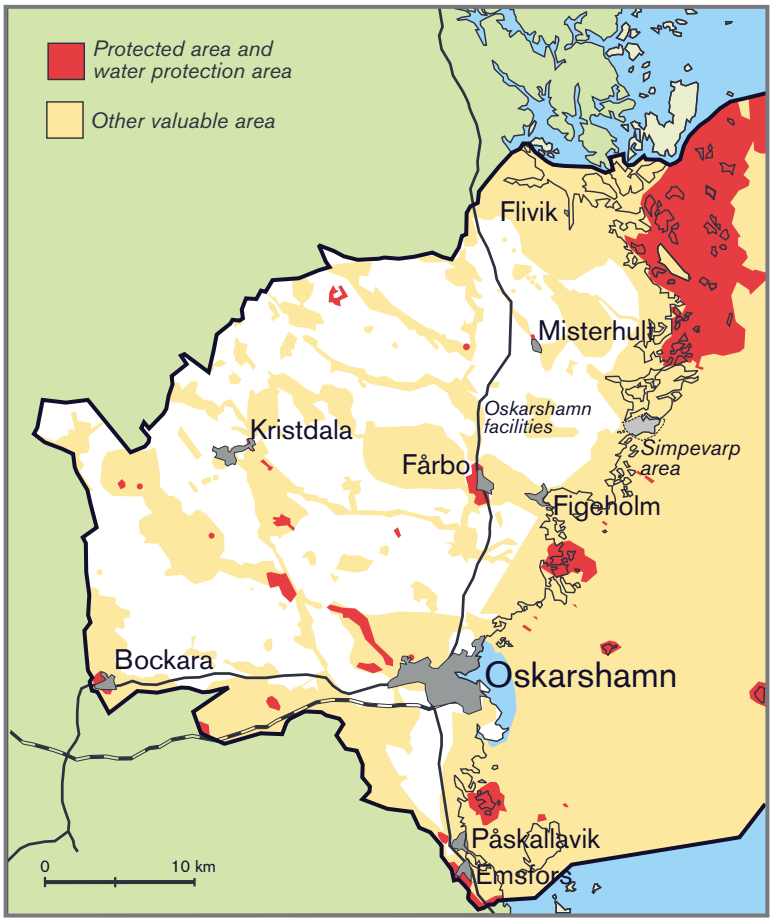

Figure 6-3. *Protected and valuable land in Oskarshamn Municipality.*

Overall assessment

SKB's overall assessment is that good possibilities exist to optimize the siting and layout of the deep repository's different parts with consideration given to protected and valuable areas and so that environmental impact is limited. There are considerable restrictions on the coast, with only a few locations permissible for siting of the deep repository.

There are better possibilities inland to site a repository without creating conflicts with areas worthy of protection. An inland alternative would, however, entail overland transport of goods, which can lead to environmental impact both in conjunction with construction of roads and/or railways and from the transport activities themselves. The Simpevarp alternative offers special advantages, since the area already houses nuclear activities. Moreover, nuclear waste transport would virtually be eliminated by such a siting, due to the nearness of the proposed encapsulation plant at CLAB.

6.1.5 Society

A deep disposal system (deep repository, encapsulation plant and canister factory) can affect socioeconomic conditions, both locally and regionally. Conditions that may be affected are, for example, the local business sector, employment, tourism and the hospitality industry. Forecasts of how a municipality may develop with or without a deep disposal system are naturally uncertain, not least in view of the long timespan (about 50 years) covered by the project, but they nevertheless give some idea of what a deep repository might entail for Oskarshamn Municipality.

Employment effects

The costs of investment and operation of a deep disposal system are estimated to amount to on the order of SEK 20 billion, distributed over about 50 years. The average number of persons directly employed at the three facilities amounts to about 300 in regular operation, of which about 220 are employed at the deep repository. More persons will be employed during the construction of the facilities. To this must be added the indirect effects on employment in the municipality and the region.

There is know-how in Oskarshamn Municipality from the heavy engineering industry, the transport sector and nuclear activities, which means there are good prospects for recruiting a large portion of the workforce locally and regionally. There is a relatively large construction sector in the region. As always in the case of large civil engineering projects, some of the building workers will probably have to be recruited from other regions during the most intensive construction phase. But there is a good base in the region. The level of education of the municipal inhabitants is considered to be fully adequate for most of the positions at the deep disposal system's facilities. When it comes to the limited number of positions requiring specialized competence, there are good recruitment opportunities in e.g. Kalmar, Växjö and Linköping. There are also good opportunities for planning and tailoring training to the needs of the deep disposal system once a siting has been decided on. This is exemplified by SKB's Canister Laboratory in Oskarshamn, where training is planned for the personnel who will staff the encapsulation plant.

Tourism and hospitality industry

Tourism and the hospitality industry are not as big in Oskarshamn Municipality as in other parts of the county. A large portion of the visitors are business travellers connected with the local business community. Nuclear installations are major visitor destinations in the municipality, with approximately 20,000 visitors annually. The facilities in a deep disposal system would also be attractive to visitors to the municipality. As regards the neighbouring municipalities, some of which have a large flow of tourists in the summertime, the question has been raised as to whether a deep repository might have a negative influence on tourism. However, the surveys that have been conducted do not indicate that the existing nuclear installations in Oskarshamn have any adverse effect on tourism in the neighbouring municipalities or the region.

Overall assessment

SKB's overall assessment is that Oskarshamn Municipality offers good societal prospects for building and operating the facilities in a deep disposal system. Professional competencies for most of the jobs at the three facilities (deep repository, encapsulation plant and canister factory) can be found within the region. Moreover, due to the existing nuclear activities in the municipality, these facilities would not disturb the existing business sector, but would rather augment the present activities. These existing facilities (OKG, CLAB, the Äspö HRL and the Canister Laboratory) also contribute to a pool of knowledge and skills on nuclear waste in Oskarshamn Municipality and to a willingness to find constructive solutions to the problems that remain for management of the spent nuclear fuel.

6.2 Holistic assessment from the feasibility study

SKB's holistic assessment is that there are good general prospects for further studies concerning the siting of a deep repository in Oskarshamn Municipality. This is mainly due to the fact that there are large areas with interesting bedrock and that the municipality's infrastructure, nuclear engineering experience and knowledge level constitute advantages in the event of an establishment.

In the preliminary final report from June 1999, two areas were singled out as being particularly interesting for further studies: The Simpevarp area and the southern part of the municipality. Geological field checks were done in these areas during the supplementary phase of the feasibility study. Furthermore, an in-depth study of land and environment aspects has been done in the areas. In both cases the field checks verified the previous assessment of the areas as interesting for further studies. The field checks did not provide a basis for any prioritizations, on geological grounds, of specific sites within the areas studied. This requires detailed characterization.

The most interesting alternative is that the surface facility is sited on the Simpevarp Peninsula with the underground facility in an area west of that. Parts of the facility's underground functions could possibly be located directly beneath the Simpevarp Peninsula. However, this requires a positive assessment of the bedrock conditions at repository depth in a future site investigation. A siting in the Simpevarp area largely eliminates any need for nuclear waste transport. Furthermore, the activities can exploit the advantages offered by a co-siting with CLAB, the encapsulation plant and the Oskarshamn NPP.

The other siting alternative entails locating the deep repository's underground facility in the geologically interesting area in the southern part of the municipality. The sites studied there for the surface facility are Oskarshamn's harbour and Storskogen. If this alternative is considered, a more in-depth study must be done of how the functions of the surface facility can be divided between the two proposed sites to best satisfy the requirements on e.g. environmental protection and a good working environment. Closely connected with this is the question of transport, where for example a tunnel from the harbour area to the underground facility constitutes an alternative to heavy transports through the town of Oskarshamn.

As far as other parts of the municipality are concerned, an inland siting is the most interesting alternative. There is a large area with potentially favourable bedrock in the northwestern part of the municipality. However, this area will only be considered if it should prove unsuitable to establish a deep repository in the priority locations.

SKB's holistic assessment from the feasibility study is that the studied alternatives, Simpevarp and the southern part of the municipality, offer good technical prospects for the deep repository, at the same time as both safety-related and environmental needs can be met. In the event of a site investigation with test drilling in the municipality, priority will be given to the Simpevarp Peninsula and the area immediately west of it, see Figure 6-4. The focus in an initial phase will be on investigating the bedrock on the Simpevarp Peninsula in depth, and conducting the surface investigations in the area to the west that are needed to single out one or more sites for drilling that are judged to have good geological prospects. Important factors to take into account include locations and properties of fracture zones and granite dykes, since these heterogeneities may be of importance for the possibilities of positioning and configuring the deep repository. If necessary, the investigations can be broadened to include areas further from Simpevarp. The investigation programme, as well as the positioning of boreholes, will be designed to limit environmental disturbances. Furthermore, the municipality must approve investigations on the site. A positive attitude on the part of concerned landowners is also essential.

Figure 6-4. *Areas where geological field checks have been performed and confirmed that they are of interest for further siting studies. The Simpevarp area is prioritized for a possible site investigation.*

7 Tierp – summary evaluation

SKB's assessment is that there are good prospects for further studies concerning the siting of a deep repository in Tierp Municipality, Figure 7-1. A large area with so-called Hedesunda granite, east of the Uppsala Ridge and north of the town of Tierp, is judged to be particularly interesting from a geological viewpoint. The area is also deemed to be suitable from an environmental viewpoint and offers good prospects as regards infrastructure. It is thereby prioritized for possible site investigations.

7.1 Siting prospects in Tierp Municipality

7.1.1 General

The municipality of Tierp is situated in northeastern Uppland County. The municipality is dominated to a great extent by traditional engineering enterprises and agriculture. Transport services are good with rail connections and highway E4, and with Arlanda International Airport approximately one hour from Tierp. SKB has conducted feasibility studies for the siting of a deep repository in three municipalities in northern Uppland County: Tierp, Älvkarleby and Östhammar. Experience and knowledge of nuclear activities exists in the region due to the Forsmark NPP and SFR (the final repository for low- and intermediate-level waste from the nuclear power plants, industry, research and hospi-

Tierp Municipality

Tierp is situated in a district with a lot of history. Today the manufacturing industry dominates the region's economy. Construction, agriculture and forestry are other important economic sectors. The largest private employers are Atlas Copco Tools AB with some 370 employees, EraSteel Kloster AB with around 250 employees, and Karlit AB with about 185 employees.

Geographically, the municipality is dominated by the Dalälven River and nearness to the Baltic Sea. It contains Central Sweden's largest wetland area, Florarna. Örbyhus Castle and well-preserved mill communities are also located in the municipality.

Location
Coastal municipality in Uppsala County. Borders on Älvkarleby and Gävle in the northwest, Heby in the southwest, Uppsala in the south and Östhammar in the east.

Land area
1,543 km^2

Inhabitants
Approx. 19,900

Towns
Tierp pop. 5,200, Örbyhus pop. 1,800, Söderfors pop. 1,700, Karlholmsbruk pop. 1,300.

Transportation
Ostkustbanan (The East Coast Rail-way) (Uppsala-Gävle) passes through the municipality. Upptåget is a train that runs from Tierp to Uppsala in just under 40 minutes. The E4 highway passes through the western part of the municipality. After many years of discussion, a rerouting of E4 nearer the town of Tierp has recently been approved. There are no harbours for heavy goods traffic, but further up the coast are the harbours in Skutskär and Gävle, and in the east Hargshamn. Arlanda Airport is situated approximately 1 hour from Tierp.

Land
Approximately 70% forest land, 15% arable land and pastureland, 15% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 24, Left Party 4, Moderates 6, Christian Democrats 3, Centre Party 7, Liberal Party 2, Green Party 2, Stop E4 West Culture Party 1.

Feasibility study decision
June 1998 – unanimous.

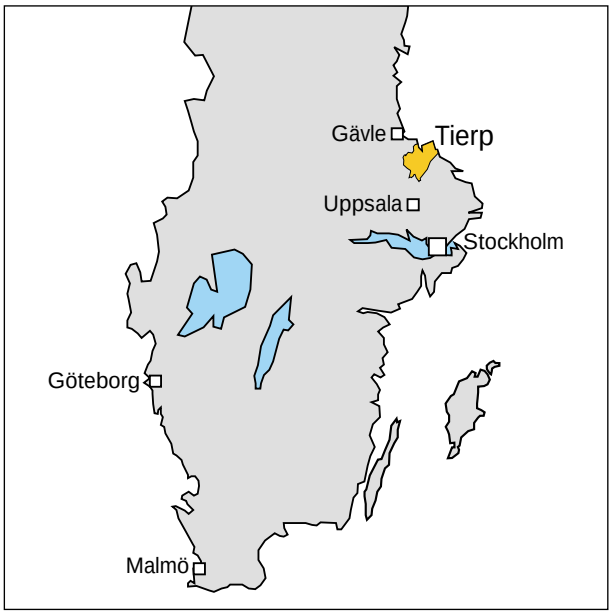

Figure 7-1. *Location of Tierp Municipality.*

tals). A hundred or so of the employees at the Forsmark NPP reside in Tierp Municipality, many companies in the municipality are subcontractors to the nuclear power plant, and representatives of Tierp Municipality sit on the Forsmark NPP's local safety committee. Against this background, the entire region in northern Uppland County is regarded as interesting for siting studies for a deep repository. However, many aspects must be weighed into the final assessment of siting alternatives for the deep repository. The most important is that the areas selected for site investigations have good prospects of satisfying the safety and environmental requirements.

7.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. A sufficiently thorough assessment of safety requires extensive knowledge of rock conditions at repository depth. Necessary information can only be obtained by means of investigations that include borehole measurements. The body of data in the feasibility study is mainly limited to compilations and analyses of existing material and field checks of the most interesting areas.

Bedrock conditions

The data that have been gathered on bedrock conditions show that the municipality is dominated by two types of granitoids: older (approx. 1,890 million years) metagranitoids and younger (approx. 1,780–1,800 million years), more well-preserved granites and associated rock types. Both types occur in different variants and are generally speaking favourable from the repository viewpoint. In the southern and eastern parts of the municipality in particular there is some presence of supracrustal rocks and basic plutonic rocks, which either have such properties or are situated and distributed in such a way that they are considered less favourable for siting of the deep repository. With the exception of some smaller areas (at Finnsjön-Åkerbysjön, at Vendel, and east of Mehedeby) there is no known ore potential that would entail restrictions in the siting possibilities.

Soil depths are moderate but vary widely between different parts of the municipality. In the southern and northwestern parts in particular, the proportion of bare rock is very low, which impedes geological mapping and thereby makes it difficult to judge conditions at repository depth from the ground surface.

A large system of plastic deformation zones, the Singö shear zone, runs through the northern and eastern part of the municipality. Fracture zones occur throughout the municipality to an extent that is normal for Swedish bedrock, as far as can be judged. Fracture zones can adversely affect safety, in part because future bedrock movements cannot be excluded in certain zones, and in part because the fracture zones often have much higher hydraulic conductivity than the rest of the rock mass. The location and layout of the deep repository must therefore be adapted to the positions and properties of the zones. However, this requires investigations on a larger scope and a more detailed scale than in the feasibility study.

Nine areas were initially identified in the feasibility study as potentially interesting for further studies. In most of these the proportion of exposed rock is low, entailing greater uncertainty in the judgements based on existing material, compared with areas with more exposed rock. Field checks were performed in two of the nine areas – one situated within the Hedesunda massif west and north of the town of Tierp, the other on Lövstabukten bight, see Figure 7-2. In the case of the Hedesunda massif, the field check largely confirmed the previous judgement. Of particular interest is an approx. 60 square kilometre area of ”Hedesunda granite” situated east of the Uppsala Ridge and north of the town of Tierp. A homogeneous, even-grained, medium-to-coarse-grained, hornblende-bearing rock dominates in the area. It can probably be classified as quartz monzonite or quartz monzodiorite, i.e. a granite-like rock but with a lower quartz content. The degree of plastic deformation is low. The fracture frequency is also low in studied outcrops. A potentially negative factor is the presence of dykes of fine-grained granite, which can affect the suitability of the bedrock if they occur to a large extent and are water-bearing. The Hedesunda massif is judged on the basis of gravity modelling to be bowl-shaped with a depth of 2–3 kilometres in the central portion of the interesting area east of the Uppsala Ridge.

Interpreted regional fracture zones within the aforementioned area delimit bedrock blocks that are large enough to accommodate the deep repository. One disadvantage is that the proportion of exposed rock is low. Thanks to the homogeneous character of the bedrock and the fact that the bedrock and the soil layers have favourable physical properties from a measurement viewpoint, this shortcoming can probably be compensated for by means of comprehensive measurements using different geophysical methods.

The field check at Lövstabukten bight (see Figure 7-2) has resulted in the dismissal of this area as an area of interest for further investigations. The fine-grained granite reported on older bedrock maps has proved to be much less extensive than the maps show, and the area is instead characterized by mainly inhomogeneous and complex bedrock. The seven areas where field checks have not been performed, and which the preliminary final report judged to be interesting for further investigations, have not been dismissed as areas of interest, but have been given lower priority than the Hedesunda massif. For one thing, most of the seven areas are smaller than the priority area in the Hedesunda massif, and the largest of them has elevated radon potential. Most of the lower-priority areas also have a small proportion of exposed rock. A small area offers less flexibility and thereby a higher risk that it will have to be abandoned in a site investigation.

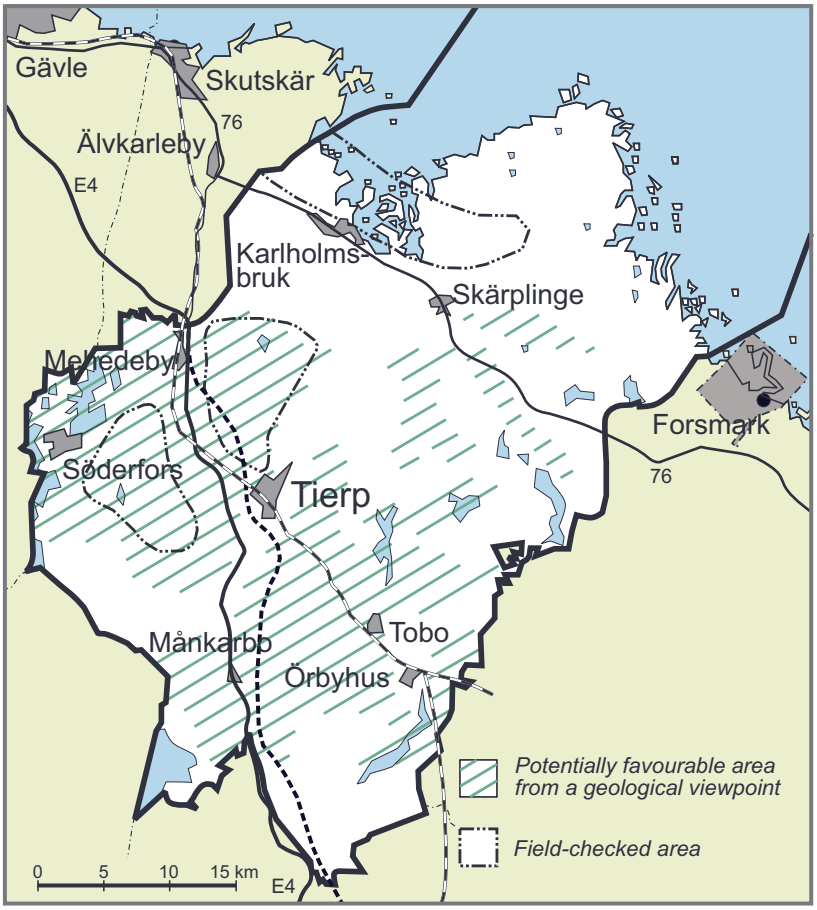

Figure 7-2. *Geologically potentially suitable areas for a deep repository in Tierp Municipality. Field checks have been performed in an area on Lövstabukten bight and in two subareas within the Hedesunda massif, which is situated west and north of the town of Tierp.*

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for a deep repository. Investigations in the municipality and on other sites show that the groundwater flow at repository depth is largely controlled by local variations in the hydraulic conductivity of the bedrock.

The terrain is flat in most of Tierp Municipality, which generally indicates small driving forces for groundwater movements. Data on hydraulic conductivity at repository depth in the municipality are only available from borehole investigations in the Finnsjön area. The most important conclusion drawn from these data is that hydraulic conductivity varies locally within wide limits, and that fracture zones account for most of the conductivity. A superficial gently-dipping fracture zone in the area contributes to a low groundwater flow beneath the zone.

The interesting area east of the Uppsala Ridge and north of the town of Tierp is also located in an area with flat terrain, which means that the driving forces for groundwater movements are low. With one or two exceptions, this part of the Hedesunda massif has no rock-drilled wells. The few wells that exist within the Hedesunda massif as a whole give a fragmented picture of hydraulic conductivity, with both high and low conductivity.

Groundwater samples from rock-drilled wells in Tierp Municipality indicate that the chemical composition of the groundwater is largely normal for Swedish bedrock. Wells with saline groundwater are relatively common, however. There are wells with both saline and non-saline water in the Hedesunda massif. Data on water chemistry at repository depth are only available from the Finnsjön area. Samples from greater depth here show groundwater that is free from dissolved oxygen, and chloride concentrations that in some parts are higher than those in today's Baltic Sea water.

Overall assessment

SKB's overall assessment is that several areas in Tierp Municipality have a bedrock that is potentially favourable for further studies concerning the siting of a deep repository. Of greatest interest for site investigations is the Hedesunda massif, and particularly that part situated north of the town of Tierp and east of the Uppsala Ridge. However, a reliable assessment of long-term safety cannot be made until after site investigations, since such an analysis requires data from deep boreholes.

7.1.3 Technology

The technical prospects for building and operating the deep repository apply to the facilities both above and under ground. Under ground, the bedrock should have properties that make it possible to build and operate the facility with adequate safety and known technology. As far as the above-ground facility is concerned, nearness to existing infrastructure is an advantage. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Underground facility

The data that have been collected on bedrock and groundwater conditions for assessment of long-term safety also comprise a basis for evaluating the technical prospects for building and operating the deep repository's underground facility. As is evident from section 7.1.2, priority is given to an area east of the Uppsala ridge and north of the town of Tierp with younger so-called Hedesunda granite for further studies. Experience from rock construction in this type of bedrock shows homogeneous conditions and good strength properties, often low fracture frequency and thereby good construction properties. As in other crystalline basement settings, facility layout and construction methods must be adapted to the locations and character of existing fracture zones. In rock chambers at great depth, high rock stresses may cause stability problems during the construction and operating periods. Furthermore, the occurrence of radon in the facility can entail special requirements on e.g. ventilation.

When it comes to hydraulic conductivity, nothing has emerged to indicate any unusual or problematic circumstances for construction and operation. The occurrence of saline groundwater may entail a higher risk of corrosion of installations and equipment in the facility. This is not regarded as any great problem, but may entail special requirements on choice of materials and on maintenance during the operating period of the deep repository.

Surface facility

The deep repository's surface facility does not make any special demands on the bearing capacity of the ground or other ground conditions in comparison with other industry. From a technical viewpoint there are good possibilities for adapting the facility to the

conditions that prevail on the site in question. Good transport services and nearness to other infrastructure are advantages, but are not requirements for an establishment.

SKB sees good possibilities to site the deep repository's surface facility within or adjacent to the Hedesunda massif east of the Uppsala Ridge and north of the town of Tierp without infringing on protected land or valuable areas. The area is large and several sitings are conceivable. If it is decided to conduct site investigations within this area, possible sitings of the deep repository's facilities, including different transport solutions, will be investigated in detail in consultation with concerned landowners, the municipality, concerned authorities, etc.

Transportation

During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel will be transported. Tierp Municipality does not have a harbour with sufficient capacity for the deep repository's shipments of nuclear waste and backfill materials. Some of the nearby harbours in the neighbouring municipalities – particularly Gävle, Skutskär, Forsmark and Hargshamn – might be suitable, however.

In the event of a siting of the deep repository's surface facility within or adjacent to the area east of the Uppsala Ridge and north of the town of Tierp, there are good options for transport of goods on existing roads and rail lines, since both E4 and the East Coast Railway pass through or near the area (see Figure 7-2). Shipments to the deep repository could, for example, go via the harbour in Skutskär and further by rail to the repository. A rail spur would have to be built between the East Coast Railway and the facility, however. Nearness to several of the towns in the municipality reduces the need for commuting.

Overall assessment

SKB's overall assessment is that the Hedesunda massif east of the Uppsala Ridge and north of the town of Tierp can offer a favourable setting with respect to construction and operation of the deep repository. Important reasons for this judgement are the availability of large volumes of homogeneous and relatively fracture-poor rock. However, factors such as rock stresses, locations and character of fracture zones and fine-grained granite dykes, as well as possible occurrence of saline groundwater must be accorded special attention in any further studies.

The transport prospects are good. There are extensive road and rail connections up to or near the aforementioned area. There are industrial ports in Skutskär, Gävle and Hargshamn that are well-suited to the deep repository's goods; the main alternative is the harbour in Skutskär.

7.1.4 Land and environment

Land and environment aspects are, in addition to safety, of great importance for the siting of the deep repository. Areas that both can offer good rock and have suitable land for an industrial establishment within a reasonable distance are therefore of particular interest. The deep repository's surface facility represents the greatest intrusion in land and environment due to the area (approx. 30 hectares maximum) needed for its various functions. The fact that the surface and underground facilities can be displaced in relation to each other offers wide flexibility to adapt to local conditions and thereby to avoid areas worthy of protection and sensitive environments.

The deep drilling performed in the investigation phase prior to the construction of the deep repository also entails some impact on the land, as well as the flora and fauna above the planned underground facility. After the repository has been taken into operation, some buildings may be needed directly above the underground facility, along with ventilation buildings along the tunnel connecting the surface and underground facilities.

Protected and valuable areas

Figure 7-3 shows protected and valuable areas for nature conservancy, protection of cultural environments and outdoor recreation, as well as water protection areas and planned land use in Tierp Municipality. All the areas marked on the map are not to be considered off-limits for siting of a deep repository, but are intended more to illustrate where areas worthy of protection are located. The area prioritized for further studies is also marked in the figure. As the figure shows, this area is located far from the majority of the most sensitive areas (the Hållnäs peninsula, the Florarna area, the Dalälv area and the Västland Ridge, all of which are coloured red in figure 7-3). The area is also located outside of the Uppsala Ridge's water protection area.

Environmental impact

A deep repository can be positioned and configured so that its environmental impact is small. A contributing cause for this is that the surface facility can be adapted to areas worthy of protection, existing and planned land use, transport routes, etc. Transport of spent nuclear fuel, backfill materials, rock spoils and personnel to and from the deep repository have an impact on the environment. Construction or rebuilding of transport routes can also lead to some environmental impact.

Overall assessment

SKB's overall assessment is that there are good possibilities to build the deep repository within or adjacent to the priority area east of the Uppsala Ridge and north of the town of Tierp without coming into conflict with protected and valuable areas or other land use. The siting and layout of the different parts of the repository, above and under ground, can be adapted so that areas worthy of protection are taken into account and any environmental impact is limited.

7.1.5 Society

As far as the question of how the deep repository might affect socioeconomic conditions, both locally and regionally, there are a number of aspects which, taken together, can provide a picture of what prospects Tierp Municipality and northern Uppland County may have for the establishment of these facilities. Conditions that may be affected to a greater or lesser degree by the project are, for example, the local business sector, employment, tourism and the hospitality industry. Forecasts of how a municipality may develop with or without a deep repository are naturally uncertain, not least in view of the long timespan (about 50 years) covered by the deep repository project, but they nevertheless give some idea of what a deep repository might entail for Tierp Municipality.

Employment effects

The costs of investment and operation of the deep repository are estimated to amount to on the order of SEK 13 billion, distributed over about 50 years. The average number of persons directly employed during the regular operation of the deep repository amounts

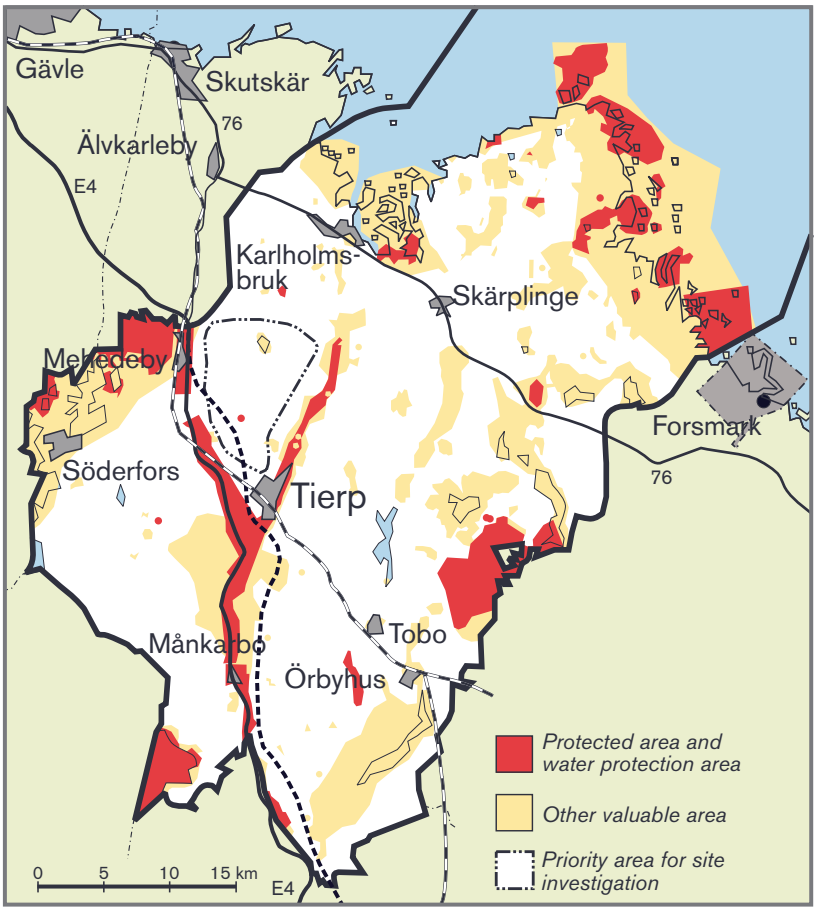

Figure 7-3. *Protected and valuable land in Tierp Municipality.*

to about 220. During the construction phase – about 5–6 years altogether – at most 600 persons will be employed at the facility. To this must be added the indirect effects on employment. There is know-how in the municipality and the region from the heavy engineering industry, the transport sector and nuclear activities, which means there are good prospects for recruiting a large portion of the workforce locally and regionally within Uppsala's labour market region. The municipality's construction sector is also relatively large in relation to the rest of the country. A large portion of the construction labour will probably have to be recruited from other regions during the most intensive construction phase, but there is a good base in Tierp Municipality. The level of education of the municipal inhabitants is considered to be fully adequate for most of the positions at the deep repository. When it comes to the limited number of positions requiring specialized competence, there is a good supply of to persons with suitable education in the Uppsala region. When all of the above factors are weighed together, it is found that a deep repository would fit well into the area's existing industrial and labour market structure.

It can be noted that the general development prospects are somewhat different in the northern and southern parts of the municipality. The southern part lies within commuting distance of the Uppsala area and therefore has good prospects of sharing in the strong expansion of the Stockholm-Uppsala region. The northern part of the municipality is heavily industrial, and its development is dependent to a high degree on the future development of the companies there.

Tourism and hospitality industry

Most of the tourists who visit Tierp Municipality today are visitors to relatives and friends or vacation cottages, along with transient tourists who, as they pass through the municipality on e.g. E4, stop to make purchases along the road. A deep repository could be a future tourist attraction in the municipality and thereby increase revenues in the hospitality industry.

An estimate of the number of visitors to a deep repository and the business travel that will be generated indicates something on the order of 5,000–10,000 visitors per year (equivalent to CLAB), according to the surveys that have been done. This would make an annual contribution to the local hospitality industry of around SEK 5–10 million. It can be assumed that international visits and other business visits will take place at other times of the year than the Swedish summer vacation, which would help to distribute the streams of visitors over the year.

Overall assessment

SKB's overall assessment is that Tierp Municipality offers good societal prospects for building and operating the deep repository. Professional competencies for most of the jobs at the facility can be found within the region. Moreover, due to the existing nuclear activities in the neighbouring municipality, along with the relatively large building sector in Tierp Municipality, the facility would not disturb the existing business sector, but would rather augment and extend the season of the existing activities. The nuclear power plant and SFR in Forsmark contribute to a pool of knowledge and skills on nuclear activities in Tierp Municipality as well, which is valuable for finding solutions to the problems that remain for management of the spent nuclear fuel. The future development potential is particularly good in the southern part of the municipality, which can share in the expansion of the Stockholm-Uppsala region. The northern part of the municipality, which is dependent to a high degree on manufacturing industry, may have a more stagnant development. Establishment of new activities in this part of the municipality may therefore provide a needed stimulus for the local economy.

7.2 Holistic assessment from the feasibility study

SKB's holistic assessment from the feasibility study in Tierp Municipality is that the Hedesunda massif, and in particular the area east of the Uppsala Ridge and north of the town of Tierp, is interesting for a site investigation regarding the siting of the deep repository (see Figure 7-4). The area is considerably larger than is needed for a deep repository. If a site investigation should be undertaken, initial studies must therefore identify where in the area the first boreholes should be drilled. Within or adjacent to the area there are good opportunities to site the surface facility so that conflicts with protected and valuable land areas and other land use are avoided or limited. The area also offers good prospects for good transport solutions, since major roads and rail lines pass through or near it. There are good connections with nearby harbours. The main alternative is to use the harbour in Skutskär.

If a site investigation is conducted in Tierp Municipality, possible siting alternatives for the deep repository's facilities, different transport solutions, build-out of utilities, business and other societal issues, psychosocial aspects etcetera will be investigated and analyzed in collaboration with the municipality, concerned landowners, neighbouring municipalities, regulatory authorities etcetera.

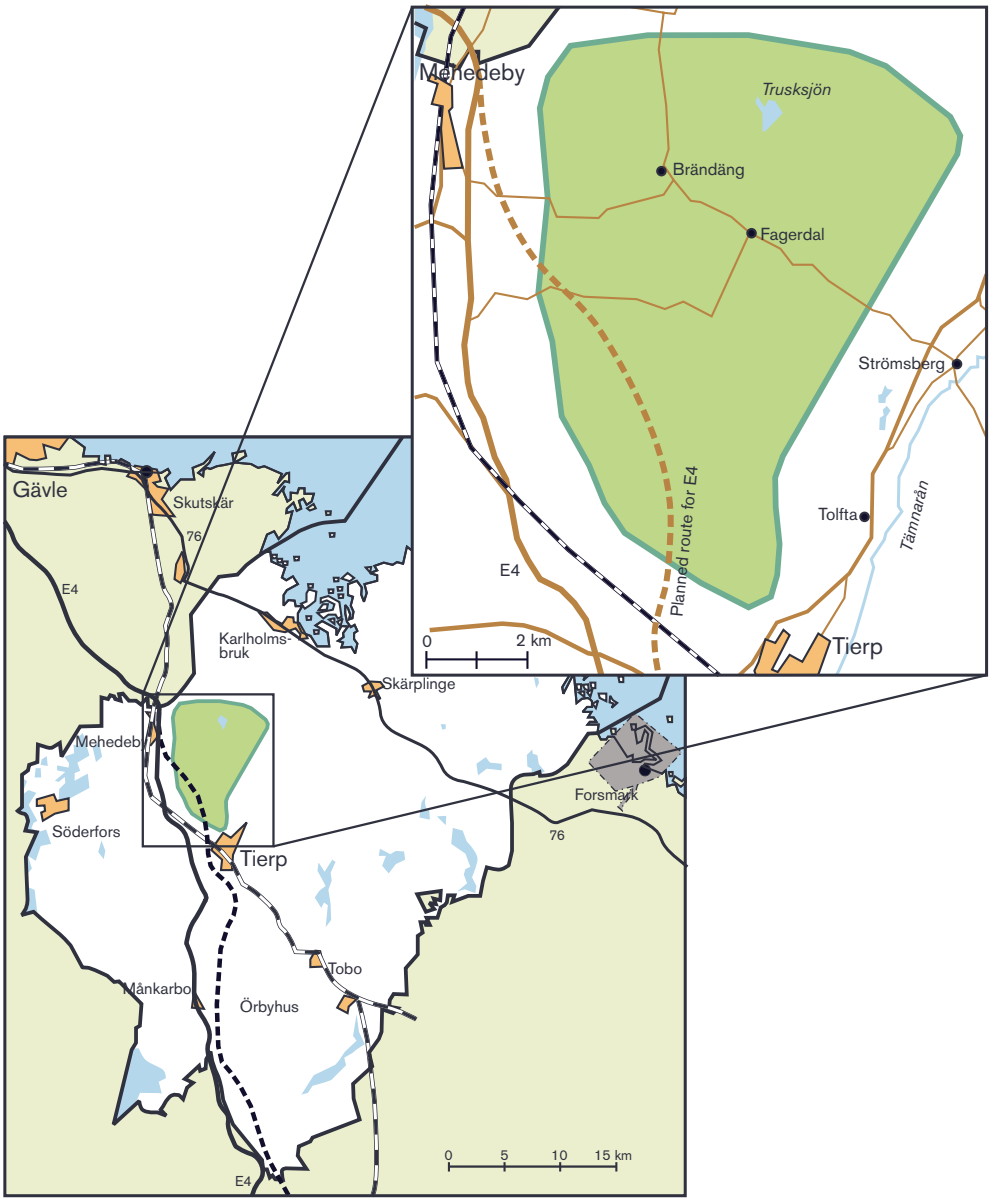

Figure 7-4. *The area east of the Uppsala Ridge and north of the town of Tierp that will be given priority in the event of a site investigation in Tierp Municipality.*

8 Hultsfred – summary evaluation

SKB's assessment from the feasibility study is that there are good prospects for further studies concerning the siting of a deep repository in Hultsfred Municipality, Figure 8-1. Two siting alternatives have been particularly examined in the feasibility study: east of Målilla and west of Hultsfred. The reason for focusing on these two alternatives is that they contain large areas where the bedrock is deemed to be potentially suitable for a deep repository, and that the technical and environmental prospects for establishing and operating the deep repository are judged to be good.

The feasibility study does not provide a basis for ranking the alternatives geologically. Both are judged to offer good prospects for further studies of the bedrock (site investigations), which in both cases would start with relatively extensive investigations from the surface to pinpoint a suitable site for test drilling. In an overall assessment, SKB gives priority to the eastern alternative for possible further siting studies.

Hultsfred Municipality

Hultsfred is heavily dominated by industry and agriculture. More than one-third of the jobs are in the manufacturing industry, where engineering and wood processing are predominant. The largest private employers are MoDo Paper AB with some 200 employees, Swedspan AB with some 150 employees, and Bergs Sågverk with some 140 employees.

Most Swedes connect Hultsfred with the annual Hultsfred Rock Festival. The municipality also has many lakes and watercourses, including the Emån River, offering wide opportunities for outdoor activities.

Location
Inland municipality in Kalmar County. Borders in the north on Vimmerby, in the east on Oskarshamn, in the south on Högsby and Uppvidinge, and in the west on Vetlanda and Eksjö.

Land area
1,125 km^2

Inhabitants
Approx. 15,300

Towns
Hultsfred pop. 5,500, Virserum pop. 2,100, Målilla pop. 1,700, Mörlunda pop. 1,100.

Transportation
Airport with scheduled service to Stockholm/Arlanda. Rail connections with Stockholm, Nässjö, Oskarshamn, Linköping and Kalmar. Highway 34 runs through the municipality in a north-south direction. Dackeleden, an alternative to E4 between Linköping and Malmö, runs through the municipality. The nearest major harbour is in Oskarshamn (about 60 km).

Land
Approximately 65% forest land, 30% arable land and pastureland, 5% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 19, Left Party 7, Moderates 5, Christian Democrats 7, Centre Party 8, Liberal Party 1.

Feasibility study decision
May 1999 – unanimous.

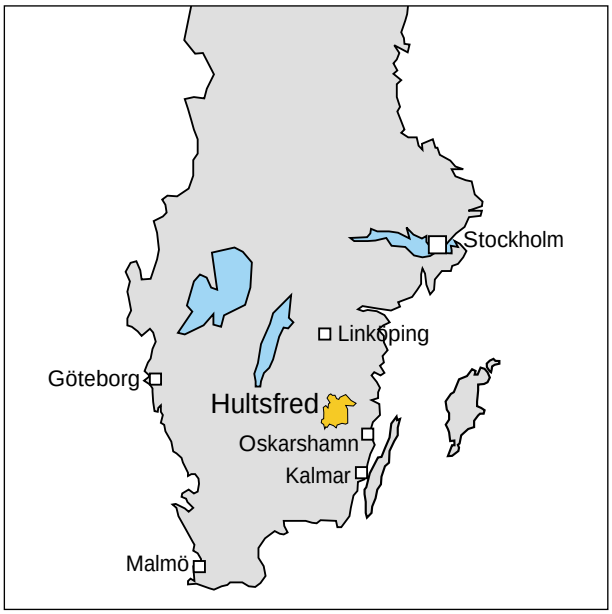

Figure 8-1. *Location of Hultsfred Municipality.*

8.1 Siting prospects in Hultsfred Municipality

8.1.1 General

Hultsfred Municipality is situated in the interior of eastern Småland in Kalmar County. The distance to Kalmar is 120 kilometres, to Oskarshamn 50 kilometres and to Linköping 120 kilometres. There is an airport in the municipality with scheduled service to Arlanda. There are rail connections with Linköping, Nässjö, Oskarshamn and Kalmar for both passenger and freight. Highway 34 between Linköping and Kalmar passes through the municipality in a north-southerly direction. Hultsfred has both industry and agriculture, with engineering and wood-processing as the dominant industrial sectors.

Of the current feasibility study municipalities, Hultsfred is the only one that is situated in the interior. This entails some general differences compared with the other feasibility study municipalities /8-1/. One consequence of a possible inland siting is that nuclear waste and bentonite clay need to be transported long distances overland. Rail is the main alternative for these transports, but road is also a possibility. The need for overland transport is a complicating factor, but in principle the greater distance does not entail anything new, since the feasibility studies in the coastal municipalities have shown that possible sitings there also require overland transport in many cases. Furthermore, SKB has previously conducted feasibility studies in the municipalities of Storuman and Malå in the interior of Västerbotten and drawn the conclusion that overland transports over much longer distances than would be necessary in the case of Hultsfred do not pose any technical or safety-related obstacles to a siting. The uncertainties mainly concern the attitude towards such transports among nearby residents and other directly concerned parties.

There are certain differences between coastal locations and inland locations as regards the bedrock as well, and in particular groundwater conditions. It is not possible to draw any general conclusions regarding the safety-related suitability of a coastal versus inland siting based on these differences, since it is the local conditions on a given site that are ultimately decisive. The differences concern more the design premises for the repository. The lower salinities in the groundwater in inland locations, for example, mean less need for maintenance in underground facilities during the construction and operating phases. This can also lead to less consumption of bentonite clay in the backfill material for the deep repository's tunnels, providing it can be shown that inland conditions will prevail in the long term as well. These factors are being studied at SKB's Äspö HRL.

8.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. A sufficiently thorough assessment of safety requires extensive information on rock conditions at repository depth. This information can only be obtained by means of investigations that include test drilling and measurements in boreholes. The body of data in the feasibility study is limited to compilations and analyses of existing material as well as general field checks in certain areas.

Bedrock

The rock types that prevail in Hultsfred Municipality are approximately 1,800 million year old granites. These rocks occur in different variants over large areas in southeastern Sweden and are usually referred to collectively as Småland granites. Like other granites they have favourable properties for a deep repository.

The soil cover in the municipality is thin as a rule and dominated by glacial till. The proportion of bare rock is relatively high. This is a positive factor, since it facilitates geological mapping and makes it easier to assess conditions at repository depth. The situation may be different in large valleys, however, with thick soil layers and few outcrops. The municipality is poor in known mineralizations. A small area around Virserum and west of there is judged to have ore potential, otherwise there is no known ore potential that would entail restrictions in the siting possibilities.

Various types of Småland granite completely dominate the bedrock in the central and northern part of the municipality, and large areas here are deemed to be potentially suitable for a deep repository. Younger volcanic rocks and granites occur in the most northwesterly part. The rich occurrence of hypabyssal rocks (dolerites, granite and pegmatite dykes) in this area gives the bedrock an inhomogeneous character, and the conditions here are judged to be unfavourable.

There is a large area in the southern part of the municipality with mainly older, usually deformed granitoids. There are also numerous intrusions of basic rock types here (gabbro, diorite). These rocks occur as large or small bodies, or as inclusions in above all the older granitoids, but also in certain nearby areas with Småland granite. Dolerite dykes are also relatively frequent in these areas. From a homogeneity viewpoint, the bedrock in large areas of the southern part of the municipality is therefore judged to be less suitable for a deep repository.

A large system of plastic shear zones passes through the southern part of this municipality in an east-westerly direction (the Oskarshamn-Bockara zone). The shear zones in this system delimit tectonic lenses which are much less affected by deformation. Fracture zones and faults occur to an extent that is judged to be normal for Swedish bedrock. Some of the regional fracture zones form marked depressions in the terrain, and divide the bedrock into regional blocks. The most conspicuous of these regional fracture zones is the one running from Vimmerby south through Hultsfred and on through Målilla. Fracture zones can adversely affect safety, in part because future bedrock movements cannot be excluded in certain zones, and in part because the fracture zones often have much higher hydraulic conductivity than the rest of the rock mass. Large fracture zones, such as the aforementioned zone through Hultsfred and Målilla, should therefore be avoided when siting the deep repository. In other respects as well, the location and layout of the repository must be adapted to the positions and properties of the zones. The fracture zones that can be interpreted in the feasibility study's investigation scale delimit bedrock blocks on the order of 10–25 square kilometres. There are wide options for positioning a deep repository within such a block.

In the feasibility study's geological survey, all parts of the municipality with potentially unsuitable conditions (certain rock types, heterogeneous bedrock, plastic deformation zones, dominant fracture zones, areas with ore potential) have been dismissed as uninteresting for further studies. After this has been done, six areas which together cover approximately one-third of the area of the municipality remain (see Figure 8-2). All these areas exhibit homogeneous bedrock, and interpreted fracture zones delimit rock blocks that are big enough to accommodate a deep repository.

Geological field checks have been performed in two areas during the supplementary phase of the feasibility study: east of Målilla and west of Hultsfred. The assessments that were made of these areas in the preliminary final report in April 2000 have largely been verified by the field checks.

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for a deep repository. On a regional scale, the elevation differences between the inland and coastal regions create conditions for a flow directed from the interior towards lower coastal areas. On this scale, the municipality of Hultsfred can, with its inland location, be regarded as a recharge area from which the groundwater continues along long flow paths in the bedrock.

Groundwater flow is affected by local factors as well, however. The municipality's rather hilly topography indicates driving forces for groundwater flow which can be greater than the driving forces caused by elevation differences on a regional scale, even at repository depth. An even more decisive local factor is the large variations known by experience to exist in hydraulic conductivity, particularly the contrasts between fracture zones and the intervening rock mass. The conclusion is therefore that it is not possible to count the inland location as a general advantage with regard to groundwater flow, since it is ultimately local conditions that are decisive.

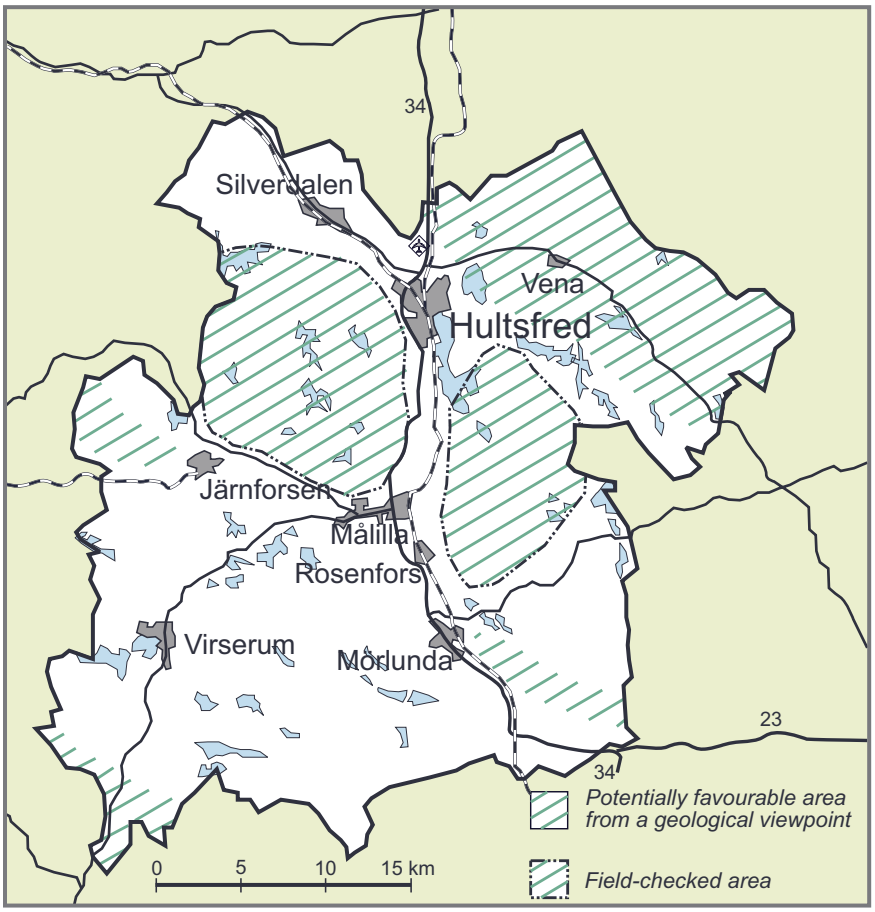

Figure 8-2. *Potentially suitable areas for a deep repository in Hultsfred Municipality. Field checks have been performed in two areas: east of Målilla and west of Hultsfred.*

Data on the hydraulic conductivity of the bedrock in the municipality are only available from rock-drilled wells, which cover the depth range down to approximately 100 metres. The most relevant information on hydraulic conductivity at repository depth is available from borehole investigations in the Klipperås area, south of Hultsfred Municipality. The total picture is that hydraulic conductivity varies locally within wide limits, and that fracture zones account for most of the conductivity. This is the normal situation in crystalline basement.

Data from the Äspö HRL in Oskarshamn Municipality indicate a higher hydraulic conductivity than is the case for many other sites SKB has studied. A study of the hydraulic conductivity of the Småland granites was made within the feasibility study in Oskarshamn in order to shed light on whether conditions on Äspö are representative of the rest of the region. According to that study, there is nothing to suggest anything else than that Småland granite is generally characterized by low hydraulic conductivity in the rock mass between fracture zones. As regards conditions on Äspö, the occurrence of many fracture zones on a relatively limited area, together with the occurrence of dykes with fine-grained granite, are judged to be contributing factors to the slightly higher values found for hydraulic conductivity than on many other sites.

The municipality's location in the interior and to a large extent above the highest coastline means that low salinities in the groundwater (non-saline groundwater) can be expected at repository depth as well. Salinities in the groundwater within the range of variation encountered in Swedish crystalline basement at the depth in question are not judged to have any significant influence on the long-term safety of the deep repository. However, the salinity does affect the design premises and the operating environment. An environment with non-saline groundwater can reduce the amount of bentonite needed in the material planned to be used to backfill the repository's tunnels. However, this presumes that an environment with non-saline groundwater will also exist after closure and in the long term. Non-saline groundwater also provides a less corrosive environment in the repository during the operating period, which reduces the maintenance need in the facility.

The deep groundwater in the Klipperås area exhibits, as expected, low salinities and reducing conditions. There are good reasons to assume similar conditions at repository depth in the bedrock in Hultsfred Municipality. All in all, this means that groundwater composition is deemed to be favourable for a deep repository.

Overall assessment

SKB's overall assessment is that large parts of the municipality have bedrock that is of interest for further studies concerning the siting of a deep repository, see Figure 8-2. This is particularly true of areas dominated by different types of Småland granite. The major fracture zones that appear on the feasibility study's investigation scale within these areas delimit bedrock blocks that are considerably larger than the area of the deep repository. This provides good possibilities to situate the repository in such a way as to avoid major fracture zones. Groundwater conditions are also generally judged to be favourable for a deep repository.

Geological field checks were performed during the supplementary phase of the feasibility study in two of the areas deemed to be of interest for further studies, see Figure 8-2. These checks have verified the previous positive assessment of the areas. No information has been obtained to occasion any major revisions of the interpretations that have been made. The feasibility study does not provide a basis for ranking the areas geologically or for prioritizing any single site within any of the areas for test drilling.

8.1.3 Technology

The technical prospects for building and operating the deep repository concern the facilities both above and under ground. The bedrock should have properties that make it possible to build and operate the underground facility with adequate safety and known technology. As far as the above-ground facility is concerned, nearness to existing infrastructure is an advantage. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Underground facility

The data that have been collected on bedrock and groundwater conditions for an assessment of long-term safety also comprise a basis for evaluating the technical prospects for building and operating the deep repository's underground facility. The areas judged to be interesting for further studies mainly contain various kinds of granites. These rock types

are generally regarded as favourable for construction and operation of rock facilities. As in other crystalline basement settings, facility layout and construction methods must be adapted to local conditions, especially the locations and character of existing fracture zones. In rock chambers at great depth, high rock stresses may cause stability problems during the construction and operating periods. Furthermore, the occurrence of radon in the facility can entail special requirements on e.g. ventilation. Areas where the bedrock has the potential to cause high radon concentrations should be avoided if possible.

Construction and operation of the underground facility must take place with good control of groundwater seepage. The hydraulic conductivity of the rock is therefore of great importance. Tunnel passages through fracture zones may require special sealing and monitoring measures, since a large portion of the water flow takes place in these zones. When it comes to the hydraulic conductivity of the granite areas in question, nothing has emerged to indicate any unusual or problematic circumstances for construction and operation.

Surface facility

The deep repository's surface facility makes roughly the same demands on the bearing capacity of the ground and other ground conditions as other industry. From a technical viewpoint there are good possibilities for adapting the facility to the conditions that prevail on the site in question.

Two proposed sitings of the deep repository's surface facility have been studied in the feasibility study: within the granite area east of Målilla and next to the town of Hultsfred. The grounds for special study of these alternatives have been the availability of areas where the bedrock may have the potential for hosting the underground facility, and good technical and environmental prospects for establishing and operating the deep repository, including transportation.

In the case of the alternative with a siting within the identified area **east of Målilla**, see Figure 8-2, no specific site can be designated for the facilities, either above or under ground, on the basis of the material obtained in the feasibility study. However, there are large contiguous forested areas within the geologically interesting area, which should provide good possibilities for positioning and configuring the surface facility to achieve good technical function, while taking into account protected and valuable areas, as well as other local adaptation needs. The preferred alternative is to locate the surface facility directly above the repository, which enables all functions to be gathered in one place. If the site above the repository is unsuitable, it is also possible to locate the surface facility laterally displaced in relation to the repository. Regardless of which layout is chosen, it is necessary to construct an operations area and a rail link to the existing railway, and to build a feeder road and utility lines to the site.

The siting alternative **next to the town of Hultsfred** refers to a specific site. Just south of the town is an industrial area where the surface facility could be built. Land intended for industrial activities can be used for this. No transport routes have to be built, since the railway (the common route of the Stångådal Railway and the Oskarshamn-Nässjö line) passes by the industrial area. This alternative presumes that the repository can be located within the geologically interesting area west of Hultsfred. The surface and underground facilities can then be connected by a 4–10 kilometre long sloping tunnel. If the distance between the repository and the industrial area is great, parts of the surface activities can be located in a smaller operations area established above the repository.

Transportation

During the operation of the deep repository, transport casks with nuclear waste and backfill materials will be transported to the facility. In addition, small volumes of goods and of personnel will be transported, mainly locally. The region's major harbours, roads and railways are shown in Figure 8-3. There are industrial ports in Oskarshamn, Stora Jättersön in Mönsterås Municipality and in Kalmar. The Stångådal Railway between Kalmar and Linköping and the Oskarshamn-Nässjö line both run through the municipality, in part along the same route. Both are single-track and unelectrified, but have sufficient bearing capacity for the heavy waste transports. The roads in the municipality and the region are of varying standard.

There are several possibilities for transporting casks of nuclear waste from the Simpevarp Peninsula in Oskarshamn Municipality to Hultsfred Municipality. The first choice is sea transport from Simpevarp to Oskarshamn's harbour, where the cargo is transloaded for rail transport to the deep repository. Another alternative is overland transport, either all the way to the deep repository or to the existing railway to Hultsfred for transloading

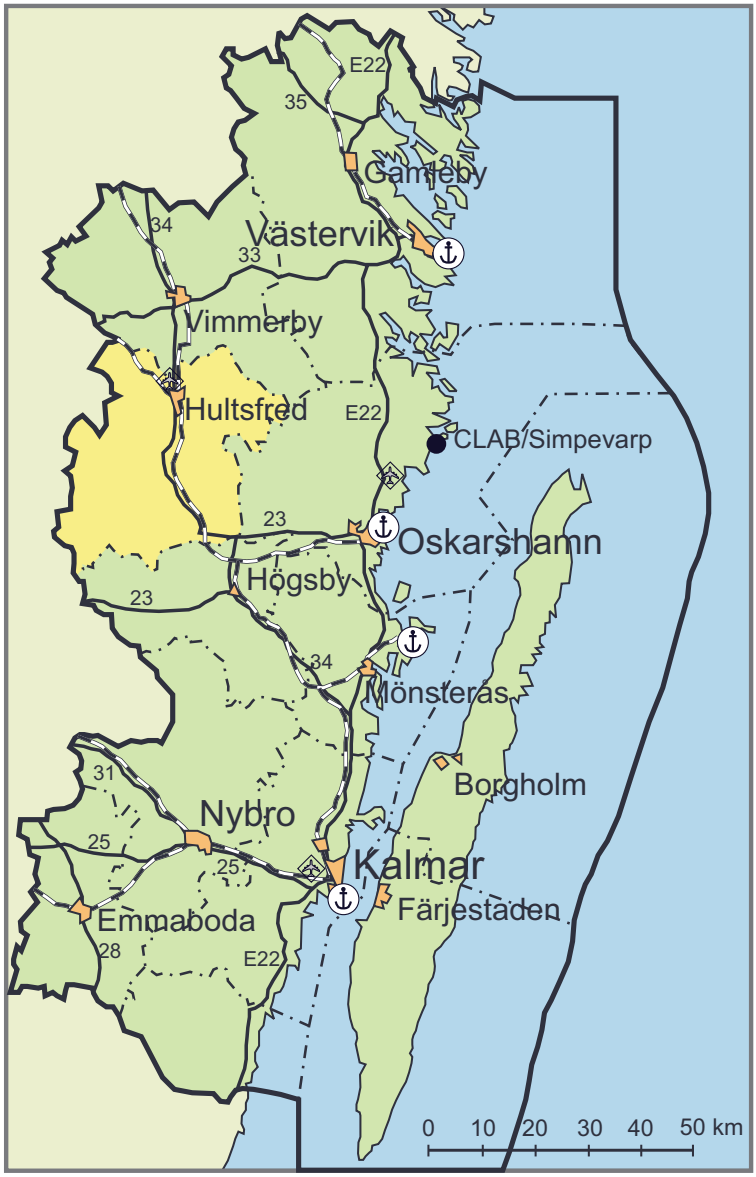

Figure 8-3. *Major roads, railways and harbours in the region.*

and further train transport. A third possibility may be to build a new approximately 25 kilometre long rail link from Simpevarp to the existing rail line. Depending on which of these alternatives is chosen, one or more of the municipalities of Oskarshamn, Högsby and Mönsterås will be affected by the nuclear waste transports. Other goods, including bentonite clay, can be shipped to one of the harbours in Oskarshamn, Stora Jättersön or Kalmar for further overland transport to Hultsfred Municipality.

Overall assessment

SKB's overall assessment is that the two granite areas that are regarded after geological field checks as potentially favourable with regard to long-term safety may also provide good prospects for establishing and operating the deep repository's underground facility. However, more detailed investigations are required, including test drilling, to determine this. Factors such as locations and character of fracture zones and rock stresses should be given special attention in any further studies.

If the underground facility is sited within the eastern area, it should be possible to locate the surface facility close to the repository. If the underground facility is sited within the western granite area, the surface facility can be located adjacent to an industrial area next to the railway, just south of the town. This then requires a tunnel connecting the facilities above and under ground. Both alternatives are judged to be technically feasible. Nearness to railway, major roads and several towns provides good prospects for construction and operation.

Regardless of which alternative is chosen, a deep repository in Hultsfred Municipality requires transport of waste casks from CLAB, as well as transport of backfill materials from a suitable harbour. The preferred alternative for the waste casks is sea transport to Oskarshamn, followed by transloading for further transport by rail to the site of the deep repository. There are, however, other alternatives that are technically possible. If site investigations should be undertaken in the municipality, transport modes and transport routes for the different goods types should be explored more thoroughly than has been possible in the feasibility study.

8.1.4 Land and environment

Land and environment aspects are, in addition to safety, of great importance for the siting of the deep repository. Areas that both can offer good rock and have suitable land for an establishment of the surface facility within a reasonable distance are therefore of particular interest. The deep repository's surface facility represents the greatest intrusion in land and environment due to the area (approx. 30 hectares maximum) needed for its various functions. The fact that the surface and underground facilities can be displaced in relation to each other offers wide flexibility to adapt to local conditions and thereby to avoid areas worthy of protection and sensitive environments.

During the investigation phases prior to construction of a deep repository, deep drilling activities lead to some impact on the flora and fauna above the planned underground facility. During the construction and operation of the facility, some buildings may be needed directly above the underground facility, along with ventilation buildings along the tunnel connecting the surface and underground facilities.

Protected and valuable areas

Figure 8-4 shows areas with varying degrees of protection for nature conservancy, protection of cultural environments and outdoor recreation. The figure also shows the location of water protection areas. All the areas marked on the map are not to be considered off-limits for siting of a deep repository, but are intended more to illustrate where areas requiring special consideration are located.

In the vicinity of the area **east of Målilla** there is a bird sanctuary on the southern part of Hulingen Lake (coloured red in Figure 8-4). In the event of a siting in the area, care must be taken not to cause any unnecessary disturbances of the bird life. A number of small areas have also been marked on the map in yellow, indicating that care must be taken in conjunction with industrial establishment. Along the railway between Rosenfors and Mörlunda, there are valuable cultural environments and cultivated landscapes that must be taken into consideration if a rail spur is built from the railway to the area east of Målilla.

The Hammarsjö area, which lies in the southern and central parts of the area **west of Hultsfred**, is of national interest for outdoor recreation. There are also two nature reserves in this area (marked in red in Figure 8-4). The possibilities of siting a deep repository while respecting areas worthy of protection are regarded as good in the north-eastern, northern and western parts.

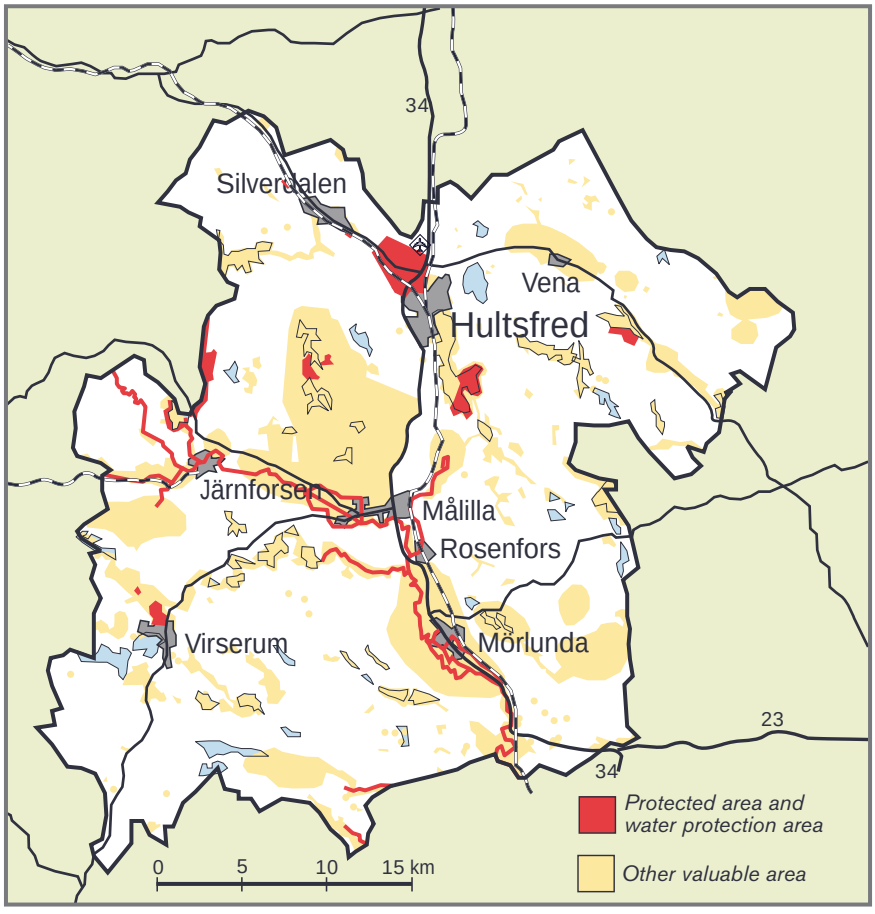

Figure 8-4. *Protected and valuable areas for nature conservancy, protection of cultural environments, outdoor recreation and water supply.*

Environmental impact

The deep repository can be positioned and configured so that it has little environmental impact. A contributing cause for this is that the surface facility can be adapted to existing and planned land use, transport routes, etc. Transport always has an impact on the environment. Construction or rebuilding of transport routes can also lead to some environmental impact which must be taken into account in a holistic assessment of different siting alternatives.

Overall assessment

SKB's overall assessment is that there are large areas where it is possible to build the different parts of the deep repository, above and under ground, with consideration given to areas worthy of protection and sensitive environments. There are also good possibilities to optimize the siting and layout of the facilities so that various protection values are taken into consideration and environmental impact is limited.

8.1.5 Society

Employment effects

The costs of investment and operation of the deep repository are estimated to amount to on the order of SEK 13 billion, distributed over about 50 years. The average number of persons directly employed during the regular operation of the deep repository amounts to about 220. During the construction phase – about 5–6 years altogether – at most 600 persons will be employed at the facility. To this must be added the indirect effects on employment. Hultsfred is a typical industrial municipality with a tradition of small and medium-sized companies. The labour market in Hultsfred also extends into the neighbouring municipalities with a similar labour market structure and a large exchange of commuters between the municipalities.

There is know-how in the municipality and the region from e.g. metalworking, building and construction, the heavy engineering industry and nuclear activities, which means there are good prospects for recruiting a large portion of the workforce locally and regionally. The construction sector is relatively small in Hultsfred Municipality, but in the whole region it is relatively large. As always in the case of large civil engineering projects, some of the building workers will probably have to be recruited from other regions during the most intensive construction phase. But there is a good base in the region. The level of education of the municipal inhabitants is considered to be fully adequate for most of the positions at the deep repository. When it comes to the limited number of positions requiring specialized competence, there are good recruitment opportunities in e.g. Kalmar, Växjö and Linköping. There are also good opportunities for planning and tailoring training to the needs of the deep repository once a siting has been decided on. When all of the above factors are weighed together, it is found that a deep repository would fit well into the region's existing industrial and labour market structure.

The deep repository can affect socioeconomic conditions, both locally and regionally. Conditions that may be affected to a greater or lesser degree by the project are, for example, the local business sector, employment, tourism and the hospitality industry. The surveys that have been conducted show that the greatest impact on socioeconomic conditions is increased employment and thereby a relatively sharp reduction of unemployment. A deep repository is not expected to directly affect the population count in Hultsfred Municipality, but may provide better chances for the municipal inhabitants to remain and work in their own municipality.

Tourism and hospitality industry

Tourism and the hospitality industry are of limited size today in Hultsfred Municipality. The biggest visitor attraction is the annual Rock Festival in June. Another major category of visitors is people visiting relatives and friends. The number of tourists is very limited, however, and they generate little revenue.

A deep repository could be a popular visitor destination in the municipality and thereby contribute to the growth of the hospitality industry. An estimate of the number of visitors to a deep repository and the business travel that will be generated indicates something on the order of 5,000–10,000 visitors per year (equivalent to CLAB), according to the surveys that have been done. This would make an annual contribution to the local hospitality industry of around SEK 5–10 million. It can be assumed that international visits and other business visits will take place at other times of the year than the Swedish summer vacation, which would help to distribute the streams of visitors over the year.

Overall assessment

SKB's overall assessment is that Hultsfred Municipality offers good societal prospects for building and operating the deep repository. Professional competencies for most of the jobs at the facility can be found within the region. Moreover, due to the existing nuclear activities and the relatively large building sector in the region, the local business sector is well-equipped to meet the demands associated with an establishment of the deep repository. The nuclear power plant and CLAB in Oskarshamn Municipality contribute to a pool of knowledge and skills on nuclear activities, but also on matters relating to siting, procurement, construction and operation of nuclear installations. This competence – available within the region – will be valuable in finding advanced ways to dispose of the nuclear waste.

8.2 Holistic assessment from the feasibility study

SKB's holistic assessment is that there are good prospects for further studies concerning the siting of the deep repository in Hultsfred Municipality. Two siting alternatives have been particularly examined in the feasibility study. Both contain large areas where the bedrock is judged to be potentially suitable for a deep repository, and the technical and environmental prospects for establishing and operating the deep repository are deemed to be good.

The one alternative is to site the deep repository within an area southeast of Hulingen Lake, east of Målilla and Rosenfors. The area, which is heavily forested, consists of the granite area which has been judged to be of interest for further studies after a field check, but with certain restrictions in its northern part due to the protection values that exist there. This alternative would require construction of an industrial area for the deep repository's surface facilities and a rail link to the existing railway. The preferred alternative is to locate the surface facility directly above the repository, but there are also other possibilities. No specific site within the area can be stipulated at this stage; that requires further investigations. In general, however, the area is judged to offer good prospects for establishing the deep repository's facilities and activities with good adaptation to local conditions and consideration given to protected and valuable areas.

The other alternative is to site the repository within an area west of Hultsfred. Further investigations are required for this alternative as well before a priority site can be designated. The surface facility can in this case be situated on an industrial area next to the town of Hultsfred, close to an existing railway and other infrastructure. The surface facility is

connected to the repository by a sloping tunnel. A smaller operations area (approximately 2–3 hectares) may also be needed on the site above the repository.

The feasibility study does not provide a basis for ranking the alternatives geologically. In an overall assessment, SKB gives priority to the eastern alternative for possible site investigations. One reason is the flexibility which this alternative allows with regard to the position and layout of the deep repository's facilities. Furthermore, the uncertainties regarding the establishment possibilities are in SKB's view smaller for the eastern alternative than for the western one. This refers in particular to the prospects of avoiding conflicts with areas worthy of protection for the environment and outdoor recreation. The viewpoints that have emerged during the municipality's circulation of the preliminary final report for review and comment have supported this view, even though other opinions have also been presented.

If a site investigation should be undertaken, initial studies should be focused on pinpointing a site for test drilling within the area east of Målilla, see Figure 8-5. This requires relatively extensive geoscientific studies from the surface. The priority site should have a good prognosis as regards the bedrock, and offer good technical and environmental prospects for establishing and operating the deep repository.

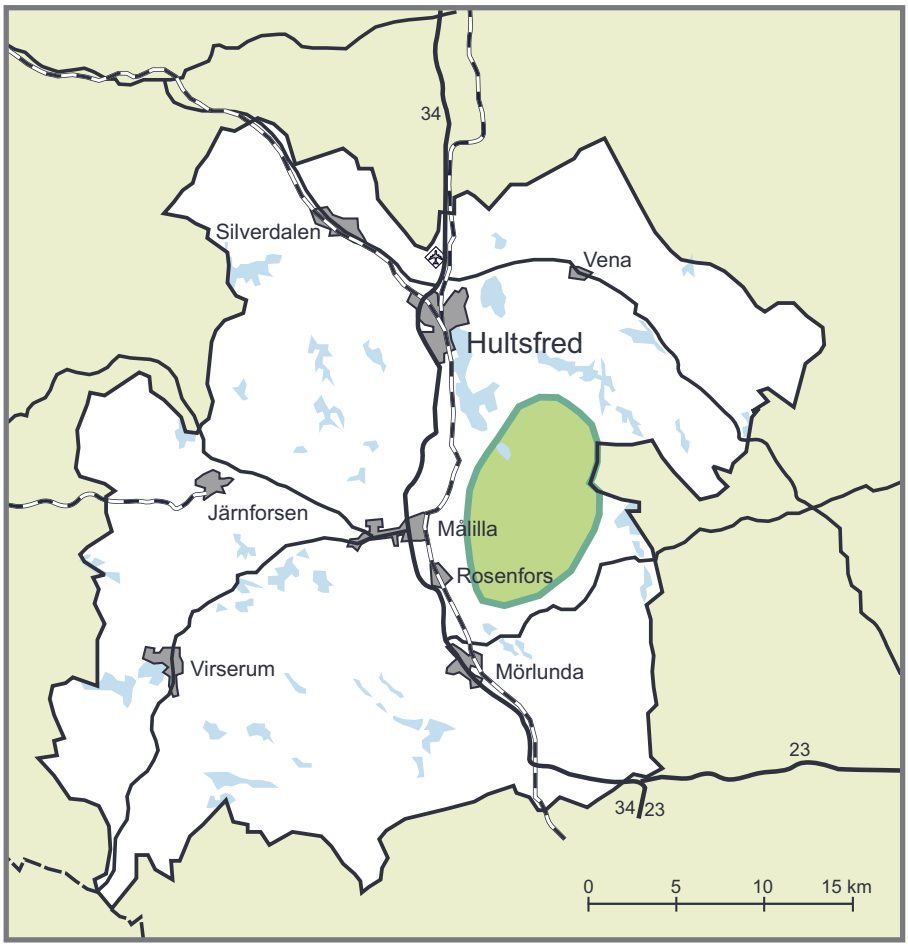

Figure 8-5. *Priority area for possible site investigations in Hultsfred Municipality. If site investigations are initiated, extensive studies must first be conducted from the surface to pinpoint a site for test drilling.*

The transport question needs to be given particular attention. Despite the inland location, there are good technical prospects for arranging transportation of nuclear waste and other goods. However, the need for overland transport entails disadvantages in the form of uncertainties regarding e.g. the attitude of nearby residents and other concerned parties, and environmental impact. These questions should be examined for different alternatives as regards transport modes and transport routes.

9 Älvkarleby – summary evaluation

SKB's conclusion from the feasibility study is that the bedrock in Älvkarleby Municipality (Figure 9-1) is complex, inhomogeneous and relatively rich in fractures. The areas checked in the field are characterized by frequent rock type fluctuations, and the rocks exhibit different degrees of deformation and metamorphosis. This makes it difficult to judge the geological prospects for the deep repository. It would require extensive test drilling and borehole investigations to determine with sufficient certainty whether the bedrock is suitable for the deep repository. SKB can therefore not recommend further studies concerning siting of the deep repository in Älvkarleby Municipality.

As far as other technical prospects are concerned – mainly harbour and transport routes – SKB's conclusion is that Älvkarleby Municipality offers good prospects if it should be decided to establish the deep repository in Tierp Municipality. Road and rail connections are extensive. Stora Enso's harbour in Skutskär would be suitable as a receiving harbour for goods transport to the deep repository.

Even if there are no plans to proceed with further studies of the prospects of siting the deep repository in Älvkarleby Municipality, SKB is still interested in a port in Skutskär. If it is decided to pursue site investigations and further siting studies for a deep repository in Tierp Municipality, studies regarding a port, the transportation system up to the deep repository and a suitable siting of the various surface activities of the deep repository will be carried out in close cooperation with Stora Enso, Älvkarleby Municipality, concerned landowners and nearby residents.

Älvkarleby Municipality

Älvkarleby Municipality has an industrial tradition dating back to the 17th century, when two ironworks were built. The district still bears a clear industrial stamp. The manufacturing industry accounts for nearly one-third of the jobs. Timber and hydropower are the basic resources, and the largest private employers are Stora Enso AB with some 500 employees and Vattenfall Utveckling AB with some 135 employees.

The Dalälven River flows through the whole municipality from south to north, discharging into the Bothnian Sea. There are ample opportunities for an active outdoor life and cultural activities. The foremost attraction for both municipal inhabitants and tourists is fishing.

Location
Coastal municipality in the far north of Uppsala County. Borders in the south and east on Tierp and in the west on Gävle.

Land area
208 km^2

Inhabitants
Approx. 8,990

Towns
Skutskär pop. 5,700, Älvkarleby pop. 1,500, Gårdskär pop. 400, Marma pop. 300.

Transportation
Both Ostkustbanan (The East Coast Railway) (Uppsala-Gävle) and the E4 motorway pass through the municipality in a north-south direction. Highway 76 runs through the central and northern parts of the municipality, while county road 291 connects to E4. There is a harbour for heavy goods traffic at the Skutskär Works. There is an airport with scheduled service in Gävle/Sandviken. Arlanda Airport is situated about two hours from Skutskär.

Land
Approximately 70% forest land, 3% arable land and pastureland, 27% built-up and other land.

Political leadership
The seats in the municipal council are distributed as follows: Social Democrats 15, Left Party 3, Moderates 3, Christian Democrats 1, Centre Party 1, Liberal Party 2, Green Party 1, Democratic List 5.

Feasibility study decision
June 1999 – 30 yes, 1 no.

Figure 9-1. *Location of Älvkarleby Municipality.*

9.1 Siting prospects in Älvkarleby Municipality

9.1.1 General

Älvkarleby Municipality is situated in northeastern Uppland County and has close labour market, trade and educational ties to the neighbouring municipality of Gävle. The municipality's central locality Skutskär is located 20 kilometres from Gävle city. Transport connections are good with railway and European highway E4. Moreover, Arlanda International Airport is located less than two hours from Älvkarleby. The municipality's business sector is dominated by pulp and energy-related companies, with Stora Enso's paper pulp mill in Skutskär as the largest private employer. The Dalälven River with its good sport fishing is a tourist attraction in the municipality.

SKB has conducted feasibility studies for the siting of a deep repository in three municipalities in northern Uppland County: Älvkarleby, Tierp and Östhammar. Experience and knowledge of nuclear activities exists in the region due to the Forsmark NPP and SFR (the final repository for low- and intermediate-level waste from the nuclear power plants, industry, research and hospitals). Thirty or so of the employees at the Forsmark NPP reside in Älvkarleby Municipality, and there are companies in the municipality who provide services to the Forsmark NPP. Vattenfall Utveckling AB conducts applied research and development in energy technology and IT. Against this background, the entire region in northern Uppland County is regarded as interesting for studies of the possibilities of siting the deep repository. However, many aspects must be weighed in when SKB assesses the results of all feasibility studies and proposes areas for site investigations. The most important is that the selected areas have good prospects of satisfying the safety and environmental requirements.

9.1.2 Long-term safety

The long-term safety of the deep repository is dependent on the properties of the bedrock on the site where the repository is built. A sufficiently thorough assessment of safety requires extensive information on rock conditions at repository depth. This information can only be obtained by means of investigations that include borehole measurements. The body of data in the feasibility study is mainly limited to compilations and analyses of existing material.

Bedrock conditions

The data that have been gathered on bedrock conditions show that the municipality is dominated by two rock types: older metagranitoids (gneissic granites) and younger granites. The first group often exhibits signs of extensive metamorphosis and deformation, while the younger granites usually are better-preserved. Both occur in different variants and are around, or slightly more than, 1,800 million years old. They are regarded as generally favourable from a repository viewpoint.

There is an area in the northernmost part of the municipality with migmatite and veined gneiss that belongs to a complex, inhomogeneous and highly metamorphosed bedrock, where the inhomogeneity is reinforced by the fact that the area is situated in a plastic shear zone. Large parts of the bedrock west of the Dalälven river are also inhomogeneous with rapid fluctuations between different rock types. In this part of the municipality, considerable portions of the bedrock also have ore potential, entailing restrictions in the siting options, since the area is of interest for prospecting. The only known ore potential in other parts of the municipality is in a small area in the southeastern part of the municipality, on the border to Tierp Municipality.

The soil depth is generally moderate, but varies a great deal between different parts of the municipality. The proportion of bare rock is mostly very low, which obstructs geological mapping and makes it more difficult to judge conditions at repository depth.

A large system of plastic shear zones runs through the municipality in an east-westerly direction. The shear zones delimit tectonic lenses which are less affected by plastic deformation. In Älvkarleby Municipality, however, it is often difficult to pinpoint the location of the plastic shear zones, mainly due to the low degree of rock exposure, which also makes it difficult to correctly delimit tectonic lenses. The field check has, for example, revealed that some of the bedrock within areas considered to lie in a large tectonic lens has undergone extensive deformation. Fracture zones occur to an extent that is normal for Swedish bedrock, as far as can be judged. They can adversely affect safety, in part because the fracture zones often have much higher hydraulic conductivity than the rest of the rock mass, and in part because future bedrock movements cannot be excluded in certain zones. The location and layout of the deep repository must therefore be adapted to the positions and properties of the zones. However, this requires investigations on a larger scope and a more detailed scale than in the feasibility study.

In the feasibility study's geological survey, all parts of the municipality with potentially unsuitable conditions (certain rock types, heterogeneous bedrock, areas with ore potential, plastic deformation zones) have been dismissed as uninteresting for further studies. After this has been done, only one small area with potentially acceptable bedrock is left along the municipality's southern boundary, see Figure 9-2. The area comprises the peripheral part of a larger granite body, the Hedesunda massif, most of which is located in Tierp Municipality. If further investigations are undertaken in the massif, it is recommended that they focus primarily on these more central portions, i.e. in Tierp Municipality.

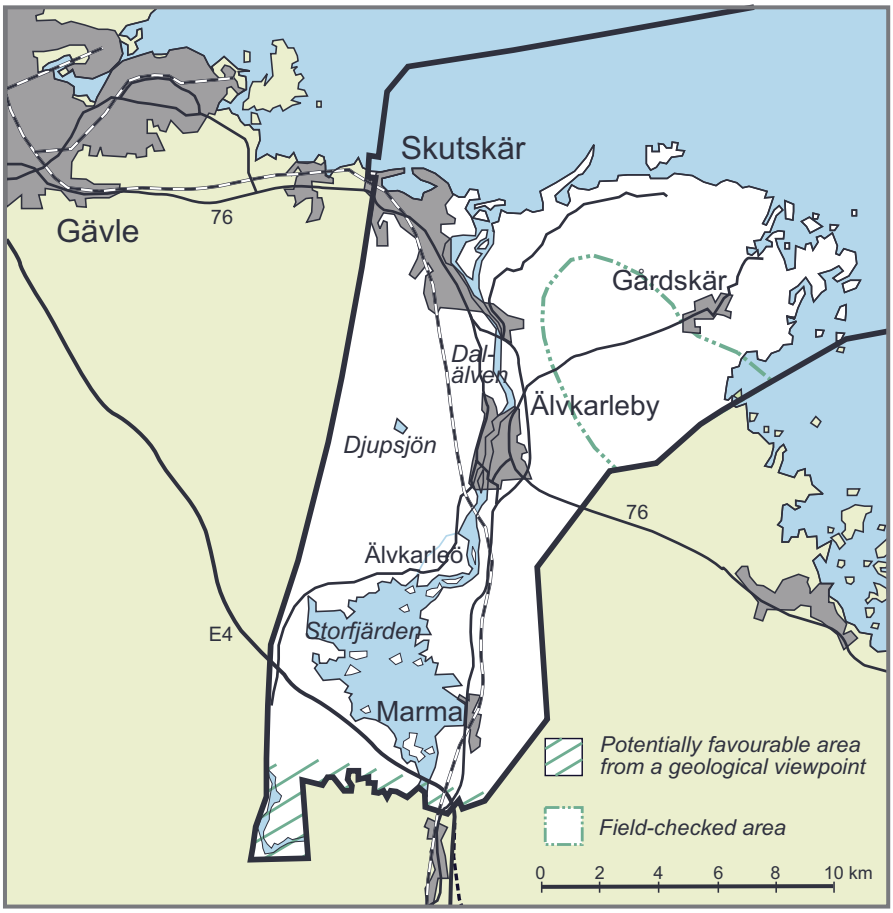

Figure 9-2. *The map shows (1) the area between Älvkarleby town and the coast which the geological field check has shown to have unsuitable conditions for further siting studies, and (2) the peripheral portion of a larger granite body, the Hedesunda massif, with potentially suitable bedrock. If site investigations are undertaken in the Hedesunda massif, it is recommended that they focus on the more central parts of the massif, i.e. in Tierp Municipality.*

Groundwater conditions

The groundwater's flow pattern in the bedrock on the site where the deep repository is situated is an important parameter from the safety viewpoint. Slow groundwater flow and long flow paths for the groundwater are favourable for the deep repository. Investigations on different sites in the country show that the groundwater flow at repository depth is largely controlled by local variations in the hydraulic conductivity of the bedrock.

Älvkarleby Municipality is located in a flat region, which generally contributes to slow groundwater flow. The body of data on groundwater conditions is otherwise very limited. No deep investigation boreholes have been drilled, and data on the chemistry of the water in rock-drilled wells are lacking. The few (44) rock wells on which data exists in SGU's well archive have a limited geographic coverage and vary widely in water discharge. The median value of the well's water discharge rate is higher than normal, but this result is uncertain due to the small number of wells and the incomplete data. The neighbouring municipality of Tierp has a much larger number (634) of rock wells, and the mean value of water discharge in these wells is close to the national average.

There are almost no data at all from the municipality on the chemical composition of the groundwater. Samples from rock-drilled wells in the neighbouring municipality of Tierp, which has similar geological and topographical conditions to Älvkarleby Municipality, reveal a composition that is more or less normal for Swedish bedrock. Wells with saline groundwater are relatively common, however.

Overall assessment

SKB's overall assessment is that most of Älvkarleby Municipality is judged to be of less interest for continued siting studies due to the presence of:

- Inhomogeneous bedrock.
- Regional plastic shear zones.
- Bedrock with ore potential.
- Thick soil layers.

The field check has shown that the area between Älvkarleby town and the coast, which was pointed out as potentially interesting early in the feasibility study, has a considerably more complex, inhomogeneous and metamorphosed bedrock than was indicated on older bedrock maps. The whole area west of the Dalälven river and north of Storfjärden can also be ruled out for a deep repository due to inhomogeneous bedrock with ore potential, as can the northernmost part of the municipality, where the bedrock is heavily metamorphosed and deformed.

After various safety-related factors are taken into account, all that remains is a small area along the municipality's southern boundary with Tierp Municipality that cannot be completely dismissed from a geoscientific point of view. The area is nevertheless not recommended for site investigations. If it should be decided to undertake further investigations in the Hedesunda massif, it is recommended that they focus on more central portions, i.e. in Tierp Municipality.

9.1.3 Technology

The technical prospects for building and operating the deep repository concern the facilities both above and under ground. The bedrock should have properties that make it possible to build and operate the underground facility with adequate safety and known technology. As far as the above-ground facility is concerned, nearness to existing infrastructure is an advantage. It must be possible to transport both nuclear waste and other goods to the deep repository with adequate safety. Access to harbours, railways and roads is an advantage.

Due to unfavourable geological conditions, Älvkarleby Municipality is no longer being considered for establishment of the deep repository's underground portion. As far as transportation is concerned, SKB's conclusion is that Älvkarleby Municipality offers good prospects. Road and rail connections are extensive. The existing harbour in Skutskär would be suitable as a receiving harbour for goods transport to the deep repository. Alternative possibilities are to build a new harbour terminal adjacent to the existing one in Skutskär or to utilize one of the harbours in the neighbouring municipality of Gävle.

The sea approach to the harbour in Skutskär is relatively difficult today. However, Stora Enso has begun extensive improvements of both the entrance channel and the rest of the port facilities. After dredging of a new entrance channel, ships with a draught of up to eight metres will be able to dock without weather restrictions. When the planned improvements of the harbour and the entrance channel have been completed, Skutskär's harbour would be well-suited as a receiving harbour for shipments to the deep repository. Different alternatives are possible with regard to port facilities for SKB's needs. One possibility is expansion within Stora Enso's harbour basin. Another alternative could be to build a new harbour just outside and east of the present-day one. Such a solution is not judged to affect Stora Enso's activities.

Stora Enso has preliminarily approved the above proposals. But there are no formal agreements. If it is decided to proceed with this harbour alternative, the requisite studies will be carried out in close collaboration with Stora Enso, Älvkarleby Municipality and other stakeholders.

Overall assessment

Due to unfavourable geological conditions, Älvkarleby Municipality is not longer being considered for establishment of the deep repository's underground portion. On the other hand, Älvkarleby Municipality offers good technical prospects – mainly harbour and transport routes – if it should be decided to establish the deep repository in Tierp Municipality (see chapter 7). Road and rail connections are extensive. Stora Enso's harbour in Skutskär would be suitable as a receiving harbour for goods transport to the deep repository. Alternative possibilities are to build a new harbour terminal adjacent to the existing one in Skutskär or to utilize one of the harbours in the neighbouring municipality of Gävle.

9.1.4 Land and environment

Land and environment aspects are of great importance for the construction of industrial facilities, roads and railways. Figure 9-3 shows different types of protected and valuable areas in the municipality. The figure represents an amalgamation of the various interests, without regard for their character.

The areas with the strongest protection are coloured red on the map. They are nature reserves, Natura 2000 areas and water protection areas. Areas that are valuable for nature conservancy, protection of cultural environments and outdoor recreation are coloured yellow. They consist of key habitats, forests with high natural values, areas included in the national mire protection plan, national interests for nature conservancy, areas included in the county administrative board's nature conservancy programme, valuable cultural environments (of national, county and local interest), national interests for outdoor recreation, and areas of national interest for tourism and outdoor recreation as set forth in Chapter 4 of the Environmental Code.

Industrial facilities, roads and railways shall not be sited in the areas coloured red in Figure 9-3, i.e. nature reserves, Natura 2000 areas or water protection areas. As the figure shows, red areas are located within the following large contiguous areas:

- The Dalälven river area.
- The coastal and archipelago area.
- The Uppsala Ridge.

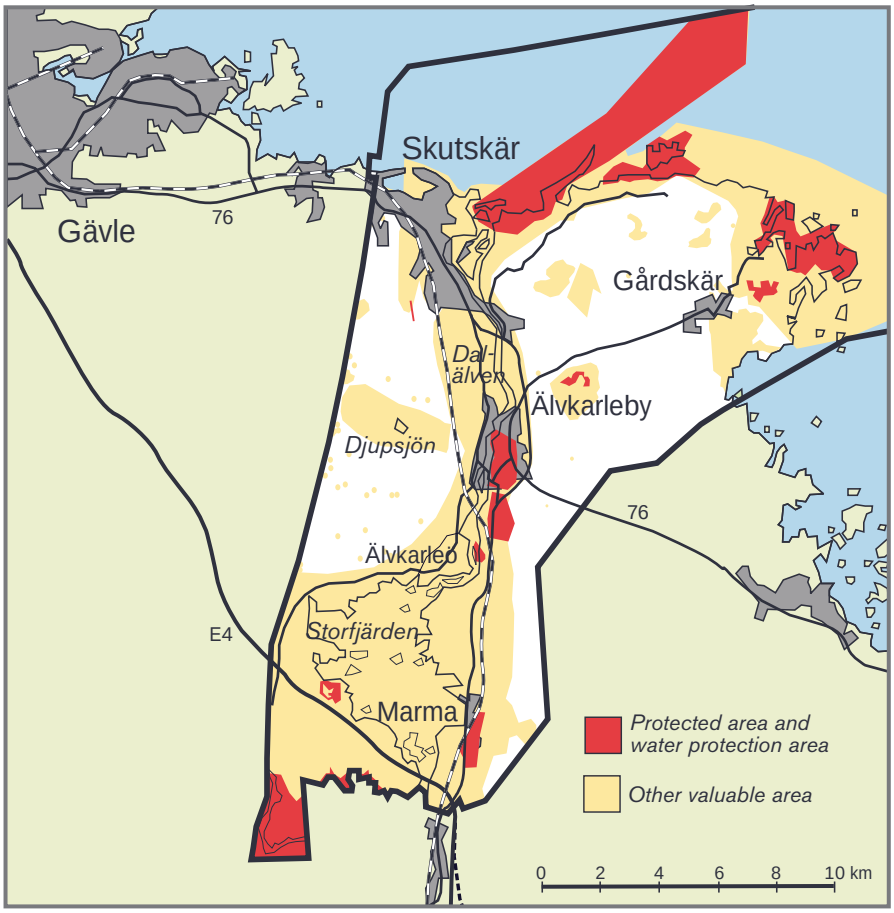

Figure 9-3. *Protected and valuable areas for nature conservancy, protection of cultural environments, outdoor recreation and water supply.*

Älvkarleby Municipality also contains land that is classified as being of national, county or local interest (yellow colour in Figure 9-3). There are values in these areas that require special consideration in connection with all types of development.

Overall assessment

As already mentioned, further studies in Älvkarleby Municipality concerning siting of the deep repository are not being considered. But if the deep repository should be established in the neighbouring municipality of Tierp, it may be advantageous to receive the spent nuclear fuel and bentonite clay via the harbour in Skutskär for further transport by rail to a suitable area in Tierp Municipality. This will require some expansion of the harbour and the rail facilities in Skutskär. These improvements, and the transport which would then be necessary through Älvkarleby Municipality, must be carried out with respect for the protected and valuable areas shown in Figure 9-3. SKB deems that there are good prospects for designing the port, road and rail facilities that would be needed without coming into conflict with protected and valuable areas, at the same time as environmental impact is limited.

9.1.5 Society

In the feasibility study, SKB studied the prospects for an establishment of the deep repository in Älvkarleby Municipality and northern Uppland County. Examples of conditions studied are the local business sector, employment, tourism and the hospitality industry and forecasts of how the municipality might develop with or without the deep repository.

Älvkarleby is a relatively small municipality with many ties to the neighbouring municipality of Gävle. These ties include education and trade as well as commuting to work. With regard to the structure of its business sector as well, Älvkarleby has much more in common with the labour market region of Gävle/Sandviken than with the rest of Uppland County.

The construction sector is relatively small in Älvkarleby Municipality, but in the whole region it is relatively large. As always in the case of large civil engineering projects, some of the building workers will probably have to be recruited from other regions during the most intensive construction phase. But there is a good base in the region. The level of education of the municipal inhabitants is considered to be fully adequate for most of the positions at the deep repository. When it comes to the limited number of positions requiring specialized competence, there are good recruitment opportunities in Gävle and the Uppsala region. There are also good opportunities for planning and tailoring training to the needs of the deep repository once a siting has been decided on.

Tourism is an important industry in Älvkarleby Municipality. The Dalälven river with its good sport fishing is a major tourist attraction which should have good potential for further development. There are also around 400 vacation homes, and summer residents are of great importance for e.g. the supermarkets in the municipality.

Overall assessment

Even though proceeding to siting studies for the deep repository is not being considered in Älvkarleby Municipality, such studies will probably be conducted in the region. SKB's assessment is that Älvkarleby Municipality then will have good prospects of contributing competencies for many of the jobs that will be created at a deep repository in northern Uppland County. In-depth studies that shed light on this and other important societal aspects are planned in conjunction with an site investigations in northern Uppland County.

9.2 Holistic assessment from the feasibility study

SKB's assessment from the feasibility study is that there are no geological prospects for further studies concerning siting of the deep repository. In the preliminary final report, SKB concluded that the area between the town of Älvkarleby and the coast could be of interest for the deep repository. Since then the bedrock in this area has been checked in the field. The field check has shown that the bedrock is complex, inhomogeneous and relatively rich in fractures. Extensive test drilling and borehole investigations would be needed to be able to judge with sufficient certainty whether the bedrock is suitable for the deep repository. SKB's conclusion is that the geological conditions are much to difficult to assess for such investigations to be recommended.

As far as other technical prospects are concerned – mainly harbour and transport routes – SKB's conclusion is that Älvkarleby Municipality offers good prospects for a deep repository establishment. Road and rail connections are extensive. The existing harbour in Skutskär would be suitable as a receiving harbour for goods transport to the deep repository. Alternative possibilities are to build a new harbour terminal adjacent to the existing one in Skutskär or to utilize one of the harbours in the neighbouring municipality of Gävle.

SKB is still interested in a port in Skutskär. The harbour in Skutskär is judged to be a good alternative for reception of goods to the deep repository if it was to be sited in Tierp Municipality (see Chapter 7). Different alternatives are possible: either improvement of the existing harbour or construction of a new harbour terminal. Stora Enso has preliminarily approved these proposals. But there are no formal agreements. If it is decided to proceed with this harbour alternative, the requisite studies will be carried out in close collaboration with Stora Enso, Älvkarleby Municipality and other stakeholders.

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