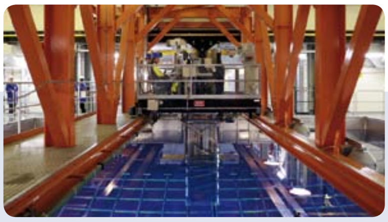
Environmental Impact Statement

March 2011





Interim storage, encapsulation and final disposal of spent nuclear fuel

Concerning Environmental Impact Statement - Interim storage, encapsulation and final disposal of spent nuclear fuel

The Environmental Impact Statement (EIS) dated March 2011, is an appendix to SKB's application for permit under the environmental code and the application for licence under the nuclear activities act. During the licensing process, up to and including September 2015, have four additions been made to the application under the Environmental Code. Portions of the content of the additions affect environmental impacts and are to be considered as supplements to the EIS. Unfortunately are these only available in Swedish.

In connection with the consultations under the Espoo Convention with neighboring countries, SKB presented an update of the non-technical summary of the EIA in English (SKBdoc 1527473, ver1.0), that is available on SKB's website: http://www.skb.se/wp-content/uploads/2016/01/B-Non-technical-summary.pdf

Kind regards,

Swedish Nuclear fuel and Waste Management Co
Department nuclear fuel

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Environmental Impact Statement

Interim storage, encapsulation and final disposal of spent nuclear fuel

Svensk Kärnbränslehantering AB

March 2011

Applicant

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Box 250
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Participants

The Environmental Impact Statement (EIS) has been prepared by Svensk Kärnbränslehantering AB (the Swedish Nuclear Fuel and Waste Management Co, SKB). Responsibility for the Environmental Impact Statement rests with Erik Setzman, sub-project manager for EIA (Environmental Impact Assessment) and consultations within the Nuclear Fuel Project. The administrators responsible for production of the EIS have been Helén Segerstedt, Pia Ottosson, Mikael Gontier, Yvonne Andersson, Petra Adrup and Elin Forsberg. The administrators responsible for the consultations have been Lars Birgersson and Sofie Tunbrant.

Other sub-projects within the Nuclear Fuel Project have contributed background material for the Environmental Impact Statement. SKB has engaged consultants to study impact and assess consequences. Studies of water operations were carried out by Emptec. Noise studies were carried out by WSP Akustik, atmospheric impact was studied by IVL (the Swedish Environmental Research Institute), the natural environment study was carried out by Ekologigruppen AB, and the cultural environment study was carried out by the National Heritage Board. Studies of water management were prepared by WRS Uppsala AB, the vibration study was carried out by Nitro Consult and the environmental risk analysis was prepared by Vattenfall Power Consultant AB. The study of radiological impact on plants and animals was carried out by Studsvik AB.

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Reading instructions

An Environmental Impact Statement (EIS) shall be prepared and submitted along with applications for permissibility and a licence under the Environmental Code and a licence under the Nuclear Activities Act for new nuclear facilities. This Environmental Impact Statement has been prepared by Svensk Kärnbränslehantering AB (the Swedish Nuclear Fuel and Waste Management Co, SKB) to be included in the licence applications for continued operation of Clab (central interim storage facility for spent nuclear fuel) in Simpevarp in Oskarshamn Municipality and construction and operation of facilities for encapsulation (integrated with Clab) and final disposal of spent nuclear fuel in Forsmark in Östhammar Municipality.

The Environmental Impact Statement consists of nine main parts with different colour themes to facilitate orientation in the document:

- Non-technical summary
- Introductory part, Chapters 1–6
- Site-specific conditions, Chapter 7
- Central interim storage facility for spent nuclear fuel (Clab), Chapter 8
- Integrated facility for interim storage and encapsulation (Clink), Chapter 9
- Final repository for spent nuclear fuel, Chapter 10
- The zero alternative, Chapter 11
- The whole system for interim storage, encapsulation and final disposal of spent nuclear fuel, Chapters 12–13
- Glossary and references, Chapters 14–15

The introductory part, Chapters 1–6, describes the background, purpose and selected method for final disposal of spent nuclear fuel and provides an overview of other methods and sites considered. It also describes the purpose and scope of the Environmental Impact Statement and how SKB has carried out the consultations pursuant to the Environmental Code. Chapter 7 describes the conditions on the sites where SKB is applying for a licence to locate the facilities for encapsulation and final disposal of spent nuclear fuel. The following chapters, 8 to 10, describe activity, facility design, impact and consequences for each facility: the central interim storage facility (Clab), the encapsulation plant (integrated with Clab) and the final repository. Chapters 9 and 10 also describe the alternative sitings that have been considered for the encapsulation plant and the final repository. The post-closure safety of the final repository is dealt with in Sections 10.1.6 and 10.2.6. Chapter 11 describes the consequences of the zero alternative, which designates the scenario where nothing is done. An integrated description of the consequences of, measures for and follow-up of the entire system for interim storage, encapsulation and final disposal of spent nuclear fuel is provided in Chapters 12–13. A comparison is also made between the system for which SKB is submitting applications – the encapsulation plant in Simpevarp in Oskarshamn Municipality and the final repository in Forsmark in Östhammar Municipality – and considered system alternatives, as well as the zero alternative.

Contents

Sub-appendices

Sub-appendix	Title	Contents
1	Consultation report	Describes how the consultations have been conducted and presents the principal issues that have emerged and how SKB has dealt with them.
2	Methods and assessment criteria	Describes the methods and assessment criteria (guideline values, environmental quality standards etc) that have been used to conduct background studies and impact assessments.
3	**Water operations in Laxemar-Simpevarp** Clab/encapsulation plant (Clink) – diversion of groundwater, intake of cooling water from the sea and construction of storm water detention pond	Describes groundwater drawdown and other water operations at Clink and their consequences.
4	**Water operations in Forsmark (Part I)** Diversion of groundwater from the final repository for spent nuclear fuel	Describes groundwater drawdown around the final repository and its consequences.
5	**Water operations in Forsmark (Part II)** The final repository for spent nuclear fuel: Water operations on the surface	Describes other water operations at the final repository and their consequences.
6	Reconciliation with environmental objectives	Describes the impact of the project on regional and national environmental objectives.

Non-technical summary

The applied-for activity

This Environmental Impact Statement (EIS) for interim storage, encapsulation and final disposal of spent nuclear fuel is a part of Svensk Kärnbränslehantering AB's (SKB's) applications for permissibility and licences under the Environmental Code and the Nuclear Activities Act.

SKB is applying for a licence to continue operating the existing interim storage facility for spent nuclear fuel (Clab) on the Simpevarp peninsula in Oskarshamn Municipality, and to build an encapsulation plant adjacent to Clab. The two facilities will then be operated as a single integrated facility, designated Clink. Further, SKB is also applying for a licence to build and operate a final repository in Forsmark in Östhammar Municipality, see Figure S-1. The EIS covers these facilities, including water operations and transportation to and from the facilities.

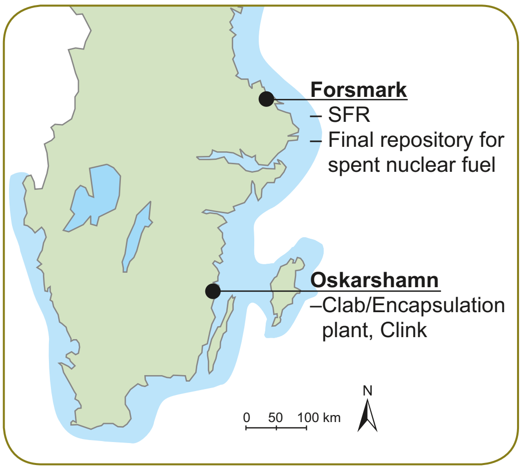

Figure S-1. SKB is applying for licences to build the encapsulation plant adjacent to Clab on the Simpevarp peninsula in Oskarshamn Municipality and the final repository in Forsmark in Östhammar Municipality.

Consultations have been held in accordance with the provisions of the Environmental Code. The consultations are described briefly in the Environmental Impact Statement and in greater detail in a separate consultation report, which is a sub-appendix to the EIS.

Background

Ever since the Swedish Nuclear Power Plants were commissioned, they have generated radioactive waste. The power plant owners are responsible for safe management and disposal of the waste and have jointly formed SKB for this purpose. SKB has been conducting research and developing methods to dispose of the waste for nearly 30 years. Today there is a final repository for short-lived radioactive waste (SFR) in Forsmark and a central interim storage facility for spent nuclear fuel (Clab) in Oskarshamn.

Nuclear fuel is made from uranium mineral. The radioactivity of the fuel increases sharply during the operation of a reactor. The fuel is taken out of the reactor after about five years, and is then at its peak radiotoxicity. Its radiotoxicity then declines as the radioactive substances decay. In its planning, SKB assumes that the reactors in Forsmark and Ringhals will be operated for 50 years and the reactors in Oskarshamn for 60 years. The Swedish reactors would then give rise to a total of about 12,000 tonnes of spent nuclear fuel.

Pre- and post-closure safety

The purpose of the applied-for activity is to dispose of the spent nuclear fuel in order to protect human health and the environment from the harmful effects of ionizing radiation from the spent nuclear fuel, now and in the future.

Nuclear facilities must comply with high standards of operational safety and radiation protection. Each facility has a safety analysis report that describes how safety and radiation protection are designed to protect man and the environment from radiation, both during normal operation and in the event of operational disturbances and accidents. Two fundamental principles are that radiation doses should be minimized as far as is reasonably possible and that the best available technology should be used.

The long-term post-closure safety of the final repository is a central issue in the licensing process and is described in a separate appendix to the applications. There SKB shows that the facility does not give rise to any significant environmental or health consequences in the future and thereby complies with the requirements of the Swedish Radiation Safety Authority. The long-term safety of the final repository is also described in the EIS.

The KBS-3 method

The method for disposing of the spent nuclear fuel is called KBS-3, see Figure S-2. KBS stands for KärnBränsleSäkerhet (Nuclear Fuel Safety) and 3 indicates that the method was presented for the first time in the KBS project's third main report. The method involves encapsulating the spent nuclear fuel in copper canisters which are deposited, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system about 500 metres down in the bedrock. The purpose of the three barriers (canister, buffer and rock) is to isolate the radionuclides in the fuel from the surrounding environment.

SKB's method development has been based on the requirements in Swedish legislation and the provisions of international agreements. In brief they are as follows:

- The owners of the nuclear power plants are responsible for managing and disposing of the nuclear waste in a safe manner.
- The waste must be dealt with within the country, if this can be done in a safe manner.
- The sea and the seafloor may not be used for this purpose.
- The system shall be designed to prevent illicit trafficking in nuclear materials or nuclear waste.
- Safety shall rest on multiple barriers.
- The final repository shall not require monitoring or maintenance.
- Management and final disposal of the nuclear waste shall in all essential respects be solved by the generations who have benefitted from the nuclear power.

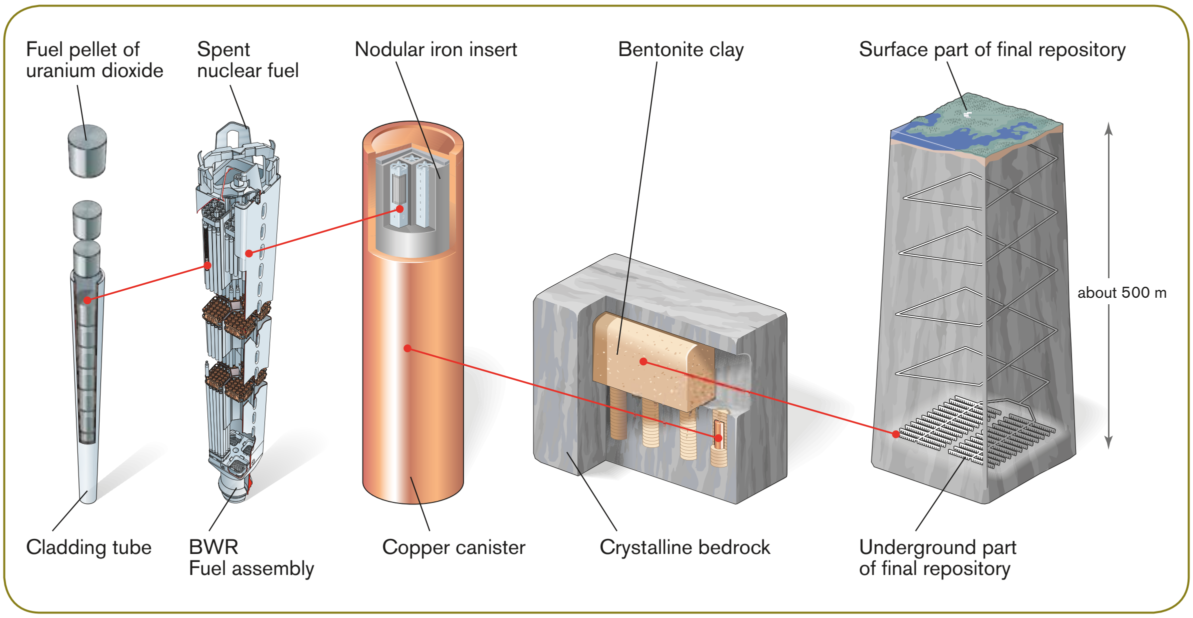

Figure S-2. The KBS-3 method. The method involves encapsulating the spent fuel in copper canisters which are then emplaced, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system at a depth of about 500 metres in the bedrock.

The support and acceptance of the community is required if the plans for the final repository are to be realized. SKB's basic principle is therefore that siting shall take place with the voluntary participation of the concerned municipalities.

Siting of the final repository

The siting work began more than 30 years ago with the acquisition of knowledge on the Swedish bedrock and what properties the rock must have in order for the final repository to be safe. SKB conducted feasibility studies in eight municipalities between 1993 and 2000. Site investigations were initiated in 2002 and continued for about five years in Forsmark in Östhammar Municipality and in Laxemar/Simpevarp in Oskarshamn Municipality.

In June 2009, a systematic comparison of the conditions on the sites showed that all things considered, Forsmark is the site that offers the best prospects for achieving long-term safety. SKB therefore decided to submit licence applications for a final repository located in Forsmark.

Other methods and the zero alternative

SKB has also studied other ways to dispose of the spent nuclear fuel besides the KBS-3 method. None of the other methods satisfy all the fundamental requirements and criteria, or they are not available at today's level of knowledge and development.

If final disposal of the spent nuclear fuel does not come about, the remaining option is to continue storing it under monitored forms. This can be done either by continued storage in Clab, or by one of the methods for monitored storage that are used internationally. With monitored storage, the environmental, safety and radiation protection requirements can be met as long as human monitoring with control and maintenance is maintained. For this reason, monitored storage is associated with uncertainties in a long time perspective. The method does not meet the fundamental requirements on a final repository, since it postpones the solution into an indefinite future. Continued storage in Clab is the so-called zero alternative in the EIS.

Description of the Forsmark area

The final repository will be located on the coast adjacent to the Forsmark industrial area, where the Forsmark Nuclear Power Plant is situated, see Figure S-3. Facilities belonging to the nuclear power plant include a water works, a sewage treatment plant, an oil depot, power lines, the Svalören near-surface repository for low-level waste and temporary housing. The industrial area also contains the final repository for short-lived radioactive waste (SFR) and the Port of Forsmark, which is serviced by the ship m/s Sigyn.

The nearby area is sparsely built-up, and no one lives within a distance of one kilometre from the planned operations area.

There are a number of national interests in the Forsmark area, one of which is the national interest for final disposal of spent nuclear fuel. Parts of the area that may be affected by the final repository are also of national interest for nature conservation and are subject to the Environmental Code's special management provisions for highly developed coastal areas.

In the site investigations which SKB has conducted, large resources have been devoted to gathering data in the field on the properties of the bedrock, the soil layers and the ecosystems. In order to fully characterize the rock, investigations on the surface have been combined with studies of drill cores and measurements in boreholes. Information on the soil layers has been obtained from soil wells. The results of the investigations have been summarized in site descriptive models.

The bedrock in the investigation area consists of the northwestern portion of a tectonic lens, i.e. an area in the bedrock where conditions have been geologically stable compared with surrounding deformation zones. The dominant rock type is medium-grained metagranite.

S-3. View over the Forsmark area with the nuclear power plant in the foreground.

There are long, water-conducting horizontal fractures within the upper approximately 150 metres of the rock. At depths greater than 400 metres, the average distance between water-conducting fractures is more than 100 metres and the groundwater flow is limited. Due to these conditions, along with the area's gently dipping topography, most of the groundwater flows take place relatively close to the ground surface, without much exchange with deeper groundwaters.

Lime-rich till is the predominant Quaternary deposit in the soil layers. The water table is situated near the ground surface. There are many lakes and wetlands in the area, but no major rivers or streams. Most lakes are small and shallow, with lime-rich and nutrient-poor water.

The Forsmark area has an unusual wilderness character for Uppland, even though parts bear the traces of large-scale agriculture. The natural values in the area consist of land uplift habitats with high botanical and ornithological values, coastal water habitats, different types of rich fens and ponds, natural forests and farming and agricultural districts with pasturelands. The natural values in the area have been inventoried and classified by means of a methodology used by the Swedish Environmental Protection Agency and the county administrative boards. The red-listed pool frog occurs in some ponds in the area. Other red-listed species also occur in the area, including birds, orchids and fungi.

A cultural environment analysis, including an archaeological survey and a landscape analysis, has been carried out. Much of the cultural environment in the area is characterized by having belonged to Forsmarks bruk (former ironworks). Since the area in question only rose above the sea a few thousand years ago, there are no prehistoric or early medieval remains.

The area's recreational value lies above all in its pristine nature, bird life and other animal life. Recreational activities such as hunting and fishing are popular. However, outdoor activities are not as extensive here as in other, more densely populated parts of the east coast.

Radiological measurements are performed regularly around the nuclear facilities in Forsmark. Most of the measured radiation consists of natural background radiation. The contribution from the nuclear power plant and SFR is about one five-thousandth of the natural background radiation, or approximately one five-hundredth of the legal limit.

Motor vehicle traffic in Östhammar is seasonally dependent and increases markedly in the summertime. Many residents along national road 76 between Forsmark and Hargshamn are exposed to noise levels above the guideline values, and the traffic noise is experienced as disturbing.

Description of the Oskarshamn area

The Laxemar/Simpevarp area in Oskarshamn has been surveyed by means of a site investigation similar to that in Forsmark. In this document, however, the site conditions are mainly described against the background of the siting of Clab and the planned encapsulation plant, see Figure S-4.

The Oskarshamn Nuclear Power Plant with associated activities, including a near-surface repository for low-level waste and a rock cavern for interim storage of low- and intermediate-level waste, are situated on the Simpevarp peninsula. Clab, SKB's site investigation office, the access tunnel to SKB's hard rock laboratory on Äspö and the Simpevarp harbour, which is serviced by m/s Sigyn are also located on the peninsula.

The nearby area is sparsely built-up. The nearest residential development is in Åkvik, about 600 metres southwest of Clab.

The Simpevarp peninsula and its surrounding area contains a number of different sites of national interest, and the Natura 2000 site Figeholm is located along county road 743.

The area around the Laxemar and Simpevarp subareas lies in a geographical region which is characterized by a joint valley landscape with small elevation differences, hardwood forests, bare skerries and rocky shores. The natural values in the area have been classified using the same method as in Forsmark. There are no natural areas on the Simpevarp peninsula that have been judged to be valuable.

The cultural heritage assets on the peninsula consist of numerous archaeological remains, including cairns and stone circles from the Bronze and Iron Age. Near Clab there are archaeological remains in the form of five prehistoric graves, indicating that there may also be remains of permanent settlements.

Radiological measurements around the nuclear facilities are performed in a similar manner as in Forsmark. The nuclear power plant's emissions are less than one hundredth of the legal limit. Clab's contribution is virtually negligible.

County road 743, which is heavily trafficked during certain periods, is used for shipments to the Simpevarp peninsula. Many residents along the way from the Oskarshamn Nuclear Power Plant to the Port of Oskarshamn are exposed to noise levels above the guideline values for road traffic noise.

S-4. View over the Laxemar/Simpevarp area with the nuclear power plant in the background.

Clab

Facility and activity

At present more than 5,000 tonnes of uranium from nearly 40 years of operation of the Swedish nuclear power plants is being stored in Clab. Certain used high-level components from the nuclear power plants are also being stored there. Clab has been in operation since 1985 and was extended in the early 2000s with a new rock cavern, which was put into operation in early 2008, see Figure S-5.

Storage in Clab takes place in pools located in rock caverns about 30 metres underground. During storage, the radioactivity and heat output of the nuclear fuel decline, facilitating further handling. The water in the pools provides protection against radiation while cooling the fuel. The water in the pools is in turn cooled by sea water in a system of heat exchangers.

The spent nuclear fuel and spent core components are transported from the nuclear power plants to Clab enclosed in special transport casks, which are designed to withstand severe accidents without consequences for the environment. Transport takes place by sea on m/s Sigyn to the Simpevarp harbour and overland on specially built vehicles.

Figure S-5. Clab is situated on the Simpevarp peninsula.

Impact, effects and consequences

Operational safety and radiation protection

Releases of radionuclides to air and water take place continuously, but are far below the legal limits and are not judged to give rise to any health consequences whatsoever for nearby residents. The exhaust air from spaces where radioactivity may be present is cleaned by particle filters, which remove most of the particle-borne radioactivity. The emissions of airborne radioactivity from the facility leave Clab via the ventilation chimney, where monitoring equipment continuously registers radioactivity releases.

Discharges of water-borne radioactivity only take place via the water purification system from the area where radioactivity can occur (the controlled area). The water is purified by filters and ion exchange resins, and the radioactivity content of the water is checked prior to each discharge.

Radioactive waste

Radioactive waste in the form of protective clothing, ion exchange resins etc is collected and taken to the near-surface repository or to SFR.

Discharges to water

Heated water that has been used to cool the facility is discharged into Hamnefjärden Bay. Water from Clab is discharged along with cooling water from the Oskarshamn Nuclear Power Plant and constitutes only a fraction of the total discharge (in the order of a tenth of a percent).

Groundwater that flows into the rock caverns is pumped and discharged into Herrgloet Bay. Both the water in the cooling system and inflowing groundwater are kept outside of the controlled area and therefore do not contain any radioactive substances.

Other environmental consequences

Neither Clab nor shipments to and from the facility are judged to affect any national interests or protected areas.

Clab's visual impact on the landscape is limited thanks to the surrounding forest.

The noise level at the facility is low and is not judged to cause any consequences for the local populace.

The local drawdown of the groundwater caused by the facility is limited in scope and extent and has not given rise to any consequences for either natural values or groundwater levels in wells.

Clink

Facility and activity

The encapsulation plant will be erected immediately adjacent to Clab, see Figure S-6, and the two facilities will be operated as a single integrated facility, called Clink. Existing functions and systems in Clab will be co-utilized wherever possible.

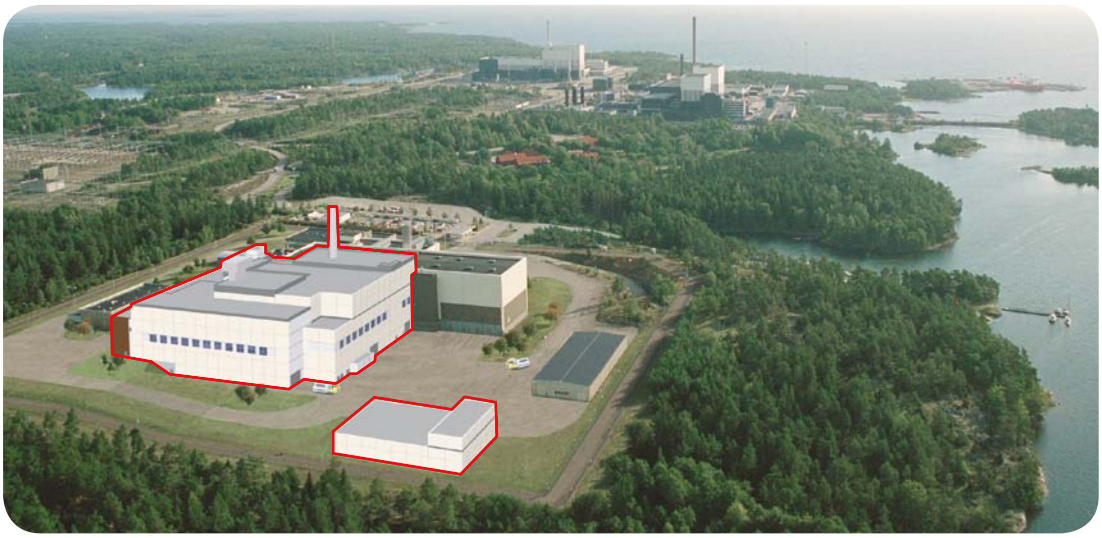

Figure S-6. The encapsulation plant will be located directly adjacent to Clab, and the two facilities will be operated as one integrated facility called Clink. The red outline indicates the part of the picture that is a photomontage.

Spent nuclear fuel will be encapsulated in the encapsulation plant prior to final disposal in the bedrock. The nuclear will be taken out of the storage pools in Clab, dried and placed in copper canisters, after which a lid will be welded on. The canisters, which are around five metres long, will arrive at the encapsulation plant ready-made. The encapsulation plant is designed for a production capacity of 200 filled canisters per year, i.e. around one canister per work day.

Filled canisters are placed in transport casks and transported by sea to the final repository. The function of the canister in the final repository is to enclose and isolate the spent nuclear fuel.

When nuclear power has been phased out and all spent nuclear fuel and other high-level waste has been transferred to the final repository, Clink will be decommissioned. SKB's current estimate is that decommissioning can begin in around 2070.

Impact, effects and consequences

Operational safety and radiation protection

The amount of radioactivity that is released per fuel assembly is much less in the encapsulation plant than in Clab, despite the larger volume of fuel and transport casks handled. This is because the radioactivity of the fuel has declined during the long period of storage. Once the fuel has been encapsulated it is no longer a source of airborne radioactivity, but radiation shielding is nevertheless required during its further handling.

The radioactivity released during handling in the pools in the encapsulation plant is collected on filters and ion exchange resins in a water purification system common for Clink. In areas where airborne radioactivity is expected, the ventilation system is equipped with filters. Airborne emissions from the encapsulation plant will take place through a ventilation chimney, and the radioactivity in the emitted air will be monitored continuously.

Clink's emissions to air and water are expected to be far below the legal limit and will not give rise to any health consequences for nearby residents or for the flora and fauna in the nearby area.

Radioactive waste

Waste from the encapsulation plant will be managed in the same way as at Clab.

Land use

The encapsulation plant is not expected to affect any national interests or protected areas.

When the encapsulation is built, land is needed for the plant itself along with temporary establishment areas for construction, for a total of nearly 30,000 square metres. Land will be used west of Clab, in a forested area without any high natural values.

In view of the archaeological remains in the form of graves found in the siting area and the nearby Bronze Age cove, it is not unlikely that prehistoric settlement sites may be affected.

Since there is already an established industrial environment on the Simpevarp peninsula, it is judged that more large-scale facilities can be built on the peninsula without altering the character of the area. The consequences for the landscape will be small, as long as the forest surrounding the facility is spared.

Transportation, noise and vibration

Construction of the encapsulation plant will give rise to noise and vibration. No appreciable disturbances are expected as a consequence of the vibration. Noise calculations show that the construction noise will not exceed the guideline value at the nearest homes, even in a worst case scenario, if noise barriers are built.

As a result of noise from road transport, no more than some 40 or so residents will be exposed to sound levels above the guideline value during construction of the encapsulation plant. There will be more events with peak sound levels when the number of heavy vehicles increases. Vibration from shipments to and from the plant are not expected to lead to any appreciable disturbance for residents along the transport routes.

During the operating phase, the noise situation in the area will be similar to what it is today. Noise suppression measures will be adopted on fans, and the guideline value for industrial noise will not be exceeded, which means that no significant disturbance for nearby residents is expected.

Other emissions to air and water

Conventional atmospheric emissions that occur from Clink (including transport emissions) are not expected to be of such a scope that they will entail any risk to health or exceed the environmental quality standard for air. Sea transport of fuel-filled canisters to the final repository will be the predominant source of atmospheric emissions.

The temperature in Hamnefjärden is elevated today due to the discharge of cooling water from the nuclear power plant, and the contribution from Clink will be marginal.

Energy and resource consumption

Heat for heating of the encapsulation plant can be extracted from the cooling water in Clab. The facility needs to be cooled in the summertime, and the excess thermal energy is then discharged to the sea.

It is estimated that approximately 44,000 tonnes of copper will be consumed in the encapsulation of the spent nuclear fuel over a 40–50-year period, which can be compared with the annual global production of copper of 15.5 million tonnes.

Final repository

Facility and activity

The final repository will consist of a surface part and an underground part. The surface part includes an operations area with the central functions for the operation of the facility. The operations area will be situated on the coast, just southeast of the nuclear power plant in Forsmark, on a site which SKB calls Söderviken, see Figure S-7. A rock heap will be established next to the operations area, along with facilities for water treatment.

The underground part's central area will be located directly beneath the operations area. From here it will be possible to access the repository area, consisting of main tunnels and deposition tunnels with deposition holes in which the copper canisters will be emplaced, surrounded by a buffer of bentonite clay. The surface and underground parts will be connected by ventilation and elevator shafts, plus a ramp for vehicle transport.

Construction of the facility will take approximately seven years and employ around 300–400 persons. Activities will be most intensive during the second half of the construction phase. A total of about 1.6 million tonnes of rock spoil will be excavated during the construction phase. The rock spoil will be temporarily stored in a rock heap within the industrial area. It is believed that the surplus that is not needed in the project can be sold in the region.

The operating phase is divided into two sub-phases, trial operation and routine operation, both of which require a licence from the Swedish Radiation Safety Authority (SSM). Routine operation is expected to last about 45 years. The main activities during routine operation are detailed characterization, mining of deposition tunnels, deposition of canisters, and backfilling and plugging of deposition tunnels. Approximately 6,000 canisters will be deposited during the operating phase.

Figure S-7. Location of the final repository on Söderviken in Forsmark (photomontage). The Forsmark Nuclear Power Plant can be seen to the left in the picture, and the area at the bottom is the rock heap. The red outline indicates the part of the picture that is a photomontage.

When all canisters have been deposited, the facility will be backfilled and closed. Altogether it is estimated that the repository's tunnels will occupy an area of 3–4 square kilometres at a depth of about 470 metres.

During the operating phase, filled canisters will be transported from the encapsulation plant to the final repository by m/s Sigyn or a similar ship.

Impact, effects and consequences

Operational safety and radiation protection

As long as the canister remains intact, no radioactive substances can escape. The canister is designed to withstand normal operation, disturbances and mishaps without a penetrating breach occurring that leads to release of radioactivity. However, the canister does emit gamma and neutron radiation and will therefore be handled with radiation shielding to protect the personnel. The radiation emitted by the canister does not have enough range to reach outside of the final repository.

Post-closure safety

According to SSM's regulations, post-closure safety will be achieved by means of a system of passive barriers that interact to contain, prevent or retard the dispersal of radioactive substances. The barriers may be engineered or natural. In addition there are regulations that stipulate what protective capability the final repository should have. An important requirement is SSM's risk criterion, which in simplified terms says that people in the vicinity of the repository may not be exposed to greater risks than the equivalent of one-hundredth of the natural background radiation in Sweden today. The analysis of the long-term post-closure safety of the repository shows that the regulatory requirements are satisfied. The aggregate risk for a final repository in Forsmark is well below the risk criterion, even in a time perspective of a million years.

National interests and protected areas

Most of the sites of national interest in the area are either not affected by, or deemed not to be harmed by, the planned activity. The Forsmark-Kallrigafjärden site of national interest for nature conservation risks being affected by a possible groundwater drawdown, with consequences for rich fens and shallow ponds. The risk of significant effects cannot be excluded, but a number of measures are planned to limit the consequences for the natural values in the area.

Land use

Most of the facility is located in areas that are already industrial land today, but land with high natural values will also be included. Three ponds, two of which are deemed to be of national interest because the red-listed pool frog has been observed, will be filled. SKB intends to create new ponds in the nearby area.

A ventilation station will be built approximately 1.5 kilometres east of the operations area. The road to the ventilation station will be designed to preserve the natural values in the form of rich fens that exist in the affected area.

No areas with bird life worthy of protection are judged to be affected by SKB's land needs. Disturbances of bird life can, however, result from the movement of people in the area. SKB will therefore implement restrictions, training and recommendations for employees who need to get to or move around in areas that are used for nesting by protected and red-listed species.

Cultural environment

Söderviken and its environs do not harbour any special cultural heritage values. No known archaeological remains are affected, and the probability that unknown archaeological remains might be affected is considered very low.

There are, however, a couple of historical remains near the siting area and the ventilation stations. They are judged to be possible to protect from development and are therefore not affected.

Landscape

The final repository will be built adjacent to the nuclear power plant, whose three large reactor units are landmarks that can be seen from a great distance in the flat wooded and coastal landscape. The final repository's largest buildings will be smaller and lower than the reactor units. The facility will nevertheless be visible from far away, mainly from the sea. The area's existing industrial character will be preserved and the consequences for the landscape are therefore deemed to be small.

Discharges to water

The activity will give rise to polluted water that needs to be managed during both the construction and the operating phase. Storm water will be managed locally. Leachate from the rock heap will be treated to remove oil and particles. Then it will be conducted for denitrification to a flooding area near the rock heap and further into a nearby lake called Tjärnpussen, where the nitrogen content of the water (explosive residues) is further reduced.

The drainage water that is pumped from the tunnels consists for the most part of groundwater, but also contains flushing water from the blasting. The drainage water will be treated underground by sedimentation and oil separation and then discharged into Söderviken. The heat content of the drainage water will be used to heat the supply air to the underground facility. The effects of the discharge are expected to be limited, since the content of nitrogen residues is judged to be low and the receiving body of water is relatively tolerant.

Groundwater level and wetlands

During work underground, the rock will be sealed by grouting where fractures and fracture zones are present. Completely preventing groundwater inflow into the facility is not possible, however, since grouting can never make the rock completely watertight. The leaking groundwater will cause groundwater drawdown, which can in turn affect water levels in wetlands. The affected area consists of a number of "swaths" that run in an east-west and north-south direction above the repository, and in areas around the cooling water channel. Most inventoried wetlands in Forsmark are deemed to be sensitive to a lowering of the groundwater table. Even moderate drawdowns of less than a decimetre cause a change in the vegetation towards drier types, and in the long run invasion by shrubs and trees. During their reproductive period, the pool frog and other amphibians are particularly sensitive to drying-out of the ponds. Seven of the ten highest classified wetland sites (national value) in the investigation area are located within or next to the impact area. Groundwater drawdown is judged to entail very great consequences for two sites (of national interest), great consequences for 15 sites and noticeable consequences for eight sites if no measures are adopted. Measures in the form of water supply to the most sensitive and valuable wetland sites are planned to mitigate the possible consequences.

Transportation, noise and vibration

Construction activities, rock handling and transport activities within the industrial area will give rise to noise. The noise will affect a forested area within an area of national interest for outdoor activities. The value of the area in question for outdoor activities is deemed to be low, however. No homes with part-time or permanent residents are affected.

Road traffic to and from the final repository consists for the most part of commuting, but haulage of material and rock spoil will also occur. The heaviest traffic will occur during the second half of the construction phase, when around 90 rock shipments per day may pass, including empty trucks to collect the rock spoil.

The road traffic noise along national road 76 is already perceived as disturbing by the residents along the road. The heavy traffic to and from the final repository will lead to an increase in the number of residents exposed to noise levels above the guideline value, at most about 20 persons. The increase will mainly occur in Johannisfors, Norrskedika and Börstil. Sleep disturbances are not expected to increase due to the transport noise, since the heaviest traffic will be in the daytime.

Heavy shipments may cause vibration along the transport routes. The vibration levels will not increase, but there will be more heavy vehicle passages. The vibration levels may entail a risk of moderate disturbance in a few buildings along national road 76.

Emissions to air

The final repository and associated transport activities will give rise to atmospheric emissions in the form of e.g. carbon dioxide, nitrogen oxides and particulates. The amounts and dispersal of the emissions have been determined and are not judged to give rise to any appreciable consequences for human health or the environment. The legal limits that exist for air quality (environmental quality standards) are not expected to be exceeded as a result of the final repository and associated transport activities

Energy and resource consumption

Ventilation is responsible for a large portion of the energy consumption expected at the facility and will therefore be need-controlled, which means that ventilation will be minimized when the facility is not in operation.

The need for bentonite clay is estimated to be around 50,000 tonnes per year or a total of 2.3 million tonnes during the operating life of the facility. The total global production of bentonite in 2007 was 15.7 million tonnes.

There are no bentonite mines in Sweden, which means that the material must be imported. The planned port of entry is Hargshamn, about 30 kilometres south of Forsmark.

Siting alternatives considered

Clab

The siting of Clab was studied in the 1970s. Changing the existing siting has not been judged to be environmentally or economically defensible, and for this reason no siting alternatives for Clab are subjected to impact assessment in this EIS.

Encapsulation plant

As an alternative to siting the encapsulation plant adjacent to Clab on the Simpevarp peninsula, a siting in the vicinity of the Forsmark Nuclear Power Plant has been studied. The nuclear fuel stored in Clab would then be shipped to Forsmark for encapsulation. Clab would need to be supplemented with equipment for drying the fuel. The fuel would then be handled dry, and no rock caverns with handling pools would need to be excavated in Forsmark.

An encapsulation plant, whether on the Simpevarp peninsula or in Forsmark, is not judged to entail any appreciable consequences or risks. The two alternatives are thereby largely equivalent from an environmental and health viewpoint. The advantages of a siting adjacent to Clab is that the personnel already have experience of handling the fuel and that several technical systems can be utilized jointly.

Final repository

A siting in Laxemar, next to Simpevarp in Oskarshamn, is described in the EIS as an alternative siting of the final repository. The consequences for the natural environment would then be less, the facility would not affect any natural values of national interest, and the Laxemar area is not as sensitive to groundwater drawdown as the natural values in Forsmark.

The consequences for the residential environment and human health are judged to be slightly greater in Laxemar, since more people there live along the transport route. The consequences for the cultural environment and the landscape are also judged to be greater in Laxemar than in Forsmark, since an establishment there would entail creation of an industrial area in a relatively pristine forest and agricultural landscape.

The biggest difference between Forsmark and Laxemar is the greater water throughflow at repository depth in Laxemar. The water throughflow is important since it can transport solutes to the buffer and canister, which can affect the long-term function of the buffer and the canister. Due to the larger water throughflow in Laxemar, poorer safety-related conditions are poorer there than in Forsmark. A comparative analysis of long-term safety shows that a final repository in Laxemar, with the current reference design, does not satisfy SSM's risk criterion.


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Introductory part

1 Criteria

SKB's (Svensk Kärnbränslehantering AB) mission is to manage and dispose of spent nuclear fuel and radioactive waste from the Swedish Nuclear Power Plants so that human health and the environment are protected in both the short and long term. SKB has developed a method for final disposal of the spent nuclear fuel, called the KBS-3 method (KBS stands for Kärnbränslesäkerhet = Nuclear Fuel Safety and 3 indicates that the method was presented for the first time in the KBS project's third main report). The KBS-3 method requires an encapsulation plant where the spent nuclear fuel is encapsulated, and a final repository where the canisters are deposited.

Today the spent nuclear fuel is temporarily stored in Clab (Central interim storage facility for spent nuclear fuel), which is situated on the Simpevarp peninsula in Oskarshamn Municipality. SKB intends to locate the encapsulation plant adjacent to Clab. The final repository will be located in Forsmark in Östhammar Municipality.

1.1 Licensing

The facilities for interim storage, encapsulation and final disposal of spent nuclear fuel require both permissibility and licences under the Environmental Code and licences under the Nuclear Activities Act. In November 2006, SKB submitted an application under the Nuclear Activities Act for licences to build and own an encapsulation plant for spent nuclear fuel and to operate it together with Clab as an integrated facility called Clink.

SKB is now applying for permissibility and licences under the Environmental Code for Clab, the encapsulation plant and the final repository. Licensing under the Environmental Code relates to Chapter 9 (environmentally hazardous activities) and Chapter 11 (water operations). At the same time, SKB is applying for licences under the Nuclear Activities Act to build, own and operate the final repository, see Figure 1-1. This procedure gives the Government an opportunity to decide at one and the same time on both licences under the Nuclear Activities Act and permissibility under the Environmental Code. It is assumed that more detailed conditions for the licences will be formulated by the Swedish Radiation Safety Authority and the environmental court.

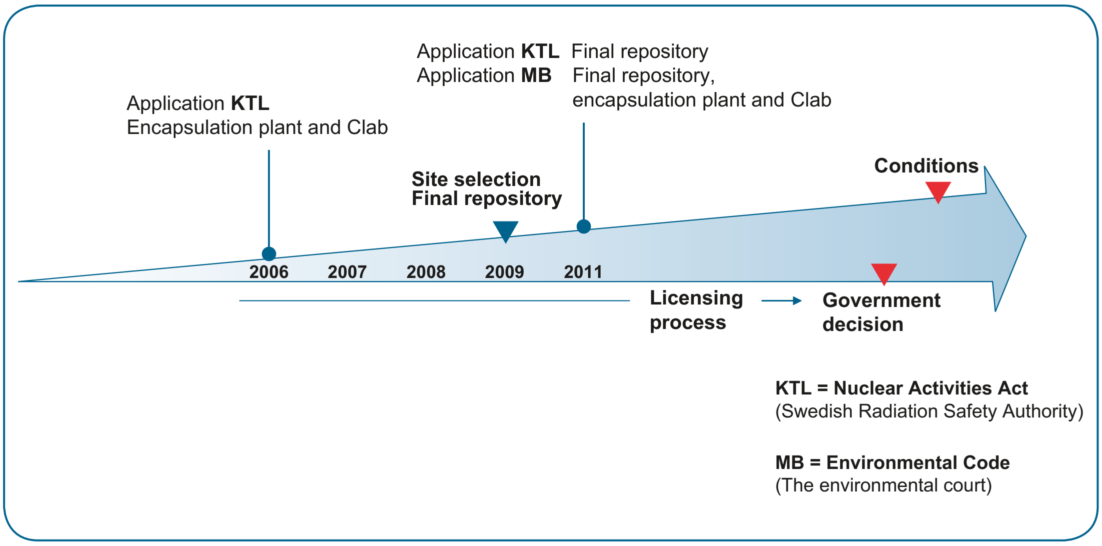


Figure 1-1. Schematic timetable for applications, processing and decision.

1.2 Safety and radiation protection

Safety and radiation protection are central concepts in relation to nuclear activities and will always guide the design and operation of nuclear facilities. Each facility must have a special safety analysis report that describes how safety and radiation protection are designed so that man and the environment are protected against radiation during normal operation, operational disturbances and accidents. Fundamental principles to be applied include "optimization" and "ALARA" (As Low As Reasonably Achievable), which entail that radiation doses should be kept as low as possible, and "BAT" (Best Available Technology), which entails that the best available techniques or technology should be used. The safety analysis reports for the final repository and Clink are appended to the applications for permissibility and licences under the Environmental Code and the Nuclear Activities Act.

The final repository for the spent nuclear fuel must protect human health and the environment against the harmful effects of ionizing radiation from the fuel for a long time. The final repository's long-term safety after decommissioning and closure is therefore a main issue for the safety analysis report and the licensing process. Long-term (post-closure) safety is also described in the Environmental Impact Statement.

Long-term safety has been assessed on a number of occasions since the first report was published in 1983. The previous safety assessment, SR-Can, was published in 2006 and was a preparation for SR-Site, the safety report that now serves as a basis for, and is attached to, the applications for licences to build and operate the final repository. The purpose of SR-Site is to investigate whether the KBS-3 method can fulfil the Swedish Radiation Safety Authority's risk criterion for the selected site in Forsmark and to serve as a basis for further development of the repository design.

The primary safety function of the final repository is containment of the spent nuclear fuel in copper canisters to prevent the escape of radioactive substances. If a canister should be damaged, the secondary safety function is to retard any release of radioactive substances from the canister so that they do not cause unacceptable consequences. According to the methodology used in SR-Site, first a reference evolution is studied that can be said to represent a possible future evolution of the repository system. The reference evolution serves as a basis for a main scenario. The evolution contains many uncertainties and it is difficult to cover all possibilities in the reference evolution/main scenario. For this reason a number of other scenarios are also studied for the purpose of ensuring that all uncertainties are covered. Post-closure safety is described in Chapter 10.

1.3 Environmental Impact Statement

In connection with an application for permissibility and a licence under the Environmental Code and the Nuclear Activities Act, an Environmental Impact Statement (EIS) must be compiled according to Chapter 6 of the Environmental Code. The work of compiling an EIS, called Environmental Impact Assessment (EIA), includes both studies and consultations.

The overall purpose of the EIA is to:

- identify and describe the direct and indirect effects which the planned activity may have on man and the environment, and permit an overall assessment of these effects on human health and the environment,
- environmentally adapt the project so that the effects on human health and the environment are as small as possible,
- give the public and other actors an opportunity to influence siting and design as well as the scope and content of the EIS.

SKB has compiled an EIS for examination under both the Environmental Code and the Nuclear Activities Act. The EIS covers the entire system of facilities for interim storage, encapsulation and final disposal as well as associated water operations. The EIS describes planned activities, from the perspective of what is relevant to enable environmental impact to be assessed, and conditions on the candidate sites. Based on a balanced appraisal of the properties of the sites and the environmental impact of the activities, an assessment is made of possible effects and consequences for the environment and human health. Where deemed warranted, measures to prevent, remedy or mitigate the possible consequences are also described. Pessimistic assumptions have been made in assessing impacts and consequences to ensure they are not underestimated.

The EIS submitted by SKB in 2006, together with the application under the Nuclear Activities Act for licences to build and own an encapsulation plant for spent nuclear fuel and to operate it together with Clab, is superseded in its entirety by the present EIS.

In comparison with the EIS submitted in 2006, the following changes have been made regarding Clab and the encapsulation plant:

- New location for alternative siting of the encapsulation plant in Forsmark.
- New solution for storm water handling at Clab and the encapsulation plant.
- More detailed studies of vibration, groundwater drawdown, environmental risks and atmospheric emissions.
- Supplementary study of impact on the landscape.
- Study of impact of radiological releases on ecosystems.

A joint safety analysis report has been compiled for Clab and the encapsulation plant, which serves as a basis for the account of safety during operation of these facilities in the EIS.

2 Purpose of the final repository system

The purpose of the applied-for activity is to dispose of the spent nuclear fuel in order to protect human health and the environment from the harmful effects of ionizing radiation from the spent nuclear fuel, now and in the future. The interim storage facility for the spent nuclear fuel is an important part of the system for management and final disposal. The spent nuclear fuel is interim-stored in a safe manner and for a sufficiently long time for its radioactivity and heat output to decline so that encapsulation and final disposal of the fuel is facilitated.

A fundamental principle for the final repository system is that the nuclear fuel from the Swedish reactors shall be disposed of within Sweden's borders with the consent of the concerned municipalities. The encapsulation plant and the final repository shall be built and operated with a focus on safety, radiation protection and environmental consideration. Both facilities shall be designed so that illicit trafficking in nuclear fuel is prevented. The post-closure safety of the final repository shall be based on a system of passive barriers and be designed so that the repository remains safe without future maintenance or monitoring. The final repository shall be established by the generations that have derived benefit from Swedish nuclear power.

The encapsulation plant is needed to encapsulate spent nuclear fuel prior to final disposal in the bedrock. Spent nuclear fuel from Swedish nuclear power plants is being interim-stored in the existing central interim storage facility for spent nuclear fuel (Clab) before being encapsulated and taken to the final repository.

The design of the final repository is based on the overall requirements and principles for management and final disposal of spent nuclear fuel which society has formulated in Swedish legislation and international treaties and agreements.

2.1 Laws and conventions

Society's requirements on those who operate, or apply for a licence to operate, nuclear activities are extensive and tough. The requirements are laid down in laws, regulations and international conventions. They are further specified, followed up and tightened if necessary via decisions and conditions in the licensing decisions, supervision and decrees of the Government, the environmental court and the regulatory authorities.

The implications of the more important provisions for the design of the final repository system are as follows:

- According to the requirements of the Environmental Code (1998:808), future generations shall be assured a healthy and sound environment. Reuse, recycling and other management of materials, energy and other resources shall be promoted.
- According to the requirements of the Act (1984:3) on Nuclear Activities (the Nuclear Activities Act) with appurtenant regulations, the holder of a licence for nuclear activities shall make sure that any resulting spent nuclear fuel is disposed of in a safe manner. Post-closure safety shall be based on a system of passive barriers, and the final repository shall not require monitoring or maintenance. The system shall be tolerant of malfunctions and have high reliability. Tried-and-tested design principles and solutions shall preferably be used.
- According to the requirements of the Radiation Protection Act (1988:220) with appurtenant regulations, the effects of ionizing radiation on man and the environment shall be calculated and shown to be acceptable both in connection with management of the spent nuclear fuel and in the future. Biological diversity and utilization of biological resources shall be protected against the harmful effects of radiation. Radiation doses shall be limited as far as possible with regard to economic and societal factors. In order to limit releases, the most effective measure that does not entail unreasonable costs shall be implemented.

Besides Swedish legislation, Sweden has pledged to comply with certain international treaties and conventions. The ones that are of the greatest practical importance for the final disposal of spent nuclear fuel are:

- The 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Nuclear Waste Convention) /2-1/.
- The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention) and the 1996 Protocol to this convention /2-2/.
- The 1968 Treaty on the Non-Proliferation of Nuclear Weapons (the Non-Proliferation Treaty) /2-3/.

In the Nuclear Waste Convention, the parties to the convention have have pledged to "take the appropriate steps to ... aim to avoid imposing undue burdens on future generations". SKB has interpreted this pledge to mean that the waste problem shall in all essential respects be solved by the generations who have benefitted from the nuclear power. This interpretation also has support in Sweden's third national report under the Nuclear Waste Convention, submitted by the Government to the IAEA in September 2008 /2-4/. Furthermore, the convention says that waste should be disposed of in the State in which it was generated.

The London Convention also applies to dumping of radioactive waste. In a protocol from 1996, a number of clarifications are made, including that sub-seabed disposal shall be classified as dumping in the oceans and therefore be prohibited.

Sweden signed the Non-Proliferation Treaty (NPT) in 1968, which means we have undertaken to use nuclear energy solely for peaceful purposes and have consented to submit Swedish nuclear material to IAEA safeguards. According to the Treaty, the system for disposal of spent nuclear fuel shall be designed to prevent illicit trafficking in nuclear materials or nuclear waste. International control is also exercised by Euratom, since the Euratom Treaty applies in Sweden through our membership in the European Union.

In brief, the requirements of Swedish legislation and the international agreements of which Sweden is a signatory can be summarized as follows:

- the owners of the nuclear power plants are responsible for managing and disposing of the nuclear waste in a safe manner,
- the waste must be dealt with inside the country, if this can be done in a safe manner,
- the sea and the seafloor may not be used for this purpose,
- the system shall be designed to prevent illicit trafficking in nuclear materials or nuclear waste,
- safety shall rest on multiple barriers,
- the final repository shall not require monitoring or maintenance,
- the problem of the management and final disposal of the nuclear waste shall in all essential respects be solved by the generations who have benefitted from the nuclear power.

Sweden has today – via SKB, legislation, regulatory authorities and ultimately the Government and the Riksdag – control over the spent nuclear fuel and management of the waste that must be disposed of.

3 Background

The Swedish power industry has been generating electricity by means of nuclear power for nearly 40 years. According to the Nuclear Activities Act, the reactor owners bear full technical and financial responsibility for ensuring that nuclear waste and spent nuclear fuel arising in these activities is managed and disposed of in a safe manner. Based on the definition given in the Nuclear Activities Act, nuclear waste can be said to consist of the radioactive contaminated waste that is formed as a result of the operation of a nuclear facility.

Different methods for disposing of the spent nuclear fuel have been studied since nuclear power began to be used for large-scale energy production during the 1960 and 1970s. The early studies took a very broad approach, studying such alternatives as launching into outer space, sub-seabed disposal, disposal beneath the continental ice sheets, etc. The work during the 1970s led to an international consensus that geological disposal is the strategy with the best chances of providing a solution to the problem of final disposal. With a view to the different geological, social and legal situations in different countries, the method for geological disposal and its technical design must be adapted to the situation in each country.

3.1 SKB's mission

The reactor owners have jointly formed SKB with the mission of managing and disposing of the nuclear waste and spent nuclear fuel from the Swedish reactors. The total quantities of nuclear waste that must ultimately be disposed of are dependent on the number of reactors and their operating time. The waste quantities influence the required capacity of the different waste facilities. The quantities do not, however, influence the fundamental steps needed to dispose of the waste.

The Nuclear Activities Act requires that the reactor owners prepare a programme for the comprehensive research and development and whatever other measures are needed to manage and dispose of the waste in a safe manner. In keeping with the requirements of the Nuclear Activities Act, SKB submits reports to the regulatory authorities and the Government on the progress of this work. This is done every three years in the RD&D programmes (Research, Development and Demonstration). The Swedish version of the most recent report was published in September 2010 /3-1/.

3.2 The existing system for management and disposal of nuclear waste

The radioactive waste from the nuclear power plants is divided into different categories according to the level and duration of the radioactivity. With reference to requirements on management and final disposal, the waste is divided into three main categories:

- Short-lived low- and intermediate-level waste.
- Long-lived low- and intermediate-level waste.
- Spent nuclear fuel (long-lived and high-level waste).

Most of the waste volume from the nuclear power plants, about 85 percent, consists of short-lived low- and intermediate level waste. This category includes spent components, filters etc from operation, maintenance and decommissioning of the nuclear power plants. Long-lived low- and intermediate level waste includes e.g. spent components from the reactor core. Radiation shielding is required in all handling, storage and final disposal of spent nuclear fuel, as well as many other types of radioactive waste.

The short-lived low- and intermediate level waste is disposed of in SFR (final repository for short-lived radioactive waste) in Forsmark. Some waste from medical care, industry and research is also disposed of in SFR. The spent nuclear fuel is interim-stored in Clab in Oskarshamn. Furthermore, there is a system for transportation of the various waste types from the nuclear power plants to the waste facilities, see Figure 3-1.

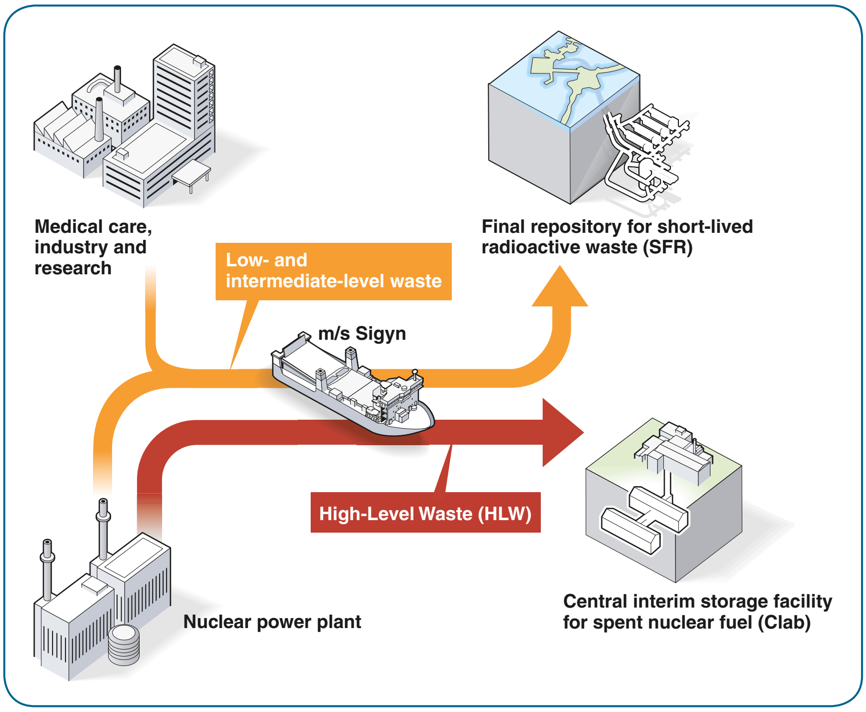


Figure 3-1. Existing facilities in the Swedish system for management of radioactive waste.

What remains to be done for final disposal of the waste from the nuclear power plants is to:

- build and commission an encapsulation plant and a final repository for spent nuclear fuel,
- build and commission a final repository for long-lived low- and intermediate level waste,
- extend SFR for disposal of short-lived low- and intermediate-level decommissioning waste.

Long-lived low- and intermediate level waste is generated mainly when the nuclear power plants are decommissioned. It is planned to be disposed of in a special repository. A more detailed description of the waste system is found in RD&D Programme 2010 /3-1/.

3.3 Spent nuclear fuel

Nuclear fuel is made from uranium mineral. The radioactivity of the fuel increases sharply during the operation of a reactor. After about five years of use, the fuel is taken out of the reactor and is then at its peak radiotoxicity. After discharge, the quantity of radionuclides, and thereby the radiotoxicity of the fuel, declines as they decay. The spent nuclear fuel is first stored for some time in pools at the power plants, after which it is interim-stored in Clab awaiting encapsulation and final disposal. The decay heat in a fuel assembly depends on the fuel's burnup (how much energy has been extracted from the fuel) and how much time has passed since it was taken out of the reactor. After about 30 years of storage in Clab, a typical fuel has a heat output of about 800 watts per tonne, which is comparable to an ordinary electric radiator or a powerful toaster /3-2/. The choice of which fuel assemblies are bundled for encapsulation will depend on their decay heat and the permitted heat output in each canister.

At present, about 5,000 tonnes of spent fuel from nearly 40 years of operation of Swedish nuclear power plants is stored in Clab. SKB's planning assumes 50 years' operating time of the reactors in Forsmark and Ringhals and 60 years' operating time of the reactors in Oskarshamn. Based on this, and with the addition of fuel from Barsebäck 1 and 2, which are out of service, the total quantity of spent nuclear fuel can be estimated at 12,000 tonnes, which is equivalent to 6,000 canisters. That is the quantity the final repository is designed for /3-3/.

The risks associated with spent nuclear fuel can be described in terms of radiotoxicity and accessibility. Radiotoxicity describes the harm which the ionizing radiation from the radionuclides can cause if people are exposed to it and is dependent on the level of activity and the type of radiation the radioactive decay gives rise to. Accessibility describes the degree to which a person can be exposed to radiation in different situations, for example during transport, interim storage or final disposal.

Whenever the spent nuclear fuel is handled, its accessibility is limited: during transport by means of special transport casks, and during storage periods by keeping the fuel in water pools. The transport casks shield off the radiation and dissipate heat. The water in the storage pools at the nuclear power plants and Clab cools the fuel and shields off the radiation emitted by the fuel. In the final repository, the fuel is kept inaccessible for man and the environment during a long time by a system of barriers. The chemical properties of the fuel and the radionuclides, for example their solubility in water, also greatly limit the transport of radionuclides from the repository to the ground surface.

Spent nuclear fuel that has been placed in a final repository is defined by law as nuclear waste. Spent nuclear fuel that has not been placed in a final repository is defined by law as "nuclear material". In everyday speech, spent nuclear fuel is referred to in Sweden as nuclear waste, since the intention is to place it in a final repository.

3.4 Radioactivity and radiation

The spent nuclear fuel contains atoms with a surplus of energy. These atoms strive to get rid of this surplus by means of radioactive decay. Radioactive decay gives rise to various forms of ionizing radiation: alpha radiation, which consists of large, heavy particles (helium nuclei consisting of two neutrons and two protons), beta radiation, which consists of electrons, gamma radiation and neutron radiation.

Ionizing radiation – definitions and units

Radioactivity is the ability of a substance to emit ionizing radiation.

The strength of the radiation source is called "activity" and is measured in disintegrations per unit time. The unit is the becquerel (Bq). 1 Bq=1 disintegration per second.

Absorbed dose is the amount of energy absorbed by a person per kilogram of body tissue. The unit is the gray (Gy). The harmfulness of the dose depends on what kind of radiation is involved.

Equivalent dose is obtained by multiplying the absorbed dose for each type of radiation by a quality factor (depending on the relative biological effect of the different types of radiation) and adding the terms. The equivalent dose is considered to be proportional to the probability of damage within a wide dose range and for many types of damage. The unit is the sievert (Sv).

Effective dose is the sum of all equivalent doses to organs or tissues, weighted for their differing sensitivity to radiation. The unit is the sievert (Sv).

Critical group is a representative real or hypothetical group of persons from the population who can be expected to receive the highest radiation doses from a radiation source.

Dose rate indicates how large a radiation dose a person receives during a given time. The unit can vary. Examples are absorbed dose (gray) per second (Gy/s) and equivalent dose per year (Sv/year).

Collective dose is the product of the average radiation dose and the number of individuals in the group exposed to a given radiation source or activity. The unit is often the man-sievert (manSv).

Alpha radiation has a short range of a few centimetres in air, is easily stopped and does not penetrate the skin. Beta radiation has a range of about ten metres in air and is stopped by heavy clothing and spectacles. Gamma radiation passes through living tissue and can have a long range. Stopping gamma radiation normally requires several centimetres of lead or a concrete wall about a decimetre thick. Neutron radiation is only emitted by a few radionuclides. But neutrons are always emitted by nuclear fission, and neutron radiation is therefore present inside reactors that are in operation. But it does not reach beyond the reactor containment and virtually ceases when nuclear fission is interrupted.

Information on radioactive substances can be given in terms of activity and half-life. Activity is measured in becquerels, which is the number of disintegrations per second for a given quantity. A high activity means that the nuclide decays rapidly to its daughter products. Its half-life is therefore short. Conversely, nuclides with a long half-life usually have a relatively low activity. Activity is also dependent on the quantity of the nuclide in question.

Most radionuclides in spent nuclear fuel decay within a few hundred years, see Figure 3-2. After that the radiotoxicity of the fuel is dominated by substances that will remain for a very long time. After 1,000 years, most of the direct radiation has disappeared, but the fuel is still toxic if it is ingested, for example if particles from the waste are eaten, drunk or inhaled.

After about 100,000 years, the radioactivity has declined to the same level as in the quantity of natural uranium from which the fuel was made.

Radiation dose is a measure of the radiotoxicity of the accumulated quantity of ionizing radiation to which a person is exposed. When radiation hits a person, the different types of radiation affect the body's organs in different ways. To allow for this, a unit is used that takes into account how the different organs in the body are affected by different types of radiation. Radiation dose is measured in sieverts (Sv), and usually given in thousandths of a sievert (millisievert, mSv). Another unit, gray, is used for the quantity of absorbed radiation, but it does not take into account what biological effect the radiation has.

Ionizing radiation causes damage by, directly or indirectly, breaking DNA molecules apart, which can cause cancer in the long term if the radiation damages cells without killing them and they continue to grow. However, most of the damage to which a cell is exposed is repaired. It is assumed in radiation protection that there is no threshold value for cancer risk. This viewpoint is based on the International Commission on Radiological Protection's (ICRP) risk model, which is based on the hypothesis of a linear relationship between radiation dose and cancer risk. This hypothesis means that the risk of cancer increases in proportion to the radiation dose. However, no relationship has been found between low radiation doses and cancer, since such cancer cannot be distinguished from cancer resulting from other causes. At high doses (above 100 mSv), however, it has been shown that the mortality rate is proportional to the radiation dose. The time between exposure and the appearance of symptoms from radiation-induced forms of cancer varies and can in some cases be more than 50 years.

An average Swede gets a radiation dose of about 4 mSv in a year. The main radiation sources are radon in homes (50 percent), medical examinations and treatments (18 percent) and natural background radiation from the ground and outer space (20 percent). Other radiation sources, for example in industry and nuclear power, are responsible for only two percent. In comparison it can be mentioned that acute radiation sickness can result from a brief exposure to a radiation dose of more than 2,000 mSv. The body's blood-forming organ (the red bone marrow) is damaged, leading to a weakened immune system. At very high radiation doses, around 10,000 mSv, nerve and brain cells are also destroyed, which is usually lethal /3-4/.

The Swedish Radiation Safety Authority decides what limit values are to apply for radiation doses in different contexts. For personnel who work in activities with ionizing radiation, the effective dose may not exceed 50 mSv per year, or a total of 100 mSv during five consecutive years. For the public, the sum of the dose contributions from activities with ionizing radiation may not exceed 1 mSv per year /3-5/.

The limit for the effective dose from nuclear activities to an individual in the critical group is 0.1 mSv per year from all nuclear facilities located in the same geographic area /3-6/.

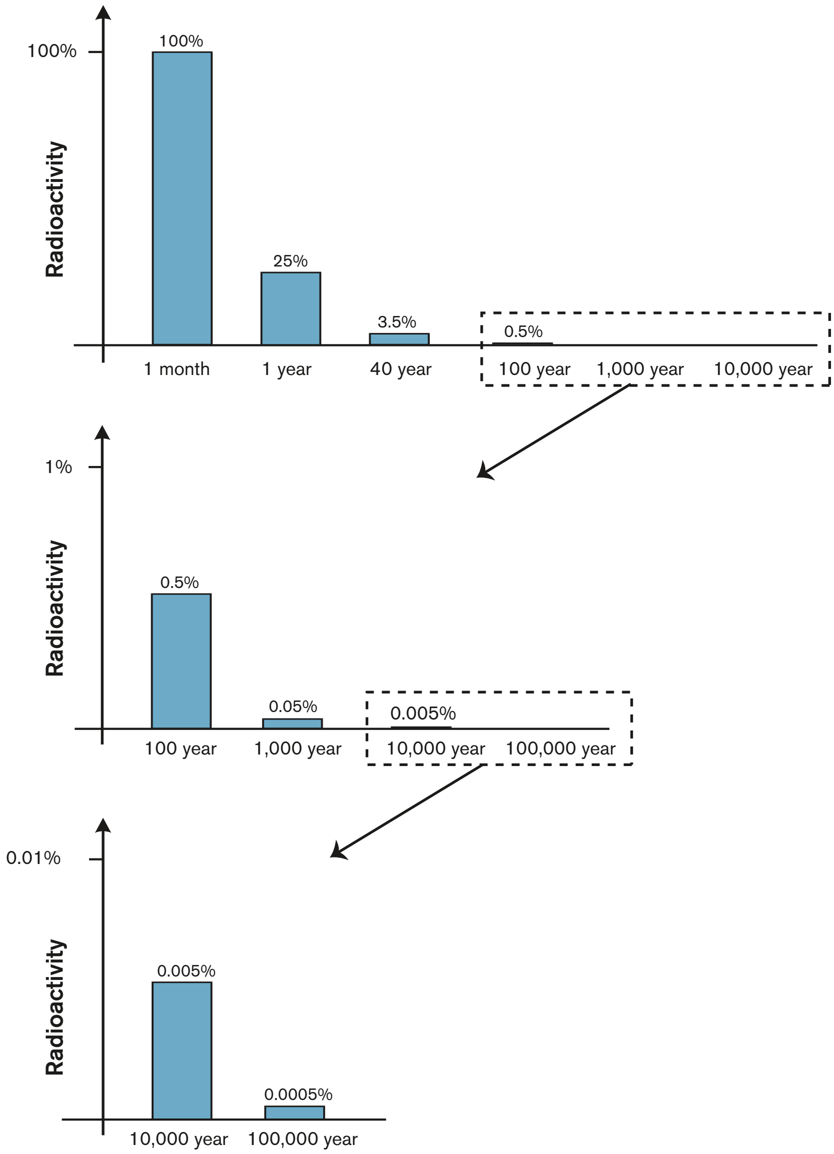


Figure 3-2. The radioactivity in a tonne of spent nuclear fuel of type SVEA 64 (a common fuel type in Swedish nuclear power plants) with a burnup of 38 MWd/(kg) U. To illustrate how radioactivity declines in a long time perspective, the figure has been divided into three parts with different activity scales. (An activity of 100 percent on the top part corresponds to an activity of $3.35 \cdot 10^{17}$ becquerels.)

3.5 The KBS-3 method

The applications for licences for the encapsulation plant and the final repository are based on disposal of the spent nuclear fuel according to the KBS-3 method. The KBS-3 method has been under development since the late 1970s /3-7/. The Stipulations Act was passed in 1977 and entailed that no new reactors could be put into operation unless the nuclear power companies could show that the high-level waste could be disposed of in a safe manner. In order to satisfy the conditions in the Act, the KBS (KärnBränsleSäkerhet = Nuclear Fuel Safety) project was started by the nuclear power companies at that time. The project presented its work in three main reports. The first report in 1977, subsequently called KBS-1, dealt with the management of vitrified waste from reprocessing. The focus in the KBS-2 report in 1978 was on direct disposal of spent nuclear fuel. Both proposals were based on deposition in the bedrock and a multiple barrier system.

In the years around 1980, the Swedish view on reprocessing as the main line for dealing with the spent nuclear fuel changed. Instead, direct disposal was seen as the most reasonable alternative. The KBS project's third report in 1983 presented the concept of encapsulation of the spent nuclear fuel in a copper canister and deposition at a depth of about 500 metres in crystalline rock, which is the basis for the current design of the method.

The method involves encapsulating the spent fuel in copper canisters which are then deposited, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system at a depth of 400–700 metres in the bedrock, see Figure 3-3. The purpose of the three barriers (canister, buffer and rock) is to isolate the radionuclides in the fuel from the surrounding environment. Before the spent nuclear fuel is encapsulated and placed in the final repository, it will have been interim-stored in Clab, where most of the activity will have decayed, see Figure 3-2.

The canister is delivered ready-made to the encapsulation plant. It is composed of a cylindrical container with a shell (overpack) of copper and a pressure-bearing insert of cast nodular iron. The insert is provided with channels for placement of fuel assemblies. The canister is about five metres long and has a diameter of about one metre. The thickness of the copper shell is five centimetres. When the canister is full, a steel lid is fitted on the insert. A copper lid is then welded onto the canister by friction stir welding /3-8/. A copper canister filled with two tonnes of spent nuclear fuel weighs 25–27 tonnes. Besides spent nuclear fuel, the main components are 7.5 tonnes of copper and 14–15 tonnes of iron /3-9/.

The final repository's underground parts are: ramp, shafts, central area and repository area with deposition tunnels. The canisters are emplaced in vertical holes, surrounded by bentonite clay, in the deposition tunnels. After the canisters have been deposited, the tunnels are backfilled. Other openings will be backfilled when all spent nuclear fuel has been deposited. When tunnels and shafts have been backfilled up to the ground surface, the repository is closed and sealed.

There is no intention to retrieve the canisters with spent nuclear fuel after deposition. However, the final repository is designed so that it is possible for deposited canisters to be retrieved. Reasons for retrieval could be that future generations may for some reason want to modify or improve the design or function of the repository, or to use the waste for other purposes. New licences will be required to carry out the extensive measures needed to retrieve the canisters after closure.

Clab, Clink and the final repository are described in greater detail in the sections *Facility design* and *Description of activities* in Chapters 8, 9 and 10.

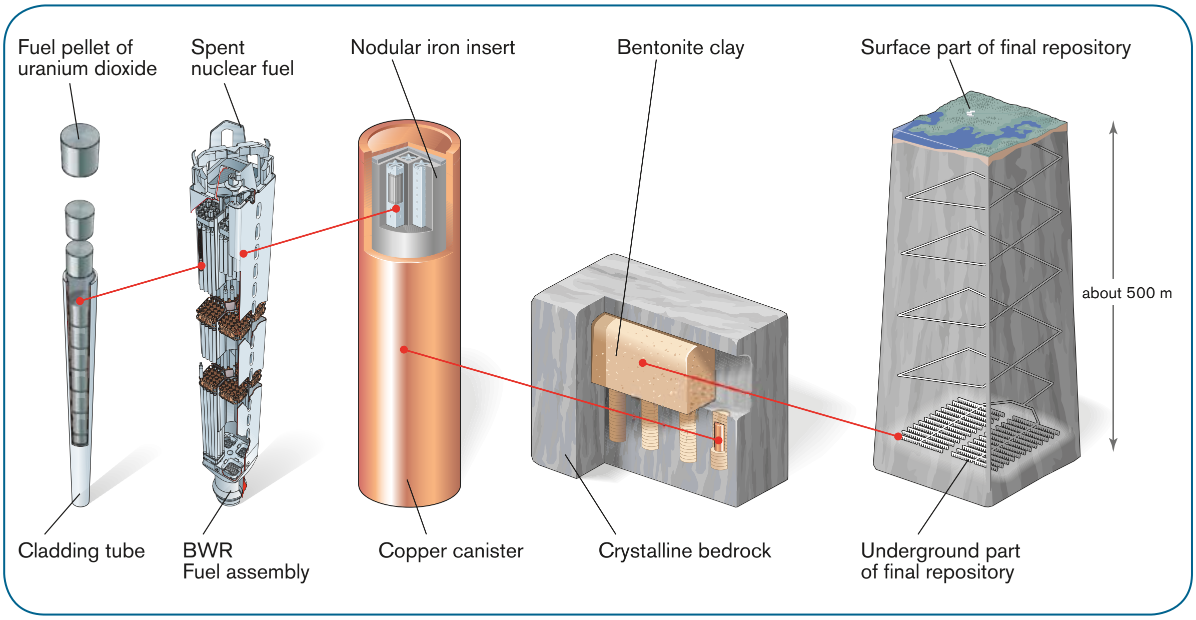


Figure 3-3. The KBS-3 method. The method involves encapsulating the spent fuel in copper canisters which are then emplaced, surrounded by a buffer of bentonite clay, in deposition holes in a tunnel system at a depth of 400–700 metres in the bedrock.

3.6 Other methods

Within the framework of the RD&D programmes, SKB has also studied other methods for disposing of the spent nuclear fuel. The requirements and criteria for management of spent nuclear fuel given in Chapter 2 are fundamental in the choice of method. The KBS-3 method has been designed with a view towards these overall requirements and criteria. None of the other methods satisfy all the fundamental requirements and criteria, or they are not available. They are therefore not dealt with in the alternatives section in the EIS. Information is, however, provided on other methods in /3-7/, which is appended to the applications.

After interim storage of the spent nuclear fuel, there are two principal options for disposal. One entails regarding the spent fuel as a resource for recovery of material for new nuclear fuel. To achieve this, the spent nuclear fuel must be reprocessed. However, reprocessing gives rise to other types of radioactive waste that must be managed and disposed of. The other option is to regard the spent nuclear fuel from the start as waste that must be managed and disposed of in a safe manner.

If final disposal of the spent nuclear fuel does not come about, the remaining option is to continue storing it under monitored forms. This can be done either in Clab, where the fuel is kept today, or by one of the methods for monitored storage that are used in other countries. However, prolonged monitored storage is no alternative to final disposal.

Reviews of different ways to dispose of spent nuclear fuel have been presented on a number of occasions, see Figure 3-4. Their advantages and disadvantages have been compared with those of the KBS-3 method, SKB's choice of method for final disposal /3-7/.

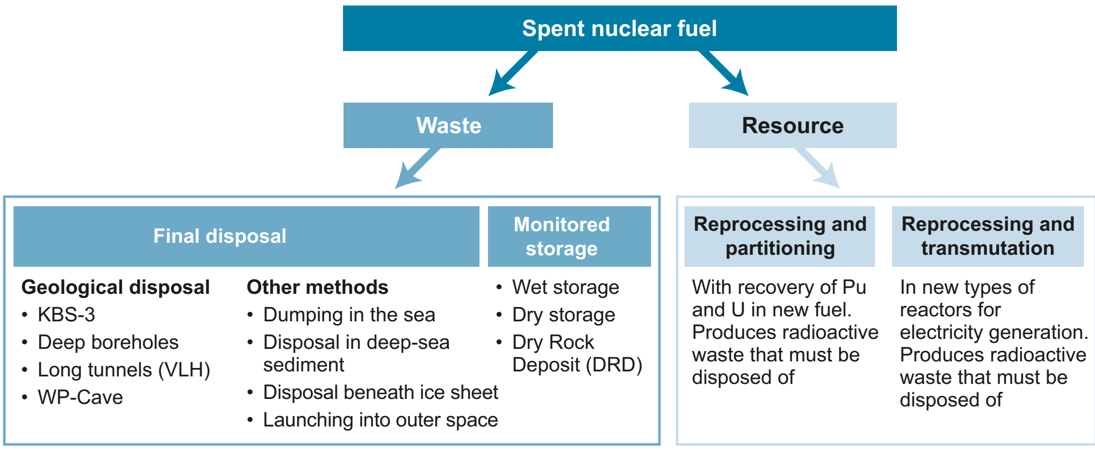


Figure 3-4. Methods for disposal of spent nuclear fuel (Pu=plutonium, U=uranium). The different methods are described in greater detail in subsequent sections.

The KBS-3 method was one of the preconditions for permits issued by the regulatory authorities and the Government to commission the Oskarshamn 3 and Forsmark 3 reactors in the early 1980s. The scientific and technical basis for the method has been continuously developed and described to the regulatory authorities and the Government every third year in the SKB's RD&D programmes. The regulatory authorities and the Government have approved the focus of the RD&D programmes on geological disposal according to the KBS-3 method with continued parallel evaluation of other methods.

The following sections provide an overview of methods for disposal of spent nuclear fuel. The overview also contains the assessments made by SKB. For more detailed accounts, see the RD&D programmes published by SKB and /3-7, 3-10, 3-13/.

3.6.1 Geological disposal

Geological disposal, emplacement deep down in the bedrock, is based on utilizing an environment that is stable in the very long term. Internationally, a broad consensus exists that geological disposal is the strategy that is best suited to disposal of long-lived radioactive waste /3-7/. Different geological environments have been studied in different countries, depending on local conditions. In addition to the KBS-3 method, SKB has studied the following methods for geological disposal, see Figure 3-5:

- Deep Boreholes.
- Long Tunnels (VLH).
- WP-Cave.

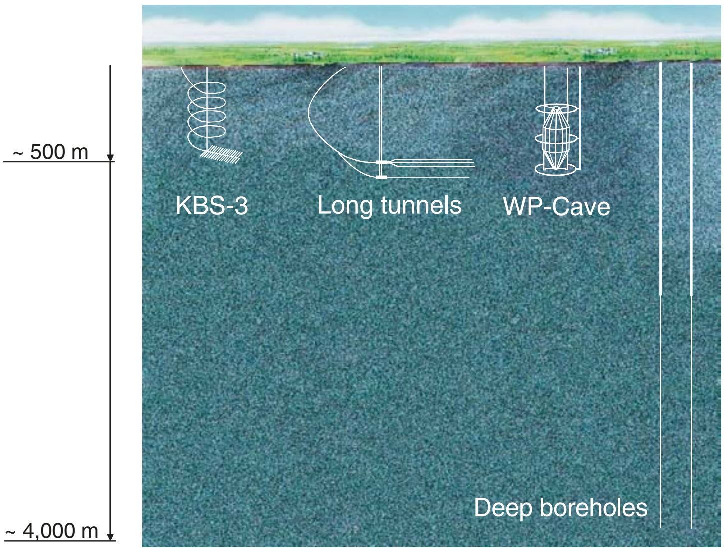


Figure 3-5. Methods for geological disposal.

A summary assessment of the different methods in relation to the KBS-3 method is shown in Table 3-1.

Table 3-1. Summary assessment of other methods for geological disposal in comparison with KBS-3.

	Requirements/comparison ground				
	Not impose burdens on future generations	Environmental requirements	Safety requirements	Radiation protection requirements	Safeguards
KBS-3	Meets the requirement. No surveillance required.	Meets the requirements. Relatively small environmental impact and good management of resources.	Meets the requirements. The final repository is safe for 100,000 years.	Meets the requirements. The impact of the ionizing radiation on man and the environment is small.	Meets the requirements. The facility is monitored during operation. Access after closure entails a large-scale operation that is difficult to conceal.
Deep boreholes	–	+	–	–	+
Long tunnels (VLH)	–	+	–	=	=
WP-Cave	–	–	–	–	=

= meets requirements as well as KBS-3 + has advantages compared with KBS-3 – has disadvantages compared with KBS-3

Since the early 1990s, SKB has also studied the possibilities of disposing of multiple canisters in horizontal holes, known as Medium Long Holes (MLH) (KBS-3 MLH). This variant of the KBS-3 method is now called KBS-3H (horizontal deposition) and is furher described in Section 5.1.3.2.

3.6.1.1 Deep Boreholes

SKB has made a comparative study between disposal in deep boreholes and the KBS-3 method in order to identify distinguishing factors /3-10/. The ambition has been to make the comparison fair, even though there are great differences in development level and data quality between the two methods.

Both disposal in deep boreholes and final disposal according to the KBS-3 method are based on the fundamental principle that any released radionuclides have decayed to harmless levels before they reach the ground surface. The main safety feature for disposal in deep boreholes and the KBS-3 method differs, however. The safety assessments that have been done of the KBS-3 method show that encapsulation of the fuel in the leaktight copper canister is the most important safety feature in the long term. In the case of Deep Boreholes, slow groundwater movements are assumed to be the most important safety feature.

A repository according to the concept of disposal in deep boreholes consists of boreholes that are about 4,000 metres deep. Canisters with spent nuclear fuel are deposited at a depth of between 2,000 and 4,000 metres in the boreholes /3-11/. The concept is based on the assumption that groundwater conditions are stagnant at great depths. The reason for the stagnant conditions is that the groundwater has high salinity (and thereby high density) and therefore tends not to mix with the lighter fresh water above. Any groundwater movements that do occur at great depth are not believed to have any contact with the ground surface. This means that radionuclides from the spent nuclear fuel could not be carried up to the surface by the groundwater. Knowledge of conditions at a depth of several kilometres in crystalline rock comes from a handful of scattered boreholes, including two in Sweden.

The design presented in /3-11/ entails that about 300 canisters will fit in a deposition hole. These canisters are smaller than the KBS-3 canisters and hold only a third as much spent nuclear fuel. This means that about 18,000 canisters are needed to encapsulate the quantity of spent nuclear fuel that arises in the reference scenario (50 years of operation of the reactors in Forsmark and Ringhals and 60 years of operation of the reactors in Oskarshamn). The canisters are surrounded by a buffer consisting of a mixture of bentonite and bentonite slurry. The upper two kilometres of the hole, the plug zone, are then filled with a combination of bentonite, asphalt and concrete. The diameter of the borehole is 0.8 metre in the deposition zone and more than a metre in the plug zone. This proposed design has been referred to internationally as the most well-thought-out concept for final disposal in deep boreholes /3-12/.

At each deposition hole, equipment is needed for drilling and preparation of the hole, for handling of drilling fluid, for interim storage and radiation shielding of canisters, for lowering of canisters into the hole and for plugging. The surface area required for this handling has been estimated at about 0.01 square kilometre per hole. It is uncertain how closely spaced the holes can be. In previous studies, a spacing of 500 metres has been assumed to be sufficient with a view to the heat output of the deposited spent fuel and deviation of the boreholes from the vertical. With this spacing, a final repository that contains all spent nuclear fuel from the reference scenario – 60 holes – would require a total area of about 15 square kilometres.

There is no practical knowledge on how canisters and buffer can be manoeuvred into the right position in such deep boreholes and what properties they can be expected to have after deposition. During deposition the canisters are subjected to large stresses and it is not possible to check the integrity of either the buffer or the canister after deposition. A deposited canister is subjected to the aggressive chemical conditions (high temperature and high salinity) and high rock stresses that prevail at such great depths. Together, these conditions mean that neither the buffer nor the canister can be counted on as a barrier in the case of disposal in deep boreholes. The rock is the only barrier that can be relied on in the long term.

In disposal in deep boreholes, the possibility of mishaps with irreparable consequences cannot be ruled out. For example, a canister can get stuck in the hole and be damaged before it has reached disposal depth. As a result, a leaky canister can get stuck in a location with flowing groundwater, without being surrounded by a protective buffer.

The safety assessments that have been conducted of the KBS-3 method have shown that the final repository with copper canisters surrounded by a bentonite buffer is resistant to the loads that can arise in connection with future earthquakes and glaciations. In a final repository according to the concept of disposal in deep boreholes, no or little protective effect can be counted on from the canister and buffer in the face of such stresses.

In summary, due to the uncontrolled deposition process and the unfavourable environment, safety will essentially be provided by the rock, the great depth and the assumption of immobile groundwater, even during future ice ages. Even though the rock is a good barrier, it can be difficult to show that it alone can meet the safety requirements. There are considerable uncertainties as to what the consequences could be for safety in a final repository according to the deep boreholes concept in the event of a future glaciation or earthquake.

Proceeding with the concept requires extensive work to develop technology for drilling, deposition and plugging. The limited knowledge that exists regarding conditions so deep down in the bedrock also means that evaluation of the safety of the system is associated with very large difficulties. In 2000, SKB estimated that it would take about 30 years, and cost at least four billion kronor in current money terms, to achieve a knowledge level that allows a safety assessment of the same quality as for the KBS-3 method to be performed. Even if these resources were invested to develop the method, it is highly uncertain whether deep boreholes would prove to be a better alternative than KBS-3. A considerable difficulty lies in showing that the assumed conditions at great depth that are advantageous for long-term safety actually exist over sufficiently large areas and will continue to exist for a sufficiently long time. SKB will, however, continue to follow developments in the field of disposal in deep boreholes.

3.6.1.2 Long Tunnels (VLH) and WP-Cave

A repository in long tunnels entails that canisters with spent nuclear fuel are emplaced in roughly five kilometre long tunnels at a depth of about 500 metres. The canisters are surrounded by a buffer of bentonite clay. A ramp leads from the surface down to repository level, where a rock cavern with transloading station is located for handling of rock spoil and canisters. Such a repository is in most respects equivalent to a KBS-3 repository, but is judged to have poorer prospects of meeting the safety requirements during the construction phase and the operating phase /3-13/.

The WP-Cave method is based on depositing encapsulated spent nuclear fuel densely in a limited rock volume surrounded in its entirety by a buffer. The buffer is surrounded by a hydraulic cage, consisting of a large quantity of vertical holes drilled to even out any differences in hydrostatic pressure. This reduces the flow of groundwater through the part of the repository where the fuel is. When the concept was developed, it was proposed that the upper part of the buffer should be located at a depth of about 200 metres. A greater repository depth is possible, however. Because the fuel is emplaced so densely, the temperature will be high. Cooling will be needed in an initial phase of 100 years. After that the tunnels and shafts can be backfilled. The primary function of a WP-Cave repository is the same as for a KBS-3 repository: to isolate the spent nuclear fuel. If the isolation function should for any reason fail in any respect, a secondary purpose of the repository is to retard the release of radionuclides. Safety is mainly based on the engineered components and the method is associated with difficulties in showing that long-term safety is ensured.

SKB does not intend to devote further study to either Long Tunnels or WP-Cave.

3.6.2 Reprocessing, partitioning and transmutation

The purpose of reprocessing, partitioning and transmutation is to make efficient use of the uranium raw material and to convert long-lived radionuclides in the spent nuclear fuel to more short-lived or stable nuclides. Employing transmutation solely for reducing the quantity of high-level, long-lived waste is not efficient, in terms of either costs or resources. There are several conceivable systems for reprocessing and transmutation. The two main alternatives – reprocessing with recycling of uranium and plutonium and partitioning and transmutation – are described below. Reprocessing with recycling of uranium and plutonium is already applied in a few countries today. Partitioning and transmutation (P&T) is the subject of research that is expected to proceed for decades before it will be possible to build commercial facilities. The information in Section 3.6.2 is taken from /3-7/.

3.6.2.1 Reprocessing with recycling of uranium and plutonium

Reuse of the spent nuclear fuel's content of fissionable substances (uranium and plutonium) requires reprocessing. In reprocessing, uranium and plutonium are separated by chemical means from other actinides and from the fission products in the spent fuel. The extracted uranium and plutonium are used to make MOX fuel, which can be used in light water reactors (LWRs), for example of the type in operation in Sweden today, or in fast reactors. Reprocessed uranium can either be mixed with plutonium in MOX fuel fabrication or be enriched for fabrication of new uranium fuel. After uranium and plutonium have been separated, other actinides, fission products and certain activation products are left. These substances form a high-level long-lived liquid waste that is vitrified to transform it into a manageable and stable form that is suitable for final disposal. The remains of the metal cladding on the fuel rods are also left after the separation process. This is a solid waste that contains small quantities of long-lived substances. Special facilities are needed to process the different waste types into a form suitable for final disposal. Furthermore, storage facilities and repositories are required for the different waste types. There are plants for reprocessing of spent nuclear fuel from light water reactors in France, the UK, Russia and Japan. The USA, China and India also have plants for reprocessing of nuclear fuel. Some of the plants reprocess both domestic fuel and fuel from other countries that have opted to reprocess their spent nuclear fuel but do not have their own plants.

The result of reprocessing with recycling of uranium and plutonium is thus that the original spent nuclear fuel has been transformed into high-level vitrified waste, spent MOX fuel and some other radioactive waste. Viewed in relation to the energy that is produced, recycling of uranium and plutonium reduces the total quantity of actinides to be disposed of, along with the total quantity of plutonium that has to be managed as waste. In principle, however, a similar system is required to dispose of the spent MOX fuel and the high-level vitrified waste as in the case of direct disposal of spent nuclear fuel.

MOX fuel was used experimentally for the first time in 1963. It has been in commercial use since the 1980s. Today MOX fuel is used in more than 30 reactors in Europe. In Sweden, the Oskarshamn Nuclear Power Plant has obtained a permit from the Government to use MOX fuel in reactors 2 and 3.

3.6.2.2 Partitioning and transmutation (P&T)

Transmutation of an element entails converting it to another element by means of a nuclear reaction – for example, nuclear fission or radioactive decay. Nuclear fission in today's light-water reactors (LWRs) is a form of transmutation. In general, however, transmutation refers to conversion of long-lived nuclides, other than uranium and plutonium, to stable or less long-lived nuclides.

The main purpose of transmutation is to reduce the quantity of transuranic elements, or transuranics, i.e. elements heavier than uranium. Transuranic elements are formed in nuclear reactors by the capture of one or more neutrons by uranium atoms, which are then transformed by radioactive decay to neptunium, plutonium, americium or curium. A few long-lived fission products (e.g. technetium-99, iodine-129) may also be of interest for transmutation. The long-lived radionuclides can be transformed to more short-lived or stable nuclides by nuclear-physical processes. Several such processes are possible, but the only process that has been used thus far for transmutation on a large scale is irradiation with neutrons. Neutrons can split the nuclei in transuranic atoms so that they are transformed into other nuclides. Large-scale transmutation of transuranic elements from spent nuclear fuel must take place in a plant that resembles a nuclear reactor, and since the nuclear fission process releases large quantities of energy the plant will resemble a nuclear reactor. The type of waste that arises and the quantities in which it arises are determined by the partitioning processes, the transmutation and the number of recyclings. The content of long-lived radionuclides decreases radically, but some high-level, long-lived waste will always remain and require similar management as in the case of direct disposal of spent nuclear fuel. The implementation of partitioning and transmutation to effectively reduce the quantity of long-lived radionuclides that must be placed in a geological repository necessitates a commitment to nuclear power for a very long time – more than 100 years.

A prerequisite for transmutation by neutron irradiation is that the nuclides to be transmuted have been separated from other nuclides in the spent fuel. In particular, residual uranium must be removed in order to prevent the formation of more plutonium and other transuranics. Separation, or partitioning, of the different elements can in principle be achieved by mechanical and chemical processes. In existing reprocessing plants, uranium and plutonium can be separated from each other and from other elements in spent nuclear fuel. The goal of current research on partitioning is to find and develop processes that are suitable for partitioning of heavier transuranics, and possibly also some fission products, on an industrial scale. The goal of current research on transmutation is to define, investigate and develop plants that are suitable for transmutation of the aforementioned long-lived radionuclides on an industrial scale.

A necessary prerequisite for the processes and plants that may result from this research and development is that they be accepted by society. They must therefore meet very tough requirements on safety, radiation protection and environmental protection. They must be economically defensible and provide good security against the proliferation of fissionable material. In order to achieve reasonable economy, the large quantities of energy that are released in the transmutation process must be utilized, e.g. for electricity generation.

SKB's assessment is that partitioning and transmutation (P&T) is not a realistic alternative for disposing of the spent nuclear fuel from today's Swedish reactors. Nevertheless, it is reasonable that Sweden should participate in the international development work and maintain competence within the country, at least as long as a considerable portion of the country's electricity production is based on nuclear energy. Competence developed in research on P&T is valuable, not just for assessing development and potential in this field, but also for development of safety and fuel supply at existing reactors. SKB therefore intends to continue to follow and support the research in this field.

3.6.3 Monitored storage

Monitored storage takes place in both wet and dry storage facilities. Wet storage entails that the fuel is stored in pools where the water provides radiation protection and cooling. In dry storage, the fuel is stored in special air-cooled containers. Both wet and dry storage require monitoring and maintenance to fulfil the safety requirements.

Experience exists of both wet and dry interim storage for a limited time, up to fifty or so years, in many countries. Clab is an example of monitored wet interim storage of spent nuclear fuel, see Figure 3-6.

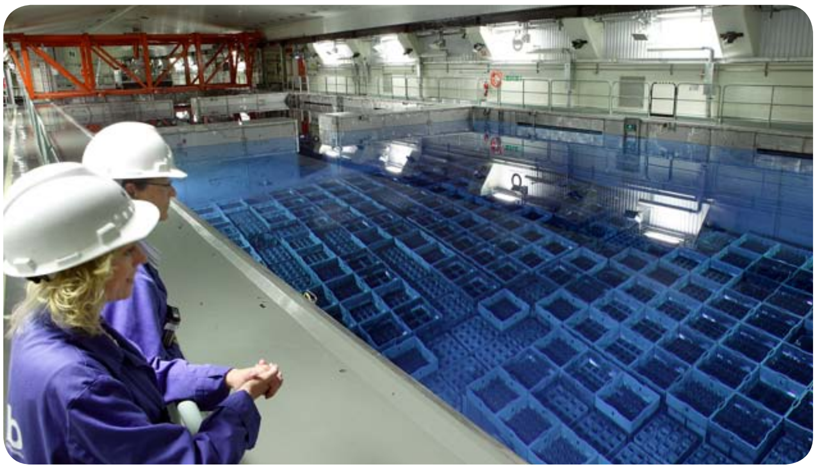
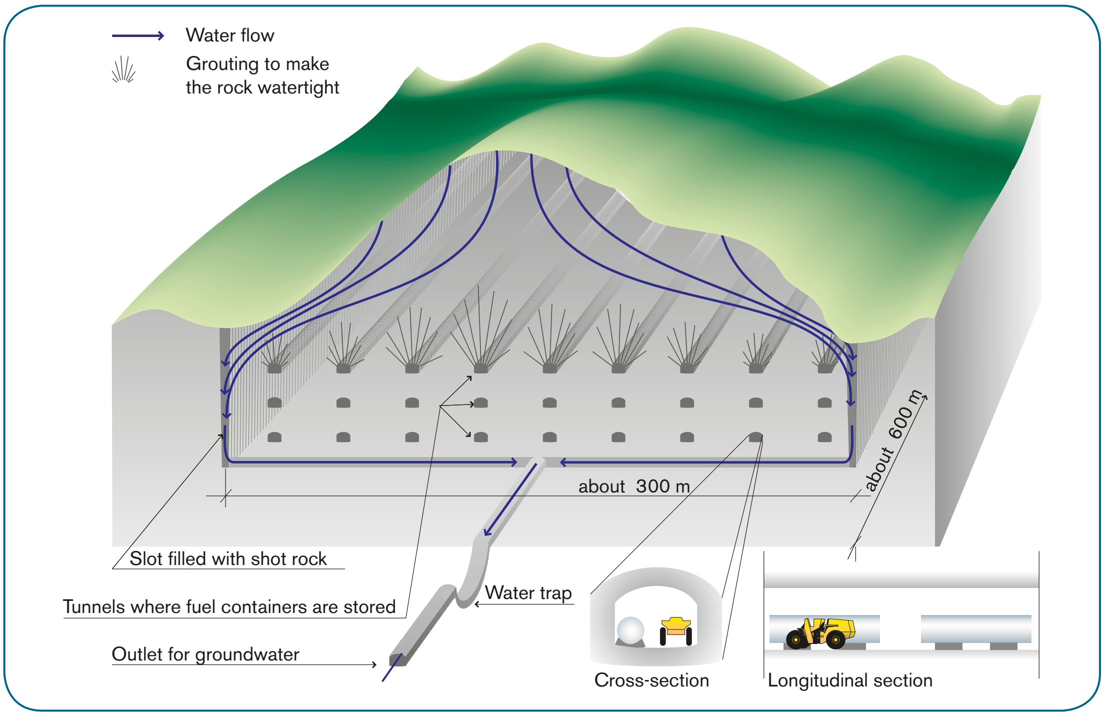


Figure 3-6. Monitored wet interim storage of spent nuclear fuel in Clab.

Environmental, safety and radiation protection requirements can be complied with as long as human supervision and control are maintained. Then both dry and wet storage can probably continue for at least a hundred years without jeopardizing safety. In a longer time perspective the uncertainties are greater.

Monitored storage does not meet the requirements made on final disposal, but simply entails a postponement of a final solution.

A variant of dry storage, DRD (Dry Rock Deposit), is intended for storage for a very long time, up to several thousand years, see Figure 3-7. In the DRD concept, containers with fuel are placed in a self-draining rock cavern built in a rock formation that has a higher elevation than the surrounding countryside. After deposition the rock cavern is closed. No drainage pumping or cooling is required /3-13/. The idea is to minimize the need for maintenance and monitoring so that storage can continue for a long time. Some form of surveillance is nevertheless needed, for example in order to prevent illicit trafficking in the spent fuel. Furthermore, it is probable that regular maintenance would be required of containers, rock support and the like. SKB's assessment is that the DRD concept does not fulfil the requirements on a final repository, since monitoring and maintenance will be required.



Figur 3-7. Principskiss över DRD (Dry Rock Deposit), en variant av torr övervakad lagring.

3.6.4 Other methods

Other methods studied and rejected by SKB include launching into outer space, ocean dumping, sub-seabed disposal and disposal beneath continental ice sheets.

Launching into outer space was studied in the USA in the late 1970s and early 1980s as a method to get rid of the spent nuclear fuel for all future time. Safety is based on the fact that the fuel can be sent to a place out in the universe and never come into contact with man and the environment on Earth again. The energy and costs needed to achieve this are virtually incalculable. Safety in launching has not been determined either.

Safety assessments show that sub-seabed disposal could be a safe alternative, but international treaties prohibit the use of the oceans or the seafloor to dump waste.

Disposal beneath an ice sheet, for example on Antarctica, would violate the Antarctica Treaty. Furthermore, current knowledge of continental ice sheets and future climate change is not good enough to be able to determine whether this is a safe alternative.

3.7 The siting work

The work of arriving at a suitable method and site for final disposal of the spent nuclear has been going on for more than 30 years, see Figure 3-8. Development work and investigations done from the start in the 1970s up to the early 1990s generated a knowledge base that was of great importance for the planning and execution of the siting procedure that was then initiated after SKB presented RD&D-programme 92 /3-14/. The ensuing project of finding a suitable site for construction of a facility for final disposal of the spent nuclear fuel has engaged not only SKB but also municipalities, regulatory authorities and other government bodies, the scientific community, the environmental movement and the Government /3-15/. The following sections provide an overview of the siting procedure up to the completion of the site investigations. The final step, choosing between the two alternatives of Forsmark and Laxemar, is described in Section 5.2.3.1. The information in Sections 3.7 and 3.8 is taken from /3-16/.

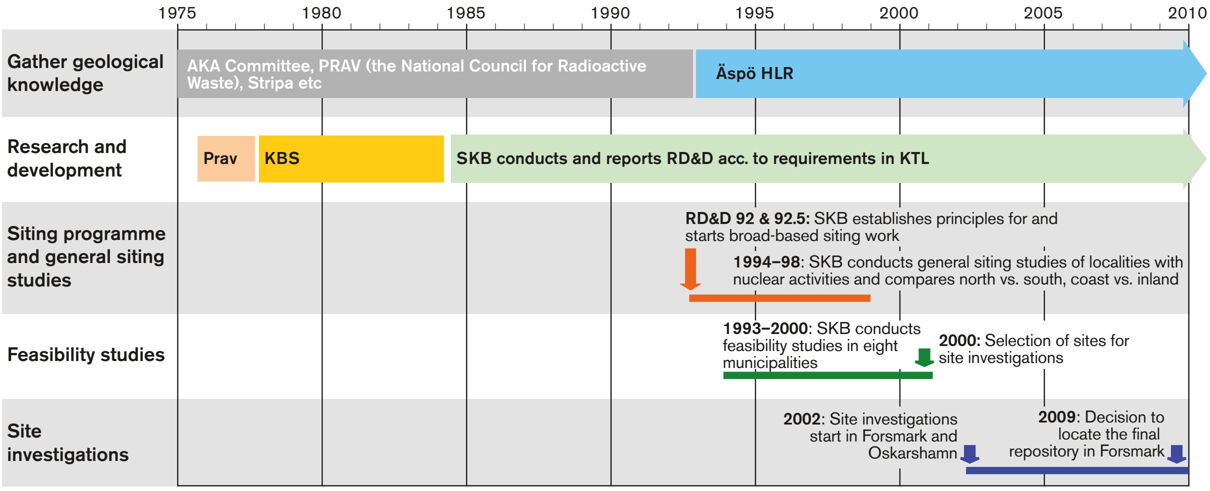


Figure 3-8. Main phases and passed milestones in the work of finding a suitable site for final disposal of spent nuclear fuel.

3.7.1 The period 1973–1985

The first concerted effort was made by the AKA Committee (the Swedish acronym AKA stands for spent nuclear fuel and radioactive waste) appointed by the Government at the end of 1972, which presented its final report in 1976.

The Committee recommended final disposal of radioactive waste in crystalline bedrock. One of the main tasks in the initial phase was therefore to acquire good knowledge of the Swedish bedrock and what properties the rock must have in order to meet the requirement of safe final disposal. The studies conducted by the Geological Survey of Sweden (SGU) for the Committee showed that Sweden had favourable geological conditions for such disposal.

Geological studies were then carried out over a long period all over the country and in different geological environments. The choice of areas for the investigations was based primarily on the following criteria:

- Flat bedrock topography.
- Low fracture frequency on exposed rock surfaces.
- Widely spaced major fracture zones.
- Uniform composition and structure of the rock mass.
- Areas with low seismic activity.
- Documented low water flow rate in the rock mass.

PRAV (the National Council for Radioactive Waste), appointed by the Government in 1975, continued and broadened the geological studies begun by the AKA Committee for the purpose of identifying areas with bedrock that could be suitable for final disposal of vitrified waste from reprocessing of spent nuclear fuel.

The passage of the Stipulations Act by the Riksdag in 1977 set the stage for the continued work. The Stipulations Act required the reactor owners to show how and where an absolutely safe disposal of the high-level waste (after reprocessing) or the spent nuclear fuel (without reprocessing) could take place in order to obtain Government permits to start the reactors that were planned or under completion. The nuclear power companies then initiated the KBS (KärnBränsleSäkerhet = Nuclear Fuel Safety) project, which was subsequently incorporated in SKB's activities and aimed at satisfying the requirements of the Stipulations Act. The KBS project carried out intensive work with test drilling and research.

In the first phase, test boreholes were drilled and investigations were conducted on three sites: Sternö (Karlshamn Municipality), Kråkemåla (Oskarshamn Municipality) and Finnsjön (Tierp Municipality). The results of these investigations formed a part of the report to the Government that served as a basis for permits to start the reactors Ringhals 3 and Forsmark 1 as well as Ringhals 4 and Forsmark 2. Similar investigations were subsequently conducted on another four sites: Fjällveden, Gideå, Kamlunge and Svartboberget. The KBS project was concluded with the presentation of the KBS-3 method, and the Government granted permits to start the Forsmark 3 and Oskarshamn 3 reactors.

The sites that were subjected to more comprehensive investigations during the KBS project came to be called study sites, see Figure 3-9. Yet another study site – Klipperås – was added after the conclusion of the KBS project. The study site investigations were concluded in 1985, after which SKB initiated investigations for the hard rock laboratory on Äspö in Oskarshamn Municipality.

A principal conclusion from the study site investigations and other studies of the bedrock was that suitable and less suitable areas cannot be attributed to any particular part of the country or any special geological environment within the crystalline bedrock. It is instead local conditions that are of the greatest importance. Another lesson was that the siting work must be based on the acceptance and trust of the local population. In several cases the investigations aroused local opinion and led to protests, and in some cases the work had to be discontinued. SKB saw no point in continuing the siting work in such a hostile community climate. These conclusions became central points of departure for the programme for siting of the final repository that was initiated in the early 1990s.

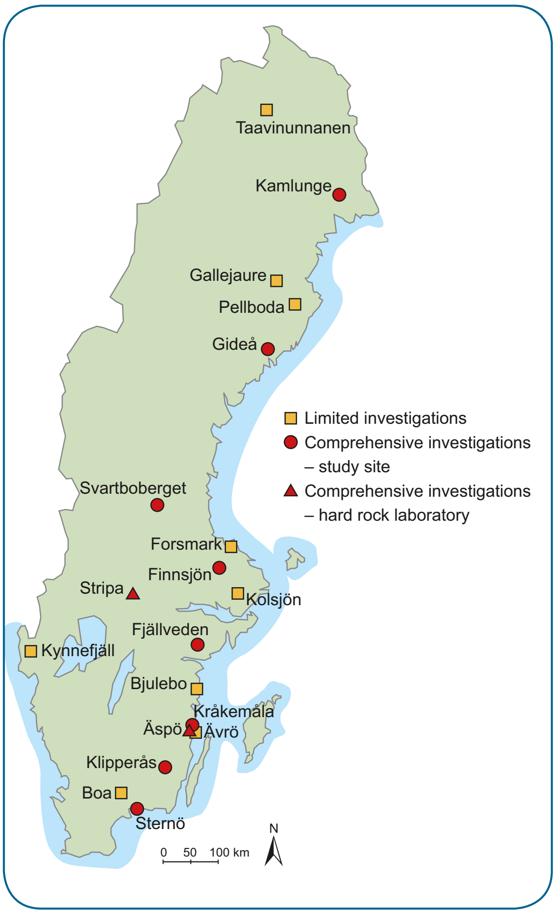


Figure 3-9. Sites in the country where SKB and others have carried out investigations to obtain knowledge of the Swedish bedrock.

3.7.2 The period 1985–2000

An important milestone for the work of management and disposal of the nuclear waste was when the Nuclear Activities Act entered into force in 1984. According to this Act, owners of reactors shall, every third year, prepare a comprehensive programme for the research and development activities required for safe management and disposal of nuclear waste. The reactor owners assigned this task to SKB. The first programme was submitted in 1986 to the concerned authority for review and evaluation.

The actual work of finding a suitable site for the final repository was initiated when SKB established a siting project in 1991. SKB reported its plans for a broadly conceived siting process in RD&D-Programme 92. Based on the knowledge that there are good prospects to find repository areas with suitable geological conditions, SKB said that it was reasonable and realistic to focus interest on municipalities where conditions were suitable and that were themselves willing to participate, or otherwise showed an interest, in further exploring the potential for a siting.

RD&D-Programme 92 was supplemented in response to Government demands, after which the Government, in a decision dated 18 May 1995, stipulated that "the siting factors and criteria reported by SKB should serve as a point of departure for the continued siting work". It was further stated in the Government decision that the applications for permits to build a final repository for spent nuclear fuel should contain material for comparative assessments showing that site-specific feasibility studies have been conducted at five to ten sites in the country and that site investigations have been conducted on at least two sites and give the reasons for the choice of these sites.

During the period 1992–2000, SKB held more or less far-reaching discussions of feasibility studies with some twenty-odd municipalities in different parts of the country, see Figure 3-10. In eight cases – Storuman, Malå, Östhammar, Nyköping, Oskarshamn, Tierp, Älvkarleby and Hultsfred – this led to a feasibility study being conducted. In other cases the discussions were discontinued, either because SKB found that a feasibility study was not warranted, or because the municipality in question chose to decline.

The purpose of the feasibility studies was to determine whether premises existed for further siting studies for a final repository in the municipality in question, at the same time as the municipality and its inhabitants were given an opportunity to form an opinion, without commitments, on the final repository project and their possible further participation. A principal task was to identify areas with bedrock that could be suitable for a final repository. Geological studies were therefore a principal component. The studies were based on existing data, but no drilling was done. Technical, environmental and societal conditions were also studied. Within the framework of the feasibility studies, SKB also carried on an active dialogue with both private citizens, the municipality and the county administrative board.

The feasibility studies were carried out according to the programme and with the siting factors that were presented in SKB's supplement to RD&D-Programme 92, which meant that above all the following questions were addressed:

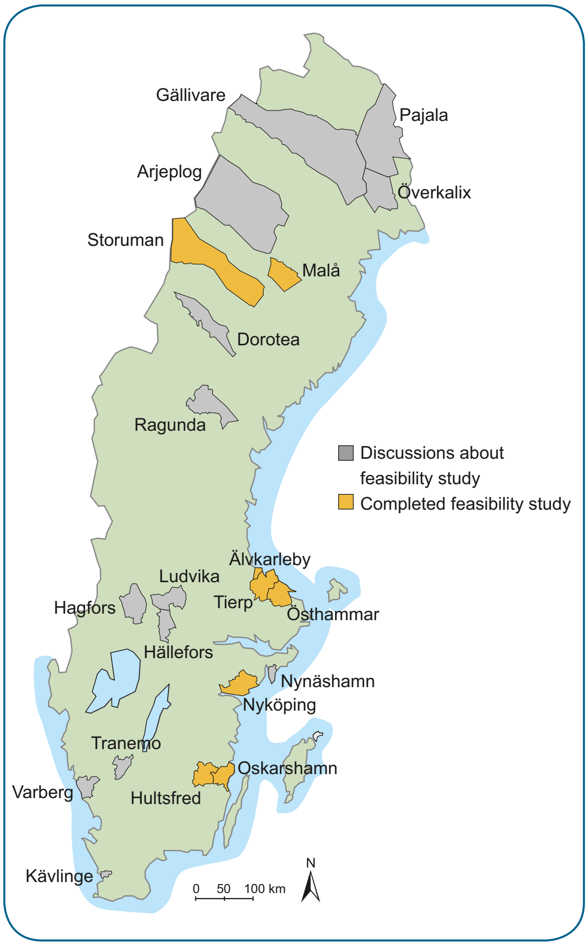


Figure 3-10. Municipalities where SKB has conducted or held discussions about a feasibility study.

- What are the general prospects for siting a final repository in the municipality?
- Where could suitable sites exist for a final repository with reference to geoscientific and societal conditions?
- How can transportation be arranged?

- What are the most important environmental and safety issues?
- What are the possible consequences, positive and negative, for the environment, the economy, tourism and other business enterprise in the municipality and the region?

The feasibility studies led to reports which contained answers to these questions and evaluations of identified siting alternatives.

The first feasibility studies were done in the municipalities of Storuman and Malå, after these municipalities had shown an interest and SKB's preliminary judgements had indicated favourable conditions there. The feasibility studies confirmed these judgements, but in both cases local referendums led to a decision not to participate further in the siting process. According to the points of departure for the siting work, SKB thereby ruled out further studies in these municipalities.

In parallel with the first feasibility studies, SKB studied the possibilities of siting the final repository in one of the municipalities in the country that already have nuclear facilities, i.e. Oskarshamn, Nyköping, Östhammar, Varberg and Kävlinge. In the cases of Oskarshamn, Nyköping and Östhammar, an extensive body of geological data existed that indicated good siting possibilities. SKB proposed and conducted feasibility studies in these municipalities. SKB also recommended a feasibility study of Varberg Municipality, but the municipality declined. In the case of Kävlinge Municipality, SKB found that a feasibility study was not warranted in view of the geological conditions, among other things.

Three more feasibility studies were carried out, in the municipalities of Tierp, Älvkarleby and Hultsfred. The reasons were, as in the previous cases, that SKB's preliminary assessments pointed towards potentially favourable conditions, in combination with an interest on the part of the municipalities.

Aside from the feasibility studies and after the Government's decision regarding RD&D-Programme 95, other siting studies were also performed in order to supplement the background material. At the end of the 1990s, SKB presented regional general siting studies for all counties (except Gotland). The studies focused on long-term safety and thereby on bedrock conditions, but also included general surveys of environmental factors, existing industry and transport infrastructure. The main conclusion was that there is bedrock in all the counties studied that could warrant further studies concerning siting of the final repository, see Figure 3-11. At the same time, large areas were identified that are probably unsuitable.

SKB also studied the advantages and disadvantages of siting the final repository in northern versus southern Sweden, as well as location on the coast versus in the inland. The studies were done at the request of the Government. The most important conclusion was that it is not possible, based on general comparisons and considerations, to give priority to either the northern or the southern part of the country. Assessments of the suitability of a siting must instead be based on studies of local conditions. The same conclusion applies to comparative evaluations of siting prospects near the coast versus in the inland.

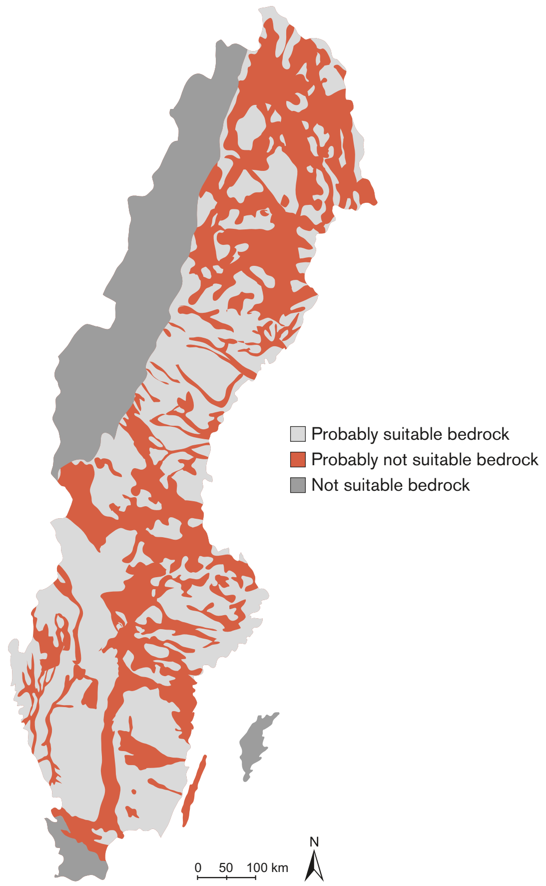


Figure 3-11. One of the conclusions from the general siting studies was that good prospects exist for siting of a final repository at many places in Swedish crystalline bedrock.

3.7.3 Selection of areas for site investigations

Based on the results of the feasibility studies and other studies, SKB concluded in 2000 that enough data were available to proceed to the next phase of the siting work: site investigations for priority siting alternatives. SKB presented site selection and the programme for the site investigation phase in the supplement to RD&D-programme 1998 that was presented in the autumn of 2000, known as the RD&D-K report.

Storuman and Malå had, after completed feasibility studies, declined further participation in the siting work, citing the outcome of municipal referendums.

The conclusion from the other six feasibility studies was that there are areas in all municipalities except Älvkarleby where the bedrock is deemed potentially suitable for a final repository. The feasibility studies revealed good potential when it comes to the technical and environmental aspects as well. General solutions to construction and transport problems had been arrived at for a number of alternatives.

In deciding which siting alternatives could be included in a "selection pool" for the selection of sites for site investigations, the results were evaluated with respect to:

- Bedrock. The properties of the bedrock determine the prospects for long-term safety and the technical prospects for building and operating the underground parts of the final repository. The safety requirements and resulting requirements on the rock distinguish the final repository from other rock facilities.
- Industrial establishment. The final repository project must be able to be implemented as an industrial undertaking. This means that construction and operation must be technically feasible, that resources must be available, and that all requirements on occupational safety and protection of man and the environment must be met. In these respects the final repository does not differ essentially from any other industrial activity.
- Societal aspects. In order for the final repository project to be realized, it must have political and popular support. SKB must deem it likely that the concerned municipality, the environmental court and the Government will accept the siting. In practice, this means that SKB and the nuclear waste programme must enjoy broad confidence in the community.

The review resulted in the identification of eight siting alternatives in five municipalities. Figure 3-12 shows names and locations. Evaluated individually, and with respect to the requirements and preferences that could be checked at this stage, all were judged to be sufficiently promising to warrant further study.

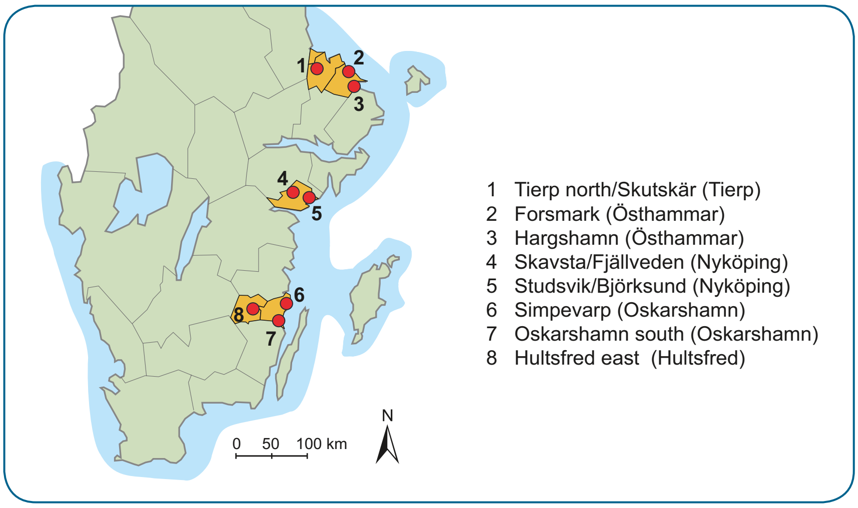


Figure 3-12. Selection pool prior to the site investigation phase.

SKB concluded that the eight siting alternatives that had been identified provided a sufficiently extensive, comprehensive and promising selection pool for an evaluation aimed at comparing the alternatives and prioritizing a smaller number for further studies, including site investigations. The comparison was made with respect to the aspects mentioned above, i.e. bedrock, industrial establishment and societal aspects. In parallel with the feasibility studies, the methodology for evaluation of the background material for siting had also been further improved, based on the latest knowledge from e.g. geoscientific research and safety assessment. The methodology was presented in conjunction with the completion of the last feasibility studies and in SKB's integrated account prior to the transition to the site investigation phase. There a set of guiding requirements and preferences for different siting factors was presented. The requirements and preferences were primarily intended as tools to guide the predicted site investigations and for clarification of how the results from the investigations would be evaluated. Certain requirements and preferences could, however, be used as a support in the comparative evaluation of the alternatives in the selection pool from the feasibility studies.

Since all alternatives were judged to satisfy the requirements that could be checked at this stage, the evaluations were concerned with the uncertainties in these assessments as well as to what extent the alternatives satisfied the preferences that had been formulated. The uncertainties mainly concerned the bedrock, where data from repository depth were lacking in most cases and the assessments were preliminary. For this reason it was not possible to rank the alternatives with respect to suitability of the bedrock. For other factors, the alternatives could be ranked to some extent. The uncertainties in the geological data speak in favour of a broad programme with investigations at several sites with different conditions, but this must be weighed against the requirements on a reasonable use of time and resources.

Table 3-2 summarizes the fundamental characteristics for the eight alternatives and SKB's overall assessment and priorities. SKB concluded that the alternatives of Simpevarp and Forsmark had clear advantages from the establishment and societal viewpoints. The forecast for the bedrock was also favourable, but this could only be verified by site investigations. Against this background it was difficult to see any reason not to proceed with these two alternatives.

Thus, Forsmark and Simpevarp stood out in all respects as clear favourites for site investigations. A programme of that scope would also satisfy the expectation expressed by the Government that the background material for siting should include material from site investigations on at least two sites. However, SKB found that a broader programme was warranted, with continued studies of additional alternatives with good prospects but with different conditions than Forsmark and Simpevarp. Of the remaining alternatives, it was mainly Tierp north and Fjällveden that could contribute to a greater breadth of the geological data. For Tierp north/Skutskär, it was judged that a site investigation in the area in question in Tierp Municipality was warranted. Further studies were also proposed for the Fjällveden alternative, since the uncertainties primarily concerned the prospects for industrial establishment, while data on the bedrock were available from boreholes drilled in the 1980s. For other siting alternatives, SKB concluded that there was no reason to either initiate site investigations or to dismiss the possibility. Hargshamn was seen as a possible alternative, if investigations in Forsmark could not be initiated or if they for some reason should show that the bedrock did not satisfy the requirements. Similarly, Oskarshamn south and Hultsfred were seen as possible alternatives to Simpevarp.

In summary, SKB's programme for the site investigation phase included the following:

- A site investigation in the Forsmark area in Östhammar Municipality.
- A site investigation in the Simpevarp area (including the area that later came to be designated Laxemar) in Oskarshamn Municipality.
- A site investigation in an area in the northern part of Tierp Municipality.
- Further study of the siting prospects in the Fjällveden area in Nyköping Municipality.

Table 3-2. Fundamental characteristics of the eight siting alternatives included in the selection pool prior to the site investigation phase, and SKB's assessment.

Siting alternatives	Fundamental characteristics (bedrock, environment for above-ground facilities, transport of spent nuclear fuel)	SKB's assessment and priorities for the site investigation phase
Tierp north/Skutskär Tierp and Älvkarleby municipalities	Large granite massif north of the town of Tierp. New establishment on forest land. Transport by rail from Port of Skutskär in Älvkarleby Municipality.	Contributes to the geological breadth of the selection pool. The area in Tierp Municipality, together with the port in Skutskär, offer good conditions for establishment. Prioritized for site investigation.
Forsmark Östhammar municipality	Gneissic granite (tectonic lens) southeast of Forsmark Nuclear Power Plant. Establishment on industrial land adjacent to the nuclear power plant. Transport by road from the Port of Forsmark.	Clear advantages with respect to industrial establishment and societal prerequisites. Good forecast for the bedrock. Prioritized for site investigation.
Hargshamn Östhammar municipality	Gneissic granite (tectonic lens). Probably new establishment on forest land near Hargshamn. Transport by road from the Port of Hargshamn.	Similar geological environment to Forsmark, but not as favourable conditions otherwise. Not prioritized for site investigation, but of possible interest if Forsmark should prove unacceptable.
Skavsta/Fjällveden Nyköping municipality	Sedimentary veined gneiss in the Fjällveden/Tunsätter area north of Nyköping. Establishment possibly adjacent to Skavsta Airport. Transport by rail or road from the port of Oxelösund.	Contributes to the geological breadth of the selection pool. Rock conditions relatively well known from previous investigations, good forecast. Doubts regarding transport and prospects for industrial establishment in other respects. Prioritized for further studies of the feasibility of an establishment.
Studsvik/Björksund Nyköping municipality	Gneissic granite in the eastern coastal area of the municipality, west of the Studsvik facility. Establishment adjacent to the Studsvik facility. Transport by road from the Port of Studsvik.	Good forecast for the bedrock, but also significant geological uncertainties. Both advantages and considerable uncertainties with respect to prospects for industrial establishment. Not prioritized for site investigation.
Simpevarp Oskarshamn municipality	Granite (Småland granite) towards the west from the Simpevarp peninsula (includes the area now called Laxemar). Establishment on industrial land adjacent to the nuclear power plant and Clab main alternative. Possibly short transport by road from planned encapsulation plant.	Clear advantages with respect to industrial establishment and societal prerequisites. Good forecast for the bedrock. Prioritized for site investigation.
Oskarshamn south Oskarshamn municipality	Granite (Småland granite) south of Oskarshamn. Establishment adjacent to the harbour in Oskarshamn. Transport by rail or in tunnel from the Port of Oskarshamn.	Similar geological environment to Simpevarp, but not as favourable otherwise. Not prioritized for site investigation, but of possible interest if Simpevarp should prove unacceptable.
Hultsfred east Hultsfred municipality	Granite (Småland granite) east of Målilla. New establishment on forest land. Transport by rail from the Port of Oskarshamn.	Similar geological environment to Simpevarp, but not as favourable otherwise. Not prioritized for site investigation, but of possible interest if Simpevarp should prove unacceptable.

3.7.4 2001 – The Government gives the go-ahead

In accordance with the procedure followed for the RD&D programmes, SKB's integrated account prior to the transition to the site investigation phase was circulated for comment. After statements of comment from the Swedish Nuclear Power Inspectorate (SKI) and from the Swedish National Council for Nuclear Waste (KASAM), the Government made a decision in November 2001 entailing a go-ahead for SKB to continue its work in accordance with the submitted account. Even before the Government had rendered its decision, Nyköping Municipality had announced its intention not to give its consent for SKB to continue siting studies in the municipality. The Fjällveden alternative was thereby no longer an option. The Government had no objections to SKB's initiation of site investigations within the three areas Simpevarp, Forsmark and Tierp north/Skutskär.

Following the Government's go-ahead for the site investigations, it was up to the concerned municipalities to decide. In Östhammar, the municipal council decided in December 2001 to consent to a site investigation in Forsmark. A similar decision regarding a site investigation in Simpevarp was made by the municipal council in Oskarshamn in March 2002. In April 2002, however, Tierp Municipality declined further participation in the siting process for the final repository. The neighbouring municipality of Älvkarleby, which would be affected by shipments to a final repository in Tierp, took a positive stand on the site investigation. The outcome of the decision process was thus that SKB was able to initiate site investigations in Simpevarp and Forsmark. SKB saw this as a fully acceptable basis for continuing the siting work.

3.7.5 National interest for final disposal of spent nuclear fuel and nuclear waste

With the support of Chapter 3 Section 8 of the Environmental Code, SKI (now the Swedish Radiation Safety Authority, SSM) decided in December 2004 that the areas in Forsmark and Oskarshamn where SKB was conducting site investigations are of national interest for final disposal of spent nuclear fuel and nuclear waste. SKI thereby stipulated in its decision that the final repository interest has the same status in a licensing process as other national interests.

3.7.6 Siting on the coast versus in the inland

In conjunction with the selection of sites for site investigations, the question of possible advantages and disadvantages of coast versus inland sitings was again brought up. More specifically, the question was whether long flow paths (and long circulation times) for groundwater from inland locations can entail advantages from a safety viewpoint, and if so whether this can be exploited in the siting.

In 2005, SKB initiated an extensive modelling project to evaluate conceptual simplifications and uncertainties in the modelling of groundwater flow on a regional scale. The results improved the understanding of the groundwater flow pattern on different scales and how the flow pattern is theoretically affected by important system characteristics. One conclusion was that most of the groundwater circulation that affects repository depth takes place within local flow cells. The study also showed that flow conditions are as a rule favourable (small flows, long breakthrough times) in rock types with low conductivity. At the same time, it was pointed out that permeability on a local scale can in reality vary within wide limits, and that the groundwater flow is heavily dependent on these variations. For individual sites, it was judged that this could influence the size and distribution of the flow much more than the variations of system parameters that were analyzed in the study.

The analyses were reviewed jointly by SKI and SSI. The review lent support to the contention that the work had contributed to a better scientific understanding of the influence of different factors on the flow pattern. At the same time, it was pointed out that the consequences of a number of assumptions and model simplifications were considered to be inadequately studied, and that the evaluation of certain results was incomplete. SSI therefore stated that the study ought to be supplemented in these respects prior to SKB's licence applications. Supplementary studies have therefore been carried out on behalf of SKB. Sensitivity analyses have been done to illustrate how stipulated model assumptions, boundary conditions etc can affect the conclusions drawn at earlier stages. In summary, these factors do not influence the results so much as to change the general conclusions presented previously.

SKB's overall conclusion is that no systematic difference can be demonstrated between coastal and inland locations with regard to the occurrence of favourable flow conditions. The main reason is that investigations and analyses have shown that as far as groundwater flow is concerned, local conditions, particularly the permeability of the bedrock, are crucial for whether or not a site is suitable for a final repository. The site investigations in Laxemar and Forsmark have confirmed this contention.

3.8 The site investigations

The site investigations began in 2002 and continued for more than five years in Forsmark in Östhammar Municipality and in Laxemar/Simpevarp in Oskarshamn Municipality (then called only Simpevarp, see Section 3.7.3). Investigations and analyses were divided into two main stages: initial site investigation and complete site investigation. A similar division into stages applies to the site-adapted design of the final repository's facilities, where two versions, D1 and D2, were produced. Data from the initial site investigation served as a basis for the D1 version and for the SR-Can safety assessment. In a similar manner, data from the complete site investigation served as a basis for version D2 of the design and for the SR-Site safety assessment. On-site data collection has been done with more checkpoints, so-called data freezes. The same applies to the different versions of the site descriptions that have been produced.

The site investigations were able to build on a solid knowledge base regarding geoscientific investigations. In response to the somewhat unique needs, strategies, methods and instruments for surface-based investigations have been developed and applied ever since the start of the nuclear waste programme. The establishment of the Äspö Hard Rock Laboratory entailed an updating of the technology and a dress rehearsal for the site investigations.

The discipline of surface ecosystems was not included in either the study site investigations or the investigations for construction of the Äspö Hard Rock Laboratory. Extensive work was therefore done prior to the site investigations to identify which conditions and properties of the surface ecosystems needed to be determined.

3.8.1 The site investigation in Forsmark

The site investigation in Forsmark commenced in 2002 and was concluded in the summer of 2007. Prior to the start, an investigation programme was prepared that mainly covered the initial part of the investigation. The programme targeted the roughly ten square kilometre area southeast of the Forsmark Nuclear Power Plant that had previously been recommended for a site investigation, known as the site investigation area, see Figure 3-13. The area comprises the northwestern part of an elongated tectonic lens, where the bedrock was expected to have been preserved relatively undisturbed in a regional environment with large deformation zones. Towards the southeast the area was bounded by the nature reserve. The focus of the investigations was on answering general and site-specific questions that were regarded as crucial for assessing the suitability of the site.

When the initial investigation phase had been completed and a preliminary site descriptive model had been constructed, the state of knowledge was cross-checked against the fundamental requirements that had been established before the site investigations were commenced. It had to be shown that the requirements were met in order for a site to be of interest for the final repository. The conclusion was that the site satisfied the requirements and that further investigations were therefore warranted, something which was subsequently verified by the SR-Can safety assessment. The cross-check also permitted remaining data needs to be identified, along with a strategy and programme for further investigations.

On this basis, a programme was drawn up for the concluding part of the site investigation. The strategy that was chosen gave priority to the northwestern part of the site investigation area, see Figures 3-13 and 3-14. The investigations had already indicated at an early stage that both the northwestern and the southeastern parts of area had bedrock that warranted further investigations. The difference that could nevertheless be noted was a higher frequency of gently-dipping, permeable fracture zones in the southeastern part. The main reasons for prioritizing the northwestern part at that time were that:

- Preliminary studies of space requirements and possible locations showed that a repository could in all probability be accommodated within the northwestern part.
- The location permitted a layout with surface facilities on existing industrial land. This was deemed to offer a number of technical and environmental advantages.

The aims of the programme for the concluding portion of the site investigation were to:

- Determine the geological boundaries of the available rock volume at repository depth.
- Characterize the available rock volume to the required extent and level of detail.
- Characterize the priority site's hydraulic boundary areas.

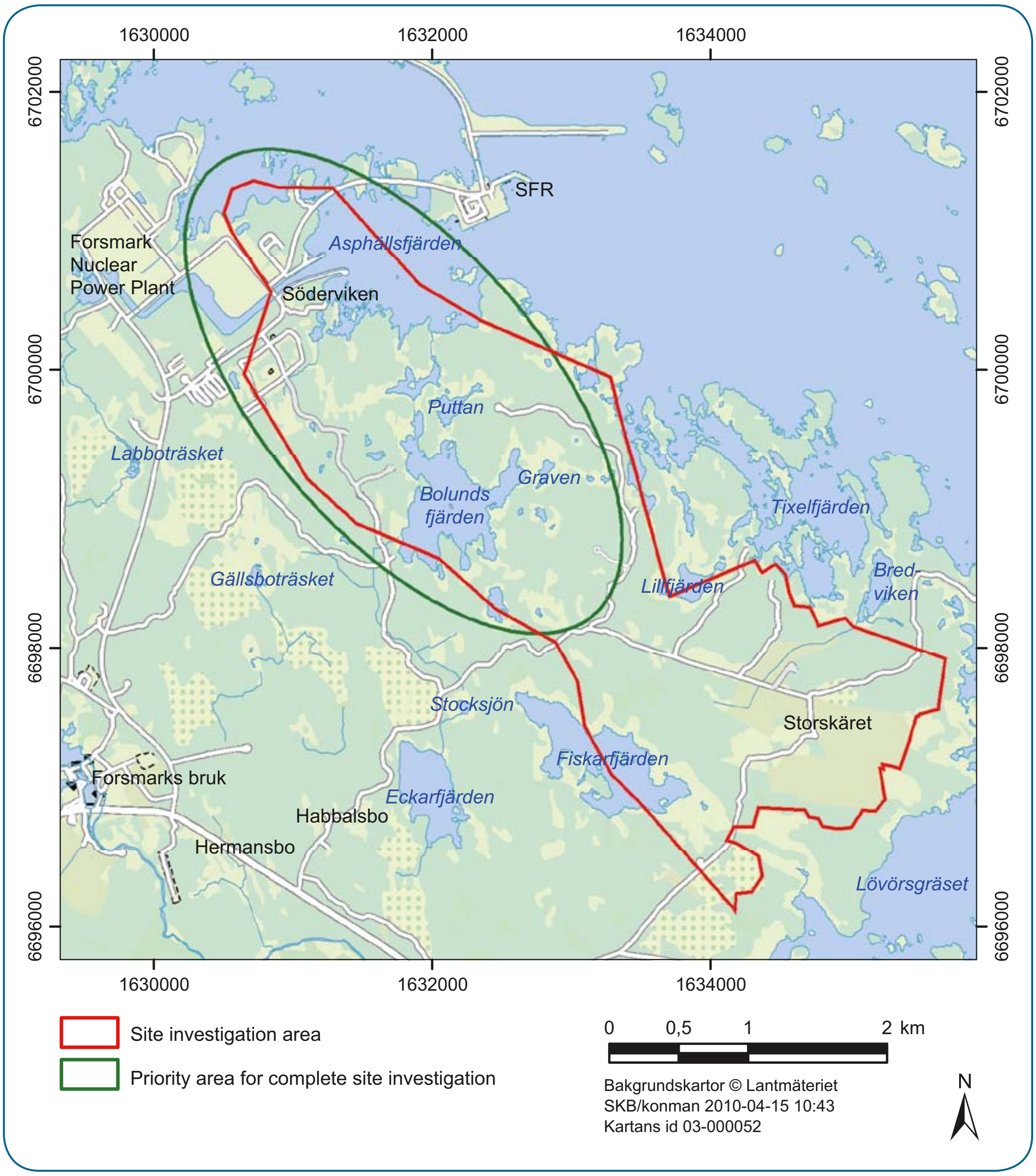


Figure 3-13. Site investigation area and priority area for complete site investigation in Forsmark.

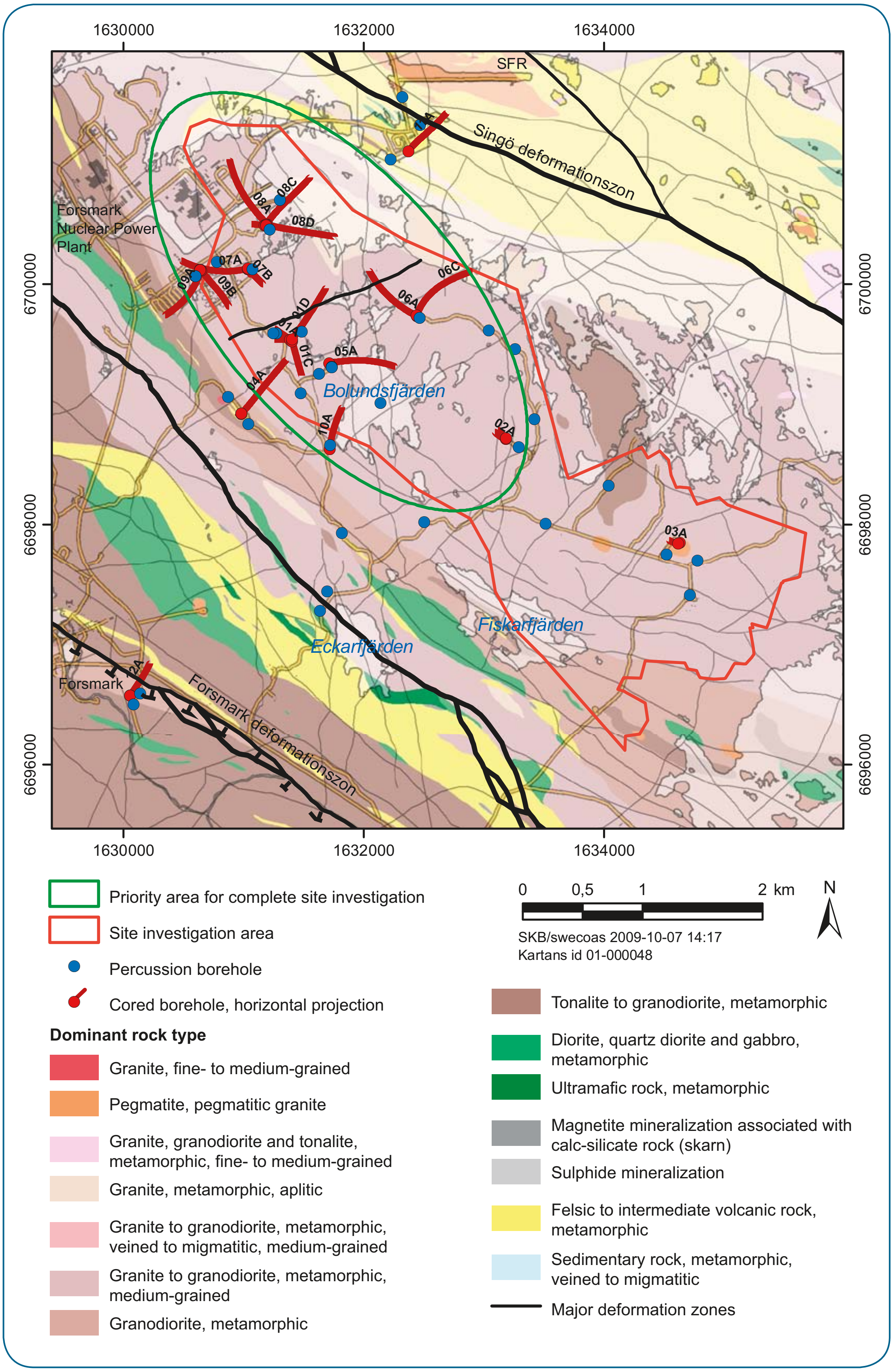


Figure 3-14. Site investigation area, priority area for complete site investigation and borehole locations in Forsmark.

3.8.2 The site investigation in Laxemar/Simpevarp

The site investigation in Laxemar/Simpevarp was concluded during the first quarter of 2008. The area that was recommended after the feasibility study for site investigation covered about 60 square kilometres and included both the Simpevarp peninsula itself and the Laxemar area to the west, see Figure 3-15. In the final phase, the investigations were concentrated to an approximately six square kilometre area within Laxemar that was given priority for a possible final repository. The priority area was the result of a progressive narrowing-down process.

The site investigation began with drilling of boreholes on the Simpevarp peninsula. However, due to the limited space on the peninsula, the area was enlarged to include Ävrö, Hålö and nearby bodies of water ("Simpevarp subarea", see Figure 3-15), after which an initial site investigation of this area was completed. The results indicated rock conditions that could satisfy the requirements for a final repository.

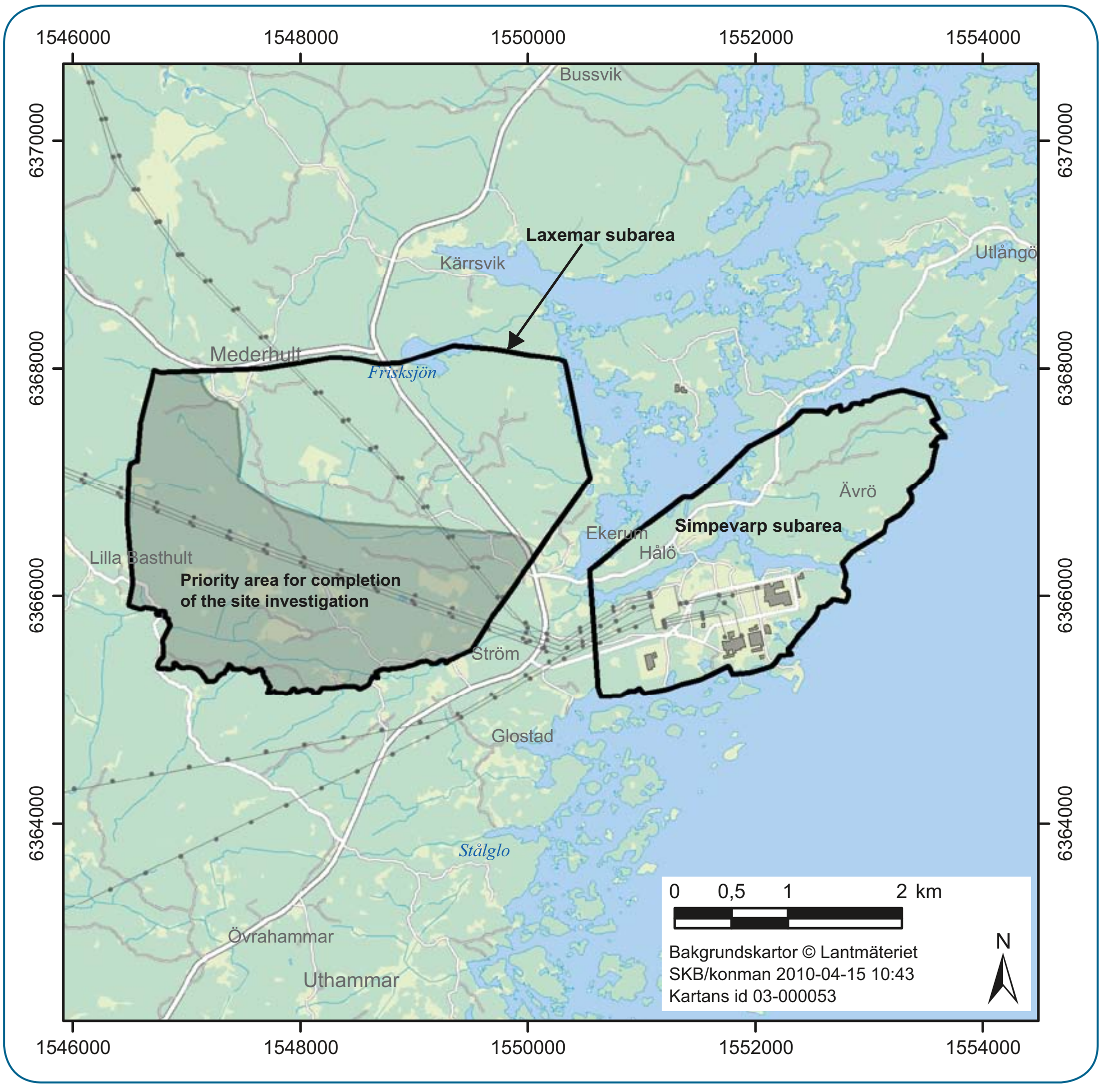


Figure 3-15. Subareas for initial site investigation and priority area for completion of the site investigation in Laxemar. (The area where completion of the site investigations took place is also called the focused area in the underlying documentation for the site investigation in Laxemar, but in order to obtain uniform terminology in Forsmark and Laxemar the area is called a priority area in this EIS).

West of Simpevarp the investigations started with helicopter-borne geophysical surveys and field checks over a considerably larger area than that shown in Figure 3-15. Based on these surveys, several areas were identified with rock conditions judged to warrant further investigations and large enough to accommodate a final repository with ample margin. The Laxemar subarea in Figure 3-15 is about nine square kilometres in size and was given priority for continued investigations. Several other areas were judged to be equivalent from a geological viewpoint. Nearness to the Simpevarp peninsula was the main argument for then choosing the Laxemar subarea. Starting in early 2004, an initial site investigation was conducted on the Laxemar subarea, after agreements had been reached with the concerned landowners.

The next milestone was to prioritize one of the subareas Simpevarp or Laxemar for a complete site investigation. When the initial site investigations were completed, the Laxemar area was given preliminary priority. The comparison material that was later obtained in the form of site descriptions, design results (stage D1) and safety evaluations for both areas did not change the preliminary judgement, and a final decision was made to proceed with Laxemar. The main arguments for choosing the Laxemar area were as follows:

- Both areas could probably accommodate a repository, but in the case of Simpevarp the margins were small. In the case of Laxemar there was plenty of space and thereby large margins. This provided flexibility for future modifications of the repository layout and for handling any geological surprises, even at late stages.
- The safety evaluations that had been presented indicated that both areas satisfy the requirements. The more homogeneous bedrock in parts of the Laxemar area could, however, offer advantages in the form of a relatively low fracture frequency and water flow rate. The great flexibility offered by Laxemar also made it easier to adapt a repository so that all safety requirements could be shown to be satisfied.
- A repository in Laxemar entails building new surface facilities and infrastructure on forest land, resulting in an impact on the environment. Simpevarp, however, is planned industrial land and the environment is already affected by the existing industrial activities. On the other hand, the availability of suitable land within the industrial area is limited, and in other parts of the the Simpevarp subarea the potential for land development is limited by nature conservation interests. The advantages and disadvantages of the areas are difficult to compare, but both alternatives were deemed to be fully acceptable.

Prior to the complete site investigation the size of the investigation area within the Laxemar subarea had to be reduced, but the available information on the properties of the bedrock was not sufficiently detailed for this. Investigations were therefore first carried out in order to obtain the required information. Then a programme was drawn up for the continued investigations in the priority area. The investigations had gradually been focused on the southern and western parts of the area, see Figure 3-15. The reason was variations in the bedrock conditions in the area. The southern and western parts are dominated by bedrock that has proved to be more homogeneous and less fractured than the bedrock that dominates the northern and eastern parts of the area. Figure 3-16 shows the locations of the investigation holes that have been drilled in the Laxemar area.

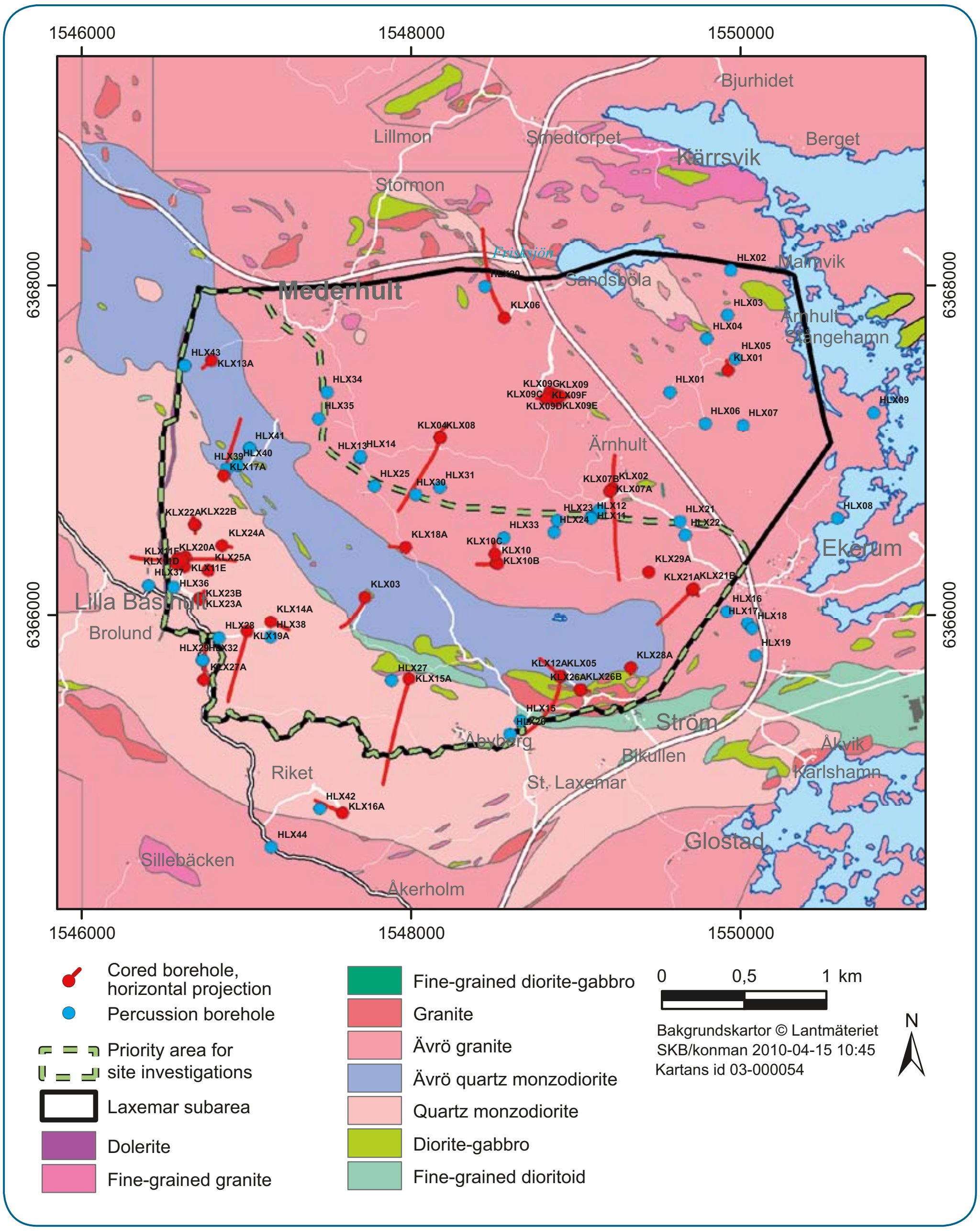


Figure 3-16. The Laxemar subarea with priority area for completion of the site investigation plus the borehole locations.

4 Consultations

According to Chapter 6 of the Environmental Code, the consultations shall concern the siting, scope, design and environmental impact of the applied-for activity or measure, as well as the form and content of the EIS. The purpose of consultations is to gather information as a basis for decisions and to provide an opportunity for an expression of ideas and opinions. Everyone who wants to get involved is given an opportunity to do so, both private citizens and organizations and public authorities.

SKB initiated the consultations in 2002 with early consultations for the final repository in both Oskarshamn and Östhammar and has since then conducted parallel consultations in the two municipalities. The consultations have concerned the examination of the encapsulation plant and the final repository under both the Nuclear Activities Act and the Environmental Code. Starting in May 2007, it was clarified that the consultations also concern the interim storage facility Clab. The consultations were concluded in May 2010, except for the consultations with the countries around the Baltic Sea under the Espoo Convention. In contrast to the consultations held with Swedish actors, the consultations under the Espoo Convention will continue after the applications have been submitted. The second and concluding portion of these consultations will begin no earlier than the autumn of 2011 and concern the finished EIS. The concluding portion of the consultation procedure does not concern the contents of the EIS, but is a part of its examination. The Swedish Environmental Protection Agency will coordinate viewpoints received from the consultations and submit them to the environmental court within the framework of the court's circulation of the applications for review and commentary.

The consultations have comprised a total of about 60 consultation occasions in different forms, including public meetings in each municipality and meetings with the Oskarshamn EIA Forum and the Forsmark Consultation and EIA Group. In conjunction with the public consultation meetings, written consultations have also been carried out. Furthermore, questions and viewpoints have come in via SKB's website.

A large number of questions and viewpoints have emerged in the consultations. They are commented on in the consultation report /4-1/. All questions and viewpoints that have emerged in the consultations, as well as SKB's replies and comments on them, are presented in their entirety in the documentation from the consultations.

4.1 Invitation, advertisement and background materia

Invitation to public consultation meetings has generally taken place via advertisements in local newspapers approximately three weeks before the meetings, and again one week before. In Oskarshamn, these advertisements have appeared in Oskarshamns-Tidningen and Nyheterna. In Östhammar, the advertisements have appeared in Upsala Nya Tidning, Östhammars Nyheter and Annonsbladet, as well as in Upplands Nyheter starting with the consultation meeting of 1 June 2006. Some meetings have also been advertised in Göteborgs-Posten, Dagens Nyheter, Svenska Dagbladet, Sydsvenska Dagbladet, Västerbottens-Kuriren and Post- och Inrikes Tidningar (the Swedish Official Gazette).

A written invitation was sent no later than two weeks before the meeting to concerned government agencies, the concerned municipality, and the organizations that receive funding from the Nuclear Waste Fund to participate in the consultations. Background material for the meeting was enclosed with the written invitations. All background material has also been available via SKB's website and at the site investigation offices in Forsmark and Simpevarp. The background material for the meeting on the preliminary EIS was sent out five weeks before the meeting. The dates of meetings with the Oskarshamn EIA Forum and the Forsmark Consultation and EIA Group were determined by the parties. SKB sent out e-mail invitations to each meeting. Starting in November 2005, all meetings with both forums were open to the public. Before that about one meeting per year in Oskarshamn was open to the public. The open meetings were advertised in the same way as the public consultation meetings.

4.2 Documentation

All consultations, whether in the form of meetings or correspondence, have been documented. Minutes were kept by SKB of the meetings with the Oskarshamn EIA Forum and the Forsmark Consultation and EIA Group and later verified by the participating parties. Up until the joint meeting of 5 December 2007, the minutes were administered by the local county administrative board; after that SKB took over administration. Minutes were kept by SKB of the public consultation meetings as well, starting with the consultation meeting in Oskarshamn on 5 April 2005. The minutes were verified by persons appointed by the meeting. Previously, SKB wrote notes that were not verified.

After the public consultation meetings it was possible to submit questions and viewpoints relating to the meeting for another two weeks. The consultation on a preliminary EIS in February 2010 was open for viewpoints for four weeks after the meeting. The questions and viewpoints that were discussed during a consultation meeting, as well as those received within the appointed time after the meeting, are recorded in the documentation from the meeting. SKB's replies and comments are also recorded there. Certain questions led to supplementary studies and further discussion. Some questions were judged to lie beyond the scope of the EIA work for the facilities in question and were dismissed from the consultations. Reasons were given for this.

When questions were asked at the meetings themselves, it is not normally evident from the notes or minutes who asked the question. In the case of written questions and viewpoints, there is a notation of who submitted them. The appendices to the minutes show written viewpoints in their entirety.

SKB has published an annual compilation of the consultations held during the year. The yearbooks include all questions and viewpoints as well as SKB's replies and comments, grouped in the following categories:

- Interim storage facility and encapsulation plant (the interim storage facility was added to the category in 2007).
- Final repository.
- Common issues.

The documentation from the consultations, background material, notes and minutes, as well as all viewpoints received, have been made available on SKB's website.

4.3 Themes for consultations

Disposal of the spent nuclear fuel is a large project that has generated a great deal of material to deal with in the consultations. It has not been possible to consult about everything related to the project on a few isolated occasions. SKB has therefore held consultations on different themes as the relevant studies have been completed, see Table 4-1. Questions and discussions at a consulta-

Table 4-1. Themes of consultation meetings.

Theme	Time period	Number of meetings
Scope, content and form of EIS	November 2003 – May 2004	6
Siting and design of final repository and encapsulation plant	November 2004 – July 2005	4
Preliminary EIS for the encapsulation plant	November 2005 – January 2006	2
Method, siting, future	May – August 2006	4
Safety and radiation protection	May – June 2007	2
– Siting, aesthetics and transportation	October 2008 – February 2009	2
Preliminary EIS for the final repository system	December 2009 – March 2010	4
Water operations	December 2009 – April 2010	2
Role of the safety assessment in the Environmental Impact Statement	May 2010	1

tion meeting have not been limited to this theme, however, but have focused on the participants' questions and viewpoints. All matters pertaining to interim storage, encapsulation and final disposal of spent nuclear fuel have been legitimate subjects for questions and viewpoints. Meetings with the Oskarshamn EIA Forum and the Forsmark Consultation and EIA Group have not had specific themes.

In addition, a total of 30 meetings were held with the EIA Forum and the Forsmark Consultation and EIA Group, 18 of which were open to the public.

4.4 Viewpoints received and SKB's replies

Most of the questions asked and the viewpoints offered at a meeting were replied to directly at the meeting or in the documentation from the meeting. The questions and viewpoints that were received in writing in connection with a meeting were replied to in the documentation from the meeting. Certain questions could not be answered until later, for example questions dealing with groundwater lowering, siting of the final repository and long-term safety. Questions of this type have been answered by SKB when possible, as is evident from SKB's replies and comments. Some questions have also resulted in supplementary studies. A total of about 2,000 questions and viewpoints have been received. In general it can be said that the stakeholders have focused on different areas:

- Nearby residents: Traffic, noise, groundwater lowering.
- Municipalities: Infrastructure, local environmental issues, pre- and post-closure safety.
- Environmental organizations: Choice of site and method, long-term safety.
- Regulatory authorities: Environmental impact, long-term safety, criteria for site selection, opportunities for and effects of retrieval of canisters.
- Neighbouring countries: Transboundary environmental impact via air and water in connection with regular operation and accidents.

Because the consultations have been going on for many years, SKB's replies to certain questions raised in the consultations are not longer valid. For example, SKB has changed the application procedure and adjusted the planning for certain work. Furthermore, SKB has developed a more consistent and transparent system for where different studies and results will be reported. In the initial phase of the consultations, it was not clear which results and assessments would be reported in the EIS itself and which would be reported in other documentation in conjunction with the applications. The fact that the structure of the reporting has been modified does not mean that there are questions that have not been answered or information that has not been reported. It is instead a question of in which documentation and at what time in the process the reporting has occurred.

Formalities surrounding the consultation process have been brought up on a number of occasions, and SKB has responded by gradually changing the forms of the meetings. Examples are that more time has been set aside for discussion and questions, and that moderators not directly associated with SKB have been engaged to lead the meetings.

The following sections present comments on questions and viewpoints from the consultations on the scope of the alternatives report in the EIS, the questions that have occasioned supplementary studies, and the role of the safety assessment in the Environmental Impact Statement.

4.4.1 The alternatives report in the EIS

As mentioned previously, consultations shall concern the siting, scope, design and environmental impact of the applied-for activity and the form and content of the EIS. According to the Environmental Code, the EIS shall also contain a description of alternative sites, if such are possible, and alternative designs.

The report on alternative methods has been discussed in several consultations. In conjunction with the applications, SKB gives a complete account of the different methods for disposing of spent nuclear fuel that have emerged from the consultations and the RD&D process. Initially, SKB planned to do this in the EIS itself, but has instead decided to provide separate documentation together with the applications. At the consultation meeting in Oskarshamn on 4 February 2009, SKB clarified that the report on alternatives to, and reasons for, the choice of the KBS-3 method will be included in the EIS. At the same time, it was also clarified that the subject will be dealt with in the appendix to the applications that deals with the activity and the general rules of consideration /4-2/ and above all in a special appendix /4-3/. As background material for this appendix, reports have been produced that deal with the development of the KBS-3 method /4-4/, principles, strategies and systems for final disposal of spent nuclear fuel /4-5/ and comparison between the KBS-3 method and disposal in deep boreholes /4-6/.

The question of how the siting process has been carried out and where an account of it will be given has been addressed repeatedly in the consultations. SKB's message has been that the EIS would contain an account of the siting process, including all sites included in the work. Furthermore, SKB has said in the consultations that the EIS will contain a coherent description of factors that influence whether the final repository is located on the coast or in the inland.

A summary of the siting work is provided in the EIS and in the appendix about the activity and the general rules of consideration. A more detailed account of the whole siting procedure, including SKB's standpoints and decisions in different phases of the work and the reasons for them, is provided in another appendix to the applications /4-7/.

4.4.2 Supplementary studies

The EIS shall include a description of any environmental impact that is judged to be significant. Noise is one of the local environmental aspects that has been discussed a great deal in the consultations. In conjunction with the presentation of the EIS for the encapsulation plant (2005), the viewpoint was offered that the EIS does not deal with low-frequency noise. This is an environmental impact that SKB does not judge to be significant, but as a result of the discussion in the consultations, low-frequency noise was included in the ongoing noise studies. Oskarshamn Municipality also wanted SKB to study an improved handling of storm water at Clink, which has been done and included in the design basis.

Other issues which SKB has judged do not cause significant environmental impact but which have been studied and are included in the Environmental Impact Statement due to the fact that they have been brought up in the consultations are effects of light pollution and risks of traffic accidents.

4.4.3 The role of the safety assessment in the EIS

The assessment of the long-term safety of the final repository, SR-Can, which was a preparatory step for the SR-Site safety assessment, comprised an important part of the background material for the consultations in the spring of 2007 and was discussed at the meeting. During these and subsequent consultations, SKB referred to the fact that SR-Site will answer many of the questions that have been posed concerning long-term safety. The consultations were concluded before SR-Site was finished. At what was intended to be the last consultation meetings (February 2010), wishes were expressed to SKB that a detailed account of long-term safety should be included in the EIS and also in the consultations. For this reason, SKB held another consultation meeting in May 2010 about the assessment of the repository's long-term safety and its role in the EIS.

At the meeting, SKB explained the place of the safety analysis report, which includes the assessment of long-term safety, in the application documentation. Furthermore, preliminary results were presented in three areas of importance for long-term safety. One concerned the extent of erosion of the bentonite clay surrounding the canisters, a risk that could not be ruled out in the previous assessment, SR-Can. Another concerned the extent of corrosion of the copper canisters, and the third area was the risk that future earthquakes could damage the copper canisters.

SR-Site is included in its entirety as an appendix to the present applications. The results of relevance to the assessment of environmental consequences are also presented in the EIS.

5 Applied-for activity and alternatives

In addition to describing the applied-for activity, an Environmental Impact Statement shall present alternative sites, if such are possible, and alternative designs. There shall also be a description of the consequences if the activity or measure is not implemented, the so-called zero alternative. Overall descriptions of the applied-for activity and alternative sitings and designs are provided here. Chapters 8–11 provide more detailed descriptions and assessments of impacts, effects and consequences of the applied-for activity and the alternatives.

5.1 Applied-for activity

SKB is applying for a licence to continue receiving and storing spent nuclear fuel at Clab on the Simpevarp peninsula in Oskarshamn Municipality, and to build and operate next to Clab a plant for encapsulation of spent nuclear fuel prior to emplacement in a final repository. Clab and the encapsulation plant will together function as an integrated facility called Clink. SKB is further applying for a licence to build and operate a final repository for spent nuclear fuel in Forsmark in Östhammar Municipality. The applications apply to final disposal of spent nuclear fuel according to the KBS-3 method.

SKB is also applying for a licence for water operations according to Chapter 11 of the Environmental Code. Water operations include diversion of groundwater from the existing Clab and later from Clink and the final repository, plus damage-mitigating measures via reinfiltration of water.

The final repository also entails other water operations such as filling of bodies of water within the operations area, utilization of rock spoil from the pier at SFR, excavation below the groundwater table for building foundations in the operations area, construction of a bridge across the cooling water channel, and regulation of Lake Tjärnpussen. In the case of Clab and Clink, cooling water intakes also comprise water operations.

The water operations are described in greater detail in the sub-appendices to the EIS /5-1, 5-2, 5-3/.

5.1.1 Clab

Clab is an existing facility situated adjacent to the Oskarshamn Nuclear Power Plant on the Simpevarp peninsula in Oskarshamn Municipality, see Figure 5-1. The spent nuclear fuel is interim-stored in pools in Clab. During interim storage, the radioactivity and heat output of the nuclear fuel decline, facilitating further handling. SKB is applying for a licence to continue operation of Clab. Clab currently has licences under the Nuclear Activities Act and the Environment Protection Act. The licences under the Environment Protection Act are considered to be issued under Chapter 9 of the Environmental Code. The reasons for the choice of the site for Clab are described in Section 5.2.1.

Clab consists of above-ground buildings and a storage section below ground. The buildings on the ground surface consist of an office building, electricity and auxiliary system facilities and a receiving section. The spent nuclear fuel arrives at the reception building and is placed in storage canisters. The storage canisters are then taken to an underground storage section for interim storage in storage pools. The storage section is located 30 metres below the ground surface and consists of two rock caverns with five pools each. The rock caverns are spaced at a distance of about 40 metres from each other, and the pools are connected by a water-filled transport channel. The water in the pools protects against radiation while cooling the fuel. The total permitted capacity is 8,000 tonnes of uranium.

Figure 5-1. Clab is situated on the Simpevarp peninsula. The Oskarshamn Nuclear Power Plant can be seen in the background.

5.1.2 Clink

SKB is applying for a licence to site the encapsulation plant adjacent to Clab, see Figure 5-2. Clab and the encapsulation plant will together function as an integrated facility called Clink. When the two facilities are integrated, existing systems and functions in Clab will be co-utilized wherever possible. The reasons for the choice of site are presented in Section 5.2.2.1.

Spent nuclear fuel is encapsulated in the encapsulation plant to permit disposal in a final repository in the bedrock. The building in which encapsulation will be carried out will be built in three storeys below ground and seven storeys above ground. The surface parts of the facility will house the encapsulation process and service and transport functions. A pool section will be built in the rock whose bottom will be 15 metres under ground. The pool section will be located above the rock caverns that hold Clab's pools.

Before the spent nuclear fuel is brought into the encapsulation plant it has been interim-stored in Clab to reduce its radioactivity and heat output. The nuclear fuel is transported from the storage pools in Clab to the handling pool in the encapsulation plant via an existing fuel elevator. The nuclear fuel is sorted in the handling pool and then dried. The dried nuclear fuel is placed in a nodular iron insert in a copper canister. When the canister is full, a steel lid is fitted on the insert. A copper lid is then welded onto the canister by friction stir welding.

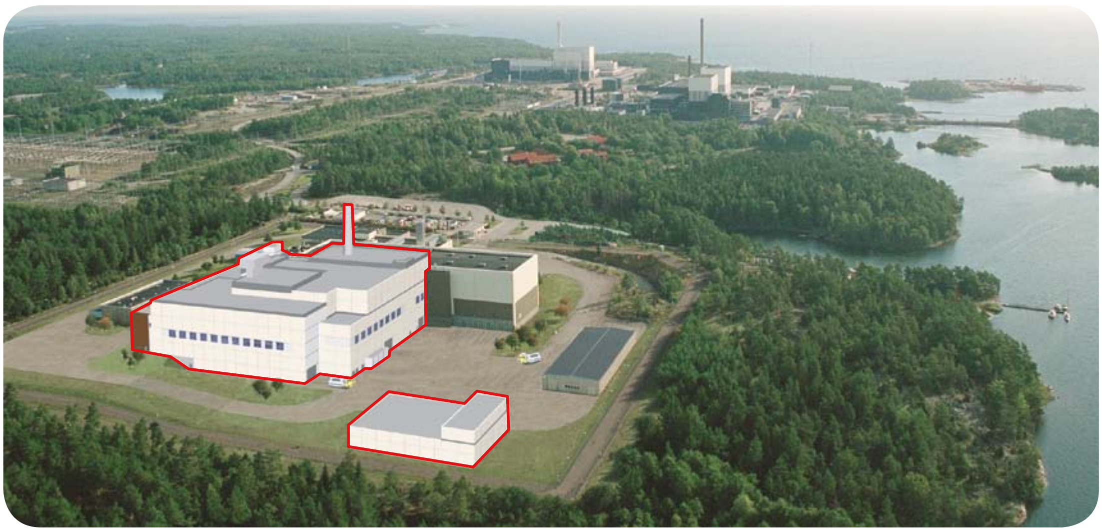


Figure 5-2. The encapsulation plant is located directly adjacent to Clab (photomontage). The red outline indicates the part of the picture that is a photomontage.

The canister is a cylindrical container consisting of a shell (overpack) of copper and a pressure-bearing insert of cast nodular iron. The insert is provided with channels for placement of fuel assemblies. The canisters, which are five metres long and have a diameter of about one metre, arrive ready-made at the encapsulation plant. The final product from the encapsulation plant is a filled copper canister placed in a transport cask and prepared for transport to the final repository.

5.1.3 The final repository

SKB is applying for a licence to locate the final repository for spent nuclear fuel in Östhammar Municipality in northern Uppland. The site is called Söderviken and is located within the Forsmark industrial area near the nuclear power plant and SFR, see Figure 5-3. The reasons for the choice of site are presented in Section 5.2.3.1.

Figure 5-3. The final repository will be located on Söderviken in Forsmark (photomontage) The Forsmark Nuclear Power Plant can be seen to the left. The red outline indicates the part of the picture that is a photomontage. The area at the bottom of the picture is the rock heap.

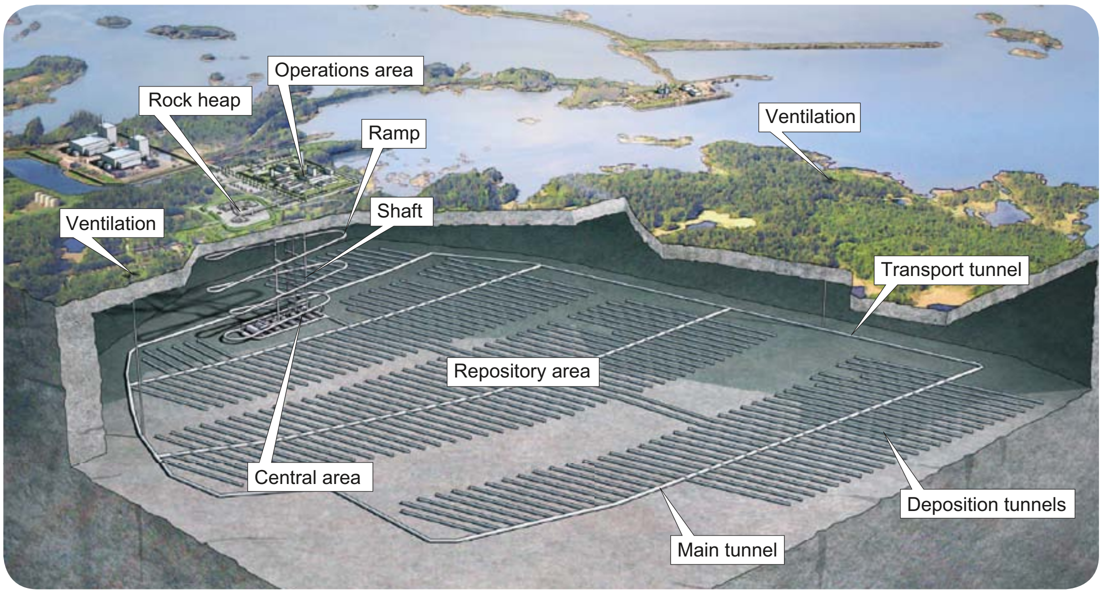


Figure 5-4. The final repository with surface and underground parts.

The final repository for spent nuclear fuel consists of a surface (above-ground) part and an underground part, see Figure 5-4. Most of the facility parts on the surface are gathered together in an operations area, which is divided into an outer and an inner part. The nuclear activities are conducted within the inner operations area, while the outer operations area houses other activities connected with the operation of the facility. In addition to the operations area, the surface part includes a rock heap and ventilation stations.

The underground part consists of a central area and a repository area plus connections to the surface part in the form of shafts for elevators and ventilation and a ramp for vehicle transport. The central area contains areas with functions for the operation of the underground part. The canisters will be disposed of in the repository area. The underground part in its entirety is a part of the nuclear facility, as are the ventilation stations that are connected to the repository area through ventilation shafts. The repository area contains main tunnels and deposition tunnels with deposition holes.

5.1.3.1 Reference design – KBS-3V

SKB's reference design, KBS-3V, is a KBS-3 repository with vertical deposition of the canisters in individual deposition holes in the floor of a deposition tunnel 200 to 300 metres in length. The deposition holes, which are spaced at a distance of six to eight metres from each other, have a diameter of 1.75 metres and a depth of about eight metres. The spacing between the deposition holes is dependent on such factors as the thermal conductivity of the rock on the site in question and the canisters' initial decay heat. When the canisters have been deposited in a deposition tunnel, it is backfilled with swelling clay and plugged at the connection to the main tunnel.

The canisters are surrounded by a buffer of bentonite that protects them, but also acts as a filter and prevents radioactive substances (radionuclides) from escaping in the event a canister is breached. The surrounding rock protects the canister and the buffer against external forces and retards the transport of radionuclides to the ground surface. The barrier function of the rock is replaced by backfill in the tunnels where canisters have been deposited.

5.1.3.2 KBS-3H – a variant of the KBS-3 method

KBS-3H is a variant of the KBS-3 method where the canisters are deposited in horizontal deposition drifts instead of in the vertical deposition holes (KBS-3V) in SKB's reference design. During the 1990s, SKB began to study the prospects of horizontal deposition as a part of the work of optimizing the design of the final repository. SKB and Posiva (Finland's equivalent to SKB) have since worked jointly to study the prospects of and develop the technology for horizontal deposition. The technology is not sufficiently developed today to be available. Considerable efforts remain to determine whether it can be used. Only when and if a safety assessment shows that KBS-3H offers equivalent or improved safety will a switch to horizontal deposition be considered.

5.1.3.3 Similarities and differences between KBS-3V and KBS-3H

There are many similarities between KBS-3V and KBS-3H, see Figure 5-5. The fuel is the same in both variants, as are the barriers canister, buffer and rock. Large parts of the facilities above and below ground are identical or similar. In KBS-3H, however, no deposition tunnels are needed; instead, 100–300-metre long deposition drifts are bored directly from the main tunnel. The deposition technology differs as well. Packages (called supercontainers) consisting of a canister surrounded by bentonite buffer and a perforated steel cylinder are emplaced in the KBS-3H deposition drifts. A distance block of bentonite clay is placed between successive supercontainers to seal the tunnel so that water flow along the tunnel is prevented and the temperature in the buffer does not get too high. A drift end plug is installed in the mouth of the deposition drift. The plug holds the supercontainers and distance blocks in place until the main tunnel is backfilled. The deposition drifts may be spaced at a distance of 25–40 metres, depending on the properties of the rock /5-4/.

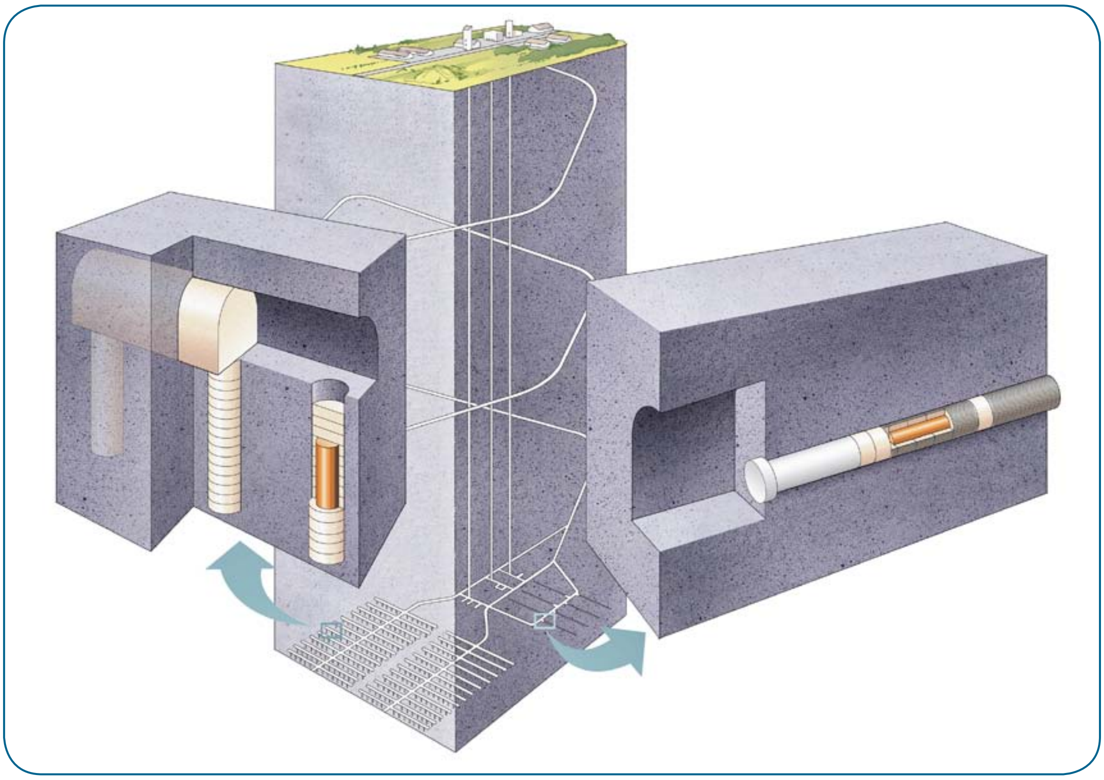


Figure 5-5. Deposition in vertical holes (KBS-3V) and in horizontal drifts (KBS-3H). The variants have great similarities since fuel, canister, buffer and rock are the same and large parts of the surface and underground parts are identical.

Due to the differences in design between the two variants, their environmental impact may differ somewhat, see below. Other aspects that can differ are working environment and safety during operation. The long horizontal deposition drifts in KBS-3H offer difficult working conditions for grouting and other work in the deposition drifts. Moving supercontainers and distance blocks is associated with a number of risks.

Environmental impact

The biggest difference in environmental impact between KBS-3H and KBS-3V lies in the handling of excavated rock and clay. There are no deposition tunnels in KBS-3H, which means that the quantity of excavated rock is reduced by about 50 percent and less clay is needed for backfilling.

The reduced handling of rock spoil and clay means that the heavy transport volume to and from the final repository is reduced by about a third compared with KBS-3V. A smaller rock extraction volume also reduces the quantity of leachate from the rock heap that needs to be treated to remove nitrogen in particular. It has not been possible to assess possible differences in groundwater lowering, since KBS-3H entails changes in the layout of the facility and a great deal of work remains before the necessary information is available. If a switch to KBS-3H is made after the facility is commissioned, parts of it will already be designed for KBS-3V. The point in time of the switch to KBS-3H therefore determines how great the difference in environmental impact will be.

Long-term safety

A preliminary assessment of long-term safety for KBS-3H has been carried out under the leadership of Posiva /5-4/. The assessment was done for a final repository in Olkiluoto, Finland, and is based on site data from there and a preliminary reference design for KBS-3H. The main conclusion of the assessment, which focused on features and processes specific to KBS-3H, is that KBS-3H offers an opportunity to meet the requirements on safety for a final repository in Olkiluoto. However, further research, development and demonstration are required in order for a comprehensive safety assessment to be done.

In the continued development work on KBS-3H, a site-specific safety assessment will be done for Forsmark. The purpose is to be able to compare the safety of the two variants (KBS-3V and KBS-3H) on the selected site for the final repository. SKB's work with KBS-3H is being conducted and the results reported within the framework of the RD&D programme, and the variant will not be dealt with in greater detail in the licence applications.

5.2 Reasons for siting and design

Reasons for the chosen siting and design of Clab, the encapsulation plant and the final repository are given in this section. The siting of the facilities is based on requirements in applicable laws and regulations. The Environmental Code states the general principle that the site shall be chosen in such a way as to make it possible to achieve the purpose of the activity with a minimum of damage or detriment to human health and the environment. The site must also be suitable and the requirement of minimum damage or detriment shall be weighed against the labour input that is required.

5.2.1 Clab

When Clab was to be built, SKB studied alternative storage possibilities for spent nuclear fuel. The alternatives studied were:

- Increasing the storage capacity of existing pools at the nuclear power plants.
- Construction of a local storage facility at each nuclear power plant.
- Construction of a central storage facility for all nuclear power plants.

At every nuclear power plant there is a storage pool for spent nuclear fuel to enable the reactor to be emptied of fuel if necessary and for storage of the spent nuclear fuel before it is sent to interim storage. The storage capacity of existing pools at the nuclear power plants was increased by installing more space-saving fuel racks, but this resulted in a relatively small capacity increase.

Constructing new storage pools adjacent to existing pools at the reactors was considered more complicated. Local storage facilities at the nuclear power plants would therefore need to be designed as separate facilities, with a design similar to that of a central storage facility, but with less capacity.

The cost of a central storage facility was estimated to be much lower than the total cost of local storage facilities at each nuclear power plant. Permanent installations, such as a receiving station for transport casks and most of the auxiliary systems, which were dominant costs, would only need to be built once. There were also co-storage gains to be made with regard to pool size. A central storage facility would, however, require more expensive transport equipment, but this was a small fraction of the total cost.

In the selection of a site, several factors judged to be essential were studied:

- National physical planning guidelines.
- Prerequisites for co-siting with other nuclear activities.
- Employment and municipal services.
- Regional policy planning.
- Technical and economic considerations.
- Suitable bedrock.

It was concluded that a co-siting with reactors had clear advantages, since harbours, roads, electricity and water supply, waste management, and control and surveillance functions could be co-utilized. A co-siting would also reduce the transport volume between the nuclear power plants and Clab. A siting at the Ringhals and Barsebäck Nuclear Power Plants was rejected. There was no room for an interim storage facility at Ringhals due to the fact that the possibilities of expansion were limited by the presence of a nature reserve and existing development. In Barsebäck, the rock was unsuitable for underground construction. The alternatives remaining for further study were Forsmark in Östhammar Municipality, Studsvik in Nyköping Municipality and Simpevarp in Oskarshamn Municipality. The three alternative sitings were assessed on the basis of such factors as land availability, geological conditions, harbour capacity, conditions in navigation channels, and options for utilities supply and waste management. Based on the results of a feasibility study, all three siting alternatives were deemed suitable. The investment costs were judged to be equivalent for sitings at Forsmark and Simpevarp, while a higher investment cost was estimated for Studsvik. From the viewpoint of the bedrock, Simpevarp was deemed to have better prospects for building the necessary rock cavern, so SKB applied for – and received – the Government's permission to build Clab in Oskarshamn.

Today about 5,000 tonnes of uranium is stored in Clab's pools, and the permitted capacity is 8,000 tonnes. The logistics for transporting the spent nuclear fuel to Clab works smoothly. The activity has been conducted in compliance with the licences and conditions for the facility. Building a new facility at another site to provide all or parts of the interim storage capacity that exists at Clab would lead to environmental impact during the construction phase, and if spent nuclear fuel had to be moved to the new facility, this would entail increased radiation doses to personnel. The shipments would also entail environmental impact in the form of atmospheric emissions and noise. There would also be two facilities to dismantle after the interim storage facilities were emptied and the spent nuclear fuel had been placed in the final repository, which would also lead to increased quantities of decommissioning waste to be disposed of.

SKB therefore concludes that no other solution than retaining Clab as an interim storage facility for spent nuclear fuel is environmentally warranted or economically defensible.

5.2.2 Encapsulation plant

5.2.2.1 Reasons for applied-for siting

Sites which SKB has judged to be reasonable alternatives for location of an encapsulation plant are either adjacent to Clab, where the spent nuclear fuel is today, or adjacent to the future final repository. In this way the transport need can be minimized and land use and environmental impact can be limited. At the time when SKB chose to locate the encapsulation plant adjacent to Clab, it had not yet been decided where SKB intended to locate the final repository. It was concluded that this location was reasonable, regardless of where the final repository was ultimately located. With a siting at Clab, the experience of the personnel with fuel handling can be taken advantage of at the same time as SKB can utilize the existing systems and plant parts in Clab for the encapsulation plant as well. A siting at Clab means that spent nuclear fuel can be transferred from interim storage to encapsulation directly via a fuel elevator. Only encapsulated spent nuclear fuel needs to be transported outside of the facility, to the final repository. Now that SKB has chosen to apply for a licence to locate the final repository in Forsmark, the assessment that a siting of the encapsulation plant adjacent to Clab is the best is still valid.

5.2.2.2 Reasons for applied-for design

Handling method

In the applied-for siting of the encapsulation plant adjacent to Clab the fuel would be handled wet in a pool, whereas handling would be dry in an encapsulation plant in Forsmark.

Building a pool in the encapsulation plant entails a slightly greater environmental impact during the construction phase, since it involves blasting and crushing of rock for shaft construction. It will also be necessary to haul away the rock in heavy haulage vehicles during the construction phase. The advantage of wet handling is that the spent nuclear fuel can be transferred from the pools in Clab to the encapsulation plant via a connecting pool.

Dry handling of the fuel between Clab and an encapsulation plant, regardless of where the latter is situated, entails increased handling of fuel and thereby higher radiation doses to personnel.

In view of the above, SKB has found that wet handling is more advantageous in the encapsulation plant. The Environmental Impact Statement therefore assumes wet handling of the fuel in a pool in the encapsulation plant at Clab.

Welding method

The welding method for sealing the copper canisters influences the design and activities of the encapsulation plant. SKB has developed two alternative welding methods: electron beam welding and friction stir welding.

In 2005 it was decided that friction stir welding would be the reference method used to design the encapsulation plant. The main reason is that the method has clear advantages as regards repeatability and stability in the process and reliability of the welding system.

Environmental impact was one of the criteria in the evaluation of the methods. It was concluded that material consumption is slightly higher for friction stir welding, due to the short life of the tools. Furthermore, a larger quantity of copper is consumed because a thicker copper lid is required. Energy consumption is also slightly higher for friction stir welding. There are no emissions to air, however. Electron beam welding gives rise to small emissions of copper vapour to air and waste in the form of filters containing copper. Due to the reliability of the welding systems, there may also be fewer rejected canisters if friction stir welding is used. The lower percentage of rejected canisters is advantageous from a resource consumption viewpoint. The higher reliability is also positive from a radiation protection viewpoint, since it reduces the probability that fuel-filled canisters will need attention. Friction stir welding has therefore been assessed to be the best available technology overall for joining the copper lid to the copper canister.

5.2.3 Final repository

5.2.3.1 Reasons for applied-for siting

The purpose of the final repository is to achieve a long-term safe disposal of the spent nuclear fuel. The basic prerequisite on the site selected for the final repository is therefore that it must have a bedrock suitable for this. In order for the site to be accessible and the project to be feasible, there must also be political and public acceptance in the concerned municipality and among nearby residents.

These basic prerequisites have guided the step-by-step multi-year siting procedure, where the final step has been a comparative evaluation of the siting alternatives of Forsmark and Laxemar /5-5/. SKB has judged the requirement of local acceptance to be well met for both alternatives, and this has therefore not been a differentiating factor in the final choice. The central factor has been the prospects for achieving long-term safe disposal, but other aspects have also been taken into consideration, such as harmony with the surrounding landscape and efficiency in the execution of the project. SKB's strategy for choosing between Forsmark and Laxemar can thus be summarized as follows:

- The site that offers the best prospects for achieving long-term safety in practice will be selected.
- If no decisive difference is found between the sites in terms of their prospects for achieving long-term safety, the site that is judged to be the most favourable from other aspects for accomplishing the final repository project will be selected.

In order to be able to apply this strategy, the sites have been compared systematically with respect to all factors that can be of importance for the overall evaluation. Figure 5-6 shows the set of siting factors, divided into four main groups, on which this comparison was based. It should be emphasized that the factors in themselves do not provide any guidance as to what SKB considered

SKB's siting factors

Technology for execution
- Flexibility
- Technical risks
- Technical development needs
- Functionality, operation
- Synergies
- Costs

Environment and health
- Occupational safety and radiation protection
- Natural environment
- Cultural environment
- Residential environment
- Resource management

Safety-related site characteristics
- Bedrock composition and structure
- Future climate evolution
- Rock mechanical conditions
- Groundwater flow
- Groundwater composition
- Solute transport
- Biosphere conditions
- Site understanding

Societal resources
- Suppliers, competence management
- Public and private services
- Transport and communications

Figure 5-6. Factors that have served as a basis for comparison of siting alternatives prior to site selection.

more or less important, what decided the site selection, or in what way. The siting factors should be regarded as a framework for structured comparisons between the sites, where different aspects were compared individually and in a systematic fashion.

In summary, the comparisons with respect to the siting factors in Figure 5-6 have provided a a comprehensive basis for integrated evaluation and site selection. Based on this, SKB has drawn the conclusion that Forsmark provides clearly superior prospects for achieving long-term safety than Laxemar. The single factor that is most advantageous for Forsmark is a considerably lower frequency of conductive (water-conducting) fractures in the rock at repository depth. This can be clearly seen in the comparative assessments of long-term safety that have been done /5-6/. The rock conditions in Forsmark also provide prospects for a more robust and efficient execution than in Laxemar. In keeping with the first point in the aforementioned strategy, SKB has therefore chosen to locate the final repository at Forsmark.

The industrial prospects for establishing and operating the final repository are deemed to be very good at both sites. The differences that do exist have not been accorded any decisive importance for site selection. The differences in impact on the environment and human health are also small. A description of the consequences for environment and health of a final repository in Forsmark versus Laxemar is provided in Chapter 10.

5.2.3.2 Reasons for applied-for design

The layout of the underground parts of the final repository in Forsmark is based on the requirement that all facility parts must fit within the part of the so-called tectonic lens that was identified prior to the site investigation. The reason is that conditions in the rock inside the lens are more favourable than in the rock outside the lens, some of which is heavily deformed bedrock. The site investigation provided a basis for a layout where all facility parts under ground are accommodated within the northwest part of the initially investigated area, see Section 3.8.1. The space there was considered sufficient and permitted a layout where the surface facilities could be located on existing industrial land.

With the location of the underground part of the facility as a point of departure, site adaptation of the final repository has been executed in two stages, called D1 and D2. Two alternative proposals were arrived at in stage D1 for the system design, i.e. the locations of the surface facilities and solutions for communication between them and the repository. In one alternative, most of the facilities were located adjacent to SFR. In the other alternative, the surface facilities were gathered in an operations area east of the entrance to Forsmark on the south part of the industrial area (where there is a barracks village for temporary accommodation today), see Figure 5-7. After a comparative evaluation, the location at the entrance was prioritized.

An important argument for prioritizing the entrance location was that this area has the "right" location in relation to the repository's central area so that rock haulage can take place via a vertical skip shaft. This provides substantial operational advantages in comparison with a layout where all heavy goods have to be transported via a ramp. Other arguments for this choice were better access to areas so that handling and temporary storage of rock spoil can take place directly adjacent to the operations area, and that all activities can be gathered in one operations area. This reduces the overall transport need /5-7/.

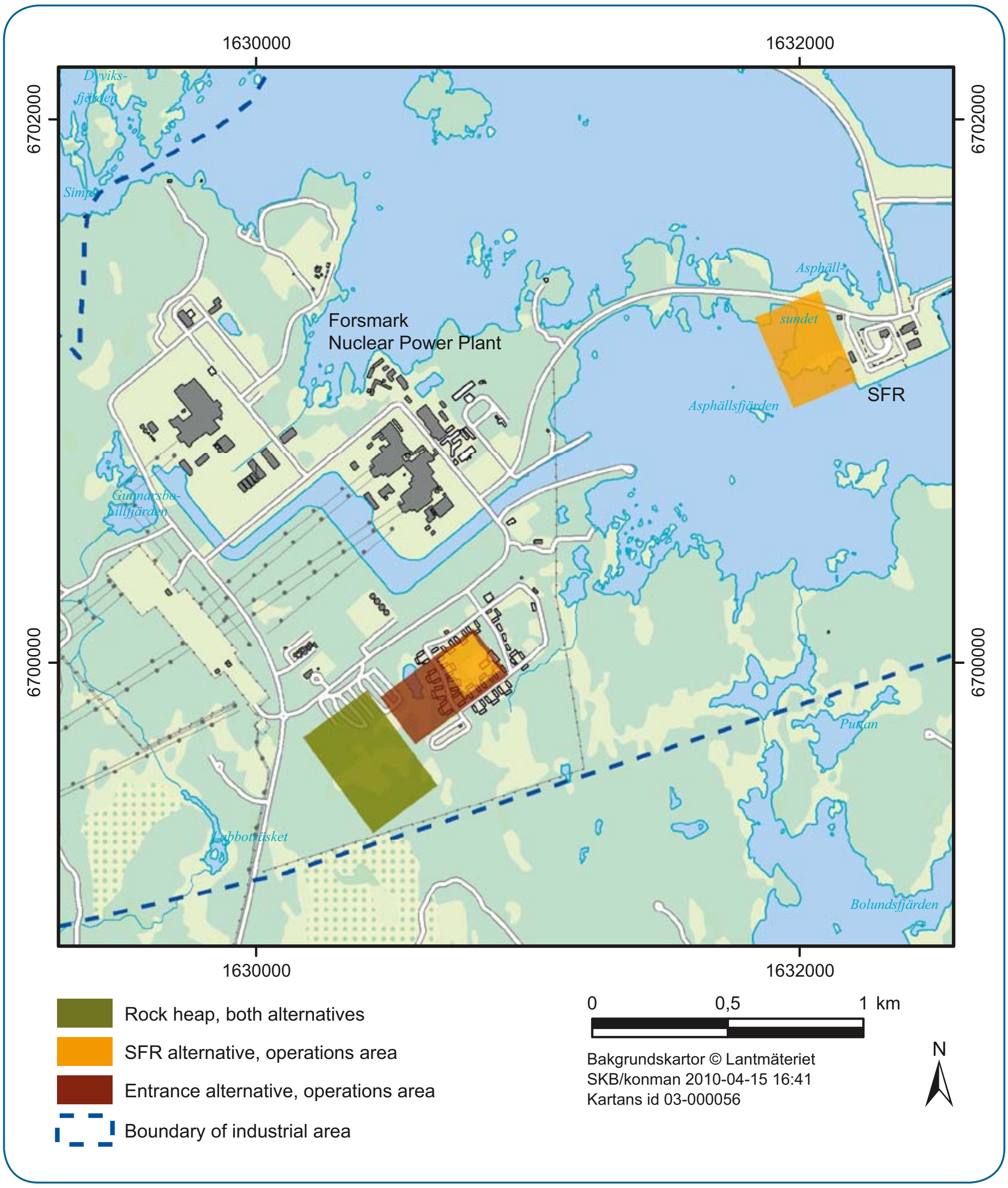


Figure 5-7. Locations by entrance and SFR. Two operations areas are needed for the SFR alternative (the yellow boxes in the figure, one of which overlaps with the operations area for the entrance location) while with the entrance location, all facilities can be gathered in one operations area (the reddish brown boxes in the figure). The entrance location was prioritized after comparative evaluation.

In design stage D2, all parts of the repository were revised and designed in detail taking into account the additional data. One change was that the depth of the repository was increased from 400 metres to 450–500 metres. One reason for this was that the rock stresses were judged to increase less with depth than had previously been assumed, and another that the frequency of water-conducting fractures decreases radically below a depth of 400 metres.

With the start of design stage D2, the improved body of geological data made it possible to optimize the location and layout of an operations area within the larger area previously identified at the entrance. This led to the identification of three possible locations – the Channel, the Barracks Village and Söderviken – with different locations for descents and central area. See Figure 5-8. The differences in the layout of the rest of the repository were marginal and only affected the northwest part of the repository. The prospects for long-term safety were thereby judged to be equivalent.

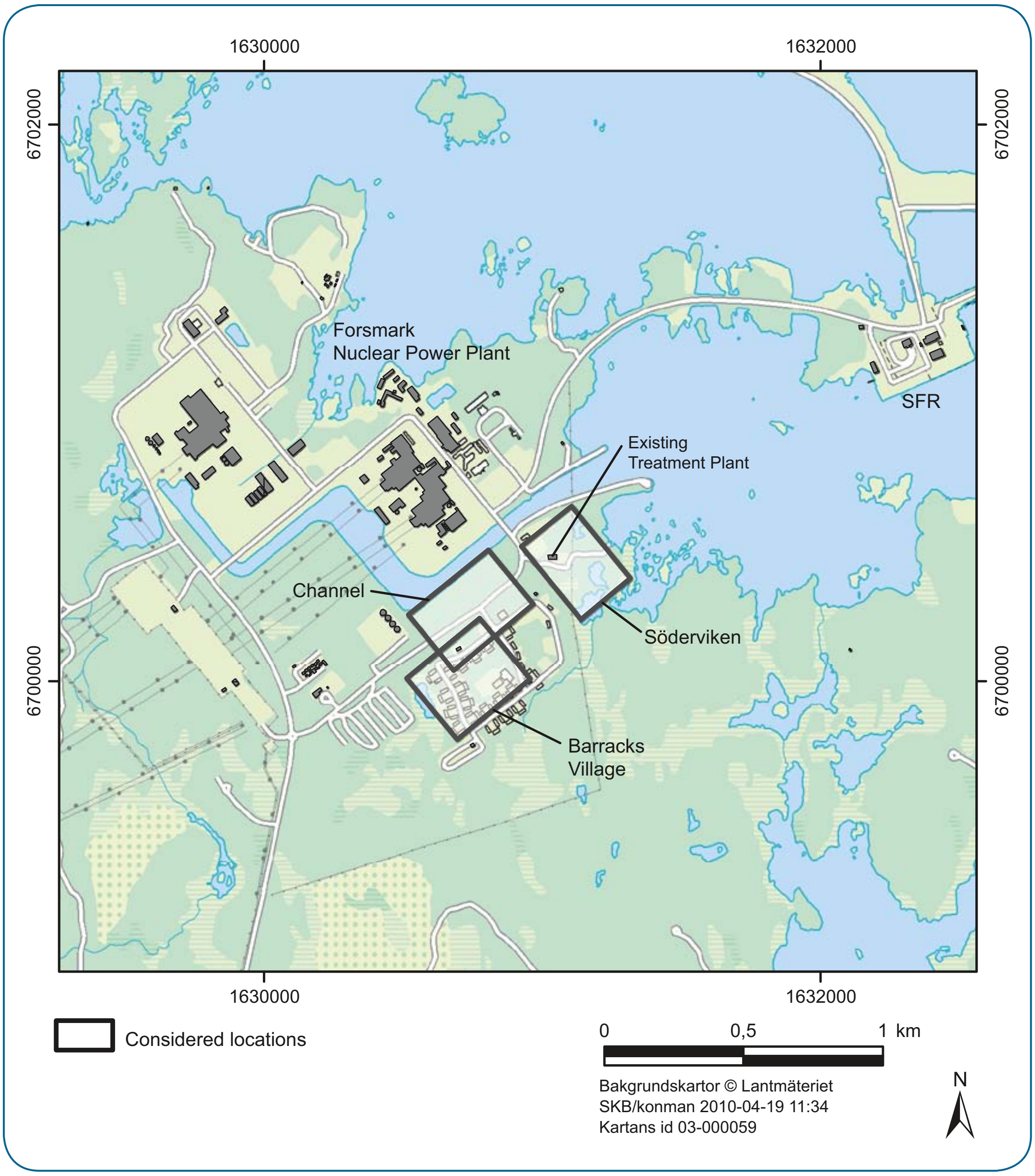


Figure 5-8. Map with the considered locations Channel, Barracks Village and Söderviken within the entrance location in Forsmark.

The main reasons for considering different alternatives within the entrance location were the fact that the upper part of the bedrock (called fracture domain FFM02 in Figure 5-9) is locally heavily water-conducting, and that the thickness of the water-conducting fracture domain decreases towards the north and northeast. In the Barracks Village location, the thickness of this part of the bedrock is therefore greater than in the other two locations, the Channel and Söderviken, see Figure 5-9.

Locating the descents at the Barracks Village would entail a longer passage through the water-conducting fracture domain FFM02, which would require more work to seal the rock and limit the inflow of water than in the other two locations. This would also entail a greater risk of technical problems, delays and cost overruns. The Channel and Söderviken were thus deemed to be clearly superior to the Barracks Village. A similar conclusion applied to rock stability and rock support needs. Here as well the Channel and Söderviken have advantages, mainly because the section of the ramp that needs to be built in the water-conducting superficial fracture domain will be shorter.

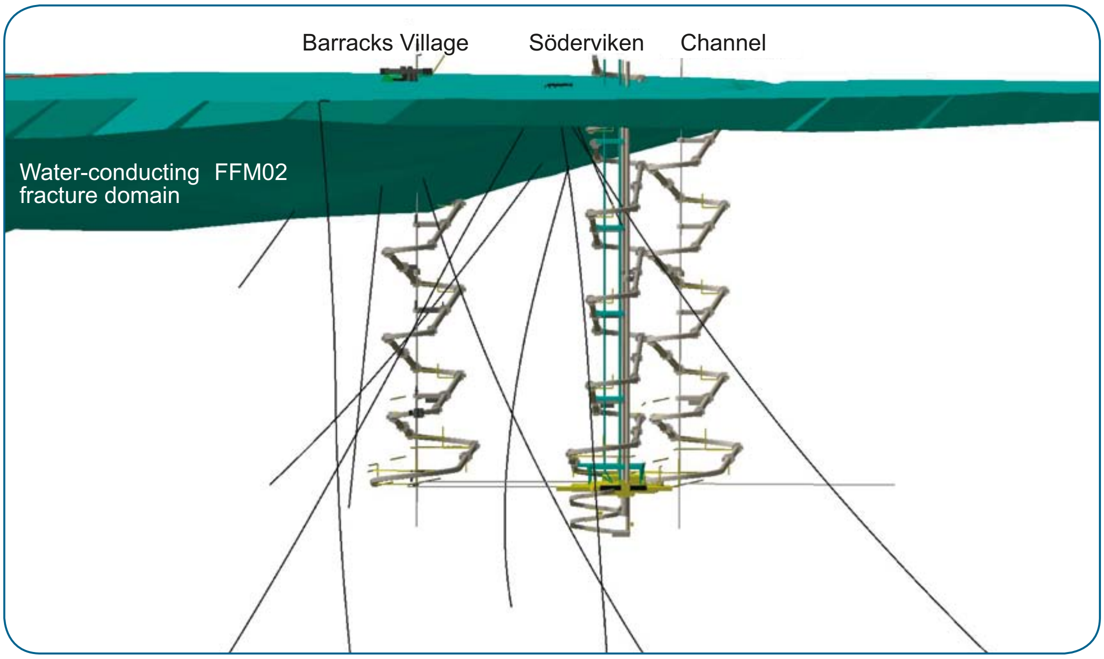


Figure 5-9. Shaft and ramp locations for the three alternative positions of the surface parts of the final repository in relation to the water-conducting fracture domain FFM02. View from northeast.

The Channel and Söderviken alternatives also differ in a number of respects. Under ground the Channel necessitates a greater number of passages through the steeply dipping deformation zone called ENE1061A in Figure 5-10, while the layout for Söderviken only comes into contact with this deformation zone near the central area /5-8/. As illustrated in Figure 5-10, Söderviken is the location that best avoids the area's steeply dipping deformation zones, offering advantages for constructability. Another disadvantage of the Channel is its very nearness to the cooling water channel, with an increased risk of hydrological contact within the fracture domain FFM02 and thereby inflow from the cooling water channel. Above ground the Channel has other drawbacks in relation to Söderviken due to nearness to the channel, the oil depot and the nuclear power plant's surface facilities on the other side of the channel. This creates difficult-to-assess risks of mutual interference and dependence. The original planning of the area is affected negatively and changes are required in the existing infrastructure.

An overall assessment of conditions above and below ground shows that Söderviken is the most advantageous location with respect to function and execution and it was therefore chosen by SKB for the final repository. The chosen location is not expected to entail any significant difference in environmental impact compared to the other locations considered. The considered locations mentioned in this section are therefore not further described in the EIS.

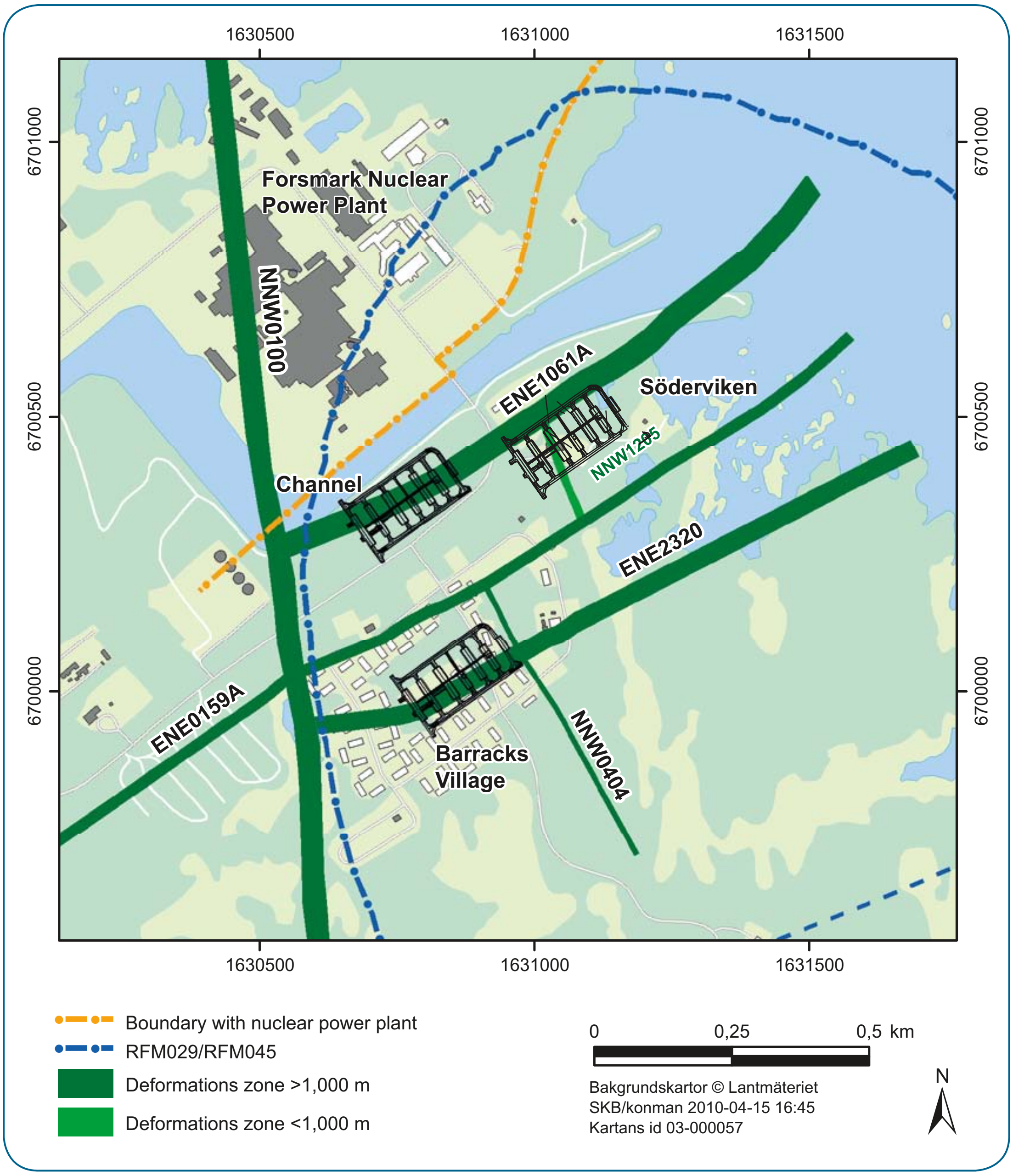


Figure 5-10. Siting of the central area under ground in relation to the area's deformation zones and the rock domains RFM029 and RFM045.

The Söderviken location utilizes existing infrastructure in a good way, but nevertheless permits a clear distinction between the activities of the nuclear power plant and of the final repository. The activities can thereby be developed independently of each other, and the risks of interference are minimized. Another bridge nearer the channel mouth will make transportation between the final repository/rock heap and SFR independent of the existing bridge. The sewage treatment plant and the communication mast must be moved to make room for the final repository, but SKB's and Forsmarks Kraftgrupp AB's joint assessment is that this is technically manageable and economically affordable. A disadvantage is the need for construction fill for establishment of the operations area. A body of water will be filled, and the near-shore environment will be affected. The consequences of this, and measures to mitigate the environmental impact of the operation, are described in the impact assessment of the applied-for activity, Section 10.1.4.

5.3 Alternative siting and design

This section provides a brief description of the alternative sitings and designs that have been considered. Most of the alternative solutions which SKB has considered comprise detailed designs when from the perspective of the KBS-3 system as a whole and are not judged to constitute alternative designs in relation to the applied-for activity in the sense of the Environmental Code. Critical choices are therefore described in another appendix to the applications /5-9/ and are justified with reference to the Environmental Code's provisions and use of "best available technology" (BAT).

5.3.1 Clab

Prior to the construction of Clab, the siting was the subject of a preliminary study that was presented in 1977 /5-10/. The feasibility study resulted in three alternatives that were further investigated: Simpevarp in Oskarshamn Municipality, Forsmark in Östhammar Municipality and Studsvik in Nyköping Municipality. Clab was built in Simpevarp between 1980 and 1985.

This EIS does not include an impact assessment of alternatives considered for siting of Clab.

5.3.2 The encapsulation plant

SKB has studied a siting of the encapsulation plant in the vicinity of the nuclear power plant in Forsmark, which means that Clab and the encapsulation plant would be located at two different sites. The proposed site has been adjusted slightly in relation to the one reported as an alternative siting in the Environmental Impact Statement for the encapsulation plant which SKB submitted in conjunction with its application under the Nuclear Activities Act in 2006. This is due in part to the fact that Forsmark Kraftgrupp AB is planning a building for temporary storage of radioactive waste within the area. In the new location, the proposal is that the encapsulation plant should be located northeast of reactor unit 3. At an encapsulation plant in Forsmark, fuel reception would be dry in order to avoid having to build a pool in the Forsmark plant with the necessary cooling and waste management systems. The spent nuclear fuel would instead by dried in Clab before being transported to the encapsulation plant.

The design of an encapsulation plant located in Forsmark – along with its impact, effects and consequences – is described in Section 9.2.

5.3.3 The final repository

As described previously in the section on site investigations (3.8), SKB has also conducted a complete site investigation at Laxemar in Oskarshamn Municipality. Within the investigated area, SKB has studied a number of locations for an above-ground operations area, with associated underground central area, for a final repository. The site studied by SKB in Laxemar was chosen because it has good bedrock conditions for construction of shafts and tunnel ramp, and the distance to the encapsulation plant would be short. Laxemar is therefore the siting alternative for the final repository in Forsmark that is described and impact-assessed in this Environmental Impact Statement. The design of a final repository located in Laxemar – along with its impact, effects and consequences – is described in Section 10.2.

5.4 Zero alternative

The zero alternative describes what will probably happen if the encapsulation plant and the final repository are not realized, which would mean that the spent nuclear fuel would continue to be stored in Clab. The consequences of the zero alternative are described in Chapter 11.

The description of the zero alternative is based on a reference scenario with 50 years of operation of the reactors in Forsmark and Ringhals and 60 years of operation of the reactors in Oskarshamn. There will not be room in the existing facility for the quantity of spent nuclear fuel that is produced in the reference scenario, and steps will have to be taken in the event of any delays in the construction of the encapsulation plant and the final repository. The capacity of Clab can be increased to 10,000 tonnes by using compact storage canisters, similar to those that are already stored in Clab today, for all fuel. However, increasing the capacity of Clab would require a change in the operating licence and an extension of the cooling chain. If this is done, Clab could receive fuel for another 10 years or so. It is also possible to extend Clab with a third rock cavern with storage pools if this should prove necessary. Such an extension is technically possible. Storing the spent nuclear fuel in Clab requires monitoring and maintenance. If this is maintained, the life of Clab is estimated to be 100–200 years, provided that certain installations are gradually replaced /5-11/.

Swedish legislation contains general requirements on management of spent nuclear fuel. The Nuclear Activities Act states that the holder of a licence for nuclear activities shall make sure that any resulting spent nuclear fuel is disposed of in a safe manner. The final repository shall be based on passive barriers and not require monitoring and maintenance. Continued storage in Clab does not meet the requirements made on final disposal, but simply entails a postponement of a final solution.

Sweden has signed the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 5 September 1997 (the Nuclear Waste Convention) /5-12/. According to this Convention, as mentioned in Section 2.1, the signatory countries shall take the appropriate steps to avoid imposing undue burdens on future generations. SKB has interpreted this pledge to mean that the waste problem shall in all essential respects be solved by the generations who have benefitted from the nuclear power.

Owing to the generation aspect and the requirements that are made on a final repository, continued storage in Clab is not a viable option. The zero alternative should therefore be regarded merely as a comparison alternative in relation to other alternatives described in the EIS.

If the applications are rejected, technology development work will continue to be pursued at SKB to find new solutions to the problem of final disposal of spent nuclear fuel, after which a new application will probably be submitted. The direction and time horizon of such development work is impossible to predict, much less to impact-assess, today. Continued storage in Clab is therefore the scenario that has been deemed reasonable and possible to describe and impact-assess within the framework of the zero alternative.

The description of the effects and consequences of the zero alternative includes an account of a) continued normal operation of Clab and b) sudden abandonment. The reason for describing effects and consequences of sudden abandonment is to illustrate what would happen if Clab should for some reason suddenly have to be abandoned in the future without an opportunity to adopt protective measures.

The zero alternative also includes a description of the probable evolution of the planned siting areas (for the encapsulation plant and the final repository with associated rock heaps and access roads) if the facilities are not built. The description is based on the assumption that today's land use will continue, which is in line with current municipal plans. The time frame for the description of the evolution of the site is 60 years, the time period for which the final repository system is planned to be operated.

6 Scope

This chapter describes the scope of the EIA work in time, space and subject matter. The scope is determined by the planned alternatives and their siting as well as by considered alternatives.

6.1 Scope of the activities

The EIS covers interim storage, encapsulation and final disposal of spent nuclear fuel and the facilities that exist or are planned for these purposes (Clab, the encapsulation plant and the final repository).

According to Chapter 16, Section 7 of the Environmental Code, the activities shall be assessed with a view to consequential activities that are necessary in order for the applied-for activity to be pursued in an efficient manner. However, the scope of the assessment must be limited so that only consequential activities with an immediate connection to the applied-for activity are considered. Based on this, the scope of the EIS includes consequential activities in the form of transport to and from the facilities as well as water operations, see Figure 6-1. Activities that are not included in the EIS, the nuclear power plants, mining of copper and iron for fabrication of canisters, canister fabrication, mining of bentonite for the final repository and facilities for disposal of operational and decommissioning waste (SFR and the final repository for long-lived low- and intermediate-level waste) are commented on in Sections 6.1.1 to 6.1.3.

The section on cumulative effects (Section 12.2) describes the activities that already exist in connection with the planned facilities for interim storage, encapsulation and final disposal of spent nuclear fuel, as well as those that can be expected to be started on the site during the time the facilities are being built and operated. By cumulative effects is meant in the EIS context how an activity or a measure, together with other ongoing and future activities, affects the environment in an area.

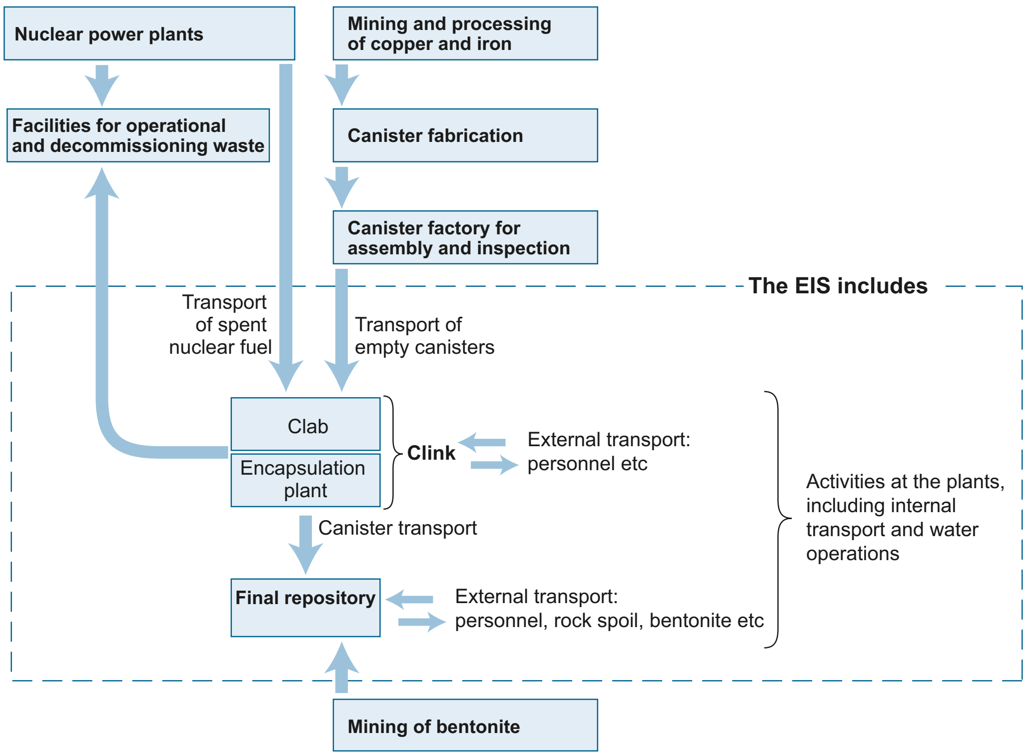


Figure 6-1. Scope of activities and facilities described within the framework of the Environmental Impact Statement.

6.1.1 The nuclear power plants

The nuclear power plants from which the spent nuclear fuel is delivered are not included in the EIS, since they have their own licences and other operators are responsible for the activities there.

6.1.2 Raw materials and canister fabrication

Mining of copper and iron for canister fabrication, as well as canister fabrication itself, are not included in the EIS. Production and inspection of the canister will take place in the canister factory that will be built in Oskarshamn Municipality. The canister factory will be dealt with later in a separate process under the Environmental Code. Suppliers of canister components will be selected when construction of the encapsulation plant begins.

Mining of bentonite also lies beyond the scope of the EIS, as does sea transport of materials such as bentonite from the mine to a port in Sweden.

6.1.3 Facilities for operational and decommissioning waste

Short-lived low- and intermediate-level waste arises during operation of Clab and the encapsulation plant and decommissioning of these facilities.

The low-level waste is taken to an existing near-surface repository for low-level waste (MLA) located next to the tunnel portal to Äspö on the Simpevarp peninsula. The short-lived radioactive waste is taken to SFR in Forsmark. SFR will be extended to accommodate the decommissioning waste as well. The facilities for operational and decommissioning waste have their own licensing processes and are not dealt with in this EIS.

Siting and construction of the facility for disposal of long-lived low- and intermediate level waste lie far in the future and are not dealt with in this EIS.

6.2 Scope of impact, effects and consequences

The terms **impact, effect and consequence** are central in environmental impact assessments. An environmental impact is a physical change in the environment. The change can lead to a deterioration in environmental quality (an environmental effect), which can in turn have environmental consequences for certain interests /6-1/. An example of how the three terms impact, effect and consequence are used in this EIS is given in the following:

Impact is the physical change caused by a facility, for example if the groundwater has to be diverted, this can cause groundwater lowering.

The effect of this groundwater lowering is the drying-up of wetlands, which changes the living conditions for the animals and plants in the wetland.

The consequence is an evaluation of the effect in terms of what it means for different interests. This evaluation is based on the size and duration of the impact and the effect, as well as on the presence of interests worthy of protection in the concerned area. In the example involving groundwater lowering, the affected wetland is evaluated based on whether it is a rare habitat, whether it harbours species worthy of protection, and its importance for the natural environment and biodiversity in the area where it occurs.

Both direct and indirect effects are included in the assessment, even if they are not referred to specifically as direct or indirect in this EIS. Indirect effects arise either as a consequence of a direct effect or as the result of a consequential activity.

Impact, effects and consequences described in the EIS are based on an assessment of what can give rise to significant environmental impact. Groundwater lowering is a type of impact that can be expected to be significant. In other cases there may be a risk of significant environmental impact, for example noise disturbances, which is why this is studied in the EIS so that it can be determined whether significant environmental impact can arise. Furthermore, the questions that have been posed in the consultations that are a part of the EIA process have determined some of the content of the EIS. As a result, some environmental aspects, such as light pollution, are described in the EIS despite the fact that the environmental impact is not significant in SKB's opinion.

The EIS includes a description of impact, effects and consequences under normal conditions and in connection with possible disturbances and accidents. The latter are described in special sections on risk and safety, which deal with both radiological and non-radiological aspects.

The impact and and the effects and consequences that are assessed to be relevant to describe in the EIS are shown in Table 6-1.

Table 6-1. Scope in description of impact, effects and consequences as well as risk and safety for Clab, Clink and the final repository.

	Clab	Clink	Final repository
Impact			
Land use		•	•
Impact on groundwater level	•	•	•
Noise and vibration	•	•	•
Radiation and releases of radionuclides	•	•	•
Emissions of other substances to air	•	•	•
Discharges of other substances to water	•	•	•
Light pollution		•	•
Resource consumption	•	•	•
Effects and consequences			
Natural environment	•	•	•
Outdoor activities and recreation			•
Cultural environment		•	•
Landscape	•	•	•
Residential environment and health	•	•	•
Risk and safety			
Non-radiological risks	•	•	•
Radiological risks during operation	•	•	•
Long-term safety			•

Land use is not described for Clab, since no new land is used. No significant consequences are expected to arise for the cultural environment and the landscape or for outdoor activities. Consequences for the natural environment are described with a view to the noise impact and the discharges to water that occur from the facility. As regards the final repository, it can be noted that releases of radionuclides during normal operation consist of radon that is emitted by the bedrock. The spent nuclear fuel will be encapsulated and will not give rise to any radioactive releases to the environment. Extraordinary events are analyzed for the operating phase and after closure of the final repository (long-term or post-closure safety).

6.3 Geographic scope

The geographic scope defines the area that will be affected by the planned activities.

6.3.1 Siting area

The siting area is the area where the facilities are located plus the surrounding land areas where there is a risk of direct physical disturbance during the construction work. Land use can entail consequences for the cultural and natural environments. Detailed studies in the form of archaeological surveys and inventories of natural assets have therefore been carried out within the siting area as a basis for the impact assessment.

6.3.2 Impact area

The impact area is defined as the area where disturbances of various kinds (groundwater lowering, noise, vibration, light pollution, and air and water pollution) can impact the environment. The impact area differs in size for different types of impact. Some impact, such as groundwater lowering and noise from the facilities, occurs in the environs of the siting area. Another type of impact occurs farther away from the facilities. Examples are bodies of water that are receiving bodies for discharges from the facilities or roads that are used for transport to and from the facilities. The transport roads are included in the impact area due to the fact that the transport causes noise, vibration and atmospheric emissions (see Section 6.3.4 on transport).

The term "critical group" is used to describe the effect releases of radionuclides have on man and to ensure that the public is fully protected. The term refers to the group of people who – due to living habits, age or location – receive higher dose increments than others due to releases of radionuclides. The critical group can be real or hypothetical. Calculations of radionuclide releases during normal operation of an encapsulation plant at Clab have assumed the presence of a critical group on the islands of Utlångö and Upplångö, about four kilometres northeast of the encapsulation plant. In calculating the environmental impact of mishaps in Clab and the encapsulation plant, the dose has been calculated for five different distances from the facilities: 200 and 500 metres, plus two, three and ten kilometres. In the case of the final repository, no such calculations are planned for the operating phase, since no events have been identified that could give rise to releases of radionuclides to the environs.

In the SR-Site safety assessment, which deals with long-term safety in the final repository, releases of radionuclides to the environs are calculated. Most of the calculations are concentrated in an area just downstream of the final repository, but doses are also calculated for all of Öregrundsgrepen, the sea bay outside Forsmark.

6.3.3 Transport of spent nuclear fuel

The geographic scope of shipments of spent nuclear fuel includes ship transport from the nuclear power plants to Clab and of encapsulated fuel to the final repository, including short overland transport.

6.3.4 Other transport

Studies of the environmental impact of material transport is based on road haulage /6-2, 6-3/. The studies of noise and emissions from the transport of materials and personnel have focused on the routes Forsmark–Hargshamn and Laxemar/Simpevarp–Oskarshamn. Dispersal calculations for emissions to air and for noise and vibration have been done for sensitive sections, for example heavily built-up areas. In order to calculate quantities of emissions to air (total emissions per year), an average transport distance of 25 kilometres (one-way journey) has been assumed. This distance is determined by such factors as where personnel live, which contractors are engaged and what the future market for rock spoil looks like, which means there is uncertainty in the assumptions.

6.4 Scope in time

The periods described are the phases when the activity has consequences. In the case of Clink it is the operating and decommissioning phases. In the case of the encapsulation plant the construction phase is also crucial. In the case of the final repository, the description includes construction, operation and decommissioning, see Figure 6-2. The post-closure period is described with respect to long-term safety, and the data have been taken from the assessment of long-term safety, SR-Site, where the scenarios for the evolution of the repository extend a million years ahead in time.

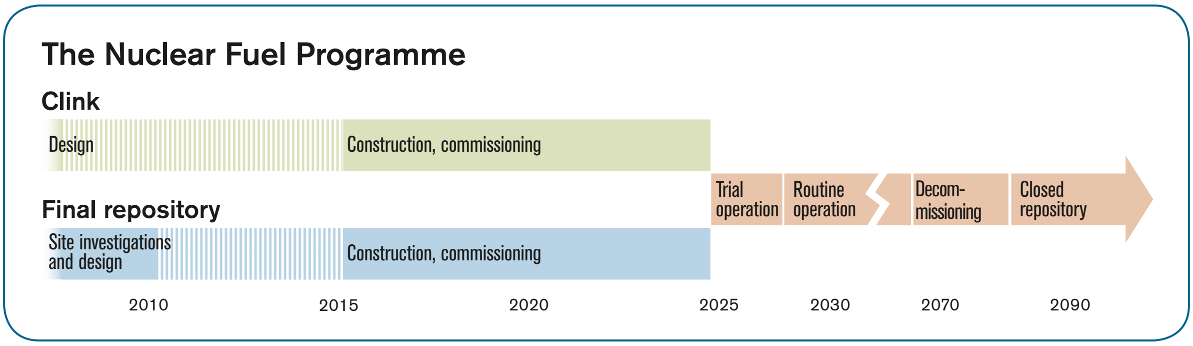


Figure 6-2. Timetable for construction, operation and decommissioning of Clab, encapsulation plant and final repository.

The years noted in the Environmental Impact Statement are examples of typical years for the different phases of the project and are dependent on when licences are granted to build and operate the facility. This means that the estimated impact may occur at another point in time, depending on how the project progresses. 2015 reflects a year during the construction phase with lower intensity for the final repository and higher intensity for the encapsulation plant, while 2018 reflects a year with higher intensity for the final repository and lower intensity for the encapsulation plant. 2030 and 2075 reflect the operating phase and the decommissioning phase, respectively.

Since decommissioning is far ahead in time, the decommissioning phase and its environmental consequences are only described in general terms in the EIS.

Site-specific conditions

7 Site conditions

The site-specific conditions, together with the impact of the applied-for activity, serve as a basis for the assessment of effects and consequences. Forsmark is the applied-for site for the final repository and the considered siting for the encapsulation plant. Laxemar/Simpevarp is the applied-for site for Clab and the encapsulation plant (Simpevarp) as well as the considered siting for the final repository (Laxemar).

The sections that are most essential for long-term safety are those that deal with geology and hydrogeology, Sections 7.1.3 (Forsmark) and 7.2.3 (Laxemar/Simpevarp).

7.1 Forsmark

The Forsmark industrial area is situated northeast of the community of Forsmarks bruk and national road 76 in Östhammar Municipality, see Figure 7-1. The Forsmark Nuclear Power Plant with three reactors, owned by Forsmarks Kraftgrupp AB (FKA), is located within the industrial area. Peripheral installations required for the operation of the nuclear power plant are also located there, such as water works, sewage treatment plant, oil depot, power lines and the Svalören near-surface repository for low-level waste. SKB's final repository for short-lived radioactive waste (SFR) is also situated east of the nuclear power plant, about 50 metres below the seabed. Low- and intermediate-level operational waste from the Swedish nuclear power plants, industry and medical care is deposited in SFR. Biotestsjön (the Biotest Basin), situated north of the nuclear power plant, was established by building embankments of surplus rock between a number of islands in the Forsmark archipelago. Heated cooling water from the nuclear power plant is pumped to the Biotest Basin.

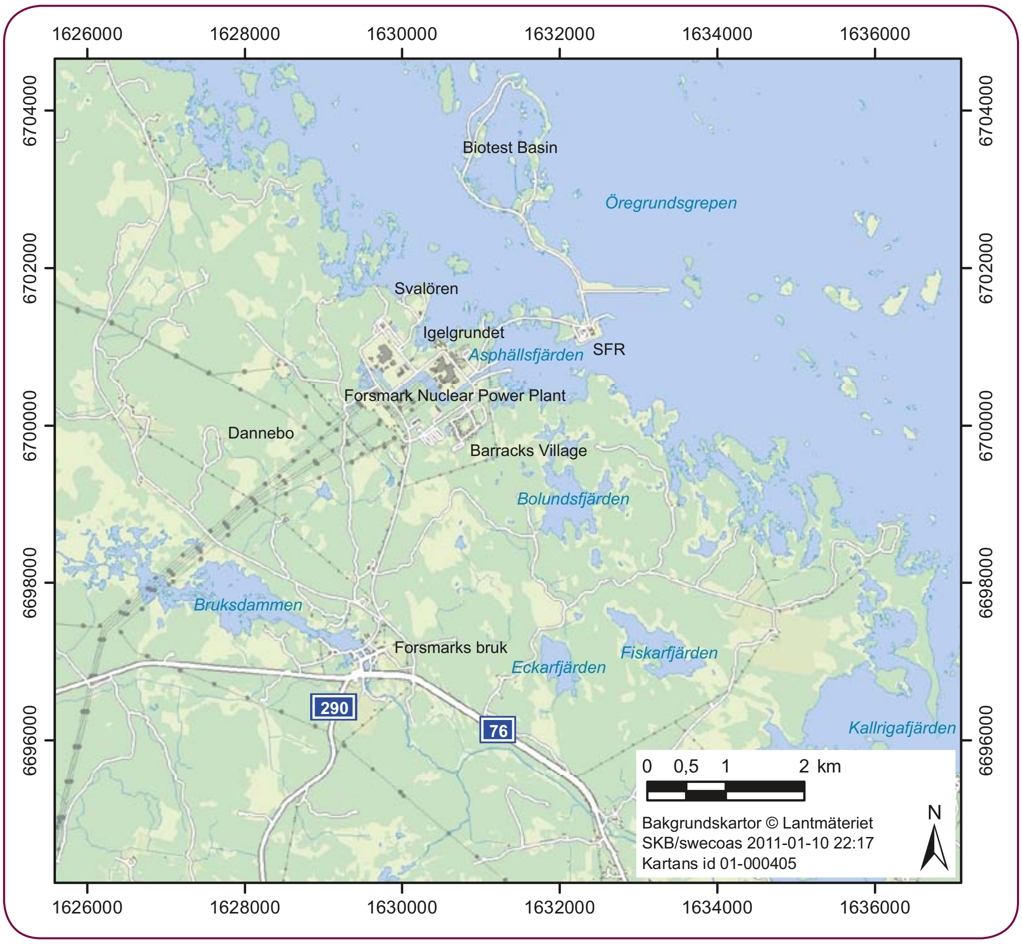


Figure 7-1. The Forsmark area in Östhammar Municipality, key map.

7.1.1 Physical planning, population and infrastructure

7.1.1.1 Comprehensive plan

The current comprehensive plan for Östhammar Municipality (ÖP 2000) was adopted by the municipal council in 2003. The area south of Forsmark is singled out in the comprehensive plan as potentially favourable for construction of a deep repository (former designation for final repository) of spent nuclear fuel. The comprehensive plan states that the municipality should maintain readiness to enable the siting of a final repository for spent nuclear fuel in the Forsmark or Hargshamn area.

7.1.1.2 Detailed development plan

The current detailed development plan for the Forsmark Nuclear Power Plant was adopted by the municipal council in 1992 and gained legal force in 1994. The plan covers a relatively large area of land and water that includes the Forsmark Nuclear Power Plant, the near-surface repository for low-level waste, the sewage treatment plant, SFR and the Biotest Basin, as well as Forsmark

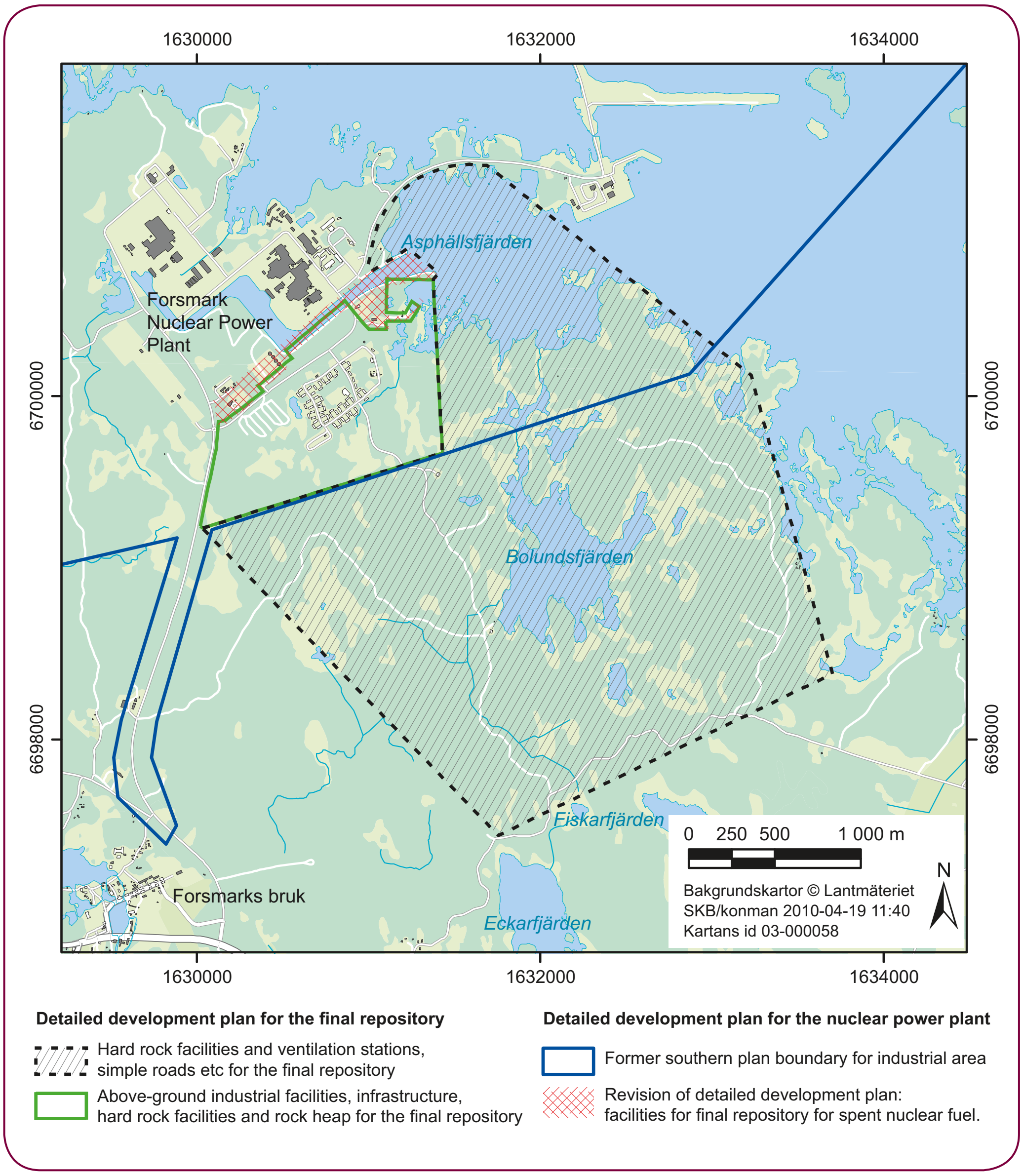


Figure 7-2. Areas covered by detailed development plans that enable the final repository's facilities.

harbour (situated at SFR). The plan creates the necessary conditions for electricity production, energy production and energy-related activities. Amendments were made in the plan in 2008 to enable a final repository to be built under parts of the plan area. At the same time, a new detailed development plan was adopted for the area southeast of the existing plan, permitting surface and underground facilities for the final repository. The new plan also replaced parts of the plan for the Forsmark Nuclear Power Plant, see Figure 7-2. The plans gained legal force in April 2008.

7.1.1.3 Population

There is virtually no residential development in the surrounding area. The nearest clustered housing is around Forsmarks bruk, about four kilometres from the nuclear power plant. Consultants, contractors and others stay at FKA's temporary accommodations near the nuclear power plant (the Barracks Village). There are no other residents within a kilometre of the Forsmark industrial area. There are about 100 registered residents within a radius of five kilometres. Aside from this there are a dozen or so vacation homes.

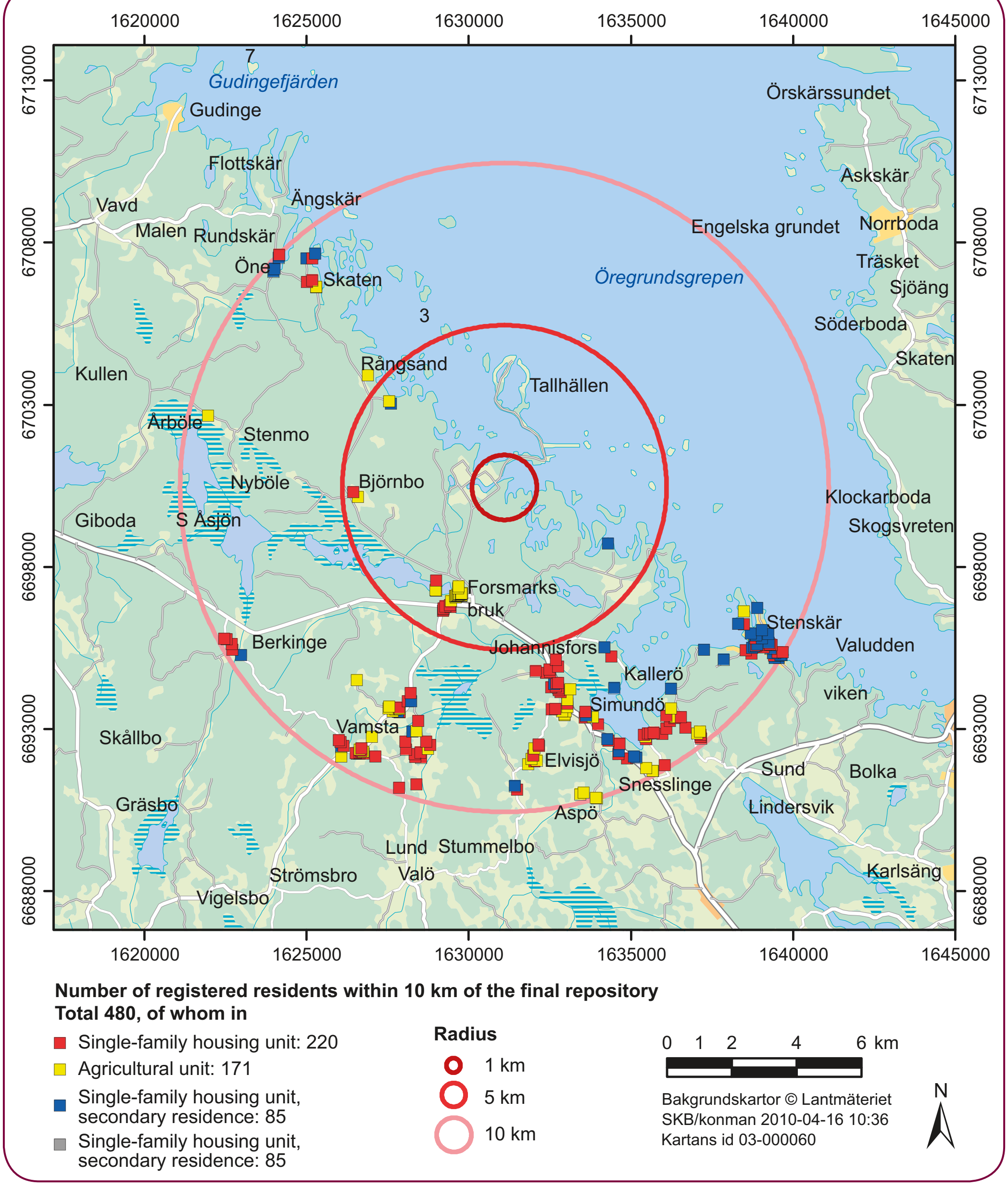


Figure 7-3. Number of residents (registered) in 2008 within ten kilometres of the planned final repository.

Table 7-1. Number of residents (registered) in 2008 within different distances of the Forsmark industrial area.

Distance	Residents, total	of whom in single-family houses	of whom in secondary residences	of whom in farms	of whom in rental housing
0–1 km	0				
1–5 km	84	20	5	59	
5–10 km	396	200	80	112	4
0–10 km total	480	220	85	171	4

7.1.1.4 Roads and conventional transport

Roads leading to the Forsmark area are county road 290 from Uppsala via Österbybruk and national road 76 from Norrtälje and Gävle, see Figure 7-4. From Östhammar, county road 288 leads to Uppsala. These roads are of the highest load-bearing class. A private road with high load-bearing capacity, owned and maintained by FKA, leads from the Forsmark industrial area to national road 76. The distance from Forsmark to Uppsala is about 80 kilometres, and to Stockholm about 150 kilometres. County road 288 is the most important link between northeastern Uppland and Uppsala with its connections to European Route E4 and national road 55. National road 76 is most important to residents and people working in Östhammar, Öregrund and Hargshamn.

The traffic load in Östhammar Municipality is seasonally dependent. Traffic in the municipality increases markedly in the summertime due to a large number of summer residents. Employment in the municipality has remained at a fairly constant level, while the number of gainfully employed persons residing in the municipality has grown. Around two-thirds of the commuter traffic is to Uppsala. According to the Swedish Road Administration's feasibility study for county road 288 Hov–Gimo from 2005, in-commuting to the municipality amounts to about 1,600 people per day, while out-commuting amounts to just under 2,900 people per day. A continued increase in in- and out-commuting is expected in the municipality.

Figure 7-4. Main roads and rail links in and around the Forsmark area.

Traffic on national road 76 in the area around Forsmarks bruk amounted to about 2,000 vehicles per day in 2006, roughly ten percent of which was heavy traffic /7-2/. Traffic on the entrance road to the Forsmark Nuclear Power Plant was around 520 vehicles per day /7-3/.

In addition to ordinary passenger traffic, temporary employees are hired during the annual refuelling outages and in different development projects at the nuclear power plant. A normal refuelling outage takes about two months for the whole nuclear power plant and involves some 500 persons. In a year with big projects, such as turbine replacement, the number of temporary employees can reach over 700. Most of them live in the Barracks Village at the nuclear power plant.

As far as the commuting pattern to and from FKA is concerned, in 2003 nine percent of the employees resided in Gävle while six percent resided in Uppsala. 66 percent resided in Östhammar Municipality, mainly in the towns of Östhammar, Öregrund and Österbybruk. With improved roads, good commuting options and faster public transport towards Uppsala, Alunda and Gimo will probably take on increasing importance for growth in the county /7-2/.

7.1.1.5 Transport of spent nuclear fuel and nuclear waste

SKB owns and operates a system for transportation of spent nuclear fuel from the nuclear power plants to Clab in Oskarshamn and of low- and intermediate-level operational waste to SFR in Forsmark. Sea transport is performed by m/s Sigyn, which has regular service to the harbour at SFR. Overland transport is performed by slow-moving terminal vehicles within the industrial area. The spent nuclear fuel and operational waste is enclosed in transport casks during transport.

7.1.1.6 Railway

The municipality is traversed by a railway for freight carriage. It departs from Hallstavik, passes Hargshamn and then continues via Gimo and Österbybruk further westward and connects to the Northern Main Line at Örbyhus. The railway is not electrified and carries no passengers. Rail is utilized to a varying degree for shipments of solid fuels to and from Hargshamn and for shipments to the paper mill in Hallstavik. A refurbishment of the railway is planned in connection with the resumption of operation at the Dannemora Mine.

7.1.1.7 Harbours and navigation channels

There are two ports in the municipality of interest for SKB's shipments /7-2/, Forsmark and Hargshamn.

Port of Forsmark

The Port of Forsmark is located about two kilometres east of the nuclear power plant. The operations area and facilities for SFR are situated right next to the harbour. The port is owned and operated by FKA and used almost exclusively for shipping radioactive waste by SKB's ship m/s Sigyn, but also for occasional shipments for the nuclear power plant. The maximum draught is 5.5 metres. The harbour is protected by breakwaters against high seas and ice from the north. A road specially built for heavy vehicular traffic leads from the harbour to the nuclear power plant.

Port of Hargshamn

The Port of Hargshamn is an industrial bulk port owned by Hargs Hamn AB. It is situated about ten kilometres south of the town of Östhammar and about 30 kilometres south of Forsmark. The port is the most important deep port in the county and now used exclusively for freight with four different berths. Rock is loaded for export today in the Port of Hargshamn. The navigation channel to Hargshamn is well suited for large vessels and adequate for vessels with a draught of 8.5 metres and a maximum length of 175 metres.

The port can handle ships of up to 50,000 tonnes deadweight, which is much larger than the vessels that will be used for shipments to the final repository. Hargs Hamn AB plans to alter the route of the navigation channel and deepen and broaden it locally to be able to serve larger ships. For this reason, Hargs Hamn AB initiated a licensing process in 2007.

County road 292 leads from Hargshamn out to national road 76 and further west. The road is of the highest load-bearing class with a width of over eight metres. Hargshamn also has a single track railway that connects to the Northern Main Line.

7.1.2 National interests and protected areas

The area being considered for the final repository's facilities has been singled out as being of national interest for final disposal of spent nuclear fuel and nuclear waste. A large part of the area is also of national interest for energy production, and part of the area is of national interest for nature conservation. The whole area is of national interest according to the special management provisions for highly developed stretches of coast in Chapter 4, Secs. 1–4 of the Environmental Code. The area of national interest for final disposal borders Forsmarks bruk on the south-west, which is of national interest for cultural heritage preservation. Forsmark and its environs are also of national interest for outdoor activities. Areas of national interest for wind power are located both on land and at sea. Öregrundsgrepen is of national interest for commercial fishing. Outside the area are three Natura 2000 sites, two of which are also nature preserves. Areas of national interest for nature conservation and Natura 2000 sites are marked in Figure 7-17, see Section 7.1.5 "Natural environment". The navigation channel into the Port of Forsmark is of national interest for shipping. All areas of national interest are marked in Figure 7-5.

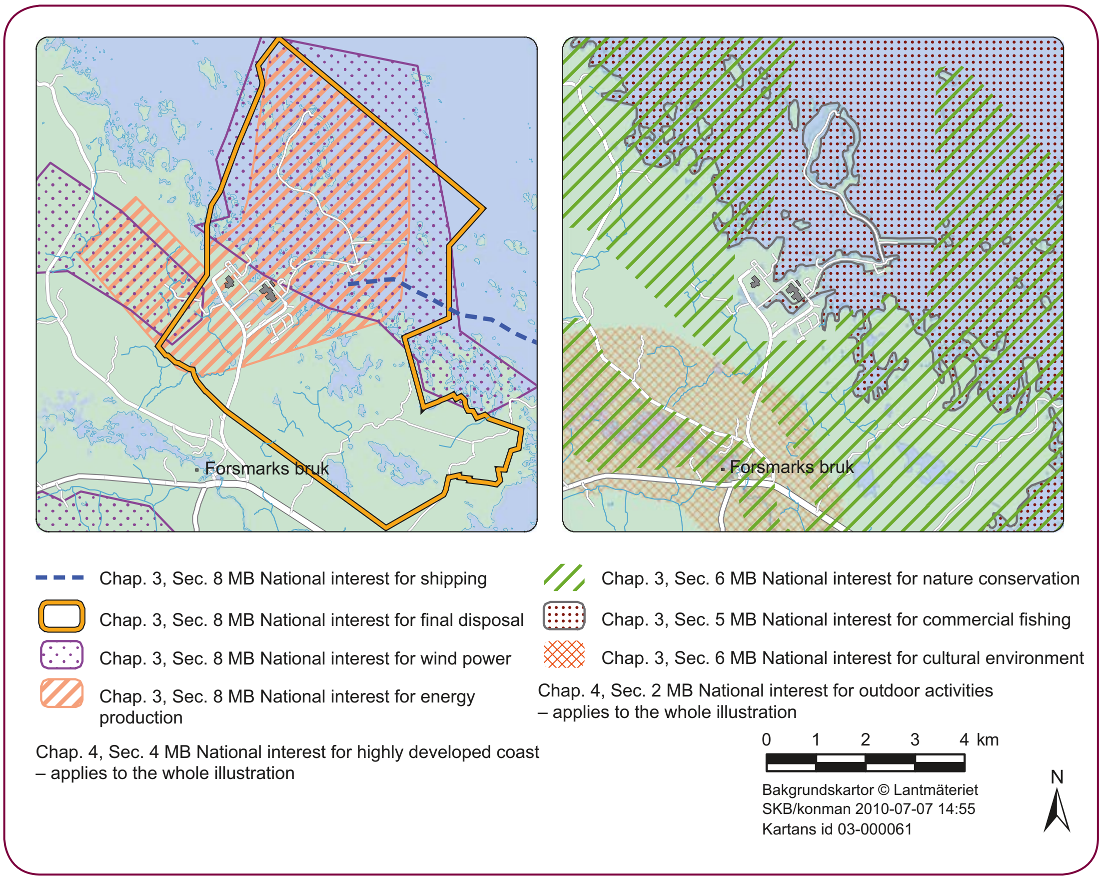


Figure 7-5. National interests in the Forsmark area.

7.1.3 Geology

During the site investigation, large resources were devoted to sampling data in the field on bedrock geology, rock mechanics, thermal properties of the rock, hydrogeology, hydrogeochemistry, transport properties of the rock and properties of the surface ecosystem, including terrestrial, limnic and marine ecosystems. In order to characterize the rock, investigations on the ground surface were combined with investigations in boreholes and studies of drill cores, see Figure 7-6. Altogether the site investigation has included 25 cored boreholes (down to at most 1,000 metres with a total borehole length of 17,800 metres) and 38 percussion boreholes (total borehole length 6,500 metres, no drill core). Information and data on the soil layers has been obtained from about 100 soil wells. The results of the investigations have been summarized in a model adapted to each different discipline. In simplified terms, site modelling is about understanding how a site works and interpreting and translating the point-related information obtained from the site investigations in the form of measurement values so that they apply to areas and volumes. A total of four dimensions are handled (length, width, depth and time). In this way a composite picture is obtained of the area where the models for the different disciplines have to agree. Site modelling aims at explaining observations at depth and on the surface, but also at linking events in the past to the observations that are made today. Within the framework of the modelling work, an account is also given of the uncertainties in the description, and an evaluation is made of what they mean for the whole. The model is a simplified picture of the entire investigation area. In order to determine the quality of the model, it is validated by comparing the model's predictions with the behaviour of the actual system. Unless otherwise specified, the information in Sections 7.1.3.1–7.1.4 is taken from the site descriptive model for Forsmark /7-4/.

Figure 7-6. The site investigations, investigation of drill cores and boreholes.

7.1.3.1 The bedrock

The bedrock in the site investigation area consists of the northwestern portion of a tectonic lens. The lens extends along the coast from the Öregrund area in the southeast to the area northwest of the nuclear power plant, see Figure 7-7. The priority area for the planned final repository is situated in the northwest part of the site investigation area. The bedrock in this part of the tectonic lens has been divided into two rock domains, RFM029 and RFM045, where rock domain RFM029 comprises the largest volume, see Figure 7-8.

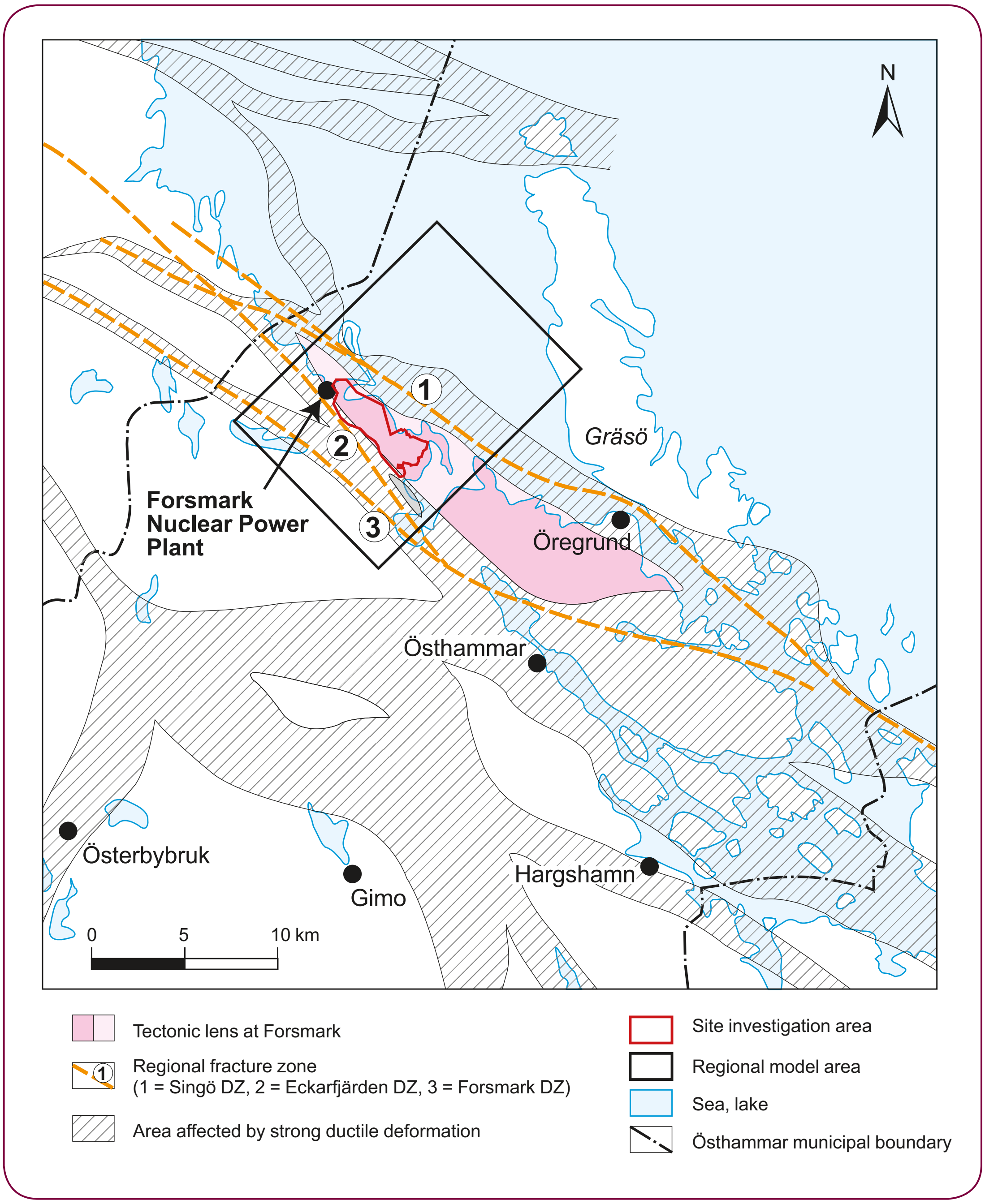


Figure 7-7. The tectonic lens in Forsmark (pink) is surrounded by rocks that have undergone intense ductile deformation (diagonally striped). The dashed lines show regional brittle deformation zones. The site investigation area (outlined in red) is located in the northwest part of the lens. The priority area is located in the northwest part of the site investigation area.

Rock domain RFM029, marked 29 in Figure 7-8, is dominated by medium-grained metagranite and contains subordinate rock types such as pegmatite, fine-grained granite and amphibolite. Rock domain RFM045, marked 45 in Figure 7-8, consists primarily of altered (albitized) medium-grained metagranite with the same occurrence of subordinate rock types as in rock domain RFM029. The rock has a high content of quartz, high thermal conductivity and good strength.

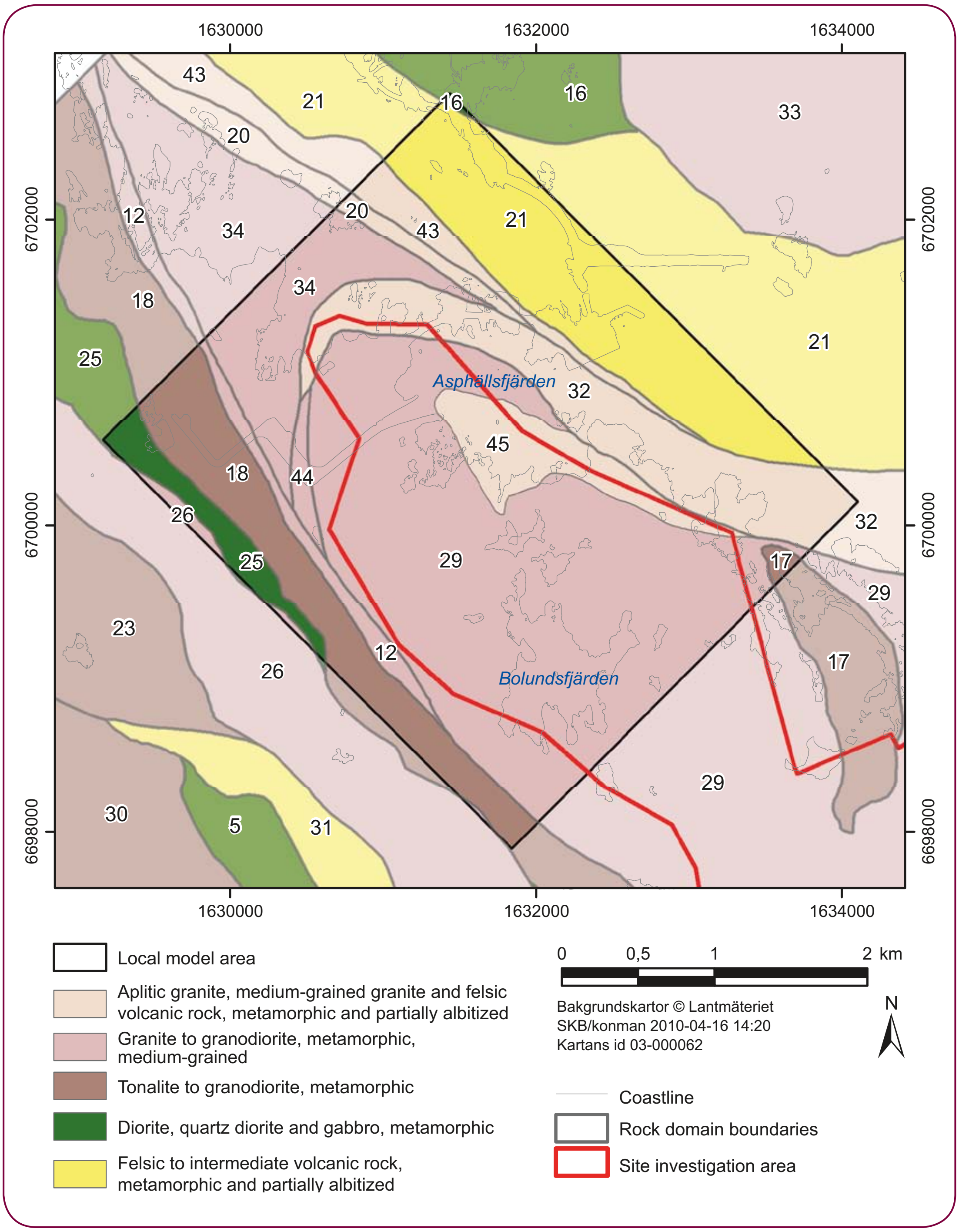


Figure 7-8. Rock domains in the priority area.

Deformation of the bedrock in Forsmark started deep down in the Earth's crust about 1.9 billion years ago at high temperature. It was concentrated in zones where the structure of the rocks was altered. The bedrock was subjected to ductile deformation. Lens-shaped areas called tectonic lenses, where the bedrock was not as strongly deformed, were formed between the tectonic bands. As long as the rock was warm, at great depth in the Earth's crust, the rock mass in the ductile deformation zones was ductile and the rock was able to move without fracturing. When the temperature in the bedrock decreased, the deformation changed from being ductile to being brittle, and fracture zones were formed whose fractures were partially filled with minerals, healing them. The largest fracture zones largely follow the direction of the ductile deformation zones, i.e. they have a northwesterly direction and surround the tectonic lens. Smaller fracture zones with a northeasterly to east-northeasterly direction, are dominant inside the lens, see Figure 7-9.

The fracture zones have been reactivated (reopened) several times and healed together again with different types of minerals in connection with different geological events. Dating of the fracture-filling mineral adularia shows that a considerable reactivation of the northeast to east-northeast fracture zones took place about 1.1 billion years ago. After that geological processes of importance took place several hundred kilometres from the Forsmark area, which had then become a tectonically stable area with a well developed (thick) crust.

Fracturing of the rock during the past 600 million years or so has taken place by loading and unloading of the Earth's crust, which has mainly affected the uppermost part of the bedrock. In addition to different types of sediments, which have been eroded away and deposited, the rapid unloading following the end of the ice age (when the pressure from the ice was relieved) has contributed to the fracturing in the upper part of the bedrock.

Both steeply and gently dipping fracture zones have been identified within the site investigation area. The fracture zones contain both horizontal and vertical fractures, most of which are healed but some are still open.

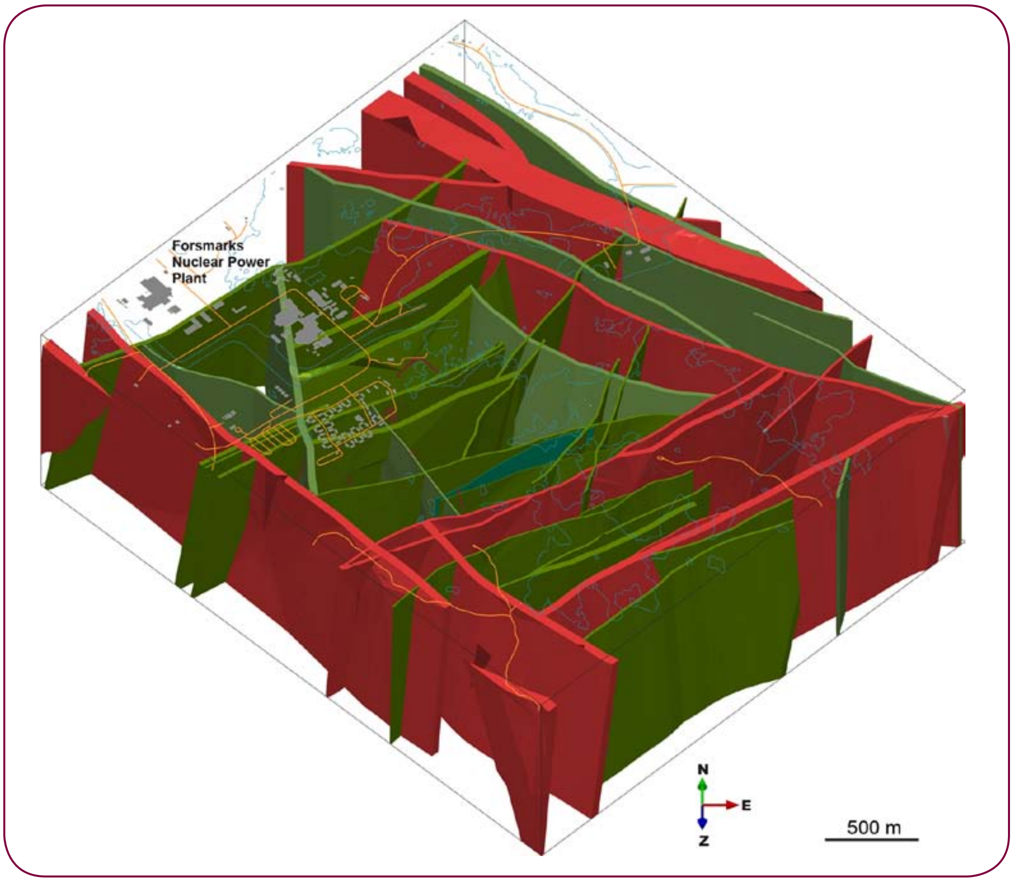


Figure 7-9. Three-dimensional model showing the vertical and steeply dipping deformation zones. The model is viewed from above off to the side looking northward. The red zones are longer than three kilometres, and the green zones are smaller zones, shorter than three kilometres.

Between the fracture zones is a more homogeneous rock. The bedrock between the fracture zones in the priority area has been divided into fracture domains in order to distinguish rock volumes with different fracture frequencies, see Figure 7-10. The fracture frequency in fracture domains 1 and 6 (FFM01 and FFM06), within which the final repository is planned to be located, is much lower than that of normal Swedish bedrock, while the upper part of the rock, which is described by fracture domain 2 (FFM02), has considerably more fractures than normal Swedish bedrock. Fracture domain 2 contains long, water-conducting horizontal fractures, see Figure 7-11.

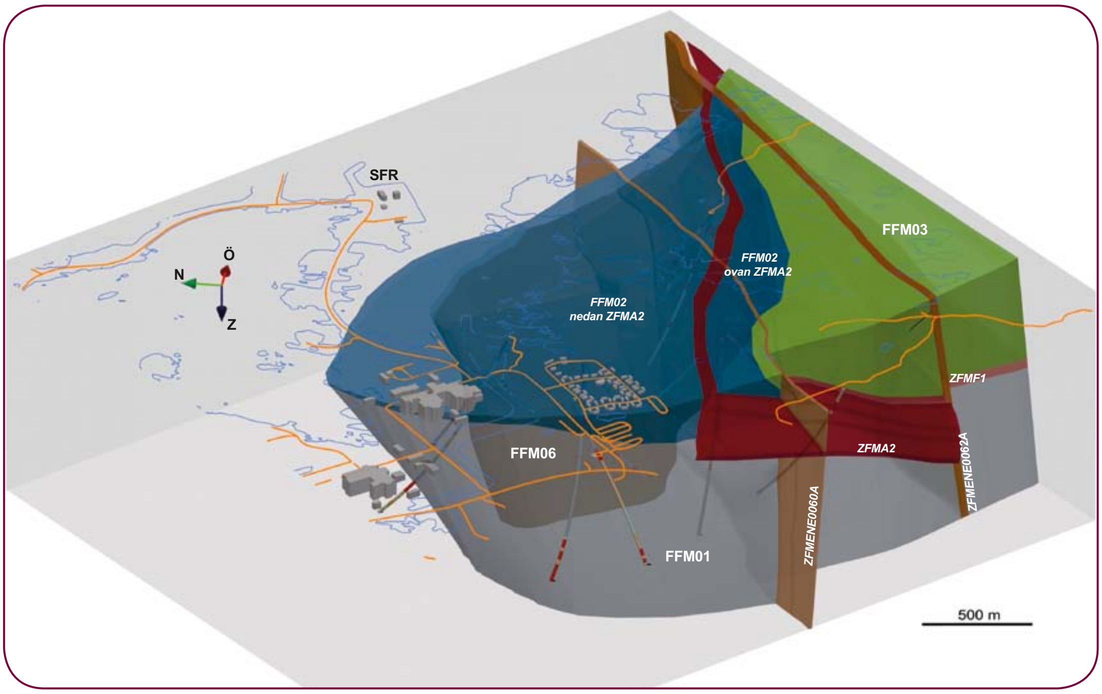


Figure 7-10. Three-dimensional model of the different fracture domains in the northwestern part of the tectonic lens in Forsmark, viewed from above towards the east-northeast. The fracture domains are FFM01, FFM02, FFM03 and FFM06. The model also shows gently dipping subhorizontal fracture zones (ZFMA2 and F1) and steeply dipping deformation zones (ZFMENE0060A and 0062A).

Figure 7-11. Example of what horizontal water-conducting fractures in fracture domain FFM02 look like near the surface. Photo taken during construction of the cooling water channel in Forsmark.

7.1.3.2 Rock stresses

The stresses (loads) in the rock are generally higher farther down in the rock than near the ground surface. The stresses are caused by both vertical and horizontal forces. The vertical load consist of the weight from the overlying rock, which naturally increases with depth. The horizontal loads are more complex and can ultimately be attributed to the forces that are generated by plate movements on a global scale. In Swedish bedrock, the horizontal stresses are generally higher than the vertical ones, so also in Forsmark. Locally, the size of the stresses is also dependent on the properties of the rock, especially the occurrence of fractures. The fewer the fractures, the higher the stresses usually are. In Forsmark the fracture frequency is very low at great depths, which is probably one of the reasons the horizontal stresses are much higher than the average background values for crystalline bedrock in Sweden.

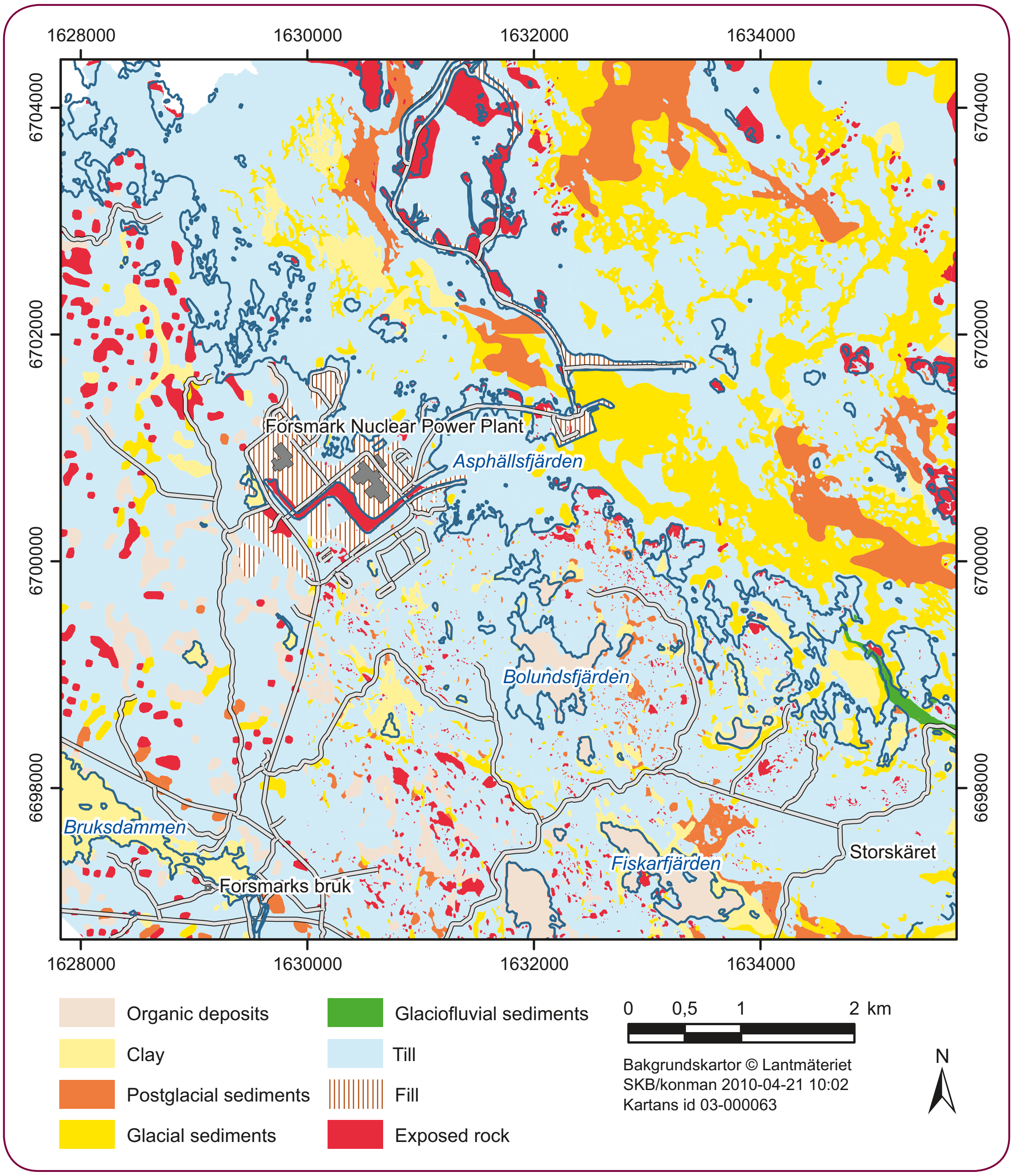


Figure 7-12. Quaternary deposit map of the Forsmark area.

7.1.3.3 Quaternary deposits

Till, which is an unsorted drift deposited beneath an ice sheet, is the predominant type of Quaternary deposits in the Forsmark area. The till is rich in lime deriving from deposits of sedimentary limestone on the seafloor outside the Gävlebukten Bay and has been transported south by the ice sheet. Exposed bedrock occurs frequently, but only comprises about five percent of the surface. Wave-washed sand and gravel, clay, gyttja clay and peat cover a smaller portion of the surface. The Börstilåsen esker is the only glaciofluvial deposit in the area. It was formed during the retreat of the latest continental ice sheet and runs in a north-south direction along the coast. Figure 7-12 shows the Quaternary deposit map that has been generated from the site investigations in the area.

Three areas with different types of till have been distinguished. The western and northern parts of the Forsmark area are dominated by sandy till, whereas clayey till dominates in the southeastern parts at Storskäret and east of lake Fiskarfjärden. In the eastern parts of the area, near the Börstilåsen esker, the till has a high boulder frequency, which means it has a higher permeability. The soil layers are generally thin, usually less than five metres in thickness. The soil layers are thicker in the southeast, in areas with clayey till.

7.1.3.4 Hydrogeology

Long, water-conducting horizontal fractures occur within the upper 150 metres or so of rock in the priority area. The permeability of the rock decreases sharply with depth. At depths greater than 400 metres, the average distance between conductive fractures is more than 100 metres. The dominant part of the groundwater flow at a depth of about 500 metres occurs within (along) the steeply dipping fracture zones, see Figure 7-13. Most of the groundwater exchange between the rock and the soil layers is assesed to occur in the limited areas where the steeply dipping zones intersect the rock surface.

Most of the Forsmark area is situated lower than 20 metres above sea level, see Figure 7-14. Due to the flat topography, in combination with the contrast between the permeability of the soil layers/upper rock and the underlying rock, most of the groundwater flow in the area takes place relatively close to the ground surface. This near-surface flow system with local recharge and discharge areas overlies deeper and more large-scale flow systems in the rock. The water flux in the near-surface system has been estimated to be in the order of 1,000–10,000 times higher than in the deeper flow systems in the rock, depending on level.

Measurement data from the site investigation area indicates a complex exchange between lake water and groundwater. Comparisons between water levels in the lakes and groundwater levels beneath the lakes generally indicate the occurrence of impervious lake sediments. The organic sediments beneath the wetlands can occur directly on top of the till, or be underlain by sand and clay on top of the till /7-5/.

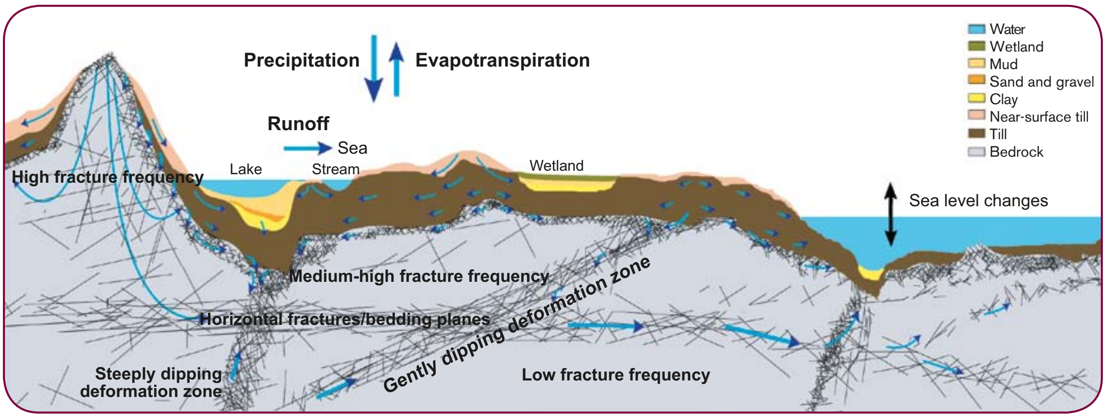


Figure 7-13. Conceptual cross-section illustrating the concept of "superficial hard rock aquifer" and its influence on the groundwater flows in the rock.

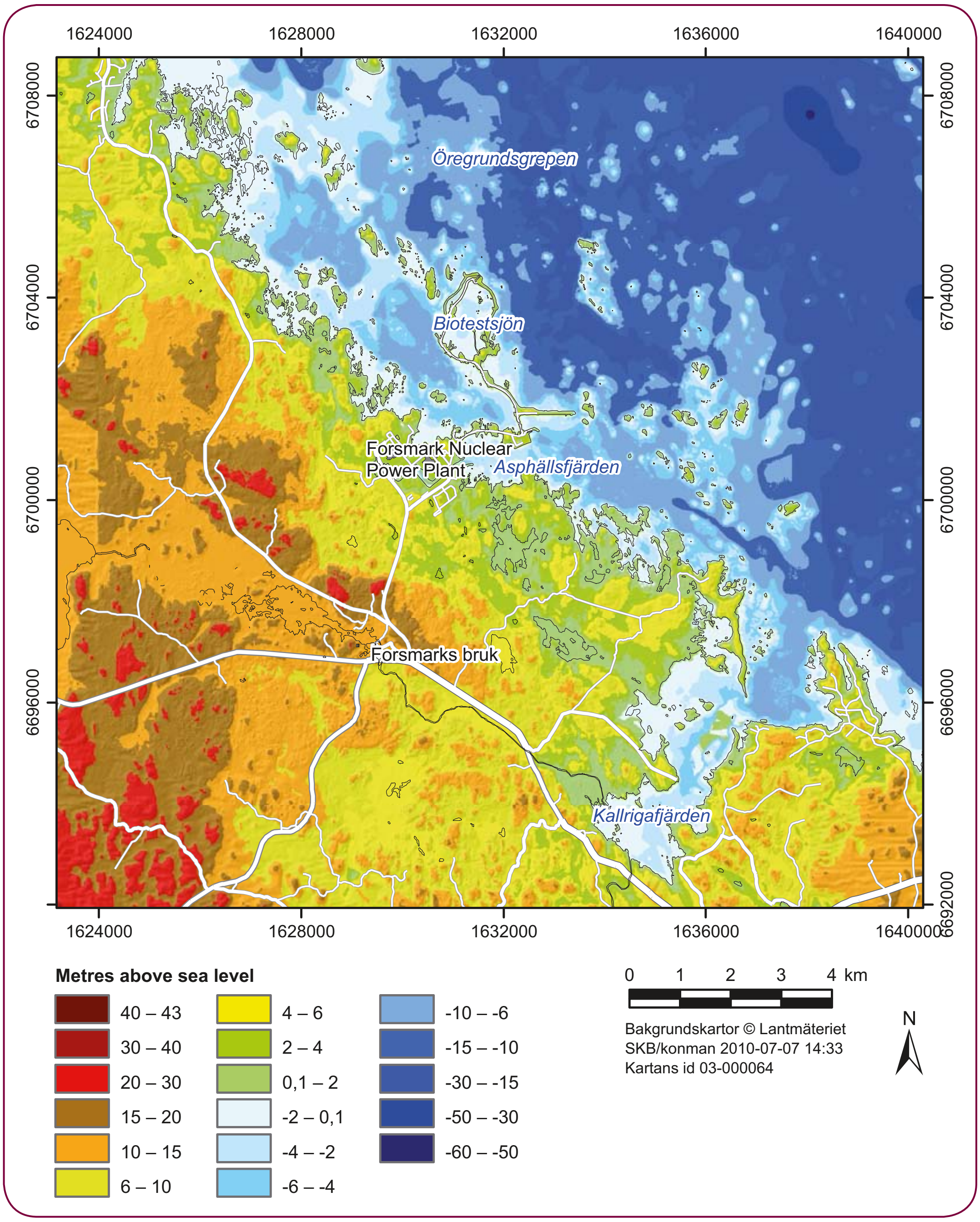


Figure 7-14. Topographical map of the Forsmark area.

In the Forsmark area the groundwater table is located on average one metre below the ground surface. Time series show that the groundwater levels vary between 1 and 1.5 metres in most observation wells. The till is lime-rich, which means that the surface water and the superficial groundwater in the area have a high pH and high concentrations of calcium and bicarbonate /7-4, 7-5/.

Investigations have shown that recent groundwater preferably occurs at depths above 200 metres. Deeper down there is several thousand year-old groundwater stemming from the Littorina Sea (a predecessor of the Baltic Sea), more than 10,000 year-old glacial water from the glacial periods, and even older and very saline groundwater. The salinity of the water increases gradually with depth, and at a depth of only 100–150 metres the chloride concentration is higher than in the sea outside Forsmark (the Littorina Sea was two to three times saltier than present-day sea water in Öregrundsgrepen). At between 200 and 600 metres depth, the chloride concentration is fairly constant in the range 5,000–6,000 milligrams per litre (mg/l), i.e. less than one percent salt. The groundwater in the very impermeable rock between the fracture zones consists of very old water with a chloride concentration between 4,000 and 10,000 mg/l. No extremely saline waters (with a chloride concentration of more than 20,000 mg/l) have been encountered within the investigation area. Oxygen-free conditions prevail at repository depth.

7.1.4 Hydrology and meteorology

According to calculations based on data from SMHI for the reference normal period 1961–1990, the annual precipitation in the areas is about 560 millimetres. The mean annual specific runoff is around 150–160 millimetres per year. Actual evapotranspiration, which is the portion of the precipitation that evaporates or transpires from plants, has been estimated to be about 400–410 millimetres per year /7-5/.

There are 25 lakes in the Forsmark area, most of which are very small. The biggest lakes in the area are Fiskarfjärden (0.75 square kilometre), Bolundsfjärden (0.61 square kilometre), Eckarfjärden (0.28 square kilometre) and Gällsboträsket (0.19 square kilometre), see Figure 7-15. The lakes are shallow, with an average depth of 0.1–1 metres and a maximum depth of 0.4–2 metres. The lakes are oligotrophic hardwater lakes, i.e. the water in the lakes is lime-rich and nutrient-poor. Phosphorus limits production in the lakes. Sea water intrusion occurs into the lakes Norra Bassängen, Puttan and Bolundsfjärden during periods with high sea levels.

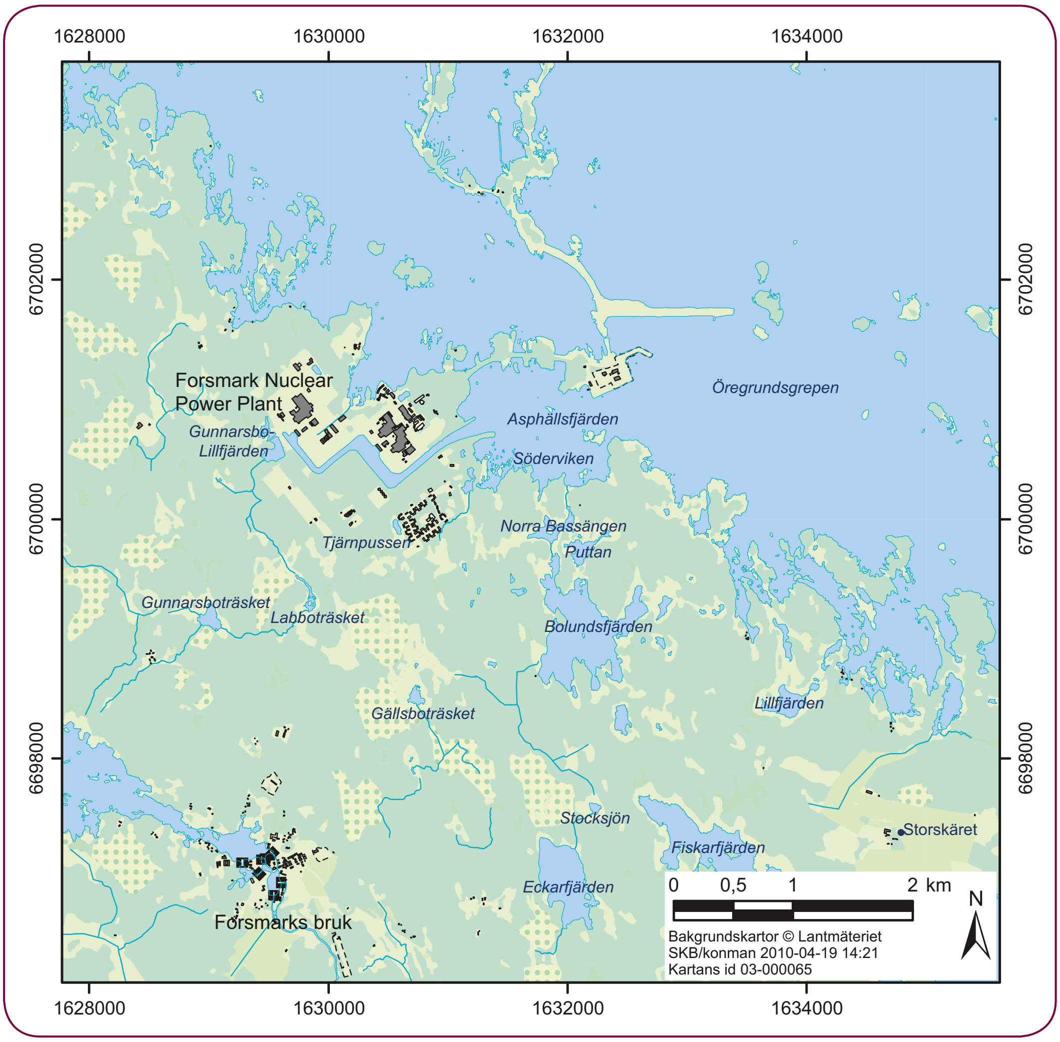


Figure 7-15. Lakes in the Forsmark area.

Wetlands occur frequently within the site investigation area. There are no large watercourses in the central parts of the area, but there are a number of ditch-like streams that dry out periodically downstream of the lakes Gunnarsboträsket, Eckarfjärden and Gällsboträsket. The receiving body of water from the area is Öregrundsgrepen, a bay of the Baltic Sea.

7.1.5 Natural environment

The Forsmark area has a wilderness character that is atypical of the region and consists for the most part of forested moraine lands with occasional rock outcrops. The area harbours high natural values, due to an interaction of several factors:

- Postglacial land uplift contributes to a shoreline displacement that is constantly creating new environments.
- The area is very flat, and small variations in the topography have led to a mosaic of different habitats.
- The soil is lime-rich.
- The area is situated in a boundary zone between northern and southern vegetation zones.
- The area around the nuclear power plant is relatively undisturbed.

The Forsmark area has a high fraction of wetlands compared with the rest of Uppland, largely due to the area's flat topography in combination with land uplift, see Figure 7-16. The wetlands are often small and varying in their openness.

Much of the area around the nuclear power plant is of national interest for nature conservation (Forsmark-Kallrigafjärden) and is surrounded by three Natura 2000 sites, two of which are also nature reserves. Natura 2000 is the EU's network of nature protection areas.

Figure 7-16. New lakes are formed in the low-lying coastal area when shallow sea bays are pinched off from the sea.

In the southeast is the Kallriga nature reserve, which has also been designated a Natura 2000 site. Kallriga is very valuable for the flora and bird life of its cultivated lands, especially during the annual migration periods when thousands of sea birds rest in the area. East of SFR are important bird islands, also designated a Natura 2000 site (Forsmarks bruk). North of the nuclear power plant lies the Natura 2000 site Skaten-Rångsen, an important spawning area for fish /7-6/. Areas of national interest for nature conservation and other protected areas around Forsmark are shown in Figure 7-17. The natural values in the areas consist of land uplift habitats with high botanical and ornithological values, coastal water habitats, different types of rich fens and ponds, natural forests and farming and agricultural districts with pasturelands. Most of the area has also been classified by the County Administrative Board in Uppsala County as being of county interest, class 2. A small area north and east of Bolundsfjärden has been classified by the County Administrative Board as being of national interest, class 1.

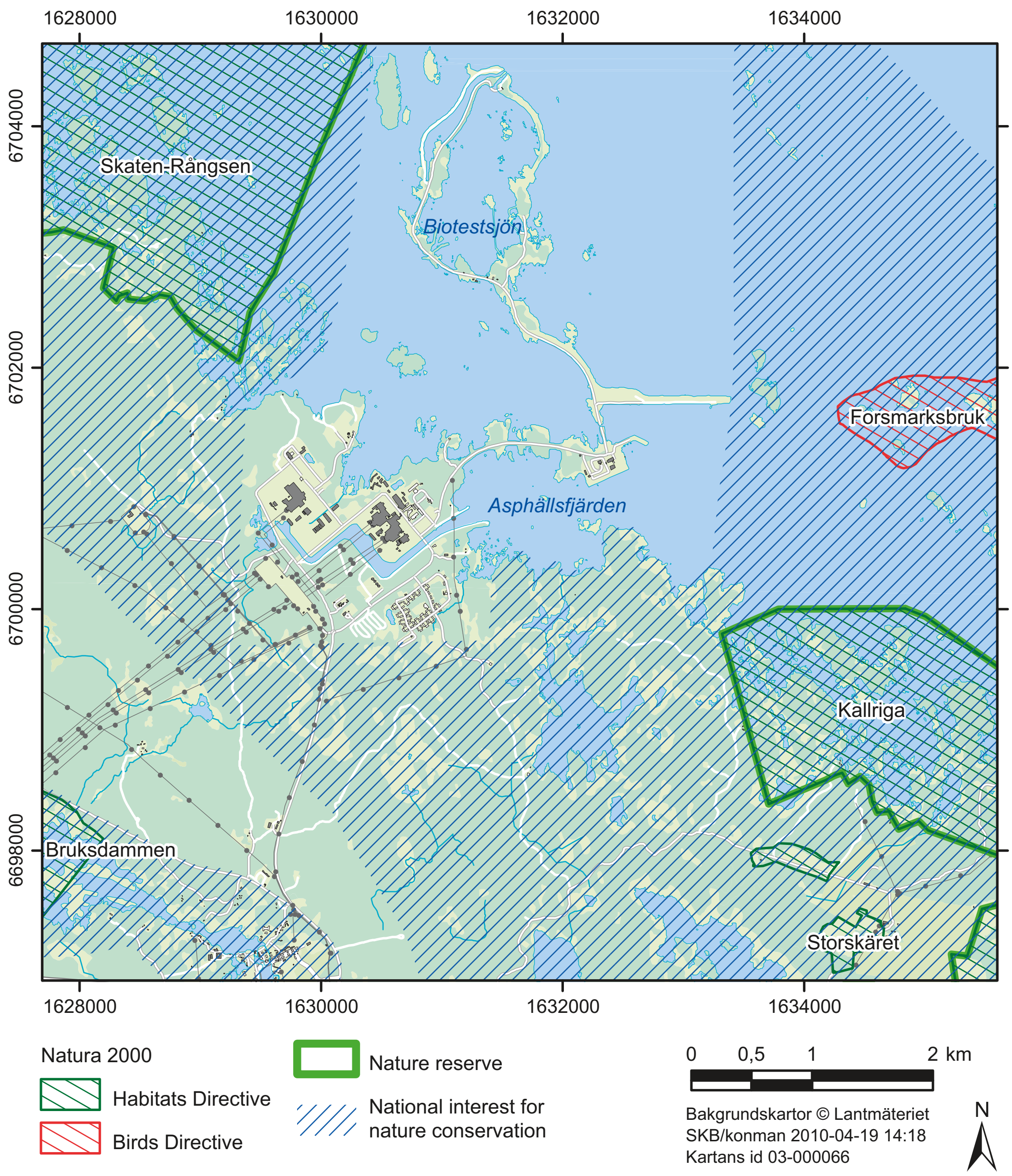


Figure 7-17. Nature protection in the Forsmark area.

A larger area around the nuclear power plant, as shown in Figure 7-18 and 7-19, was inventoried during the 2008 vegetation period for the occurrence of valuable natural environments /7-6/. The natural values in the area have been classified by means of a methodology used by the Swedish Environmental Protection Agency and the county administrative boards and divided into four classes: national, regional, municipal and local value. The area south of the nuclear power plant was assessed to contain numerous valuable natural attractions, especially around Bolundsfjärden. They mainly consist of different rich fen environments and lime-rich ponds where red-listed species occur. There are also various kinds of coniferous forest environments on lime-rich soil, some of which are of a natural forest character. Many of these natural attractions, particularly the wetland environments, are assessed to have very high natural values. Some of the attractions contain habitats covered by the EU's Habitats Directive, and Sweden has pledged not to reduce their area /7-6/. During the inventories, red-listed species of mammals, bats, insects, reptiles, vascular plants, mosses, fungi and fish have been encountered within the investigation area, including pool frog, fen orchid, Geyer's whorl snail and flea sedge. The pool frog (see Figure 7-20) is only found in Sweden along the northern coast of Uppland, and the environments south of Forsmark are an important part of the pool frog's total habitat in the country. Several of the ponds also host an interesting dragonfly fauna with species such as yellow-spotted whiteface and dark whiteface /7-6, 7-7/.

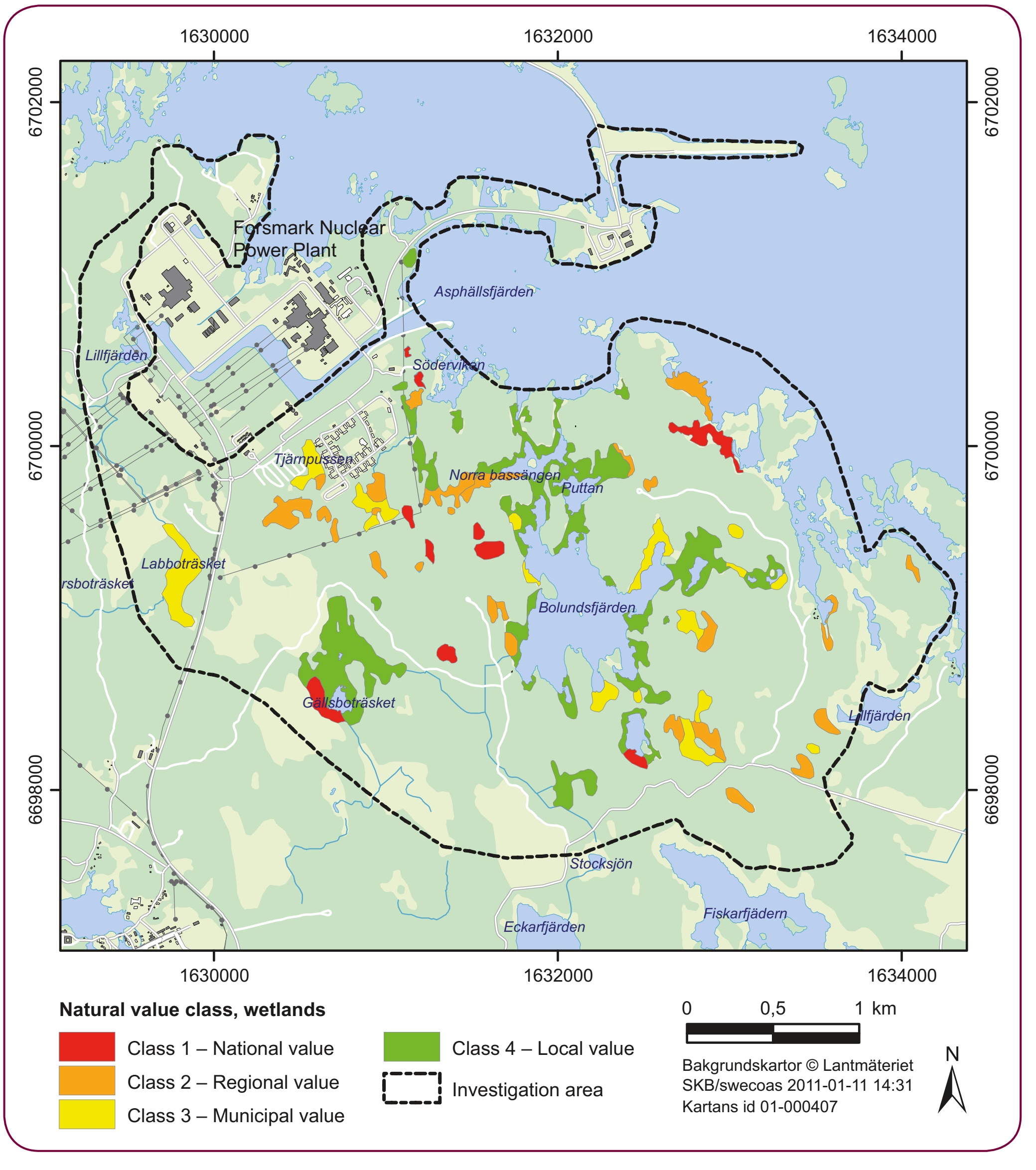


Figure 7-18. Identified natural values in the form of wetlands in the Forsmark area.

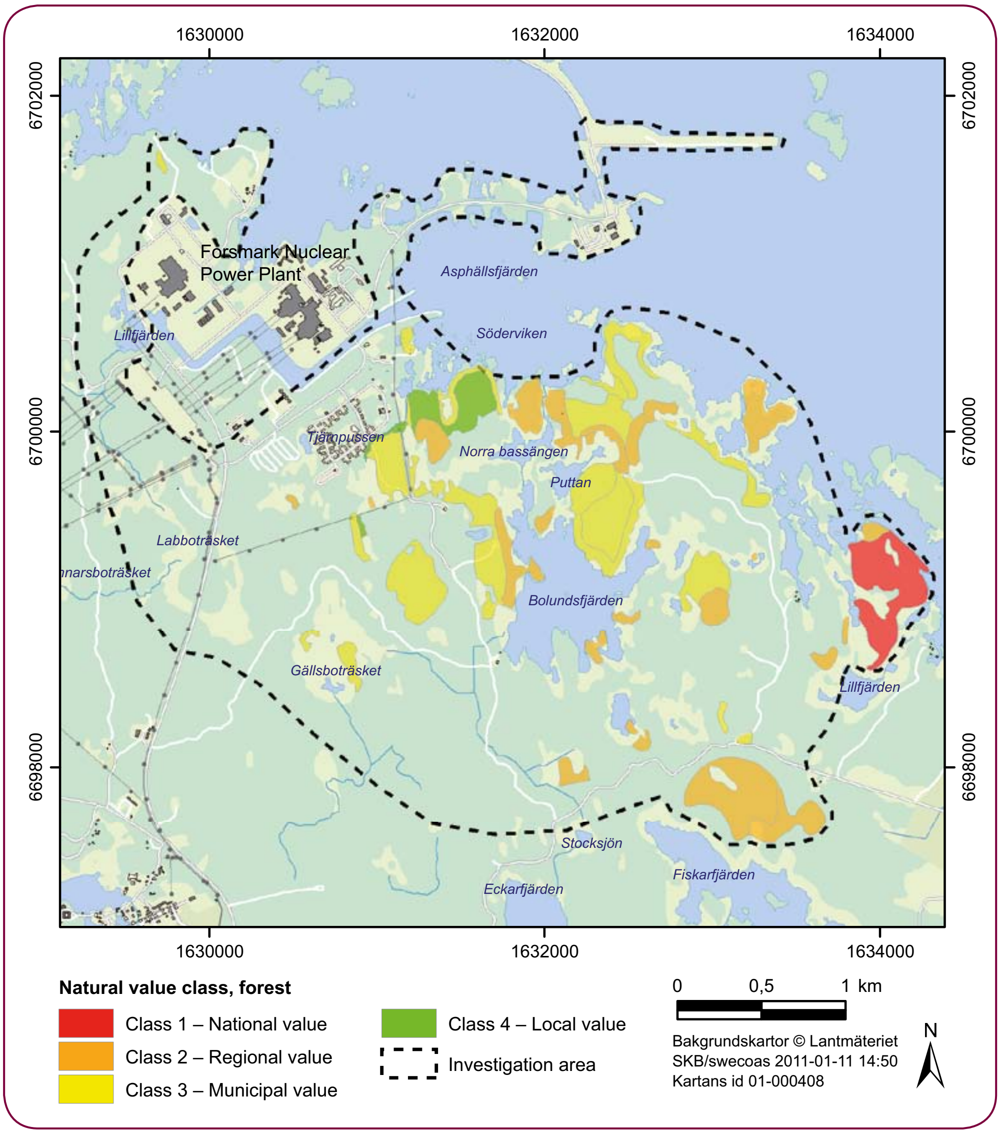


Figure 7-19. Identified natural values in the form of forest in the Forsmark area.

Not only do the wetlands in the area have high natural values individually; they also reinforce each others' values. Dispersal corridors exist for most rich fen species, but they are particularly important for threatened species. The pool frog's dispersal corridors are of great interest, since the species is dependent on suitable wetland environments for its reproduction. The population in Forsmark is separate from other populations in the north (Hållnäs) and on Gräsö and is thereby more sensitive to disruptions in the dispersal corridors in the area. Valuable dispersal corridors also exist for the area's species-rich coniferous forests and the species that have these forests as their habitats, for example lime-loving soil fungi /7-5/.

Inventories of key habitats and other natural values in forest land are conducted by the National Board of Forestry and large-scale forestry enterprises (landowners with more than 5,000 hectares of land plus the state, the municipalities, the county councils and foundations, regardless of the size of the holding). SKB has conducted additional inventories using the National Board of Forestry's methodology. The forests in the area are heavily affected by commercial forestry. One consequence of the forestry operations in the area are the many clear-felled sites at different stages of plant and shrub invasion. Despite the influence of forestry, there are also older forest stands, some with such high natural values that they have been classified as key forest habitats or sites of natural value (areas than can eventually achieve key habitat status). In the forest environments, more than 20 red-listed species of fungus have been encountered, the majority of which are associated with herb-rich calcareous coniferous forests.

Figure 7-20. The red-listed pool frog occurs in several ponds in the Forsmark area.

The area around Forsmark is very rich in birds, including numerous red-listed species. The forest environments harbour species such as hazel hen, wood grouse and Eurasian three-toed woodpecker, while Caspian tern is found in the coastal area. Large birds of prey such as honey buzzard, white-tailed eagle and Ural owl also occur in the area, see Figure 7-21. All of these species are listed in the EU's Birds Directive. In Asphällsfjärden, which is judged to be of municipal interest for the natural environment, there are a number of valuable bird skerries, and the shallow and vegetation-rich southern parts of the bay are probably also valuable as a nursery ground for fish /7-6/. According to the fish sampling done by the National Board of Fisheries' in the area since the 1980s, perch dominates the catches and comprises 75 percent of all individuals caught /7-4/. Some of the area's lakes, such as Norra Bassängen and Bolundsfjärden, are also of importance for spawning fish /7-8/.

7.1.6 Cultural environment and landscape

A cultural environment analysis and an archaeological survey have been carried out in the area. In connection with these, a landscape analysis has been done based on the visual perception of the landscape. The studies are summarized in /7-9/.

Figure 7-21. White-tailed eagle in the Forsmark area.

According to the landscape analysis, the Forsmark area can be divided into five different landscape types: wooded coastal landscape, industrial landscape, lake-rich forest landscape, cultivated landscape and mill town landscape, see Figure 7-22.

The Forsmark area exhibits great and interesting contrasts. The modern, large-scale industrial aspect of the nuclear power plant is contrasted with the older, softer aspect of Forsmarks bruk. There is also a contrast between the predominant lake-rich coniferous forest and the open agricultural environment of Storskäret. The forest meets the sea along a flat but convoluted coastline where the small, enclosed coves are similar in character to the lakes further inland. The forest goes all the way down to the shoreline. Thanks to the variation of the forest and the presence of the water, this landscape is rich and is perceived as small-scale and intimate. In the older forest stands there is also a feeling of pristine nature.

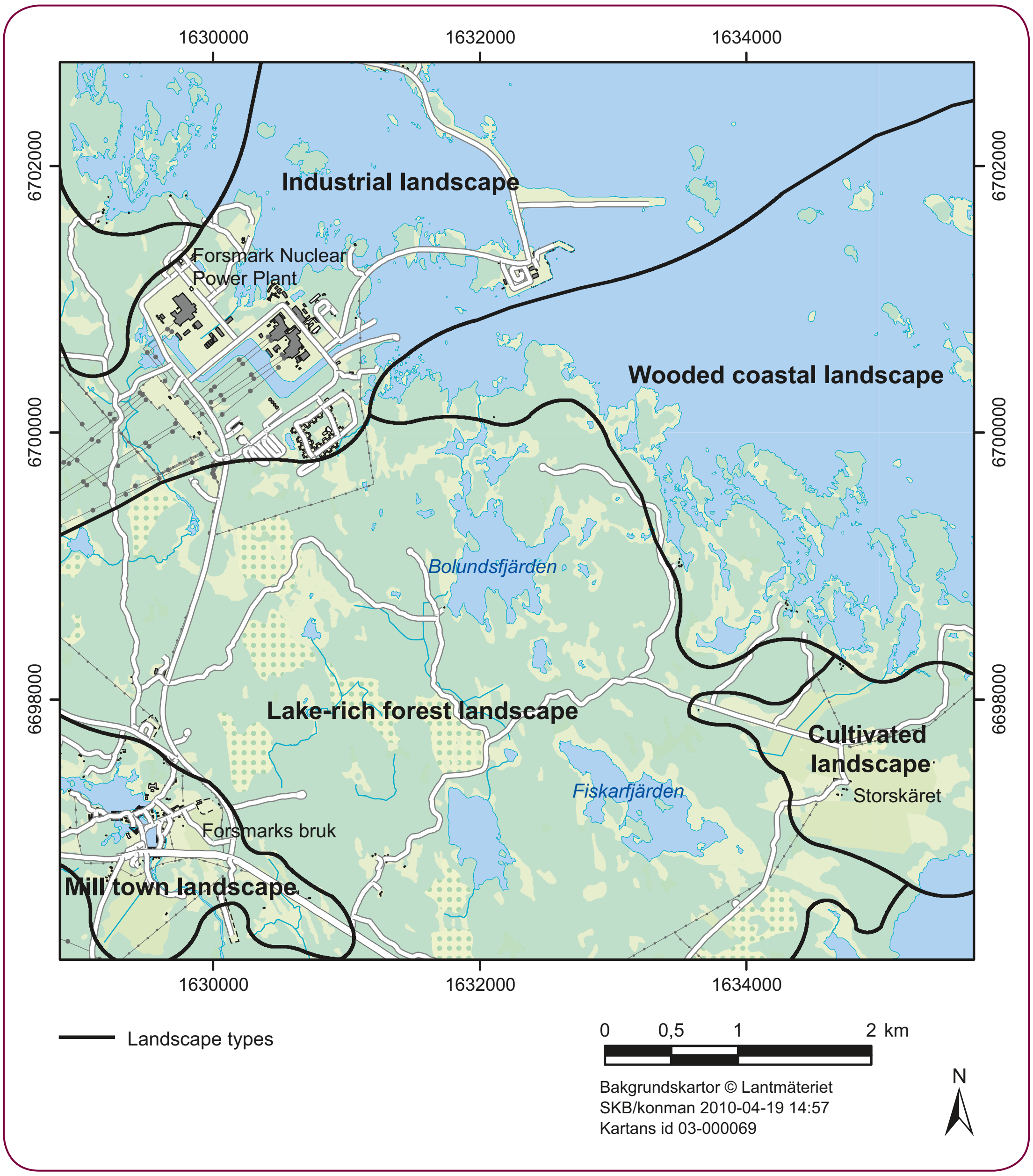


Figure 7-22. Landscape types in the Forsmark area (the area inside the coast in the northwest is of the lake-rich forest landscape type).

The area south of the power plant is of national interest for cultural heritage preservation. Besides the mill environment, it also contains cultivated landscape, croft environments and ancient crop-land. The mill area itself has been declared a historic landmark since 1975 by virtue of its being one of the country's most valuable mill environments, with uniform and lavish buildings from the 18th and 19th centuries and a unique English park.

At Storskäret there are traditionally tended meadow- and pasturelands that comprise a conservation area of national interest. Forsmark Church is subject to landscape protection (Section 19 of the Nature Conservation Act, the Environmental Code).

The cultural environment in the area is characterized by its three foremost natural resources: sea, forest and iron. Large parts of the Forsmark area belonged to the iron works, and land use was adapted to the needs of the iron works, mainly for energy for the iron furnaces (charcoal) and food for the mill workers (fishing, cattle raising and crop farming). A farm run by mill workers was started at Storskäret. In the southwest part of the area there are also some mine holes which – along with charcoal beds, remains of charcoal-burner cabins and mill roads in the woods – are the concrete traces of the mill era in the area.

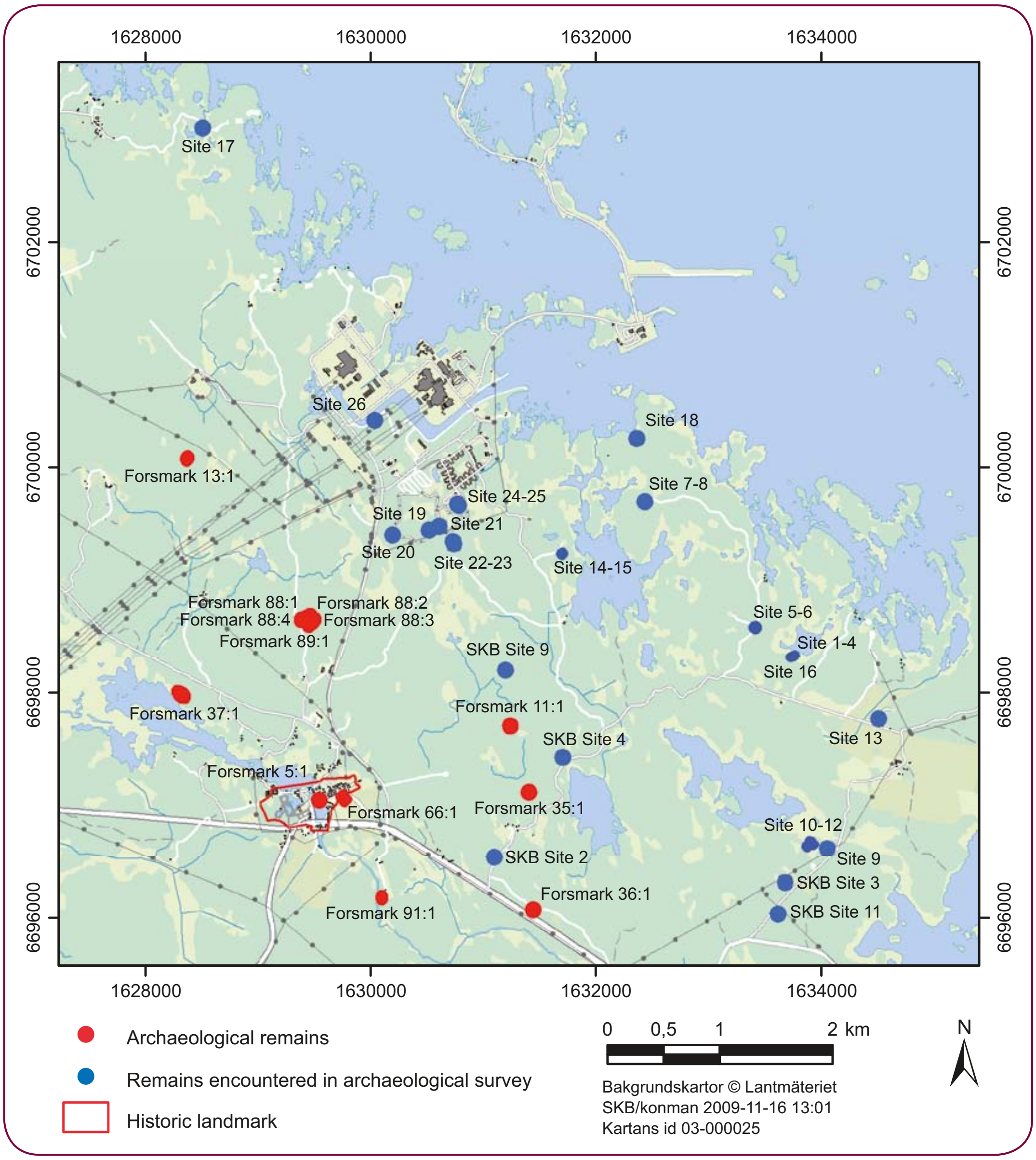


Figure 7-23. Map of registered cultural environment sites around Forsmark. Sites 1–4 are archaeological remains. Other sites consist of other historic remains. "SKB Site" is a site observed during geological surveys conducted by SKB.

There are traces of other eras in the area that are not as prominent as the mill era. Since large parts of the Forsmark area only rose above the sea a few thousand years ago, there are no prehistoric or early medieval remains in the archipelago and near-coastal areas. There are, however, occasional prehistoric graves in the forest lands to indicate that there may be coastal settlements from the Iron Age in the higher parts of the area.

Within the area for the cultural environment analysis, shown in Figure 7-23, four archaeological remains have been identified as traces from a fishing camp (boat remains and three building foundations). There are also a number of historic remains in the area consisting of a fishing camp, building foundations, charcoal-burner cabins and charcoal beds, croft remains, boundary markers, a well/cold spring, a waste heap or burial mound, a cellar pit, a modern cairn and ancient cropland.

7.1.7 Recreation and outdoor activities

The area around Forsmark has been dominated by one large landowner, and the land around the nuclear power plant was poorly accessible for a long time. Outdoor activities in the area are therefore less extensive than along other parts of the east coast. The main value for outdoor activities in the area lies in the pristine countryside, the animal life and the bird life, see Figure 7-24. Recreational activities such as hunting and fishing are also popular. There are facilities for exercise and recreation near the nuclear power plant, such as sports centre, tennis court, illuminated trails and bathing areas /7-10/.

Figure 7-24. The Forsmark area is rich in bird life and popular with birders year-round.

7.1.8 Noise

Current activities and heavy traffic affect the sound level around the nuclear power plant and the access roads. To ascertain the existing sound conditions, a combination of measurements and calculations of the sound level have been carried out in the area around the nuclear power plant /7-3/. The measurements were carried out in 2004 during a spring/summer period, an autumn period and a winter period. The measurement positions were located in areas where there are normally people present without this affecting the measurement results. The positions were also chosen to cover different wind directions in relation to the nuclear power plant.

The measured sound levels exhibit great variations and seasonal differences. The lowest sound levels were recorded during a period with new snow. Sound levels as low as below 20 dBA have been recorded at night, which is "absolute" quiet. During other measurement periods the sound level is 25–30 dBA at night, see Figure 7-25. At sunrise the sound level increases at all measurement positions due to bird song, causing the sound level in the forest to increase by 15–20 dBA for a few hours /7-11/.

The calculations that have been done for the area assume sound propagation with a tailwind in all directions simultaneously, which can be regarded as a "worst case". The calculations and the measurements (background level) are in fairly good agreement. Both calculations and measurements show that the most important noise source in the area is the Dannebo static converter

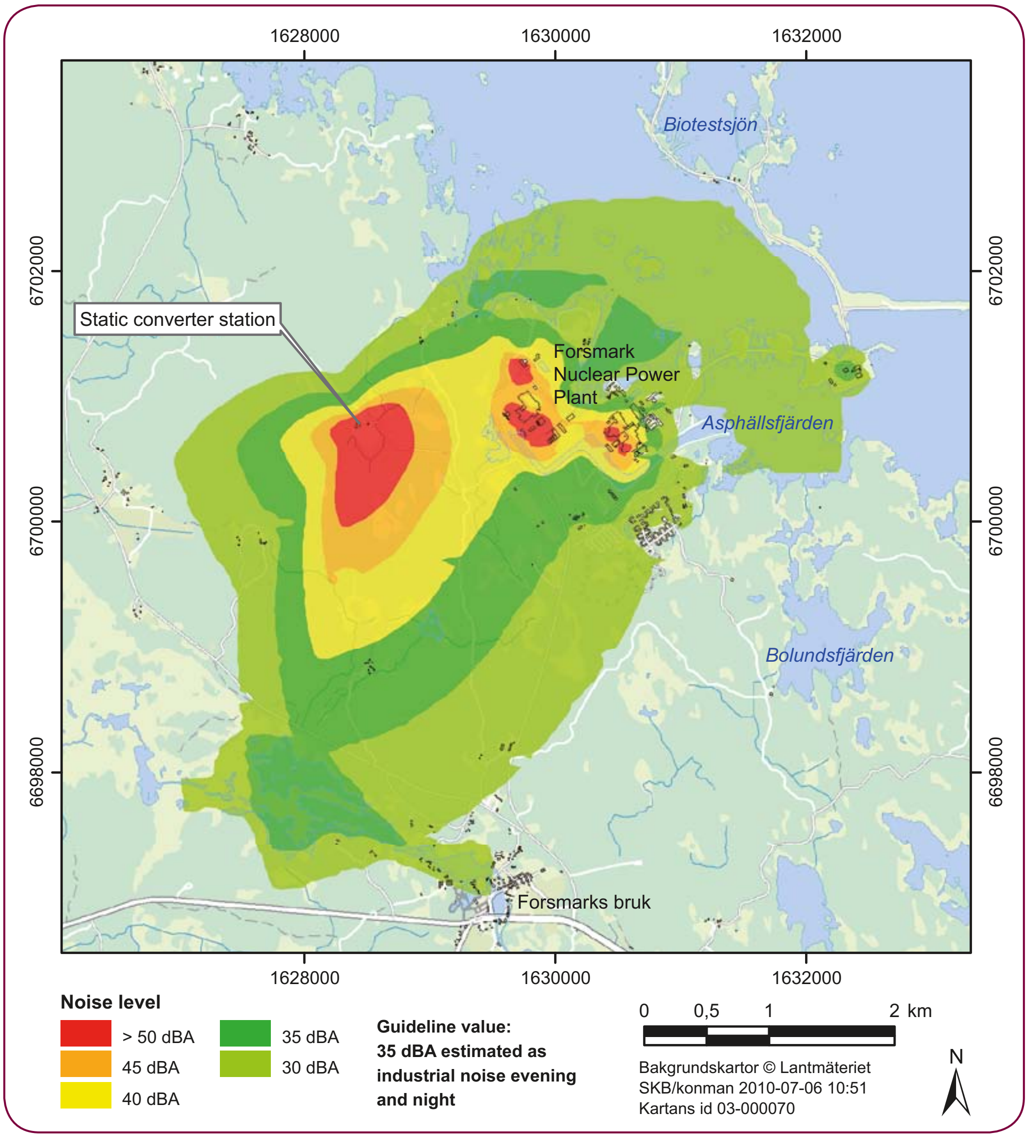
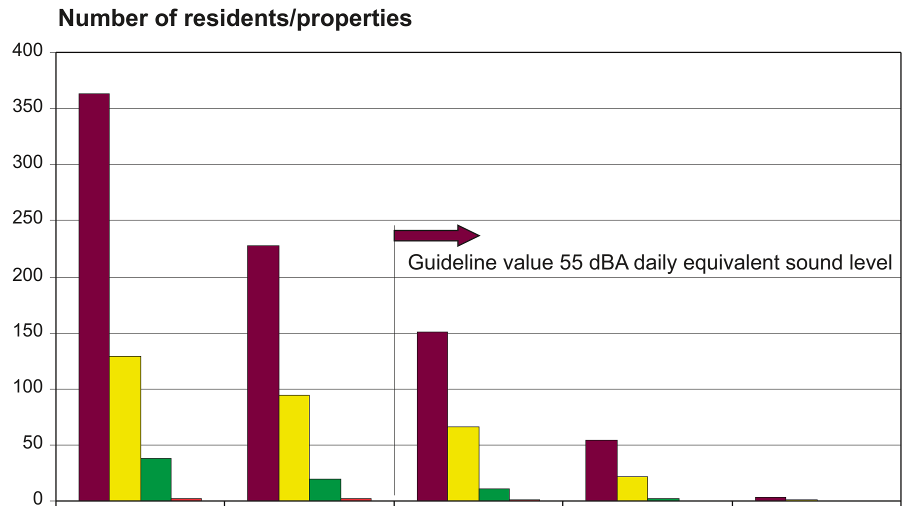


Figure 7-25. Calculated equivalent sound level at night.

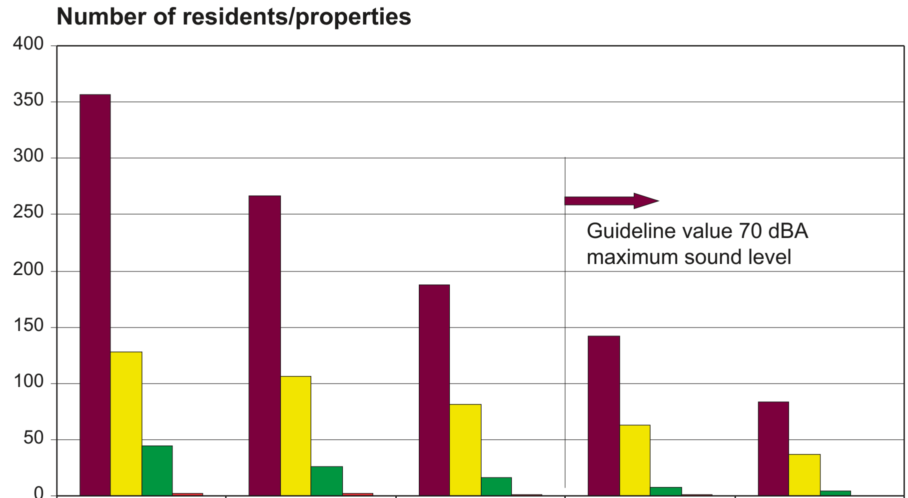
station, situated about one kilometre west of the nuclear power plant. The nuclear power plant also gives rise to some noise, mainly caused by fans and transformers. No permanent residents are exposed to sound levels above 35 dBA, which is the guideline value for industrial noise. In the area for temporary residents, the Barracks Village, the sound level varies between 30 and 35 dBA /7-3/.

Road traffic noise has been studied along national road 76 between Forsmark and Hargshamn. The road has a relatively high traffic load, at the same time as many homes are situated near the road. Around Johannisfors and Norrskedika, noise from road traffic is perceived to be a big problem today. The calculations show that many residents are exposed to traffic noise that exceeds the guideline values established for equivalent and maximum sound level, 7-26 and 7-27.



Equivalent sound level	> 45 dBA	>50 dBA	>55 dBA	>60 dBA	>65 dBA
Residents	363	228	151	54	3
Single-family houses	129	94	66	22	1
Secondary residences	38	20	11	2	0
Schools	2	2	1	0	0

Figure 7-26. Number of residents and properties exposed to a daily equivalent sound level above 45 dBA along the road between the Forsmark Nuclear Power Plant and Hargshamn in 2006.



Maximum sound level	> 55 dBA	>60 dBA	>65 dBA	>70 dBA	>75 dBA
Residents	357	267	188	142	84
Single-family houses	128	106	81	63	37
Secondary residences	44	26	16	8	4
Schools	2	2	1	1	0

Figure 7-27. Number of residents and properties exposed to a maximum sound level above 55 dBA along the road between the Forsmark Nuclear Power Plant and Hargshamn in 2006.

7.1.9 Emissions to air

Measurements of atmospheric pollutant concentrations are lacking in the Forsmark area. Based on existing concentration data on the east coast at the Järinge monitoring station in the vicinity of Forsmark (nitrogen dioxide, NO_2) and Aspvreten outside Stockholm (particulate matter, PM10), regional background concentrations for NO_2 and PM10 have been estimated /7-12/. By "regional background concentrations" is meant atmospheric pollutant concentrations that are unaffected by nearby emission sources. Since measurement of daily mean values is lacking at Järinge, measurement data from Råö outside Gothenburg have been used to estimate daily mean values for background concentrations of NO_2 (98th percentile day) in Forsmark. By 98th percentile is meant that the air has a higher concentration two percent of the time and a lower concentration 98 percent of the time. The estimated regional background concentration of NO_2 in Forsmark is two micrograms per cubic metre /m (µg/m^3) as an annual mean and eight µg/m^3 as a daily mean (98th percentile day). Hourly measurements of background concentration are lacking in Sweden.

The estimated regional background concentration of particles (PM10) in Forsmark is 12 µg/m^3 as an annual mean, 19 µg/m^3 as a daily mean (90th percentile day) and 30 µg/m^3 as a daily mean (98th percentile day). Compared with other air pollutants, PM10 exhibits relatively high background concentrations in both rural and urban areas. One reason for the high background concentration, which occurs all over Sweden, is the transport of fine particles into Sweden from the continent. They mainly come from combustion processes in Europe.

Carbon dioxide emissions in the county amounted to 1.2 million tonnes in 2004. Carbon dioxide emissions have declined in the county since 1990, mainly due to the heating sector's conversion to renewable fuels, but the reduction is counteracted by increasing traffic emissions. The county trend is better than the national trend when it comes to reductions of greenhouse gas emissions.

Air pollution is deposited on soil and vegetation by different processes. Particles can also be taken up directly by plants or absorbed on different surfaces such as leaves, stems or objects. Particles are also deposited directly on the ground, plants or objects. This type of deposition is called dry deposition. Gases and particles can also be washed out of the atmosphere with precipitation, called wet deposition. The total deposition (wet + dry) of nitrogen around Forsmark amounts to about 0.6 g/m^2.

7.1.10 Radiological conditions

Radiological measurements are performed regularly around the nuclear facilities in Forsmark, both directly on outgoing process water and exhaust air and in the form of radiological environmental monitoring, with sampling of water, plants and animals. Most of the measured radiation is natural background radiation. The main source of artificial radioactivity in the Baltic Sea is the accident in Chernobyl in 1986. Other sources are fallout from the atmospheric weapons tests performed in the late 1950s and early 1960s, and releases from the reprocessing plants at Sellafield in England and La Hague in France. The radioactivity emitted from the existing nuclear facilities (the nuclear power plant and SFR) to the environs with the process water and via the ventilation system contributes very little to the total radioactivity in the Baltic Sea. Emissions to air are dominated by noble gases, which are not deposited on the ground or the vegetation. Samples from the terrestrial ecosystems therefore seldom exhibit any detectable concentrations, except of cobalt-60, which occurs sporadically in different kinds of samples, and cesium-137, which mainly comes from the atmospheric weapons tests and from the Chernobyl accident. Elevated concentrations of radionuclides in the aquatic environment are easier to see. Concentrations in sediments varied during the period 2002 to 2004 between 2.2 and 1,100 Bq/kg dry weight for cesium-137 and between 13 and 4,200 Bq/kg dry weight for cobalt-60. Concentrations in the surface layer of the sediments and in bladderwrack of cobalt-60, which is the most frequent radionuclide originating from the nuclear power plant, decline with the distance from the emission source.

Emissions of radionuclides from the nuclear facilities give rise to very low radiation doses to humans, far below the limit values stipulated by SSM. The annual dose to the critical group from the nuclear power plant and SFR is around $2 \cdot 10^{-4}$ mSv, which is approximately one five-hundredth of the legal limit and approximately one five-thousandth of the natural background radiation /7-13, 7-14/.

7.1.11 Natural resources

7.1.11.1 Agriculture and forestr

Forestry is the predominant land use in the Forsmark area. Active agriculture is only practiced at Storskäret, approximately two kilometres southeast of the southeastern boundary of the priority area.

7.1.11.2 Water resources

The entire municipal drinking water supply, which supplies 70 percent of the inhabitants of Östhammar Municipality, comes from groundwater from large esker formations. The esker formation located closest to Forsmark is Börstilåsen, from which water is taken to supply the towns of Östhammar, Norrskedika, Öregrund and Hargshamn. The withdrawal area in Börstilåsen located closest to the siting area for the final repository is situated about eight kilometres southeast of the eastern part of the siting area. Additional potential for water withdrawal in Börstilåsen is designated in the municipal comprehensive plan, but not in the part of the esker north of the town of Östhammar.

Today, 30 percent of the inhabitants of the municipality have private water supplies. Information has been compiled on existing private wells within a radius of three kilometres of the planned final repository. The information has been taken from a well inventory done by SKB in the Forsmark area in 2001, from a follow-up inventory at the end of 2009 and from SGU's well archive. A total of 14 private wells that are in use have been identified within the area in question. Of these, four are dug wells, nine are drilled wells and one is of unknown type (information not available).Of the four dug wells, one has been replaced by a drilled well on the same property, and one dug well is used for irrigation, cooking and laundry. One of the dug wells is not currently in use. Of the nine drilled wells, one is used as a heat source and one is used for irrigation, cooking and laundry. One drilled well is in the well archive but has not been located, despite assistance from the property owner (FKA).

The rock caverns in SFR are located in bedrock beneath the bottom of the sea near Forsmark harbour. Six litres of water per second (0.006 cubic metre per second) is the current pumping rate for drainage of SFR. An extension of SFR is planned.

The current pumping rate for drainage beneath the reactor buildings at the nuclear power plant is approximately 1–2 litres per second (0.001–0.002 cubic metre per second). According to a water rights court ruling, FKA is allowed to divert 85 litres per second (equivalent to 0.085 cubic metre per second) from Bruksdammen in the Forsmarksån River at Forsmarks Bruk for water supply. Furthermore, FKA may withdraw 200 cubic metres of cooling water per second from the sea via the cooling water channel and discharge heated cooling water in the Biotest Basin /7-5/.

7.1.11.3 Commercial fishing

Öregrundsgrepen is of national interest for commercial fishing. According to the National Board of Fisheries, there are eleven licensed fishermen in Östhammar Municipality (May 2009) who pursue small-scale near-coastal fishing.

7.1.11.4 Ore deposits

A large portion of Östhammar Municipality is located in the Bergslagen ore province. A hundred or so iron ore deposits have been mined in recorded history. Most have been or are small. Only the Dannemora Mine has been of significant importance, and there are plans to resume operation of the mine. Other deposits that have been mined on a large scale are the Ramhäll, Vigils, Romberg and Norrskedika mines. There is still plenty of iron ore in the region. However, the ores are located in volcanic rocks, not in granites of the type found in the priority area. The priority area does not contain any ore deposits or other valuable mineral resources /7-4/. An iron oxide mineralization was found during the site investigation southwest of the site investigation area. However, the deposit was judged to be too small to be economically worth mining today or in the future.

7.2 Laxemar/Simpevarp

Both Simpevarp, where Clab is located and the encapsulation plant is planned, and Laxemar, which is the considered siting that has been studied for the final repository, are described below. The Laxemar and Simpevarp areas are situated next to each other on the coastal road (county road 743).

The Oskarshamn Nuclear Power Plant, with three reactors operated by OKG, is located on the Simpevarp peninsula. A near-surface repository for low-level waste (MLA) and a rock cavern for low- and intermediate-level waste (BFA) are also located near the nuclear power plant. Besides Clab, SKB's site investigation office and the access tunnel to SKB's hard rock laboratory on Äspö, as well as the Simpevarp harbour, are also located on the peninsula.

7.2.1 Physical planning, population and infrastructure

7.2.1.1 Comprehensive plan

Comprehensive plan 2000 for Oskarshamn Municipality was adopted by the municipal council in 2003. The comprehensive plan describes a large area between European Route 22 and the nuclear power plant as suitable for in-depth investigations for the final repository. A smaller development area west of Clab is described as suitable if additional land is needed for the construction of a final repository.

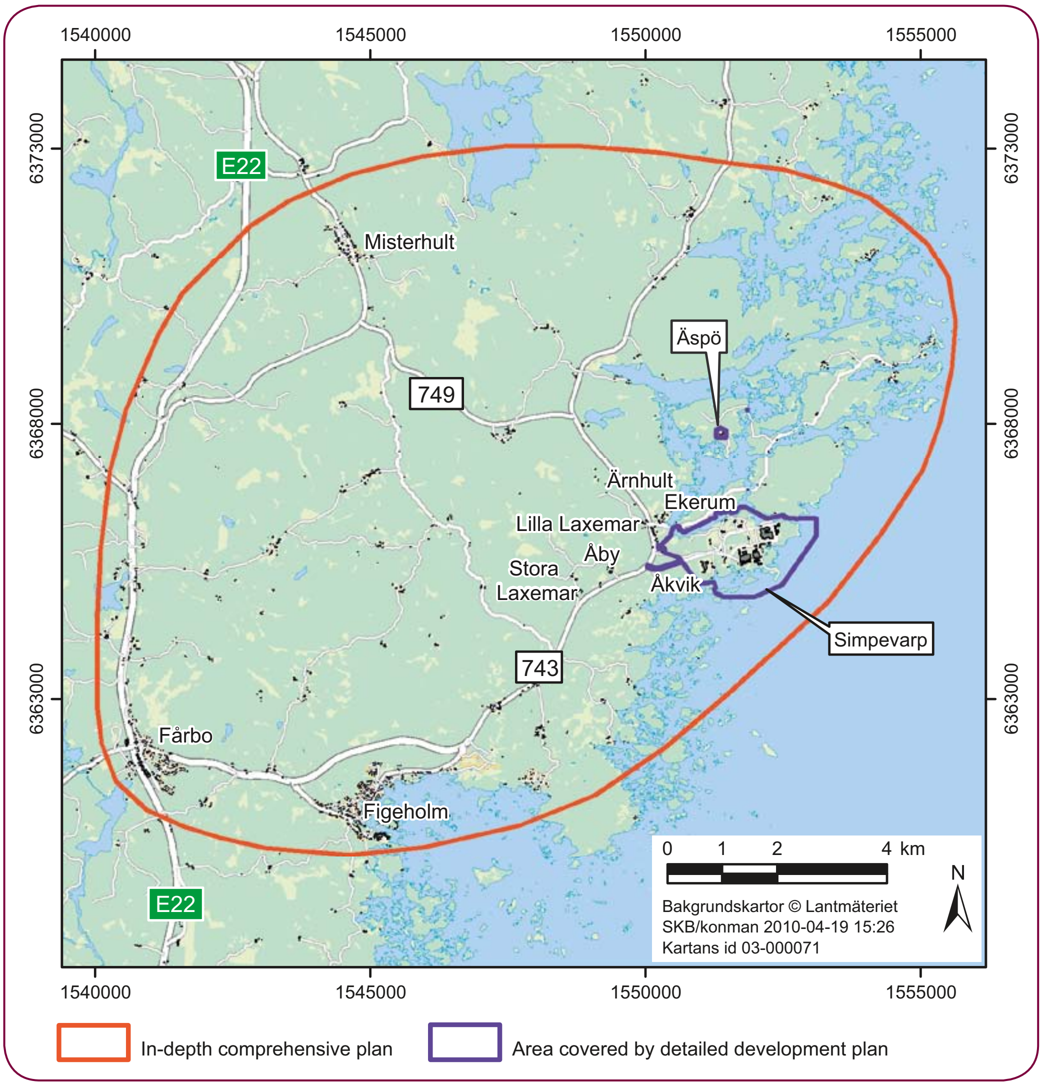


Figure 7-28. Area covered by detailed development plan in Simpevarp.

7.2.1.2 In-depth comprehensive plan

An in-depth version of the municipality's comprehensive plan – Comprehensive plan 2000, Simpevarp and Laxemar area etc – was adopted by the municipal council in 2007, see Figure 7-28. The purpose of the plan was to commence the municipality's physical planning for possible construction of a final repository in the Laxemar area and an encapsulation plant adjacent to Clab. The in-depth version of the comprehensive plan replaces the previous municipality-wide comprehensive plan for the areas it covers.

7.2.1.3 Detailed development plan

A detailed development plan for the Oskarshamn Nuclear Power Plant's activity area was adopted in 1988, see Figure 7-28. Detailed development plans also exist for the Äspö Hard Rock Laboratory (adopted 2001) as well as OKG, Clab and other facilities in the area (adopted 2006). The most recent detailed development plan for Clab that has been adopted and gained legal force permits erection of the encapsulation plant at Clab.

7.2.1.4 Population

The Laxemar/Simpevarp area is sparsely developed. Fewer than five persons live within a kilometre of Clab, while around 115 persons live within five kilometres and approximately 1,300 persons within ten kilometres, see Figure 7-29 and Table 7-2 /7-15/.The nearest development on the Simpevarp peninsula is in Åkvik, about 600 metres southwest of Clab. About 15 persons live within one kilometre of the Laxemar area, about 150 persons within five kilometres, and just under 2,000 persons within ten kilometres, see Table 7-3. The development in the Laxemar area consist of a few small villages in the northwest (Mederhult), in central Laxemar (Ärnhult), and villages along county road 743, especially Lilla Laxemar and Stora Laxemar, Ström and Åby. The nearest town is Figeholm, which is situated about eight kilometres southwest of the Simpevarp peninsula. Consultants, contractors and others stay at OKG's temporary accommodations near the nuclear power plant.

Table 7-2. Number of residents (registered) in 2009 within different distances of Clab.

Distance	Residents, total	of whom in single-family houses	of whom in secondary residences	of whom in farms	of whom in rental housing	other residents
0–1 km	3	3				
1–5 km	113	67	5	41		
5–10 km	1,162	913	32	73	131	13
0–10 km total	1,278	983	37	114	131	13

Table 7-3. Number of residents (registered) in 2009 within different distances of the Laxemar area.

Distance	Residents, total	of whom in single-family houses	of whom in secondary residences	of whom in farms	of whom in rental housing	other residents
0–1 km	16	4		12		
1–5 km	129	75	16	38		
5–10 km	1,827	1,517	30	111	169	13
0–10 km total	1,972	1,596	42	161	169	13

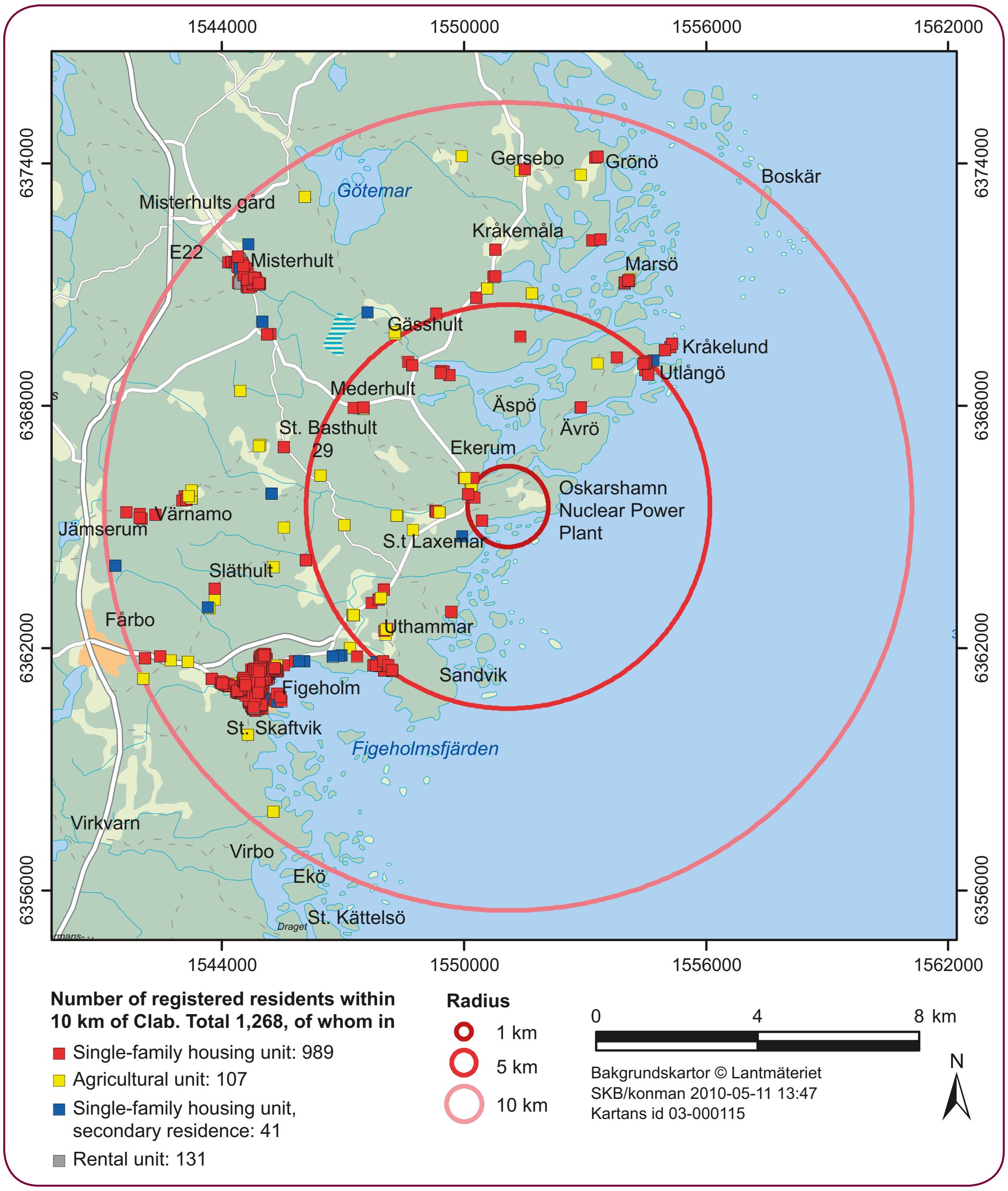


Figure 7-29. Number of residents (registered) in 2009 within ten kilometres of Clab.

7.2.1.5 Roads and conventional transport

E22 passes through the municipality. County road 743 links E22 with the coast and comprises, together with an approximately one kilometre long road, the link to the Oskarshamn Nuclear Power Plant, see Figure 7-30. There is also a connection northward to E22 via county road 749 past Misterhult. All of these roads are of the highest load-bearing class. Much of county road 743 is narrow, only 5.7–6.6 metres wide, and carries heavy one-way traffic in the mornings and evenings. A bypass around Fårbo was built in 2005, which has led to great improvements in the community of Fårbo, which previously suffered from traffic disturbances. The distance between the Laxemar/Simpevarp area and Oskarshamn is about 25 kilometres. The distance to Kalmar and Växjö is around 95 and 150 kilometres, respectively.

The periodically high traffic load on county road 743, together with the many different types of traffic – cars, trucks, buses, cyclists, pedestrians, tractors and agricultural equipment have to share this road – creates hectic conditions for both road users and residents. A conceptual study has been conducted on behalf of SKB. It describes the present situation and ideas for future improvements of county road 743 /7-16/.

Traffic on county road 743 in the area around Basteböla in 2006 amounted to about 1,500 vehicles per day, about seven percent of which were heavy vehicles /7-17/. Traffic on the entrance road to the nuclear power plant amounted to about 950 vehicles per day /7-18/.

In addition to the ordinary passenger traffic, there are the temporary employees who are hired during the annual refuelling outages and in different development projects at the nuclear power plant. A normal refuelling outage takes about two months for the whole nuclear power plant and involves some 500 persons. In a year with big projects, such as turbine replacement, the number of temporary employees can reach above 700. Most of them live at the nuclear power plant or in a nearby holiday village, but the hotels in Oskarshamn also notice when it is time for a refuelling outage at the nuclear power plant.

According to statistics from 2004, 2,687 persons commuted into Oskarshamn Municipality and 1,229 commuted out of the municipality. The surplus was thereby 1,458 persons. More than 80 percent of the in-commuters come from municipalities in the same county, with a clear majority coming from the municipality of Mönsterås (80 percent). Data are lacking regarding the commuting pattern to and from OKG /7-17/.

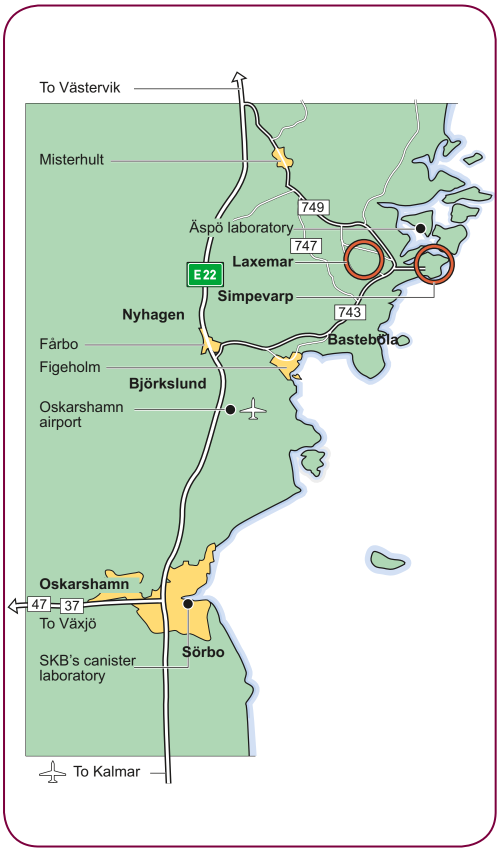


Figure 7-30. Main roads that connect to the Laxemar/Simpevarp area.

7.2.1.6 Transport of spent nuclear fuel and nuclear waste

Sea transport of spent nuclear fuel and nuclear waste takes place by m/s Sigyn, which docks regularly at the Simpevarp harbour. Overland transport is performed by slow-moving terminal vehicles within the industrial area. The spent nuclear fuel and operational waste is enclosed in transport casks during transport.

7.2.1.7 Railway

Oskarshamn is linked to the rest of the railway network via the Oskarshamn–Berga line. Passenger traffic to Oskarshamn ceased in the spring of 2005. Today, freight traffic is carried on the line five days a week by diesel locomotive, since the line is not electrified. The Regional Council in Kalmar County has presented different proposals for possible development of the county's public transport. In the report, which presents several alternatives, an idea is proposed of a new railway along the Baltic Sea coast, the "Småland Coastal Railway", between Kalmar and Linköping via Oskarshamn–Simpevarp–Västervik. SKB's believes that this potential railway project lies far in the future.

7.2.1.8 Harbours and navigation channels

The Simpevarp harbour is located on the southern part of the Simpevarp peninsula right next to the Oskarshamn Nuclear Power Plant. The harbour is not public, but is used primarily to receive spent nuclear fuel from the nuclear power plants and to ship low- and intermediate level waste to the final repository in Forsmark. The material is carried by m/s Sigyn. The maximum draught in the channel is 5.5 metres, and the depth of the harbour basin is about six metres. A road specially built for heavy vehicular traffic leads from the harbour to the the Oskarshamn Nuclear Power Plant and Clab.

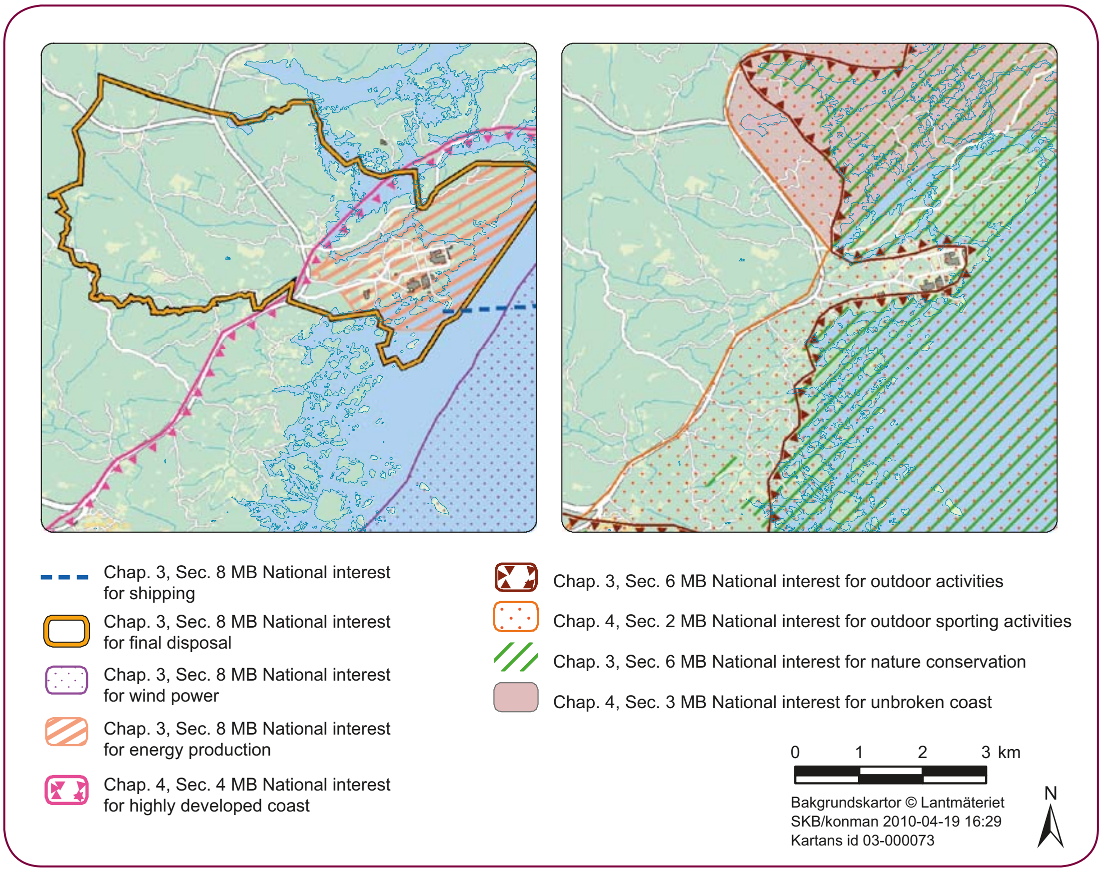
The Port of Oskarshamn handles oil, paper, bulk cargo, container cargo, paper pulp and saw timber. The ferry service to Gotland is an important part of the port's activities. The port has seven berths today, three of which are for ferry traffic. The entrance channel to the harbour is allowed for vessels with a maximum draught of 10.5 metres. The port has a railway connection via an industrial spur /7-17/.

7.2.2 National interests and protected areas

There are a number of areas of national interest within the immediate area, as illustrated in Figure 7-31. The Simpevarp peninsula and most of Ävrö and part of Hålö with nearby marine area are of national interest for energy production as well as of national interest for final disposal of spent nuclear fuel and nuclear waste. The navigation channel outside Simpevarp harbour is of national interest for shipping. The Västervik and Oskarshamn archipelagos are of national interest for nature conservation, and all of the Småland archipelago is of national interest for outdoor activities. Two areas out at sea southeast of Ävrö are of national interest for wind power.

The entire coastal and archipelago area is an area of national interest under the special management provisions for highly developed stretches of coast in Chapter 4, Sections 1–4 of the Environmental Code. The provisions of Section 2 say that the interests of tourism and outdoor activities, in particular outdoor sporting activities, shall be given particular consideration when assessing the permissibility of development projects or other environmental intrusion.

According to the provisions in Section 4, nuclear facilities may only be established on sites where certain types of facilities, such as nuclear facilities, already exist, while Section 3 states that certain facilities, for example nuclear facilities, may not be established in any case. The boundary between coastal areas covered by Sections 3 and 4 goes at Simpevarp. A study of the geographic boundary between these areas shows that the area south of county road 743 is subject to the provisions in Section 4 /7-19/.



7-31. Areas of national interest in Laxemar and Simpevarp.

A study area for a nature reserve is located within the area, and the Natura 2000 site of Figeholm is located along county road 743. Areas of national interest for nature conservation and Natural 2000 sites are designated in Figure 7-39, Section 7.2.5 "Natural environment".

7.2.3 Geology

The site investigation in the Laxemar/Simpevarp area has been conducted in the same way as in Forsmark. The results of the investigations have been summarized in a site descriptive model adapted to each different discipline /7-20/. The area where completion of the site investigations took place is also called the focused area in the underlying documentation for the site investigation in Laxemar. In order to obtain uniform terminology in Forsmark and Laxemar, this area is called a priority area in this EIS. Unless otherwise specified, the information in Sections 7.2.3.1–7.2.3.4 is taken from /7-20/.

7.2.3.1 The bedrock

The bedrock in the priority area has been divided into three main rock domains from north to south: RSMA01 (A01), RSMM01 (M01) and RSMD01 (D01), where the biggest volume consists of rock domain RSMD01, see Figure 7-32.

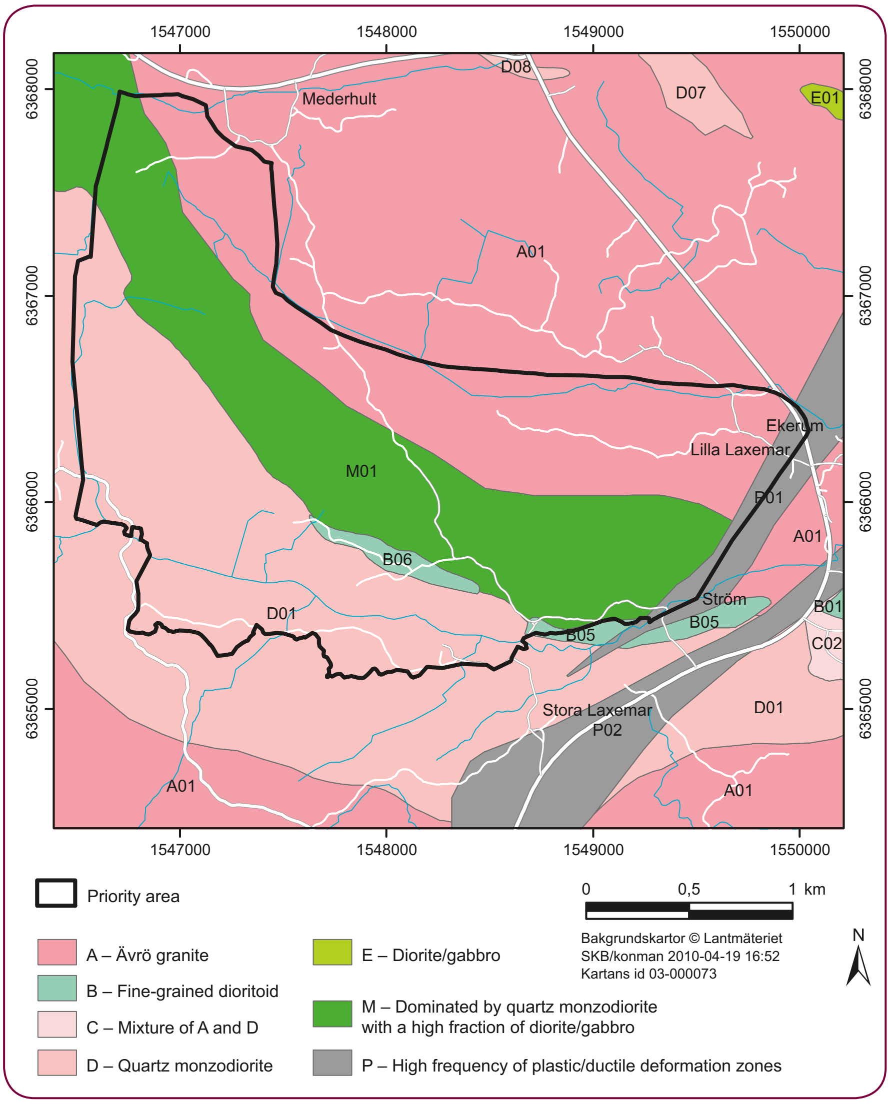


Figure 7-32. Rock domains in the priority area in Laxemar.

Rock domain RSMD01 is dominated by quartz monzodiorite and contains subordinate amounts of rock types such as fine-grained granite, fine-grained diorite-gabbro, pegmatite and occasional occurrences of dolerite. Rock domain RSMM01 consists primarily of Ävrö quartz monzodiorite with a greater occurrence of diorite/gabbro than other rock domains, but otherwise with a similar occurrence of subordinate rock types as in rock domain RSMM01. Rock domain RSMA01 is dominated by Ävrö granite and contains subordinate rock types such as fine-grained granite, fine-grained diorite-gabbro, fine-grained dioritoid and quartz monzodiorite. The rock types are generally characterized by a low quartz content, relatively low thermal conductivity and varying strength.

Deformation of the bedrock in Laxemar started deep down in the Earth's crust in conjunction with the formation of the rocks about 1.8 billion years ago at high temperature, in other words at relatively great depth. The bedrock was subjected to ductile deformation concentrated in deformation zones within which the structure of the rocks was altered. Two major northeasterly oriented deformation zones, one of which is the Äspö shear zone, are located at the boundary with the Simpevarp peninsula and Äspö. Another major deformation zone is located west of the

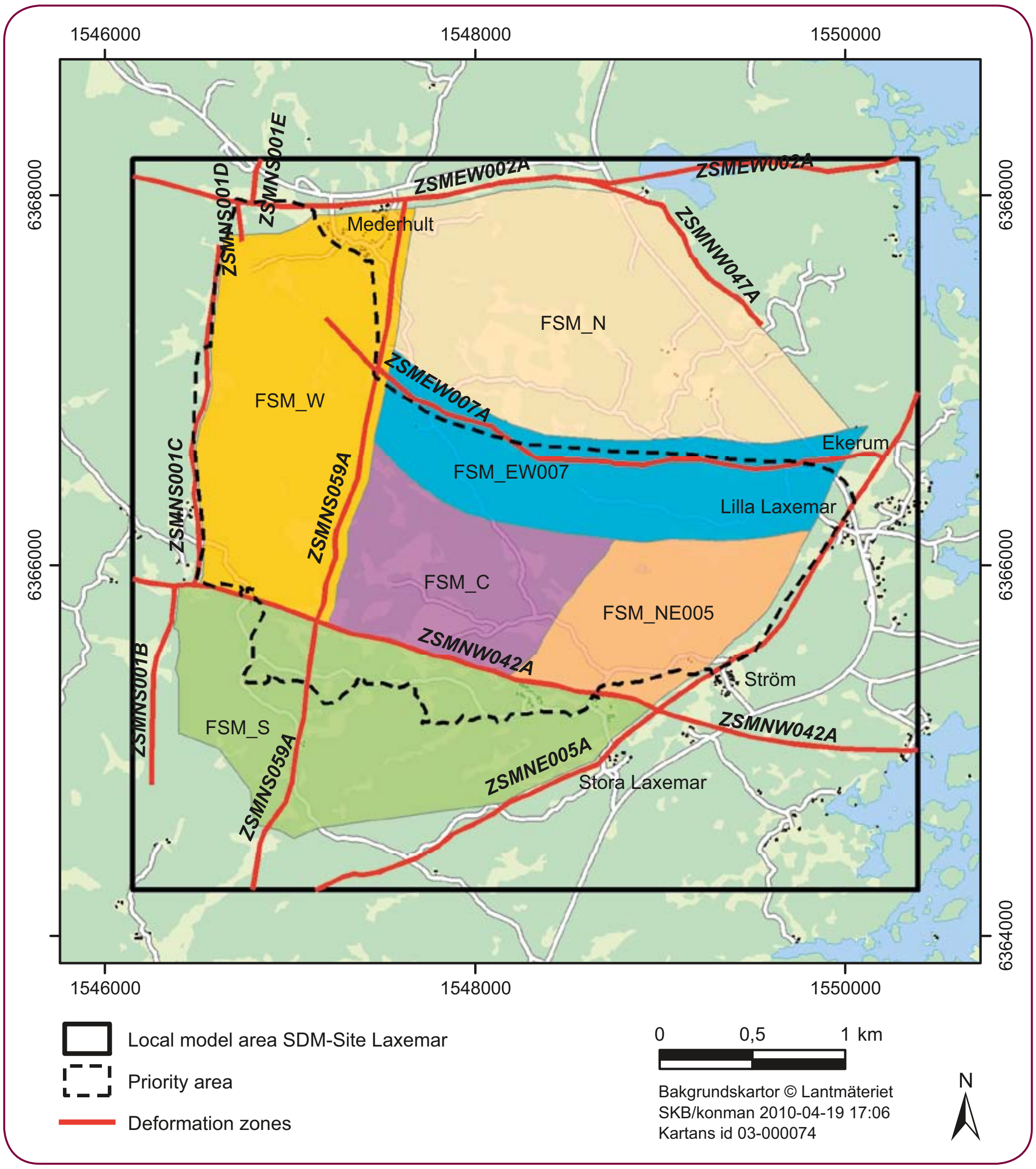


Figure 7-33. Projection on the ground surface of fracture domains (coloured polygons) and deformation zones in Laxemar. The priority area is bounded by major northeast-oriented regional deformation zones.

priority area. As long as the rock was hot, at great depth in the Earth's crust, the rock mass in the ductile deformation zones was ductile and the rock was able to move without fracturing. When the temperature in the bedrock fell, the deformation changed from ductile to brittle, and fracture zones were formed whose fractures were partially filled with minerals, healing them. These fractured zones constitute preferred flow paths for groundwater. Within the priority area there are a number of interpreted deformation zones, primarily grouped in the directions NE-SW, NS, EW and NW-SE, as well as a gently dipping group of zones. The deformation zone ZSMEW007A is an exception since, unlike most other zones, it exhibits only brittle deformation. There are minor zones of varying size and direction between the major deformation zones. An illustration of the deformation zones is provided in Figures 7-33 and 7-34.

The fracture zones have been reactivated (reopened) several times and healed together again with different types of minerals in connection with different geological events. Dolerite also occurs in the deformation zones ZSMNS001C, which runs along the western boundary of the Laxemar area. The dolerite has been dated and found to be about 900 million years old and was probably formed when magma was pushed up along already existing deformation zones in the rock. The most recent reactivation of deformation zones in the area took place about 400 million years ago.

No major gently dipping deformation zones have been identified in the priority area. However, the deformation zones contain both horizontal and vertical fractures, most of which are healed but some are still open.

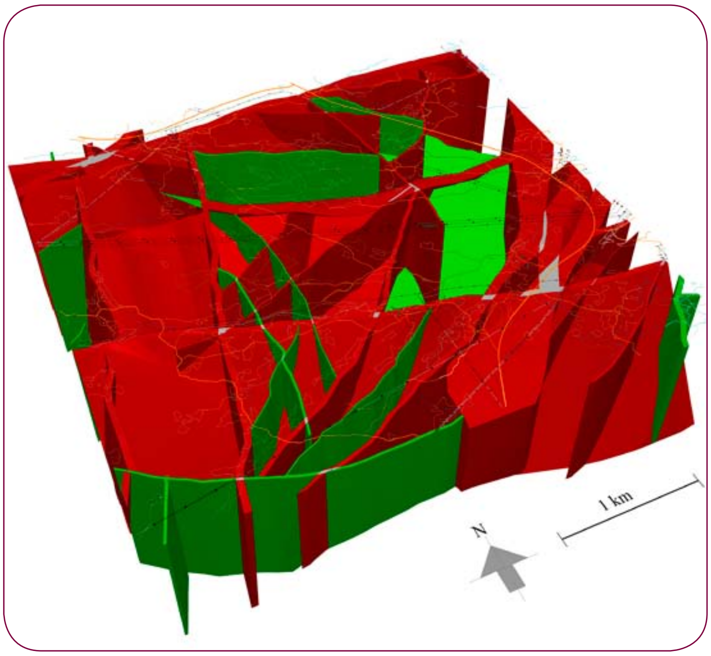


Figure 7-34. Three-dimensional model showing the vertical and steeply dipping deformation zones in Laxemar. The model is viewed from above off to the side looking northward. The red zones are deterministically modelled with high confidence, and the green zones are modelled with medium confidence.

The bedrock between the deformation zones in the priority area has been divided into fracture domains in order to distinguish rock volumes with different fracture frequencies, see Figure 7-33. Six distinct fracture domains were identified within the priority area in Laxemar. The fracture frequency in these fracture domains is normal for Swedish bedrock, with the exception of fracture domain FSM_EW007, which has a higher fracture frequency.

On the southern part of the Simpevarp peninsula, where Clab is situated, the site investigations showed that fine-grained dioritoid dominates. The northern part of the peninsula is dominated by Ävrö granite and quartz monzodiorite. The Simpevarp peninsula is surrounded and traversed by a number of deformation and fracture zones. The zone ZSMNE015A, with an interpreted length of two kilometres, is situated close to Clab. Before the site investigations began, local detailed investigations were conducted of the bedrock at and immediately surrounding Clab in conjunction with the construction of the rock caverns Clab 1 and 2. According to these investigations, steeply dipping aplite and pegmatite dykes occur at Clab. The investigations also showed that the rock nearest the rock caverns has a high fracture frequency in the order of 2–6 fractures per metre. See also /7-21/.

7.2.3.2 Rock stresses

The stresses (loads) in the rock are higher farther down in the rock than near the ground surface. The stresses are caused by both vertical and horizontal forces. The vertical load consists of the weight from the overlying rock, which increases with depth. The horizontal loads are more complex and can ultimately be attributed to the forces that are generated by plate movements on a global scale. In Swedish bedrock, the horizontal stresses are generally higher than the vertical ones, so also in the Laxemar area. Locally, the size of the stresses is also dependent on the properties of the rock, especially the occurrence of fractures. The rock stresses measured at a depth of about 500 metres in Laxemar are normal for Swedish crystalline bedrock. The largest horizontal stress at this depth is oriented in a northwest-southeast direction. Similar results exist from the Äspö Hard Rock Laboratory, where the measurements have been verified by large-scale measurements around tunnels.

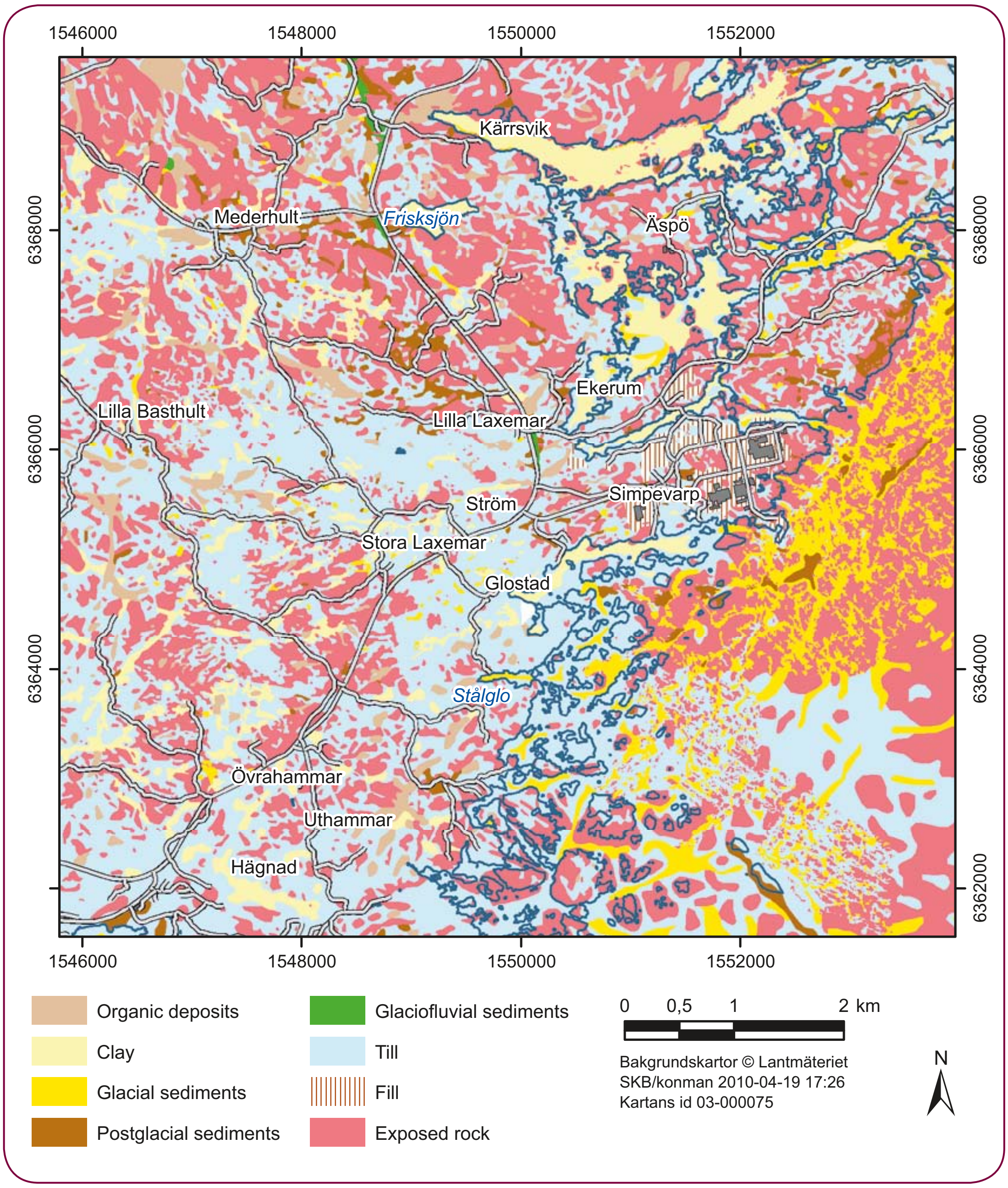


Figure 7-35. Quaternary deposit map of the Laxemar/Simpevarp area.

7.2.3.3 Quaternary deposits

The Laxemar area is characterized by a relatively flat rock surface intersected by a number of fissue valleys. Exposed bedrock occurs frequently, particularly in the northern part of the area. Till, which is an unsorted drift deposited beneath an ice sheet, is the predominant type of deposit and is overlain in low-lying areas by sand and/or clay. There are often boulders on top of the fine-grained soils, sometimes even at greater depth. The thickness of the soil layers averages about 2–3 metres and is greatest in the valleys. There is a large esker just west of E22. This esker, Fårboåsen, is the most prominent Quaternary deposit in the entire area. There are also some smaller ridges in the northern part of the area.

The Simpevarp peninsula is dominated by exposed rock and the soil thickness is generally moderate (a metre or so at most). The soil layers in the area nearest Clab are dominated by fill, and till occurs a bit farther away, see Figure 7-35. Most of the fill consists of shot rock from the construction of the nuclear power plant.

7.2.3.4 Hydrogeology

The ground surface in the Laxemar/Simpevarp area slopes from west to east, from a level of about 30 metres above sea level at E22 to sea level at the coast, see Figure 7-36. The upper 150 metres or so of the rock in the priority area has a relatively high frequency of water-bearing fractures, with an average spacing of about a metre. In the depth interval 150 to 400 metres, the average spacing between water-conducting fractures is 2–13 metres (depending on the fracture domain studied), while the equivalent distance at a depth of between 400 and 650 metres is 4–17 metres. At even greater depths (> 650 metres), the frequency of water-conducting fractures is very low, with an average spacing of more than 100 metres, but the estimate here is uncertain due to a limited quantity of data. The permeability of the rock, which is dependent to a great extent on the frequency of water-conducting fractures, generally decreases with depth.

Most of the groundwater flow at repository level takes place within (along) the steeply dipping fracture zones. Most of the groundwater exchange between the rock and the soil layers is judged to occur in the limited areas where the steeply dipping zones intersect the rock surface, mainly in the valleys. Figure 7-37 shows a conceptual illustration of a typical east-west valley in the Laxemar area where the Quaternary deposits and the thickness of the soil layers vary along the valley.

Due to the contrast between the permeability of the soil layers/upper rock and the underlying rock, most of the groundwater flow in the area takes place relatively close to the ground surface. The valleys constitute discharge areas for groundwater, where the preferred flow also takes place along the zone in the soil layer and the superficial rock. This near-surface flow system with recharge areas in high-lying terrain and discharge areas in valleys and at the coast overlies deeper and more large-scale flow systems in the rock. The water flux in the near-surface rock is estimated to be about 400 times higher than at repository depth.

Comparisons between water levels in the lakes and groundwater levels beneath the lakes indicate that interaction between the lakes and groundwater in underlying Quaternary deposits mainly takes place in near-shore areas /7-22/.

The groundwater table in the Laxemar/Simpevarp area generally lies 0.5–2 metres below the ground surface and follows the topography. Time series show that the variations are in the order of one metre during the year in most monitoring wells. However, it should be noted in this context that there is a great overrepresentation of groundwater monitoring wells at the edges of valleys.

Investigations have shown that relatively young and fresh (< 900 mg/l chloride) to older and brackish groundwaters preferably occur down to a depth of 250 metres. Deeper down there are brackish glacial waters from the most recent glacial period and even older non-marine and much more saline groundwaters with retention times of 10,000 years or more. Beneath lower-lying areas nearest the coast, there are traces of several thousand year-old sea water stemming from the Littorina Sea (a predecessor of the Baltic Sea). The salinity of the water in Laxemar increases gradually with depth, and is about 10,000 milligrams per litre (mg/l chloride) at a depth of 900 metres. The groundwater in the fracture-free rock at repository depth is very old, with a salinity varying between 5,000 and 8,000 mg/l chloride. Very saline water with a chloride concentration of more than 20,000 mg/l has been encountered at depths greater than 1,200 metres within the investigation area. Oxygen-free conditions prevail at repository depth, with a neutral to weakly alkaline pH.

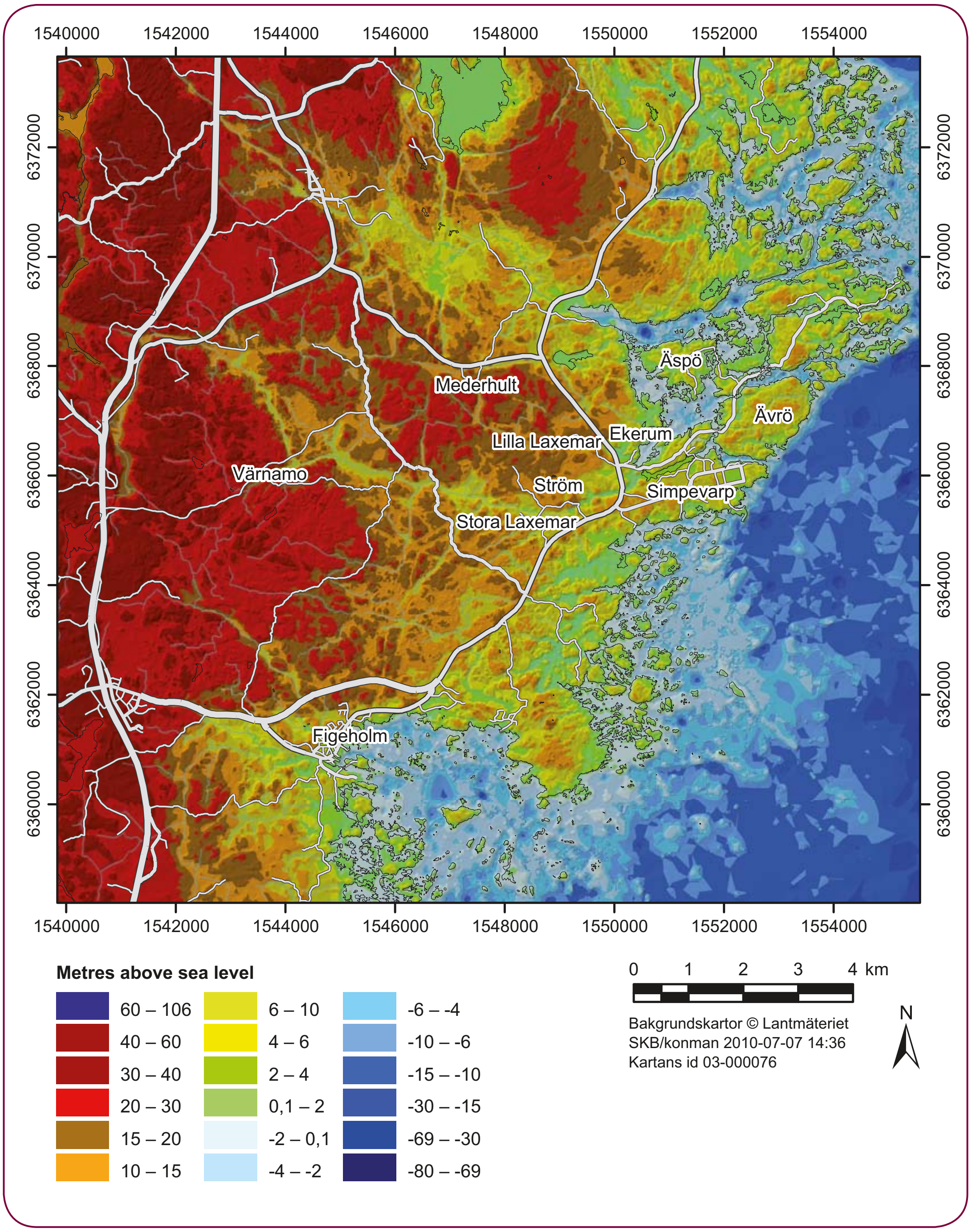


Figure 7-36. Topographical map of the Laxemar/Simpevarp area.

On the Simpevarp peninsula, where Clab is situated, hydraulic tests were also performed within the framework of the site investigations. There is a deformation zone close to Clab, but it was judged to have low permeability. The tests further indicated very low permeability in the rock between the zones on the Simpevarp peninsula. Hydraulic tests were also performed in conjunction with the construction of Clab and showed a relatively high permeability in the local fracture zones identified closest to Clab. During construction of Clab 1 and 2, pre-grouting of the rock caverns was done to reduce groundwater inflow. Aside from a couple of local fracture zones, however, many of the fractures encountered during construction of Clab were not water-conducting. See also /7-2/.

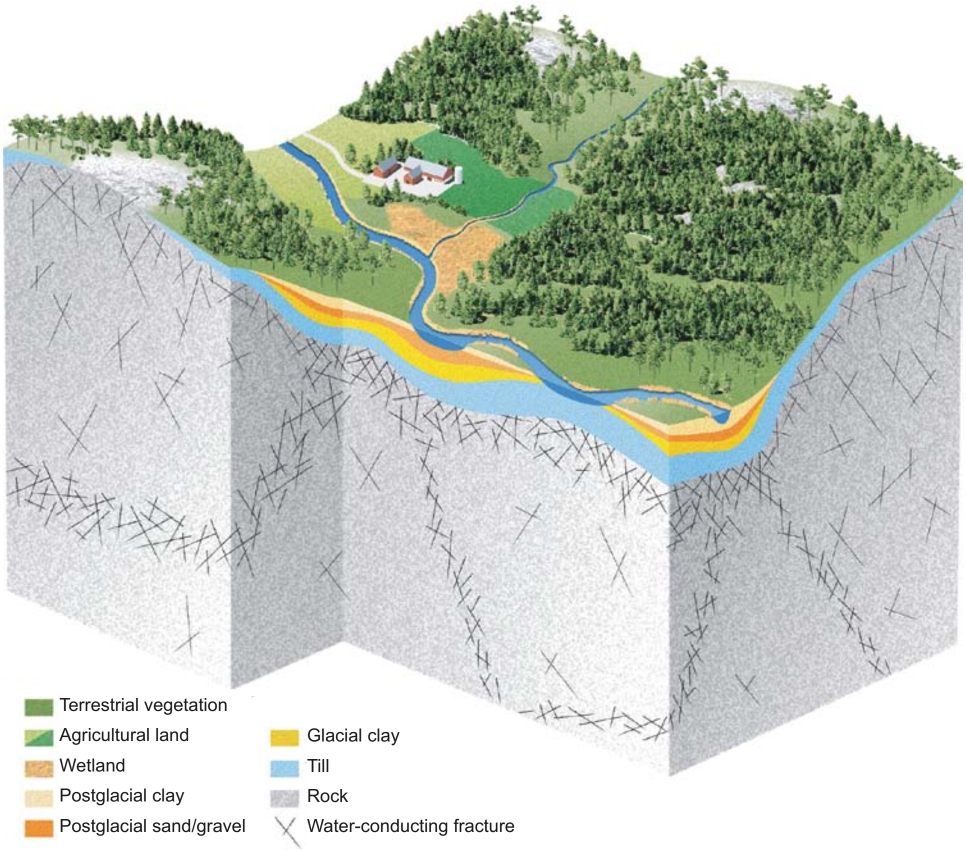


Figure 7-37. Conceptual illustration of a large valley in the Laxemar area. The illustration shows how the Quaternary deposits and the thickness of the soil layers vary along the valley, which means that the conditions for water exchange between near-surface groundwaters and surface waters also vary along the valley.

7.2.4 Hydrology and meteorology

According to data from SMHI for the reference normal period 1961–1990, the mean annual precipitation in the area is about 600 millimetres. The mean value of the annual specific runoff is about 160–170 millimetres per year (slightly lower at the coast). Actual evapotranspiration, which is the portion of the precipitation that is bound in the vegetation and evaporates, has been estimated to be about 430–440 millimetres per year /7-21/.

The lakes in the Laxemar/Simpevarp area are relatively small (0.03–0.24 square kilometre) and shallow, with a mean depth varying between about one and four metres and a maximum depth varying between about two and eleven metres. There are six lakes in the area, the largest of which are Jämsen and Frisksjön, see Figure 7-38. All lakes are situated several metres above sea level, which indicates that sea water intrusion does not occur. There are several wetlands in the area.

The Laxemar/Simpevarp area is dominated hydrologically (with respect to the size of the catchment areas) by the Kärrviksån and Laxemarån watercourses and their tributaries. The headwaters of these watercourses are in the higher-lying terrain to the west and they run out into bodies of water that are directly connected to the Baltic Sea. Between these watercourses there are four smaller watercourses: Mederhultsån, Ekerumsån, Pistlanbäcken and Kåreviksån. Oxhagsdiket, a tributary of Laxemarån, drains the areas for the considered siting of the operations area for the final repository. Virtually all watercourses are affected by human activity (drainage, straightening etc). There are many manmade ditches and drainage systems in the Laxemar/Simpevarp area, and it is likely that if not for them, many areas would probably be lakes or wetlands /7-21/.

There are no watercourses on the Simpevarp peninsula. The Lake Sörå, which is situated about 600 metres north of Clab, consists of a dyked-in sea bay (Söråviken) and is used today by OKG as an emergency water supply (fire pond).

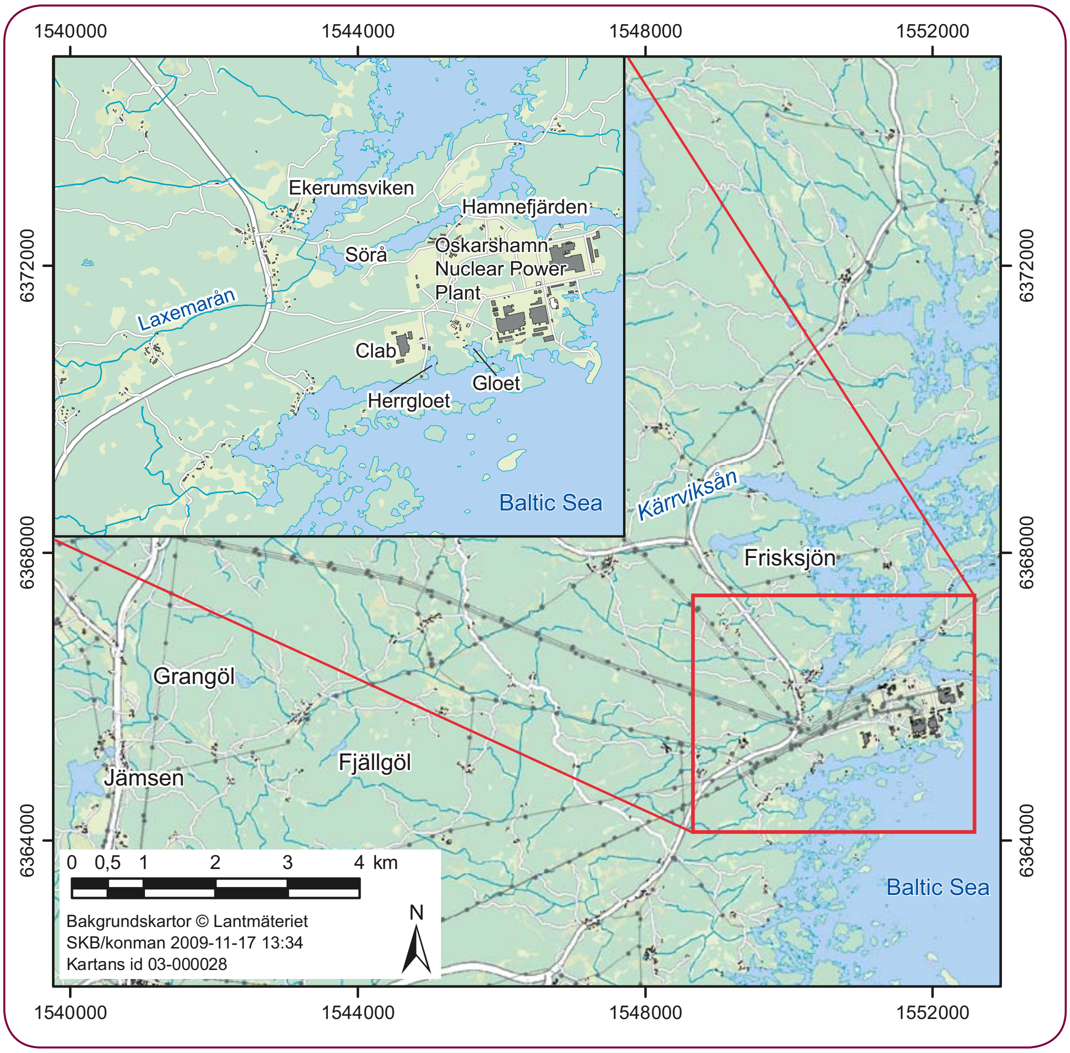


Figure 7-38. The lakes in the Laxemar/Simpevarp area.

7.2.5 Natural environment

The area around the Laxemar/Simpevarp area lies in a geographical region which is characterized by a joint valley landscape with small elevation differences, deciduous forests, bare skerries and rocky shores. The forests and the many joint valleys dominate the landscape. The fracture valleys have loose soils, and this is where most of the farmed land is. The cultivated landscape around Ströms Farm and Laxemarån consists of a multi-facetted landscape with pasturelands and deciduous forests.

The area of national interest of the Västervik and Oskarshamn archipelagos is located partly within the investigation area that was delineated in the natural environment study /7-23/. There are no Natura 2000 sites in the investigation area in question. However, the Natura 2000 site of Figeholm is located along county road 743, consisting of deciduous forest and conifer-dominated mixed forest with a high occurrence of red-listed species and indicator species. Areas of national interest for nature conservation and other protected areas around the Laxemar/Simpevarp area are shown in Figure 7-39. There is no nature reserve in the area today, but there is background material for a study for such an area at the County Administrative Board in Kalmar County. No concrete jobs have been started and no decisions exist today. The area is a designated core area for deciduous forest, which covers large parts of the investigation area.

Small bodies of water, wetlands, springs and open ditches in agricultural land are covered by general habitat protection under Chapter 7, Section 11 of the Environmental Code (1998:808) and Sections 5–8 of the Ordinance (1998:1252) on Area Protection under the Environmental Code.

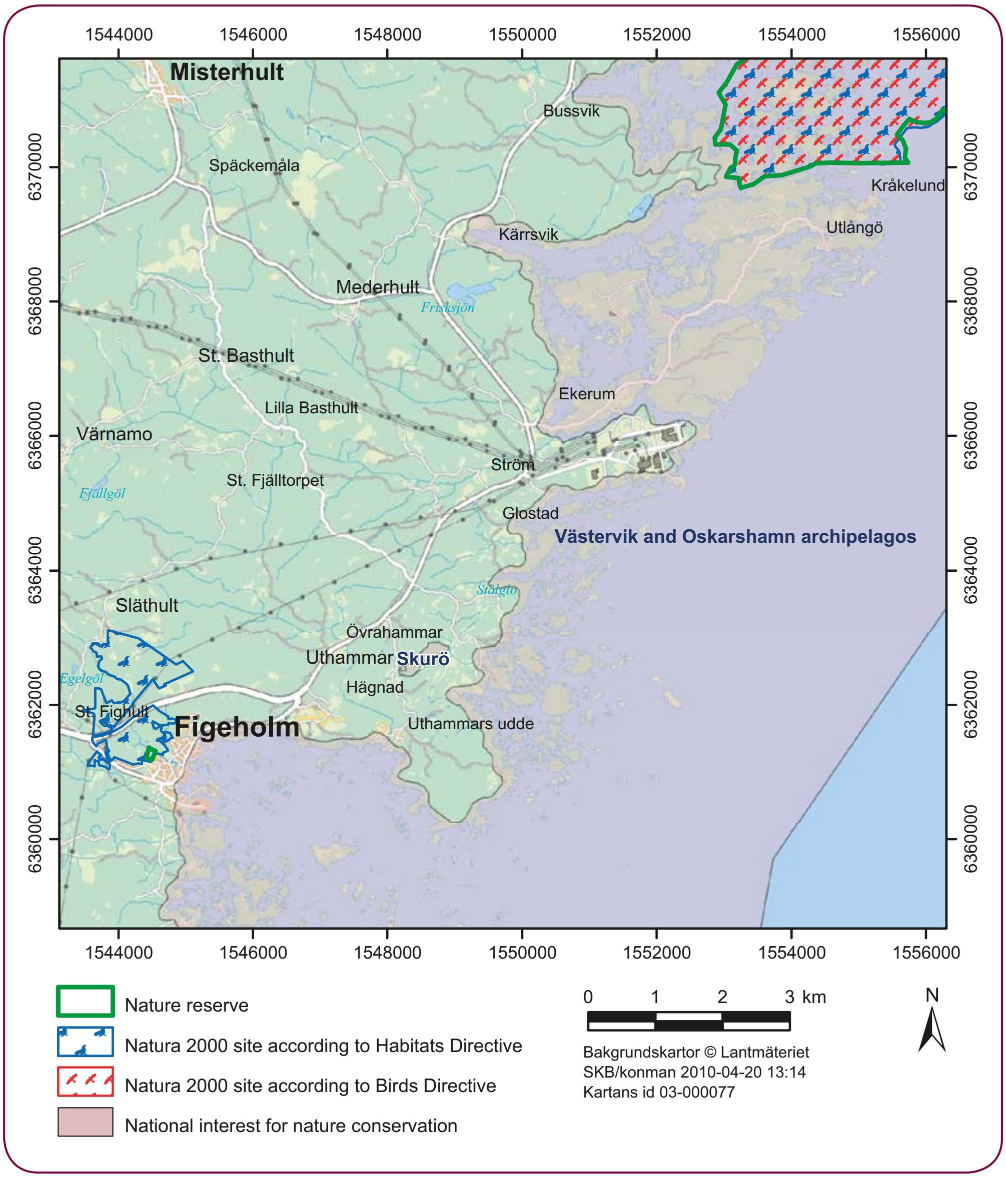


Figure 7-39. Areas of national interest for nature conservation and protected areas around the Laxemar/Simpevarp area.

An exemption from the habitat protection must be sought from the County Administrative Board. There is a natural monument at Ström in the form of two large-girth oaks.

The countryside in the investigation area is varying but almost all of it shows signs of former and current farming and forestry operations. The valuable natural environments in the area are largely associated with former traditional land use in the form of grazing and haymaking, or with deciduous forest and old deciduous trees. The investigation area was inventoried during the 2008 vegetation period for the occurrence of valuable natural environments. The results of the inventories are presented in /7-23/ and /7-24/. The natural values in the area have been classified by means of a methodology used by the Swedish Environmental Protection Agency and the county administrative boards and divided into four classes: national, regional, municipal and local value. Identified natural values are designated in Figure 7-40. Most of the identified natural values are associated with the agricultural landscape's deciduous forests and pasturelands, see Figure 7-41, above all along the valley of the Laxemarån. Some twenty-odd examples of valuable deciduous forest environments are found along Laxemarån and south of the river. Approximately half have regional natural values, others have municipal values. The high values are attributed to old, large-girth oaks as well as lime, ash and maple trees that bear traces of pollarding (pruning). The ground vegetation in many places consists of a rich woodland flora with such species as black pea, spring pea, bearded couch and woodruff. Furthermore, there are indicator species of e.g. lichens and fungi, of valuable natural environments. The cultivated landscape is generally judged to have high natural values (regional and municipal values) as a result of preserved structures and species (e.g. dropwort, maiden pink, pyramidal bugle, bulbous buttercup and mat-grass) associated with traditionally tended environments. The landscape around Ströms Farm and Laxemar is included in the County Administrative Board's conservation plan for the cultivated landscape.

Wetland environments, watercourses and lake environments within the study area are all clearly affected by human activity and generally judged to harbour limited natural values. Laxemarån is a fresh water environment judged to have municipal value. Despite impact due to drainage ditching and straightening, the river has retained a certain degree of naturalness, with stretches of running water and coarse bottom sediments. The flora and fauna consist of ordinary species. The river is an important reproduction ground for the fish species ide and is the only watercourse in the area with running water all year round. Laxemarån is a eutrophic forest watercourse with brownish water whose periodically low oxygen concentrations clearly influence the composition of the benthic fauna.

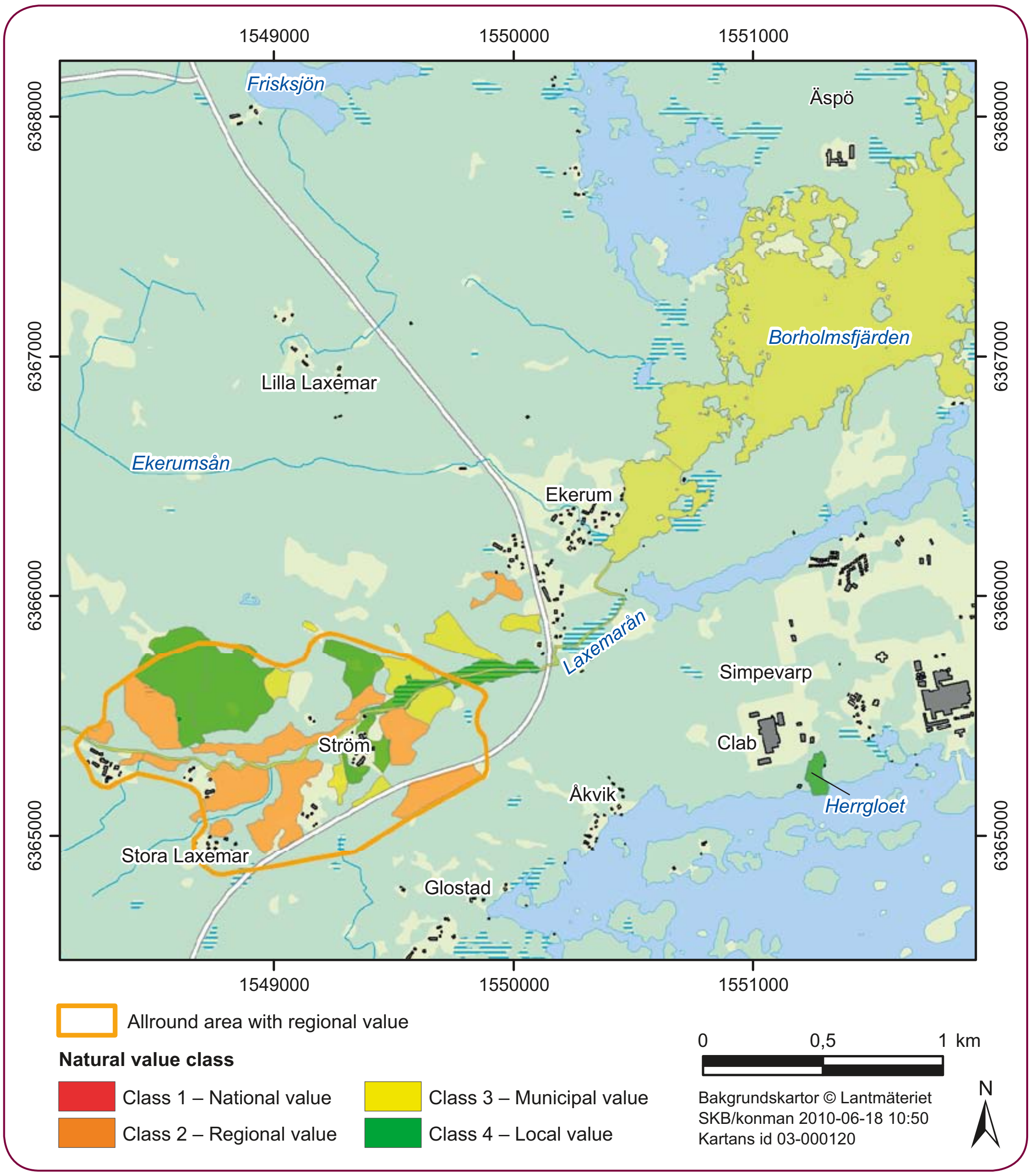


Figure 7-40. Identified natural values in the investigation area and their classification.

Figure 7-41. There are valuable natural values in the investigation area associated with deciduous forest and the cultivated landscape.

Ekerumsviken Bay is a marine environment that is assessed to be of municipal value, above all due to its ecological relationship with the Laxemarån River and Borholmsviken Bay. Ekerumsviken constitutes a discrete basin with a threshold towards Borholmsfjärden. The aquatic vegetation and the benthic fauna are relatively species-poor due to the effect of nutrients from Laxemarån. From Ekerumsviken, the fish species ide and roach swim up into Laxemarån to spawn. Borholmsfjärden is also judged to be of municipal value. It has potentially important spawning grounds for fish species such as pike, perch, Baltic herring etc. Compared with nearby shallow areas along the coast around Oskarshamn, Borholmsfjärden is deemed to be less valuable for fish and other groups of species due to the impact of nutrients from Laxemarån.

Honey buzzard, shrike, lesser spotted woodpecker, black woodpecker, Eurasian pygmy-owl, black grouse and Eurasian crane are examples of birds that breed or have their territory in the Laxemar area. They are all red-listed and/or listed in the EU's Birds Directive. Red-listed species of bats, insects, reptiles and vascular plants have also been encountered within the investigation area and along county road 743. Eel probably occurs in Borholmsfjärden and Ekerumsviken, but this has not been substantiated /7-23/.

Inventories of key habitats and other natural values in forest land are conducted by the National Board of Forestry and large-scale forestry enterprises (landowners with more than 5,000 hectares of land plus the state, the municipalities, the county councils and foundations, regardless of the size of the holding). SKB has also conducted additional inventories using the National Board of Forestry's methodology. The natural values in most of the key habitats in the investigation area are associated with deciduous forest environments, several are associated with aspen (especially in the eastern part of the area) and some are associated with mixed coniferous forests.

The area around Clab consists mainly of industrial area and otherwise of bordering forest area dominated by flat-rock pine forest. The forest harbours no natural values except for occasional old trees with future values. Southeast of Clab is the small cove of Herrgloet, which is assessed to harbour natural values of local interest. The archipelago in the east has rich and varied vegetation, from the outermost skerries where almost only lichens can grow, via grass- and herb-covered islands to various types of forest on the larger islands. The archipelago has a rich bird life, and most plant-covered bottoms are important spawning grounds for many fish species.

7.2.6 Cultural environment and landscape

A cultural environment analysis and an archaeological survey, stage 1, have been carried out within the Laxemar/Simpevarp area. In connection with these studies, a landscape analysis has been done based on the visual perception of the landscape. The studies are summarized in /7-25/.

According to the landscape analysis, the Laxemar/Simpevarp area can be divided into five different landscape types: industrial landscape, outer archipelago, coast without archipelago, inner archipelago and forest landscape with cultivated joint valleys, see Figure 7-42.

Most of the analyzed area is characterized by a rather barren, pine-covered flat-rock landscape. Almost everywhere the forest is of an elderly, peaceful character. The archipelago landscape in the east provides a long coastline due to the numerous islands and inlets. The largely undeveloped coast and archipelago and the small-scale forest landscape criss-crossed by joint valleys stand in sharp contrast to the large-scale industry surrounding the nuclear power plant. When the nuclear power plant was established on the Simpevarp peninsula, the older landscape underwent a total transformation, where both the cultivated fields of Simpevarp village and many of the area's archaeological remains were eliminated. One concession made to the natural environment has been preserving flat-rock forest in a zone near the shores, see Figure 7-43. This has great value in screening off the large-scale industrial environment from the surrounding cultural environments. The power line corridors that radiate from the Simpevarp peninsula introduce an industrial touch into an otherwise unspoiled forest landscape interspersed with traditional agriculture. The impact on the cultural environment in the area is otherwise relatively limited.

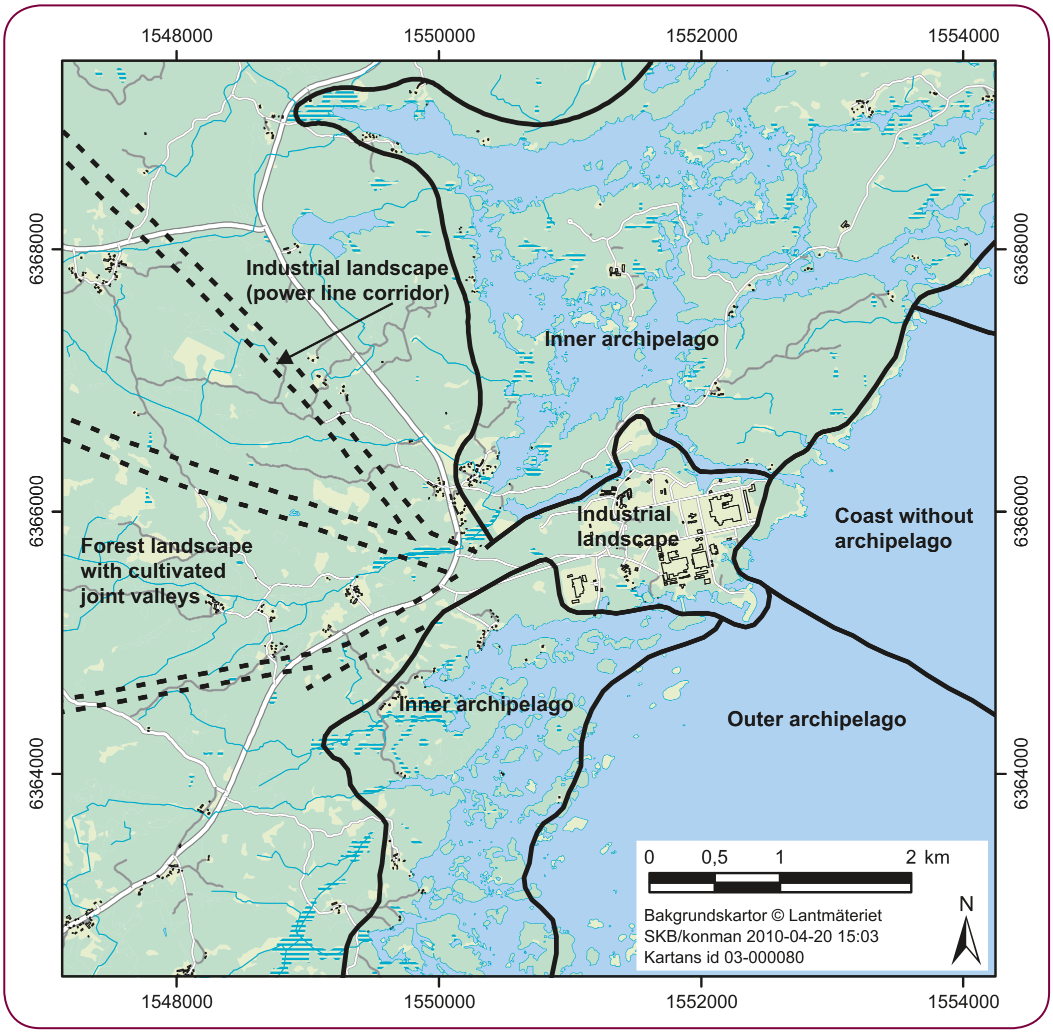


Figure 7-42. Existing landscape types in the Laxemar/Simpevarp area.

Figure 7-43. Aerial photo of the Simpevarp peninsula. A zone of flat-rock pine forest has been left untouched near the shores to screen off the large-scale power plant complex from the surrounding cultural environments.

The villages in the area represent 1,000 years of cultural tradition in a coastal district. They are located in a band inside the coast and have, since the Middle Ages, been the hub of both farming and maritime livelihoods such as fishing, hunting, shipping, shipbuilding, pilot age etc. By living in the interface between different landscape types, the people here have optimized their nearness to their most important sources of livelihood. There is archaeological source material here that can be used to clarify how this wooded coastal district was colonized and developed during the Iron Age and the Middle Ages. Environments with small-scale agriculture, similar to those found in the Misterhult district, can be found at many places along the southern island-strewn coast of the Baltic Sea. What distinguishes this part of the Baltic coast is its low level of development. Source material and historic structures are therefore still preserved.

There are no national or regional areas of interest for the cultural environment in the Laxemar/Simpevarp area, but archaeological remains and other historic remains in the area are fairly plentiful, see Figure 7-44. There are fourteen known settlement sites, a large number of cairns and stone circles and a large number of farm or village sites within the study area. There are known archaeological remains in the form of five prehistoric graves next to Clab. Also in the vicinity of Clab is Simpevarp village, a seaside village dating back to the 18th century. Today OKG has a permanent exhibition in the village, about the coastal district and today's nuclear power facilities.

Changes in the shoreline over time suggest that there may be settlement sites from the Stone Age in the highest parts of the Simpevarp area and from the Bronze and Iron Age on the slopes towards the sea in the south. The graves near Clab indicate that there may be remains of permanent settlements, but there are no obvious locations where they may be. Areas with loose, fine-grained soils near the graves may conceal archaeological remains such as prehistoric settlement sites. No sites where concealed archaeological remains might occur have been identified in the Laxemar area.

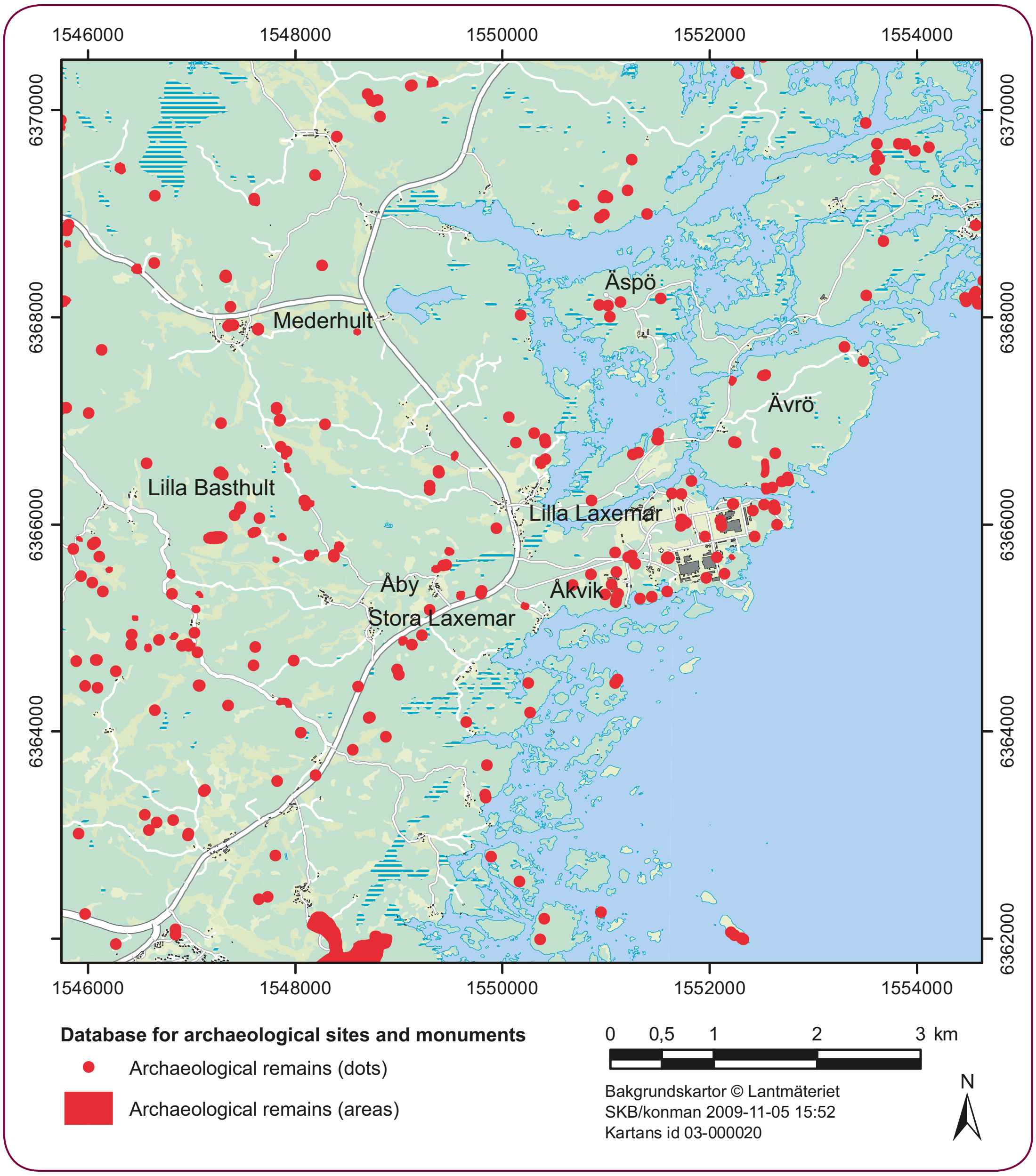


Figure 7-44. Registered cultural environment sites in the Laxemar/Simpevarp area.

7.2.7 Recreation and outdoor activities

The coastal and archipelago area, which is of national interest for tourism and outdoor activities, has been judged to have the highest values for recreation and outdoor activities in the Laxemar/Simpevarp area. The near-coastal area offers excellent conditions for bathing, fishing, boating, canoeing, kayaking and diving. The area is also popular for hiking, cycling and hunting. Östkustleden (the East Coast Trail) passes nearby, and there are two smaller trails on the Simpevarp peninsula, the Äspöstigen (the Äspö Path) and Simpevarvet, which is located near the village of Simpevarp, see Figure 7-45. Kråkelund and the Simpevarp peninsula are popular birding areas, with rich bird populations. The warm cooling water effluent has made Hamnefjärden a popular place for bathing, canoeing/kayaking and birding year-round /7-26/. The recent reinforcement of the physical protection around the Oskarshamn Nuclear Power Plant has, however, led to a prohibition on bathing and canoeing/kayaking in Hamnefjärden.

Figure 7-45. Äspöstigen with information signs.

7.2.8 Noise

In order to ascertain current sound levels, a combination of measurements and calculations of sound levels have been carried out on the Simpevarp peninsula /7-18/. The measurements were performed in 2004–2005 during a spring period, an early summer period and a winter period. The measurement positions were located in areas where there are normally people present without this affecting the measurement results. The positions around the Oskarshamn Nuclear Power Plant were also chosen to cover different wind directions in relation to the nuclear power plant.

The measured sound levels exhibit great variations and seasonal differences. The lowest sound levels were recorded during a period with new snow. Sound levels as low as below 20 dBA have been recorded at night, which is "absolute" quiet. During other measurement periods the sound level is 25–30 dBA at night, see Figure 7-46. At sunrise the sound level increases at all measurement positions due to bird song, causing the sound level in the forest to increase by 15–20 dBA for a few hours /7-27/. Noise measurements show that it is mainly the transformer station and fans at the nuclear power plant that give rise to noise in the area.

The calculations that have been done for the area assume sound propagation with a tailwind in all directions simultaneously, which can be regarded as a "worst case". The calculations and the measurements (background level) are in fairly good agreement. The calculations show that no permanent residents are exposed to sound levels above 35 dBA, which is the guideline value for industrial noise. In the area for temporary residents, the sound level varies between 30 and 40 dBA /7-18/.

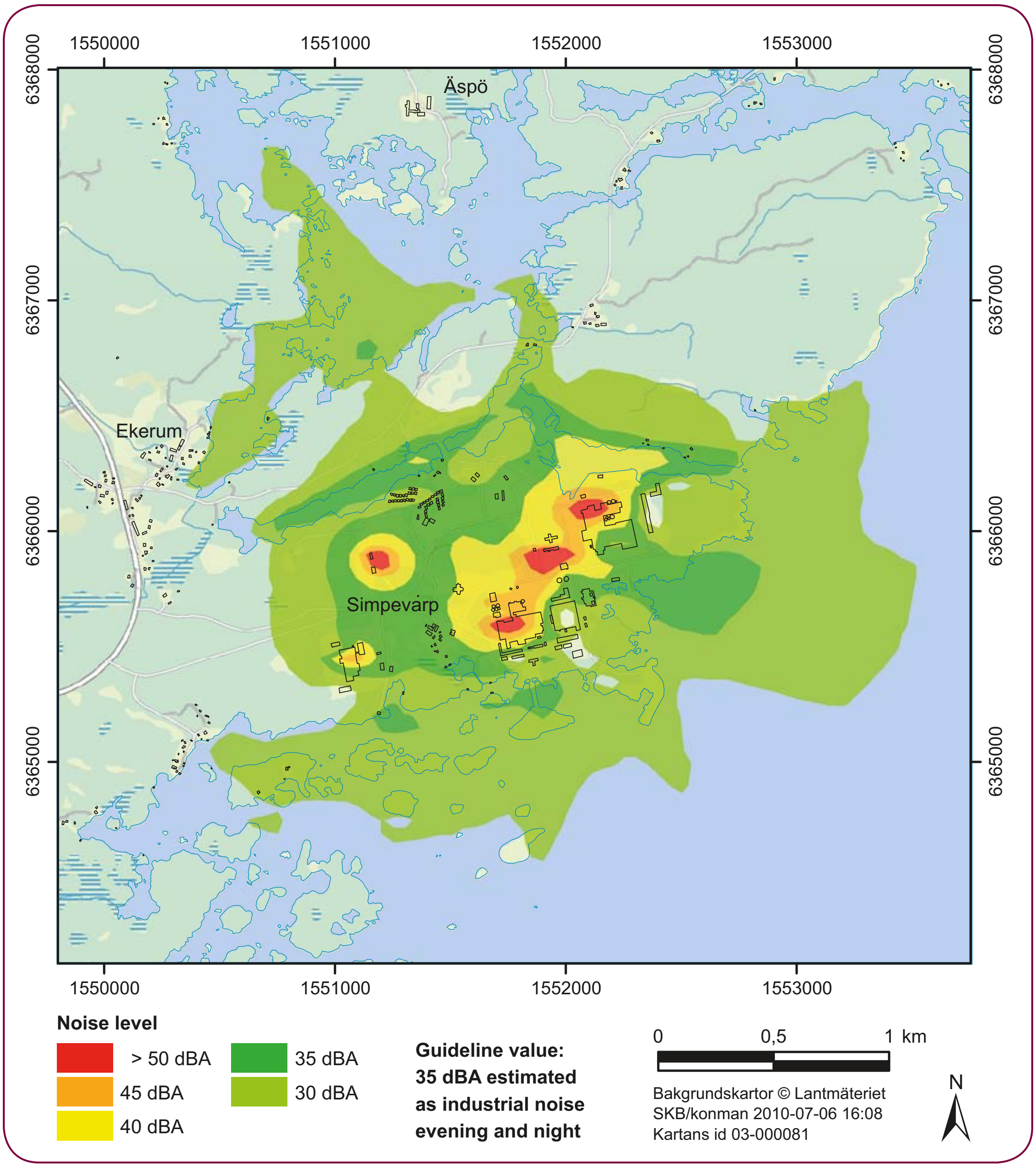
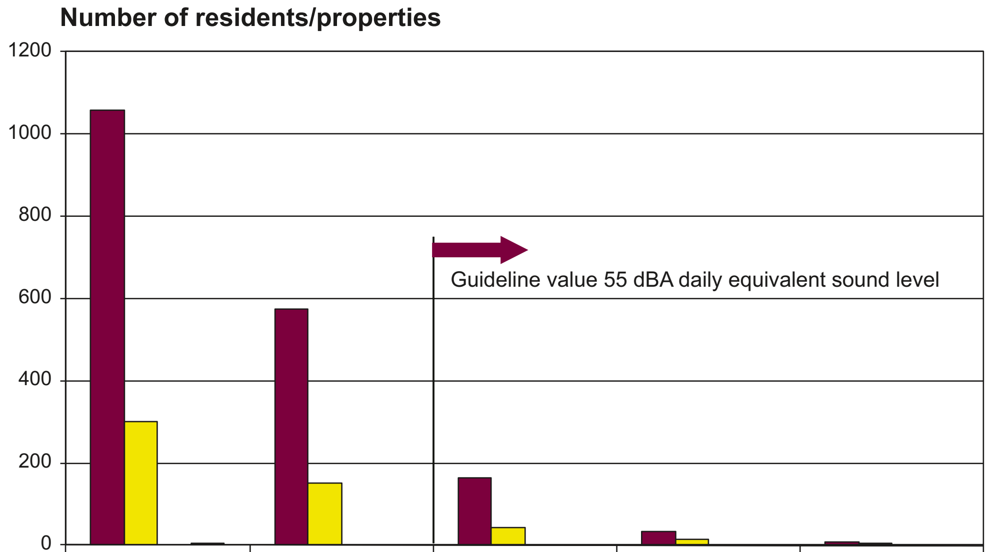


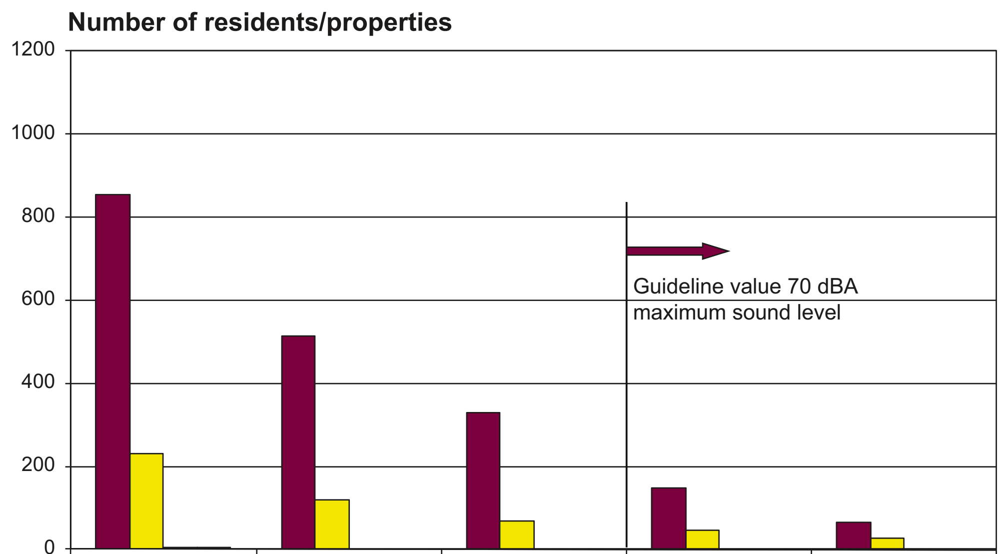
Figure 7-46. Calculated equivalent sound level at night today.

Road traffic noise has been studied between Simpevarp and the harbour in Oskarshamn. Of the roads studied, the largest traffic volumes are on roads through Oskarshamn and on E22. The roads around Simpevarp have relatively little traffic. The new bypass at Fårbo has relieved the urban area around Fårbo, which was previously exposed to high noise levels. The calculations show that road traffic noise is a problem. Many residents are exposed to noise levels that exceed the guideline values established for equivalent and maximum sound level, see Figure 7-47 and Figure 7-48.



Equivalent sound level	> 45 dBA	>50 dBA	>55 dBA	>60 dBA	>65 dBA
Residents	1057	575	165	34	8
Single-family houses	300	151	44	15	4
Secondary residences	0	0	0	0	0
Schools	1	0	0	0	0

Figure 7-47. Number of residents and properties exposed to a daily equivalent sound level above 45 dBA along the road section between the Oskarshamn Nuclear Power Plant and the harbour in Oskarshamn in 2006.



Maximum sound level	> 55 dBA	>60 dBA	>65 dBA	>70 dBA	>75 dBA
Residents	854	514	331	149	65
Single-family houses	230	118	70	47	27
Secondary residences	3	0	0	0	0
Schools	1	0	0	0	0

Figure 7-48. Number of residents and properties exposed to a maximum sound level above 55 dBA along the road section between the Oskarshamn Nuclear Power Plant and the harbour in Oskarshamn in 2006.

7.2.9 Emissions to air

Measurements of atmospheric pollutant concentrations are lacking in the Laxemar area. Based on existing concentration data on the east coast at the Rockneby monitoring station in the vicinity of Kalmar (nitrogen dioxide, NO_2) and Aspvreten outside Stockholm (particulate matter, PM10), regional background concentrations for NO_2 and PM10 have been estimated /7-28/. By "regional background concentrations" is meant atmospheric pollutant concentrations that are unaffected by nearby emission sources. Since measurement of daily mean values of NO_2 is lacking at Rockneby, measurement data from Råö outside Gothenburg have been used to estimate daily mean values for background concentrations (98th percentile day) in the Laxemar area. By 98th percentile is meant that the air has a higher concentration two percent of the time and a lower concentration 98 percent of the time. The estimated regional background concentration of NO_2 in Laxemar is 2.3 micrograms per cubic metre /m (µg/m^3) as an annual mean and eight µg/m^3 as a daily mean (98th percentile day). Hourly measurements of background concentration are lacking in Sweden.

The estimated regional background concentration of particles (PM10) in Laxemar is 12 µg/m^3 as an annual mean, 19 µg/m^3 as a daily mean (90th percentile day) and 30 µg/m^3 as a daily mean (98th percentile day). Compared with other air pollutants, PM10 exhibits relatively high background concentrations in both rural and urban areas. One reason for the high background concentration, which occurs all over Sweden, is the transport of fine particles into Sweden from the continent. They mainly come from combustion processes in Europe.

The most important greenhouse gas emitted in Kalmar County is carbon dioxide from the use of fossil fuels. A total of 1.46 million tonnes of fossil carbon dioxide was emitted in the county in 2002. Cars, non-road mobile machinery and industry are the foremost sources. Traffic accounted for about 50 percent of the carbon dioxide emissions in the county in 2003.

Air pollution is deposited on soil and vegetation by different processes. Particles can also be taken up directly by plants or absorbed on different surfaces such as leaves, stems or objects. Particles are also deposited directly on the ground, plants or objects. This type of deposition is called dry deposition. Gases and particles can also be washed out of the atmosphere with precipitation, called wet deposition. The total deposition (wet + dry) of nitrogen around Laxemar amounts to about 0.5 g/m^2.

7.2.10 Radiological conditions

Radiological measurements are performed regularly around the nuclear facilities on the Simpevarp peninsula, both directly on outgoing process water and exhaust air and in the form of radiological environmental monitoring, with sampling of water, plants and animals. Most of the measured radiation is natural background radiation. The main source of artificial radioactivity in the Baltic Sea is the accident in Chernobyl in 1986. Other sources are fallout from the atmospheric weapons tests performed in the late 1950s and early 1960s, and releases from the reprocessing plants at Sellafield in England and La Hague in France. The radioactivity emitted from the existing nuclear facilities (the nuclear power plant and Clab) to the environs with the process water and via the ventilation system contributes very little to the total radioactivity in the Baltic Sea. Emissions to air are dominated by noble gases, which are not deposited on the ground or the vegetation. Samples from the terrestrial ecosystems therefore seldom exhibit any detectable concentrations, except of cobalt-60, which occurs sporadically in different kinds of samples, and cesium-137, which mainly comes from the atmospheric weapons tests and from the Chernobyl accident. Elevated concentrations of radionuclides in the aquatic environment are easier to see. Concentrations in sediments varied during the period 2002 to 2004 between 9 and 530 Bq/kg dry weight for cesium-137 and between 0.47 and 5,000 Bq/kg dry weight for cobalt-60. Concentrations in the surface layer of the sediments and in bladderwrack of cobalt-60, which is the most frequent radionuclide originating from the nuclear power plant, decline with the distance from the emission source.

Emissions of radionuclides from the nuclear facilities give rise to very low radiation doses to man, far below the limit values stipulated by SSM. The annual dose to the critical group from the nuclear power plant and Clab is around $4 \cdot 10^{-4}$ mSv, which is less than one hundredth of the legal limit and less than one thousandth of the natural background radiation /7-13, 7-14/.

7.2.11 Natural resource

7.2.11.1 Agriculture and forestry

Forestry is the predominant land use in site investigation area. Agricultural land comprises less than ten percent of the ground surface /7-20/.

7.2.11.2 Water resources

Oskarshamn Municipality's groundwater supply in Fårboåsen supplies the communities of Fårbo and Figeholm with drinking water. Oskarshamn Municipality has a permit to withdraw 410,000 cubic metres of groundwater per year. A water protection area has been established for the water supply.

Private wells are common in the Laxemar area, and some 50 or so private wells are situated near (within 500 metres) the considered site for the final repository. SKB has a permit to withdraw groundwater from the borehole HLX22 on the property Lilla Laxemar 2:16 for supplying water to Lilla Laxemar village. The ruling stipulates a maximum withdrawal of 7,300 cubic metres per year. The withdrawal from the borehole has replaced the water supply from 18 private wells in Lilla Laxemar.

Drinking and process water (150,000–200,000 cubic metres per year) is pumped by OKG from Lake Götemaren (about eight kilometres north-northwest of the Laxemar area). Furthermore, OKG has a permit to divert water from Laxemarån to Lake Sörå (Söråviken), which is used as an emergency water supply for drinking and process water (pumping is only done occasionally every other year or so to maintain the volume of water in the lake). OKG also has a permit for withdrawal of cooling water (115 cubic metres per second) from the sea /7-21/.

A total of 25–70 litres per minute (equivalent to 0.0004–0.0012 cubic metres per second) and 0.02 cubic metre per second, respectively, is currently pumped for drainage of SKB's hard rock facilities Clab and Äspö Hard Rock Laboratory. The permits do not stipulate any conditions on diverted water volume. For Clab there is a permit for withdrawal of cooling water (0.6 cubic metre per second) from the sea and for discharge of heated cooling water in Hamnefjärden.

In addition to aforementioned water activities, there is considerable surface drainage, which is regulated within various joint drainage units in the Laxemar/Simpevarp area.

7.2.11.3 Commercial fishing

According to the National Board of Fisheries, there are twelve licensed fishermen in Oskarshamn Municipality (May 2009) who pursue small-scale near-coastal fishing. The fishing rights belonging to the villages of Simpevarp and Ävrö have been acquired by OKG by purchase of the villages' agricultural property units. Some of these fishing rights are leased by the former owners.

7.3.11.4 Ore deposits

There are no known ore deposits or mineralizations in the Laxemar/Simpevarp area /7-20/.

Central interim storage facility for spent nuclear fuel (Clab)

8 Clab

Clab, central interim storage facility for spent nuclear fuel, is a facility located in Oskarshamn Municipality on the Simpevarp peninsula, about 700 metres from the Oskarshamn Nuclear Power Plant, see Figure 8-1. Clab was built between 1980 and 1985 and was put into operation in June 1985. Clab was extended between 1999 and 2004, and the new rock cavern was put into operation in early 2008.

When the encapsulation plant is put into operation, it and Clab will be operated as one integrated facility, called Clink. Up until then, the existing Clab facility will be operated alone. Impacts, effects and consequences of the operation of Clab – as well as impacts, effects and consequences of transportation to and from the facility – are therefore described in this chapter. Clab will be decommissioned and dismantled when all spent nuclear fuel has been encapsulated and at the same time as the encapsulation plant. This phase is described in Chapter 9 about Clink.

Figure 8-1. Map of the Simpevarp area with the nuclear power plant and Clab.

8.1 Applied-for activity – Existing facility in Simpevarp

SKB is applying for a licence to continue the activity involving reception, handling and interim storage of spent nuclear fuel at Clab.

8.1.1 Facility design

Clab consists of above-ground buildings and an underground storage facility, see Figure 8-2. Most of Clab's buildings are fenced-in. Above ground, Clab consists of the following technical and administrative buildings:

- Reception building
- Personnel building
- Auxiliary systems building
- Electrical building

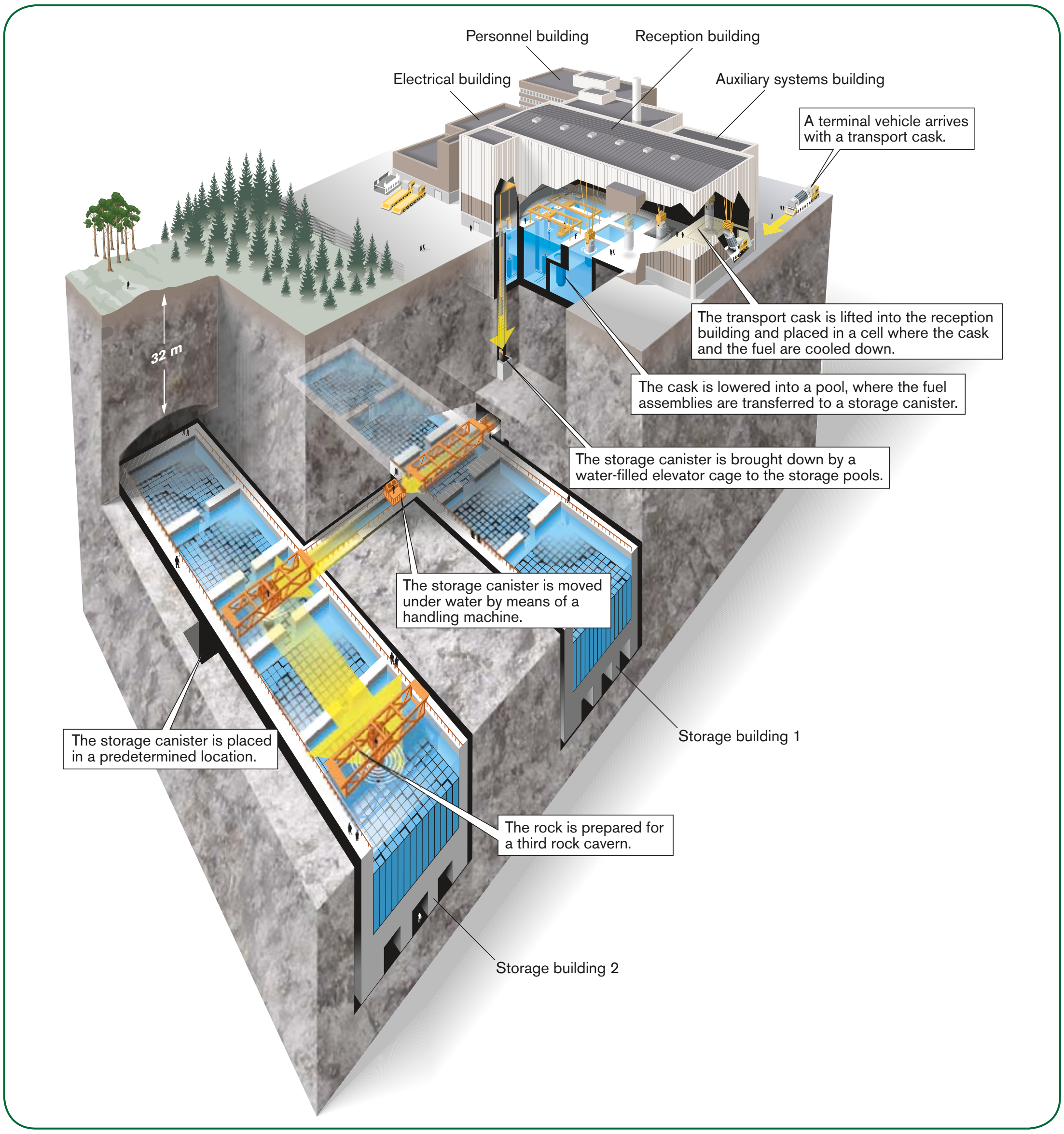


Figure 8-2. Clab's different surface buildings and cutaway view of the rock with rock caverns and pools for handling and interim storage of spent nuclear fuel.

Clab's underground part consists of two parallel rock caverns, Clab 1 and Clab 2, situated about 30 metres below the ground surface. Each rock cavern contains five storage pools in which the spent nuclear fuel is stored. The pools in both rock caverns hold a total of 30,000 cubic metres of water, which provides radiation protection while cooling the fuel. The pools are connected via a 40-metre long water-filled transport channel.

Operation of Clab gives rise to different water flows, such as process water, waste water and stormwater. These different water flows are treated inside the facility, diverted to other facilities for treatment or discharged immediately adjacent to the facility, see Figure 8-3.

8.1.1.1 Treatment and discharge of water from controlled areas

Clab has a system for receiving and cleaning process water from controlled areas so that it can be reused in the process or discharged to the cooling water channel, see Figure 8-3.

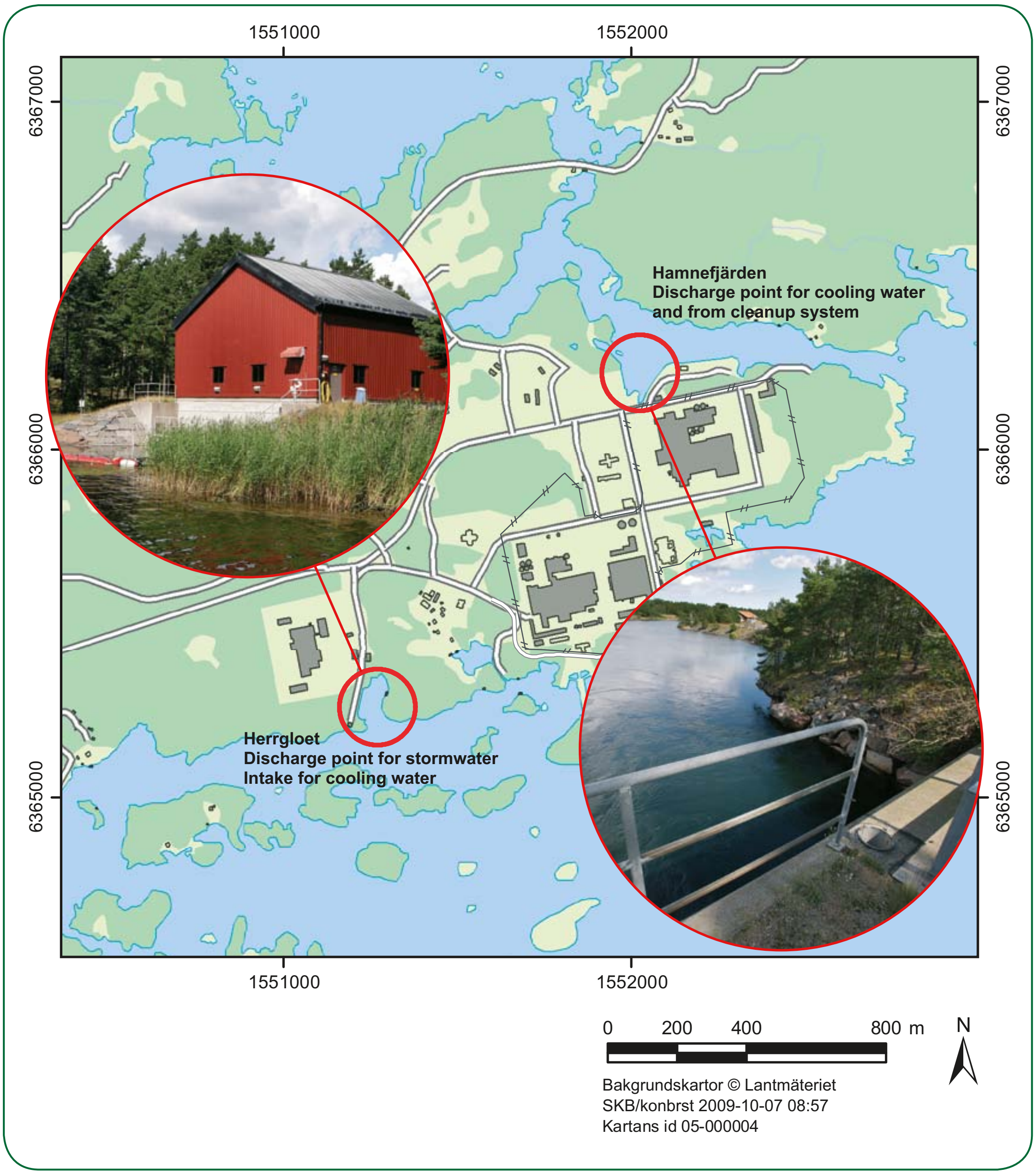


Figure 8-3. Discharge points for purified water and stormwater from Clab and intake and discharge point for Clab's cooling water.

The water that cools the fuel in the transport cask and the water that cools and cleans the receiving and storage pools is conducted to the system for treatment of process water. The process and floor drainage water is treated to remove particles in mechanical filters and ion exchange resins. After approved tests for activity and conductivity, the process water can be reused in the system. The floor drainage water is collected in tanks where radiological and chemical measurements are performed, see Figure 8-4. After approved testing, the water is pumped out into the cooling water channel that opens out into Hamnefjärden; otherwise it is sent back for further treatment.

Figure 8-4. Collection tanks for process water at Clab.

8.1.1.2 Stormwater and drainage water

The activity area for Clab occupies approximately 73,000 square metres of land. A large portion of the surface is built-up or paved and stormwater collects within the area. Based on local precipitation, it is estimated that the stormwater flow could amount to 23,000 cubic metres per year /8-1/. An improvement of stormwater management at Clab is planned in conjunction with the construction of the encapsulation plant. The new stormwater management system will be based on a combination of several technical solutions, mainly the principles of stormwater best management practice /8-1/. Among other things, stormwater will be transferred from the western portion of Clab's main building to the stormwater management system for the encapsulation plant and infiltration in surrounding forest land, see Figure 8-5. Digging of open ditches (filled with crushed rock or grass-covered) to drain some of the driving surfaces and the entrance parking lot will reduce the volume of stormwater from paved surfaces. A holding pond of about 400 square metres is planned in a depression east of the facility for sedimentation and equalization of stormwater from the remaining surfaces, instead of discharging the stormwater directly in Herrgloet, as is the case today. A pond surface area of 400 square metres is equivalent to about three percent of the paved surface from which the stormwater is collected and is deemed adequate for achieving the desired treatment efficiency.

Drainage water stems from groundwater inflow to rock caverns. The water is kept outside controlled areas at all times. In the existing system, the water is collected and pumped to be discharged in Herrgloet, see Figure 8-3. When the equalization pond has been built, the drainage water, along with a portion of the stormwater, will be conducted to it to ensure a steady flow of water to the pond. This prevents stagnation and oxygen deficiency and thereby contributes to better treatment efficiency. In facility parts where oil is present, for example in the workshop, oil separators are installed in Clab's stormwater management system.

8.1.1.3 Cooling system

The decay heat from the spent nuclear fuel generates heat. Sea water is used to cool the fuel. According to a water rights court ruling /8-2/, the permitted sea water withdrawal rate for Clab is 0.6 cubic metre per second, and an average of 0.16 cubic metre of sea water per second was pumped during 2009. The intake building for cooling water is located immediately west of Herrgloet, see Figure 8-3. After having passed a heat exchanger in the facility, the heated sea water is conducted via an underground pipe to the cooling water outlet from the the nuclear power plant's reactor unit 1 and back into the sea. Clab's future cooling water supply is currently under study.

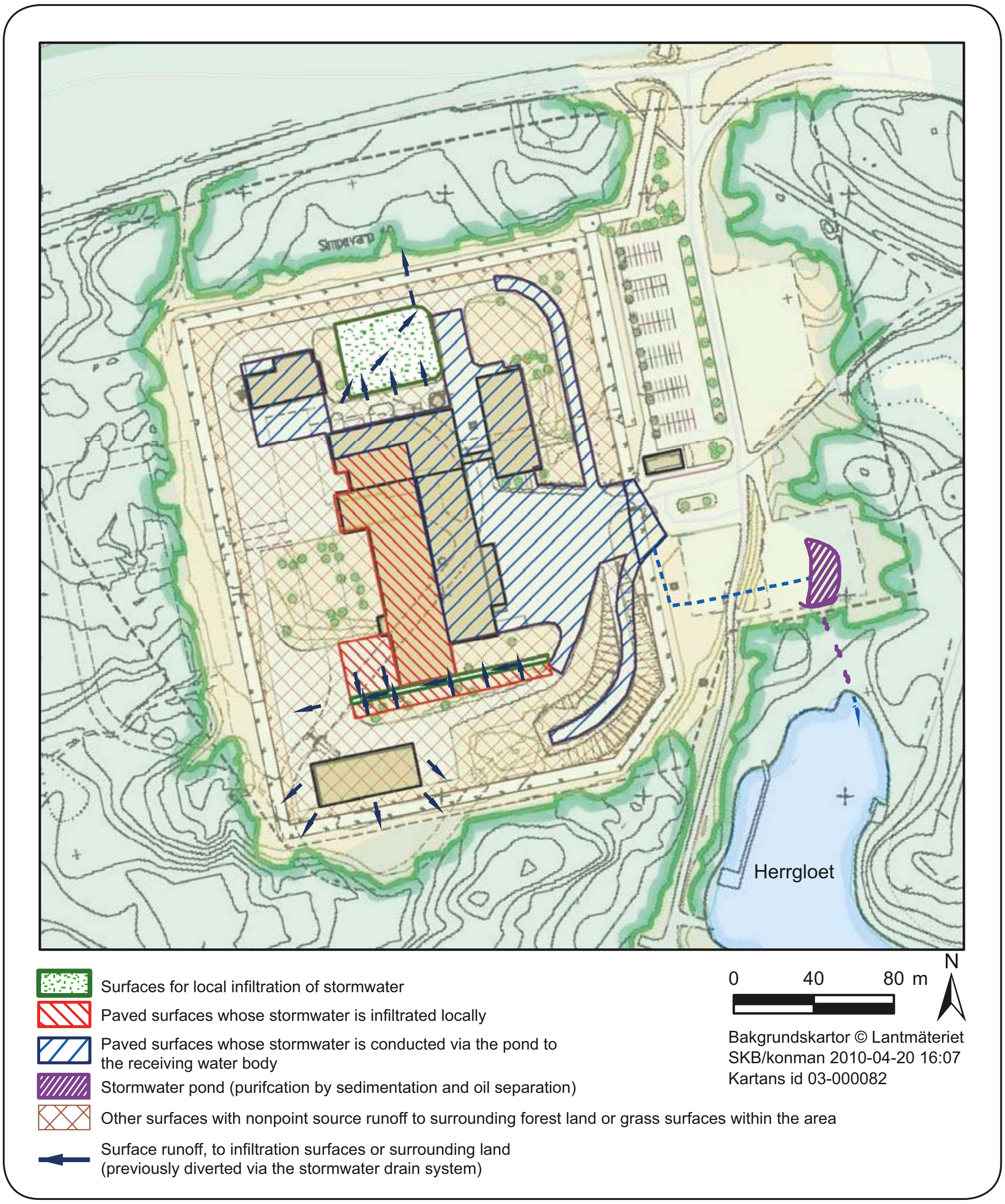


Figure 8-5. Proposal for improved stormwater management for Clab.

8.1.1.4 Water supply and sanitary sewage

Raw water is taken from Lake Götemaren, about eight kilometres north-northwest of Simpevarp, and piped to OKG's water treatment plant. Here the water that is used for Clab's activities, both tap water and deionized water, is purified.

Waste water from Clab is treated in OKG's sewage treatment plant on the northeastern part of the Simpevarp peninsula at Hamnefjärden, after which it is discharged to the receiving water body outside Hamnefjärden, see Figure 8-6.

After the reactors in the Oskarshamn Nuclear Power Plant have been shut down, alternative solutions for water supply and waste water treatment may be found, since Clab's (and eventually the encapsulation plant's) needs are small in relation to OKG's needs.

8.1.1.5 Heat

Heat from the cooling water is recovered today by several heat exchangers. The intake air to the ventilation system is heated by the hot water before it returns to the sea water cooling system. Heat is also recovered from the ventilation air before it leaves the building via the ventilation chimney. A modernization of the existing heating system for Clab is planned in connection with the construction of the encapsulation plant in order to make even better use of the heat from the storage pools.

Figure 8-6. Discharge pipe from the sewage treatment plant at Hamnefjärden.

8.1.2 Description of activities

Spent nuclear fuel is interim-stored in Clab until it is removed for encapsulation and deposition in a final repository. The purpose is to keep the fuel cool and store it safely awaiting disposal. The fuel arrives at Clab in a transport cask and then passes through several handling steps before finally being stored in the water pools. Clab receives some 100 transport casks per year. The handling steps are as follows:

- Cooldown: The transport cask and its contents are cooled with water until both temperature and activity are stabilized below set limits.
- Unloading: Begins in the cask pool and continues in the unloading pool, where the fuel assemblies are lifted out of the transport cask and placed in a storage canister.
- Unloading in service pools: The service pool is used for unloading of transport casks that are not designed for the connection in the cask pool.
- Removal of empty transport cask: After unloading, the empty transport cask is connected to a cleaning and cooling system. If necessary it can be cleaned externally.
- Storage: After the fuel has been placed in a storage canister, it is lowered into the storage pools via a fuel elevator, see Figure 8-7.

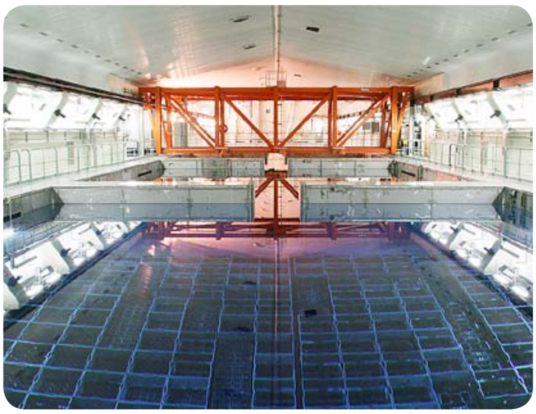


Figure 8-7. Storage pool in Clab.

Today about 5,000 tonnes of uranium is stored in Clab's pools, and the permitted capacity is 8,000 tonnes. Clab's capacity can be increased to 10,000 tonnes if compact storage canisters are used. In the current operating scenario for the nuclear power plants, the average storage period will be about 45 years. Besides spent nuclear fuel, the radioactive operational waste to which Clab gives rise is also managed in the facility. However, it is not stored but is packaged and sent to SFR. Core components are also stored temporarily in Clab awaiting transport to suitable final disposal.

Some 100 persons work at Clab, and the facility is manned round the clock.

8.1.2.1 Transport of spent nuclear fuel and nuclear waste

Spent nuclear fuel and core components are transported in transport casks which are cooled via self-circulation and convection. The transport cask is licensed to IAEA requirements for type B packages. This means that it meets special requirements regarding strength, radiation protection and protection against stresses in connection with various events /8-3/. The transport cask also dissipates the decay heat so that neither the canister nor the surface of the cask gets too hot, see Figure 8-8. During transport the fuel is dry and the interior of the cask is filled with nitrogen gas at negative pressure.

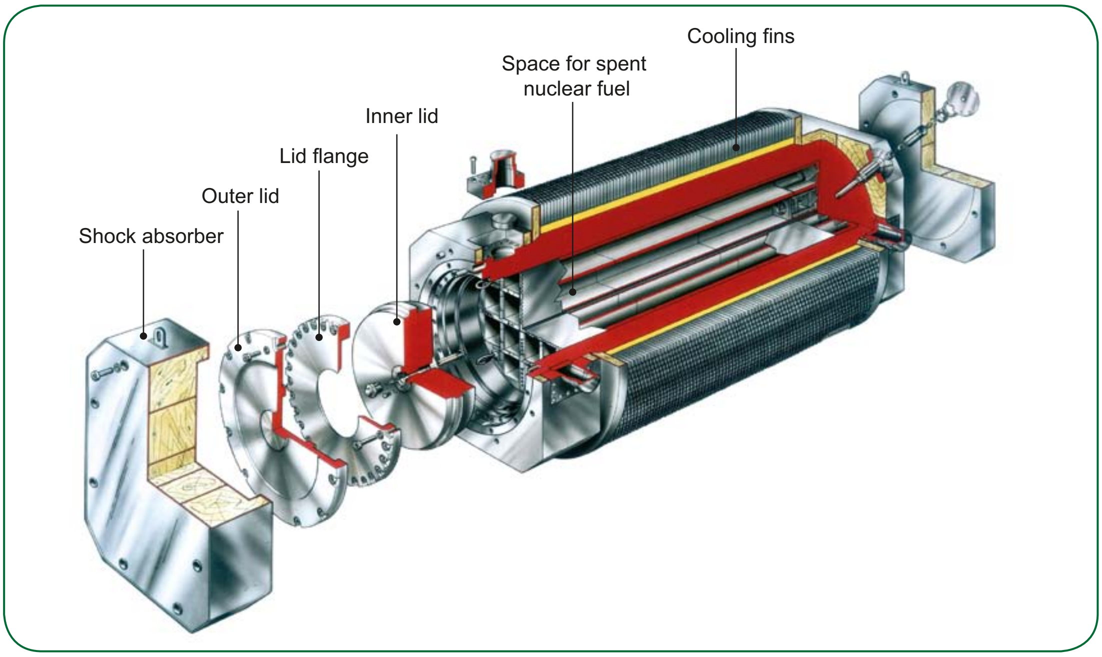


Figure 8-8. Cutaway view of transport cask for spent nuclear fuel.

Spent nuclear fuel and nuclear waste are transported at sea by the ship m/s Sigyn from Forsmark, Ringhals and Barsebäck to Clab, see Figure 8-9.

Transport between the ship moored in port and the various facilities – the nuclear power plants and Clab – takes place by a specially designed terminal vehicle, see Figure 8-10. The transport casks are collected directly by the terminal vehicles from OKG's facilities in Simpevarp. The vehicles are specially designed to carry heavy loads, with load platforms that can be raised and lowered hydraulically. The engines are equipped with emissions control for carbon monoxide, hydrocarbons and particulates.

M/s Sigyn (see Figure 8-11) is specially designed to transport spent nuclear fuel and radioactive waste. It was built in 1982 and began to be used for shipments to Clab in 1985. The ship has an overall length of 90 metres, an overall breadth of 18 metres and a draught fully laden of four metres. It is built for unrestricted ocean service and has a reinforced hull designed for navigation in ice. The ship has a double hull and a double bottom and is divided into a number of watertight compartments. It has a payload capacity of 1,400 tonnes. Fuel consumption at normal speed is estimated at 40 litres of diesel per nautical mile.

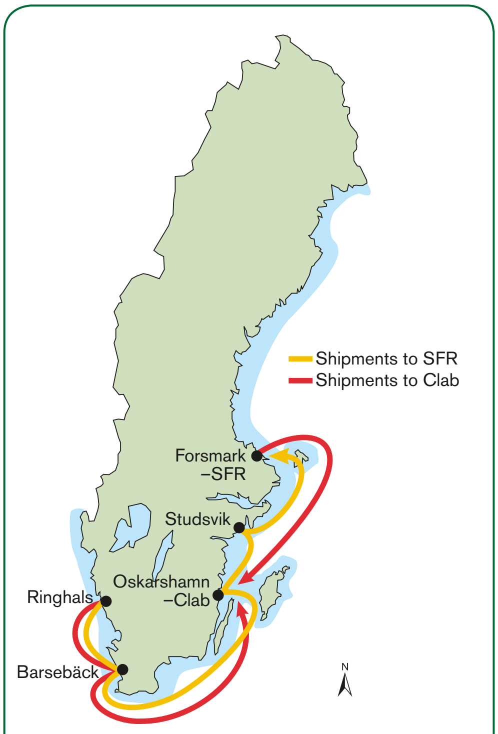


Figure 8-9. Sea transport from the nuclear power plants to Clab and SFR.

The distance between Simpevarp and Forsmark is 240 nautical miles (about 440 kilometres) and takes about 20 hours. The distance between Ringhals and Simpevarp is 380 nautical miles (about 700 kilometres) and takes about 35 hours. About 20 to 30 round trips are made annually to Clab, and five to ten round trips to SFR, with variations from year to year. The ship travels in a public fairway.

M/s Sigyn will be replaced by a new ship, which will meet SKB's needs for transportation of the radioactive waste.

Figure 8-10. Terminal vehicle used for overland transport between the facilities (the nuclear power plants and Clab) and m/s Sigyn.

Figure 8-11. M/s Sigyn.

8.1.2.2 Other transport

Operation of Clab entails passenger transport for both employees and visitors as well as goods transport to the facility, see Table 8-1 /8-4/.

Table 8-1. Material and passenger transport to and from Clab, round trip.

	Number of round trips per day
Employees at Clab (cars)	50
Visitors to Clab (cars)	1
Visitors to Clab (buses)	3 per week
Goods shipments	5

8.1.3 Impact

8.1.3.1 Impact on groundwater level

The construction of Clab's rock cavern resulted in a change in the groundwater level at the facility. Clab's pools and the resulting inflow cause a lowering of the groundwater in the rock, while the groundwater in the the soil layers is less affected /8-5/. Details on hydrogeological effects of Clab 1 and Clab 2, in the form of inflow and changes in groundwater level, are reported in /8-6/. Since 1998, groundwater levels and electrical conductivity have been measured in boreholes around Clab within the framework of the monitoring programme for construction of Clab 2 /8-7/. A number of private wells located at Åkvik about 600 metres southwest of Clab are checked regularly and have not shown significant level changes since Clab 2 was built. It is only in boreholes that are in direct connection with Clab that the measurements show a change in the groundwater level. This also confirms that the impact is limited, since most monitoring points do not show signs of changed groundwater levels. Measurements of electrical conductivity indicate relatively high chloride concentrations, which is explained by a probable influx of sea water from areas south and east of Clab. The inflow rate before Clab 2 was built had stabilized at about 30–40 litres per minute (l/min) and increased to about 40–60 l/min after Clab 2 was built, which agrees with the prediction that was made prior to the construction of Clab 2 /8-8/. Data on the inflow into both Clab 1 and Clab 2 for the period 1985–2004 is compiled in report form /8-9/.

8.1.3.2 Noise and vibration

During the operating phase, the noise level at and around the facility is low, see Figure 8-12, and falls below 40 dB at just a short distance from the facility. The main sound sources at Clab are the ventilation fans.

The operation of Clab does not cause any vibration.

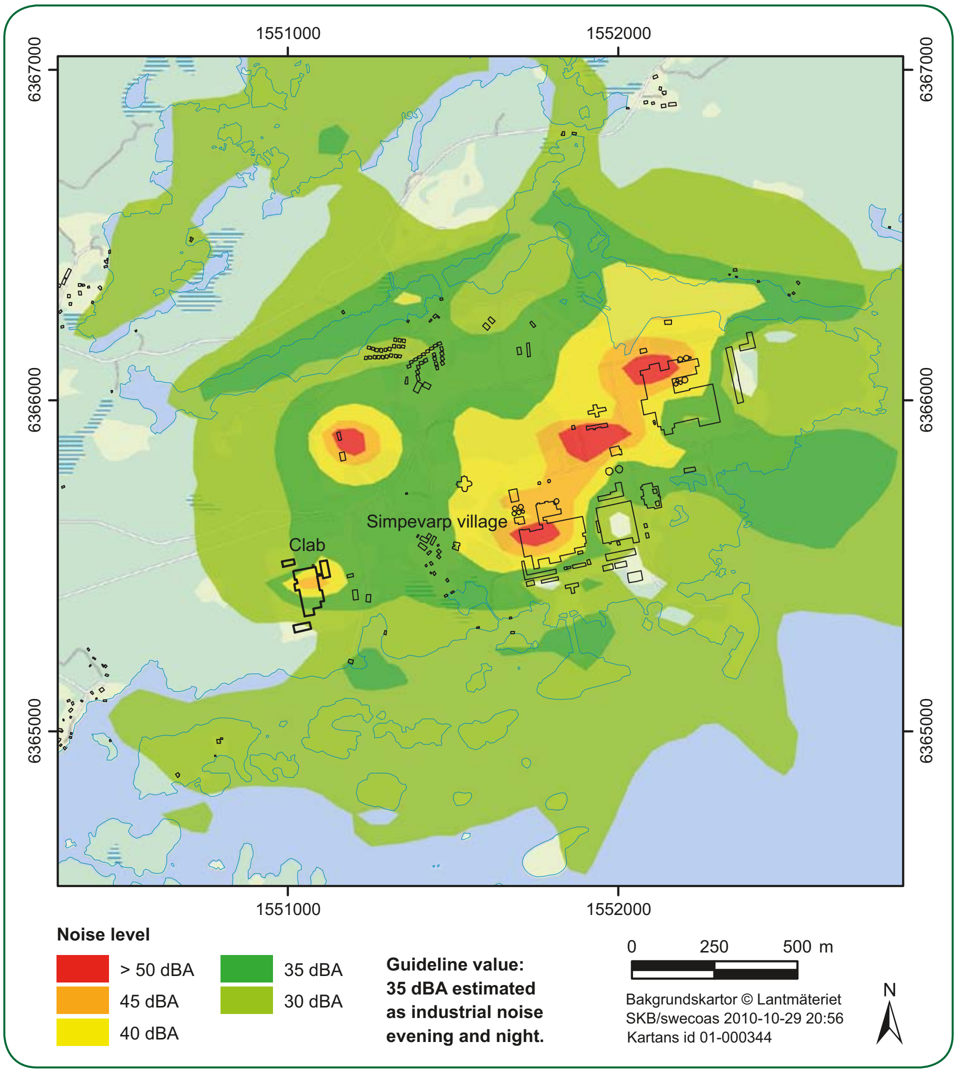


Figure 8-12. Equivalent sound level around Clab during the evening and night.

8.1.3.3 Radiation and releases of radionuclides

This section reports radioactive releases during normal operation, while releases in connection with disturbances or mishaps are reported in section 8.1.5, "Risk and safety issues". Information on radioactivity and radiation is provided in section 3.4.

The safety analysis report for Clab describes how the safety of the facility is arranged in order to protect man and the environment as required by the relevant legislation /8-10/. The safety analysis report is updated regularly during the operation of the facility. Calculations of radionuclide releases are based on pessimistic assumptions so as not do underestimate the impact and the consequences that arise, or could arise, due to releases during normal operation or in connection with disturbances and mishaps.

Radiation protection and radiation sources

The basic principle for radiation protection is often summarized by the acronym "ALARA" which stands for "As Low as Reasonably Achievable". The radiation protection in Clab has been designed according to calculations of the strength of expected radiation sources and with the aid of experience from own and similar activities. The areas in Clab have been divided into radiation classes with different radiation protection requirements.

The radiation in Clab comes from the spent nuclear fuel. It gives rise to two different types of sources for dispersion of activity in the facility: fission products and actinides from the fuel, and neutron-induced activity.

Fission products and actinides are the new substances that are synthesized or formed by fission of uranium. Neutron-induced activity comes from atoms that have been exposed to neutrons from nuclear fission and are activated (become radioactive) in the process.

Fission products and actinides from the fuel are only spread as a result of damage to the cladding material, while neutron-induced activity outside the fuel is present in the engineering material and in activated corrosion products deposited on the surfaces of the fuel assemblies, known as crud.

Fission products and the neutron-induced activity both emit beta and gamma radiation as they decay. Only the gamma radiation is crucial for the design of the radiation protection. Among the nuclides in the fuel, cesium-134 (Cs-134) and cesium-137 (Cs-137) are the dominant sources of gamma radiation, while cobalt-60 (Co-60) is clearly dominant for neutron-induced activity.

Radioactivity release in the facility

Activity is released in different parts of Clab during the different steps in the handling and further storage of the spent nuclear fuel:

- Unloading pools: Activity can be introduced when radioactive water from the transport cask is mixed with the pool water and when radioactivity on the fuel cladding is released during unloading, see Figure 8-13.
- Fuel transport cask: Activity can be released to transport casks in the form of crud or fission products from damaged fuel rods.
- Storage pools: Activity from the stored fuel is released in the form of crud particles detached from the surfaces of the fuel assemblies.
- Cooling and cleanup system: Activity that is released to water in different handling steps collects on filters and ion exchange resins in connecting cleanup systems.
- Waste system: Filter and ion exchange resins are solidified and other components, such as collection filters and filter rods, are taken to a conditioning cell for further treatment.

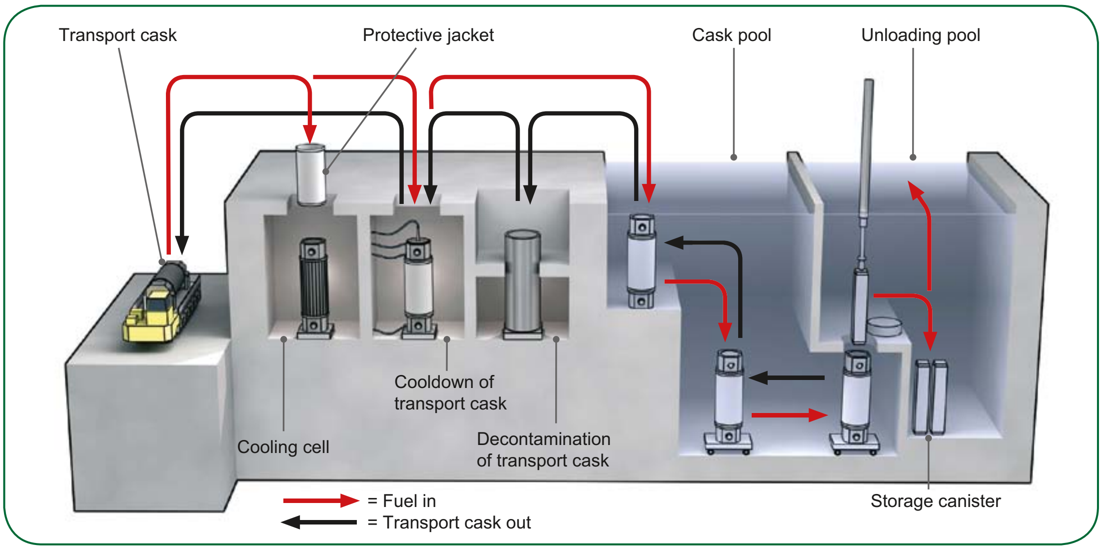


Figure 8-13. Handling of transport casks in Clab's reception building.

Clab received its original operating licence based on an application that contained a preliminary safety analysis report, which included calculations based on pessimistic assumptions for release of activity in the facility. Since Clab has been in operation since 1985, it is now possible to compare the calculations with measured activity concentrations in the pools and activity quantities that are collected annually in the different cleanup systems.

Table 8-2 shows the calculated concentrations of Co-60 and Cs-137 in the storage pools and the cleanup systems, along with measured values for comparison. The table includes Co-60 and Cs-137 because they are the two most important radionuclides in the releases from the facility. The table shows that measured concentrations in pools, and radioactivity quantities that are collected in the cleanup systems, are far below the licensing calculations. The input of activity is expected to increase as the amount of fuel stored in the pools increases, but at the same time the decay of certain nuclides will offset the increasing storage.

Table 8-2. Pessimistic calculations and measured concentrations of radioactivity in storage pools and cleanup systems.

Nuclide	Radioactivity concentration in the storage pools [[Bq/m³]	Radioactivity in cleanup systems [Bq/year]
Co-60 calculated for maximum storage (8,000 t U)	$8.9 \cdot 10^{7}$	$5.1 \cdot 10^{14}$
Co-60 measured average 2000–2009	$1.8 \cdot 10^{6}$	$1.1 \cdot 10^{13}$
Cs-137 calculated for maximum storage (8,000 t U)	$2.1 \cdot 10^{8}$	$1.2 \cdot 10^{15}$
Cs-137 measured average 2000–2009	$2.2 \cdot 10^{5}$	$1.2 \cdot 10^{12}$

During cooling of the transport casks, the uptake of Co-60 in the filters varies between 0.1 and 1.7 gigabecquerels per tonne (GBq/t) of uranium for different years, while the licensing calculations gave a value of about 500 GBq/t U. The highest activity concentration in the water from the transport cask was calculated to be 145 GBq/m³ of water in the licensing calculations, while operating experience from Clab shows that no transport cask has had an activity concentration from Co-60 higher than five GBq/m³. In the reception pools, Co-60 that is collected in the cooling and cleanup system varies between one and six GBq/t U, while the same activity quantity is estimated at 120 GBq/t U in the licensing calculations.

Dose to personnel

Individual dose is measured in sieverts (Sv). One sievert is a very large radiation dose, so the unit millisievert (mSv) is normally used. Collective dose is calculated to provide a picture of how much radiation an activity gives rise to and is in this case the sum of the radiation doses to a group of individuals. Collective dose is measured in the unit man-sievert (manSv) or milliman-sievert (mmanSv).

In conjunction with the planning and design of Clab, the dose to personnel was estimated pessimistically to be 276 mmanSv per year, which results in an average dose of 4.6 mSv per individual, assuming that 60 persons work with the operation of Clab. The goal was that the dose per individual should be less than five mSv per year. The collective dose was estimated taking into account the different types of work included in the operation of the facility such as reception, handling, supervision and maintenance, which give rise to different dose contributions.

Experience shows that the collective dose measured for personnel and contractors at Clab during the period 1985–2009 varied between 18 and 135 mmanSv per year (see Figure 8-14) and was therefore far below the pessimistic estimate made during design.

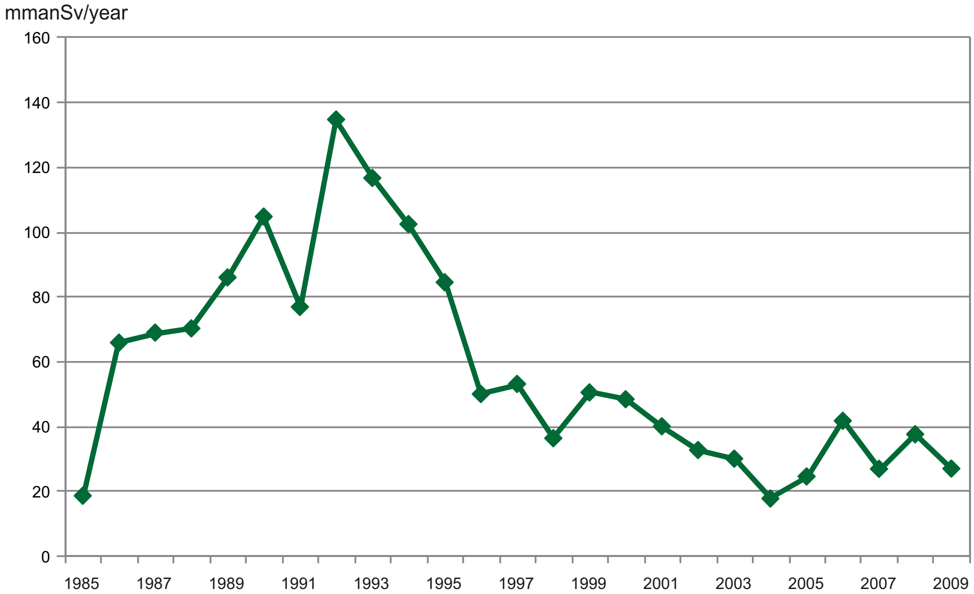


Figure 8-14. Annual collective dose of radiation in Clab.

Releases of airborne radioactivity to the environment

The areas where airborne radioactivity can occur during normal operation are fitted with filters in the ventilation exhaust. Exhaust air from all subsystems is brought together and leaves Clab via the ventilation chimney, where measurement equipment continuously registers radioactive releases, see Figure 8-15.

Experience from operation of Clab and other equivalent facilities abroad shows that releases of airborne activity from the pools are undetectable. Airborne radioactivity from Clab comes from the handling of the fuel and the facility's different cleanup systems. Table 8-3 shows measured mean values of radioactive releases from Clab's chimney for specific nuclides during the period 1996–2009.

The prediction for releases to air from Clab is that the release rate will be unchanged compared with the past ten-year period.

Figure 8-15. Clab's ventilation chimney and measurement equipment for radioactive releases to air.

Radioactive discharges via water to the environment

Radioactive discharges via water only occur from the cleanup system for water from controlled areas, see section 8.1.1. This water is mixed with cooling water from the facility. During the period 2003–2009, an average of about 1,700 cubic metres of purified process water from Clab was discharged to Hamnefjärden /8-11/.

The radioactivity content in the water is checked before each discharge. Very little radioactivity is discharged. Measured mean values of Clab's radioactive discharges to water for certain nuclides during the period 1996–2009 is shown in Table 8-4.

Table 8-3. Annual radioactive releases to air via Clab's ventilation chimney. Mean values of measured releases during the period 1996–2009.

Nuclide	Measured releases [Bq/year]
Cobalt-60	$1.6 \cdot 10^{7}$
Strontium-90	$6.1 \cdot 10^{4}$
Cesium-137	$5.7 \cdot 10^{4}$
Plutonium-238/Americium-241	$2.4 \cdot 10^{4}$
Americium-243	$8.0 \cdot 10^{3}$
Krypton-85	$5.6 \cdot 10^{11}$

Table 8-4. Annual radioactive discharges from Clab to the receiving water body. Mean values of measured discharges during the period 1996–2009.

Nuclide	Measured releases [Bq/year]
Tritium	$2.6 \cdot 10^{9}$
Manganese-54	$3.9 \cdot 10^{6}$
Cobalt-58	$1.3 \cdot 10^{6}$
Cobalt-60	$3.8 \cdot 10^{8}$
Strontium-90	$2.6 \cdot 10^{5}$
Cesium-134	$2.7 \cdot 10^{6}$
Cesium-137	$5.5 \cdot 10^{7}$
Plutonium-238/Americium-241	$2.9 \cdot 10^{4}$

Proposed measures to reduce releases and discharges

In 2009, nominal discharges from Clab to water of the most important radionuclides aside from tritium amounted to 100 MBq/year. A prediction shows that discharges from Clab may increase if no measures are adopted, due to three factors /8-12/:

- The concentration of Cs-137, which constitutes a considerable fraction of the radioactive discharges to water, is increasing steadily in the storage pools.
- Spent ion exchange resins at Clab have been stored in tanks pending future solidification. This has been a way to reduce radiation dose to personnel and comply with radiological specifications for final waste packages. When the ion exchange resin is solidified, it is assumed that the activity releases to water will increase.
- Connection of the encapsulation plant will increase the load on Clab's cleanup system.

If no measures are adopted, future discharges from Clab will increase significantly. Possible measures for maintaining and further reducing the radioactive discharges to water have therefore been studied /8-12/. The study resulted in a number of proposals for measures, but practical tests are required to determine whether they can be implemented. Further study is also required to determine whether the measures can be implemented in a manner that does not adversely affect safety, radiation protection and waste management at the facility. If all measures can be adopted, the discharges could theoretically be reduced by 95–99 percent. This would mean that current discharges could be significantly reduced, despite an increasing load.

Further treatment measures are not deemed to be justified for releases to air.

8.1.3.4 Ecosystem impact of releases of radionuclides

Radiological impact on the biosphere, i.e. possible impact on animals and plants, due to releases from Clab is dealt with in the chapter on Clink, section 9.1.3.5.

8.1.3.5 Non-radiological atmospheric emissions

For Clab, the dominant source of atmospheric emissions is sea transport by m/s Sigyn. The ship has been equipped with a catalytic converter to reduce emissions of nitrogen oxides (NO_x). The catalytic converter is operational about 50 percent of the time, when the engines are running at 60 percent load or more, and reduces NO_x emissions by more than 80 percent when it is running. Calculations or estimates of annual emissions from m/s Sigyn are shown in Table 8-5. Even though total emissions are significant, m/s Sigyn's emissions should be viewed in relation to the large volume of other shipping in the seaways. The current workload for m/s Sigyn is less than one shipment per week. When a new ship is taken into service, atmospheric emissions will decrease, since the new ship will have better performance and be equipped with the latest in emissions control technology.

Operation of Clab also entails overland transport. An estimate of the emissions from overland transport associated with Clab for 2015 is shown in Table 8-6. FC indicates fuel consumption, PM_{exh} stands for exhaust particulate matter and PM_{res} for resuspended particulate matter. Emissions of sulphur dioxide are negligible, since diesel of environmental class 1 and 95 octane petrol are used as fuel /8-13/.

Table 8-5. Annual emissions from m/s Sigyn (tonnes per year).

Substance	Quantity (t/y)
CO_2	2,293
SO_2	0.7
NO_X	26
CO	0.5
HC	0.7

Table 8-6. Emissions and fuel consumption for overland transport to and from Clab (t/y).

Substance	2015
NO_X	0.19
CO	0.10
HC	0.014
PM_{exh}	0.003
PM_{res}	0.19
FC	21
CO_2	65

8.1.3.6 Non-radiological effluents

With the existing system, stormwater is conducted via an underground pipe and discharged in the sea bay Herrgloet. In conjunction with the construction of the encapsulation plant, some of the stormwater from Clab will also be conducted to the stormwater management system for the the encapsulation plant in order to take advantage of the possibilities of infiltration in nearby forest land, see also 8.1.1.2. This will reduce the quantity of pollutants that reaches Herrgloet.

Waste water is purified in OKG's treatment plant before being discharged outside the sea bay Hamnefjärden. The quantity of waste water diverted from Clab today is about 32 cubic metres per day /8-11/.

Cooling of the pools in Clab gives rise to heated cooling water, which is discharged together with the cooling water from the nuclear power plant in Hamnefjärden. On average, 0.16 cubic metre of sea water per second was discharged in 2009. Based on the design capacity and flow, cooling in the facility leads to a temperature increase of about seven degrees after the water has passed Clab. This can be compared with the effluent from the nuclear power plant (after the power increase), where approximately 96 cubic metres per second is discharged with a temperature increase of 12.5 degrees /8-14/.

8.1.3.7 Waste

Operation of Clab gives rise to waste, hazardous waste and radioactive waste. The radioactive operational waste is handled and packaged for further transport to SFR. The low-level waste is taken to the near-surface repository for low-level waste (MLA) located next to the tunnel portal to Äspö on the Simpevarp peninsula. Between 2003 and 2009, Clab gave rise to an average of 37.8 tonnes of radioactive waste per year. During the same period, an average of 10.4 tonnes of waste per year was sent for recycling or reuse, while 17.3 tonnes of waste was sent for disposal, incineration or biological treatment. 4.5 tonnes of hazardous waste was sent for recycling, incineration or treatment /8-11/. M/s Sigyn generated about 100 tonnes of hazardous waste (sludge) in 2009. Sludge is an oil-containing bilge water that comes from leakage, machinery and equipment and cleaning of such machinery and equipment. The sludge is collected when the ship arrives at port.

8.1.3.8 Energy use

Between 2003 and 2009, energy use at Clab was on average 16–17 GWh per year. Fuel consumption by the terminal vehicles and other vehicles for on-site transport during the same period amounted to an average of seven cubic metres of diesel per year. Clab also has a standby power unit that is test-run regularly and has an annual fuel consumption of 1.5 cubic metres of diesel. Yet another unit has been installed but not taken into service. More than 1,000 tonnes of diesel fuel was consumed by sea shipments from the nuclear power plants to Clab during 2009.

8.1.3.9 Water consumption

The nuclear power plant's water treatment plant meets Clab's need of process and deionized water. Clab's total water consumption averaged about 14,300 cubic metres per year between 2005 and 2009. Clab's fire extinguishing system is also supplied with water from the nuclear power plant's water treatment plant.

8.1.3.10 Chemicals use

Chemicals are used for cleaning and maintenance of the facility. Table 8-7 shows the annual average consumption of chemicals at Clab for the period 2003–2009 or 2007–2008.

Table 8-7. Chemicals consumption at Clab.

Chemical	Quantity/year (weight or volume)	
Cleaning agents and lubricants	850 kg	(2007–2008)
Refrigerants	23 kg	(2003–2009)
Paints and solvents	1,900 kg	(2007–2008)
Ion exchange resins (powdered)	350 kg	(2003–2009)
Ion exchange resins (granular)	1.4 m^3	(2003–2009)
Hydrazin Levoxin	11 kg	(2003–2009)

8.1.4 Effects and consequences

8.1.4.1 Natural environment

The heated water from the cooling water channel gives rise to both direct and indirect effects in the surrounding environment. It is mainly Hamnefjärden that is affected. Besides the direct temperature increase, the effluent leads to altered current conditions inside and outside the bay. The flora and fauna in the environment are also affected. OKG's environmental monitoring shows that the hot water provides a good supply of oxygen and nutrients and thereby promotes growth of both flora and fauna, resulting in an altered species composition. However, the effects on the natural environment are generally considered to be positive for the development of certain fish species as well as for the flora and fauna on the seafloor. Clab's contribution is negligible, since the volume used at Clab comprises less than 0.2 percent of the total volume of heated water. A more detailed description of the effects of cooling water on the natural environment is provided in the Environmental Impact Statement for the Oskarshamn Nuclear Power Plant /8-14/.

8.1.4.2 Landscape

The landscape around the Simpevarp peninsula is characterized by both the archipelago and the nuclear power plant's facilities. Clab is situated on the coast and is clearly visible from the sea.

In order to assess the visual impact of Clab on the landscape, a visibility analysis has been done showing from where in the landscape buildings in the operations area are visible. In addition to the topography, the vegetation, and particularly the forest, is of great importance for how visible the facility is. Figure 8-16 shows two separate scenarios: one where the vegetation is retained and one where all forest, except that which is protected in e.g. nature reserves, has been felled. With today's vegetation, the facility is less visible than if the forest is felled.

The two scenarios demonstrate the role of the forest in concealing the facility from the sea. The proportion of deciduous trees can also influence visibility in the wintertime. The forested shore area south of Clab conceals the facility today to those looking from the southwest, from Strömsö. From the southeast, from Långskär and the marina, the forest screen is thinner and Clab is visible from the water.

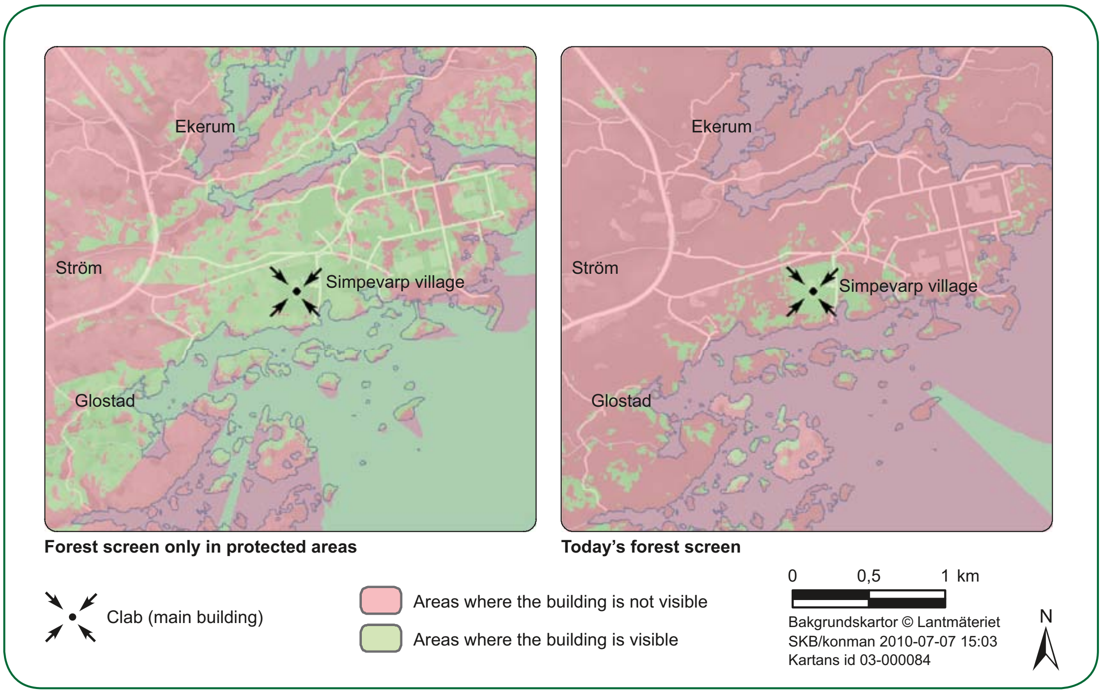


Figure 8-16. Visibility analysis for Clab. The map at the left shows the visibility of the building in the surrounding landscape when only protected forest has been retained. The map at the right shows the same visibility analysis where today's vegetation has been retained.

8.1.4.3 Residential environment and health

Water supply and subsidence

Results and analyses of measurements from the monitoring programme in conjunction with the construction of Clab 2 indicate a limited impact on the groundwater level in Clab's environs, since only boreholes in direct connection with the facility have exhibited a change in groundwater level /8-6/.

The existing groundwater lowering around Clab will not be changed as long as the facility exists, which means that no consequences are expected for drinking water wells or systems for drinking water supply. Nor is any subsidence expected.

Noise

The existing noise levels at and around Clab are low and are not considered to have any consequences for the local population /8-15/.

Emissions to air

M/s Sigyn uses the public fairways for sea transport to and from Clab. M/s Sigyn, along with other shipping, contributes to emissions of hazardous substances. These emissions may be of importance for the collective exposure to hazardous air pollutants in build-up areas located near major fairways or downwind direction from fairways /8-16/. In view of the fact that the number of journeys with m/s Sigyn is limited and that the ship mainly travels in public fairways, the atmospheric emissions generated by the nuclear fuel shipments are not assessed to make significant contributions in relation to other shipping.

Emissions from overland transport associated with Clab are not considered to have any effects for residents /8-13/.

Radioactive releases

Releases of radionuclides to the environment occur via both air and water. Airborne radioactivity is released via Clab's ventilation chimney. The age group 7–12 year-olds has been used in calculations of dose rates to the critical group, since this groups receives the highest dose. Significant nuclides in emissions to air are cobalt-60 (Co-60), strontium-90 (Sr-90), plutonium-238 (Pu-238)/americium 241 (Am-241), americium-243 (Am-243) and krypton-85 (Kr-85). Figure 8-17 shows the dose to the critical group for these nuclides during the period 1998–2009. The relatively high value for 2001 is due to the fact that a major release was caused by a dust puff during cleaning of an insert drum with a wet vacuum cleaner.

The activity in the water is measured before it is mixed with cooling water from the facility and conducted to the discharge channel for cooling water. The release of activity from Clab via water is very small. The annual waterborne discharge and resulting dose to the critical group (age group 7–12 year-olds) is shown for the period 1998–2009 in Figure 8-18, which shows that the actual doses have declined with time and are far below the licensing calculations of $5 \cdot 10^{-5}$ mSv.

For nuclear facilities there is a requirement that the combined dose to the critical group from facilities in the same geographic area may not exceed 0.1 mSv per year. The dose limit should therefore be applied jointly for the nuclear power plant and Clab. Radioactive releases from the nuclear power plant and Clab amount to less than one-hundredth of the limit value, see Figure 8-19 /8-17/.

Figure 8-17. Dose to critical group from annual releases to air from Clab during the period 1998–2009.

Figure 8-18. Dose to critical group from annual discharges to water from Clab during the period 1998–2009.

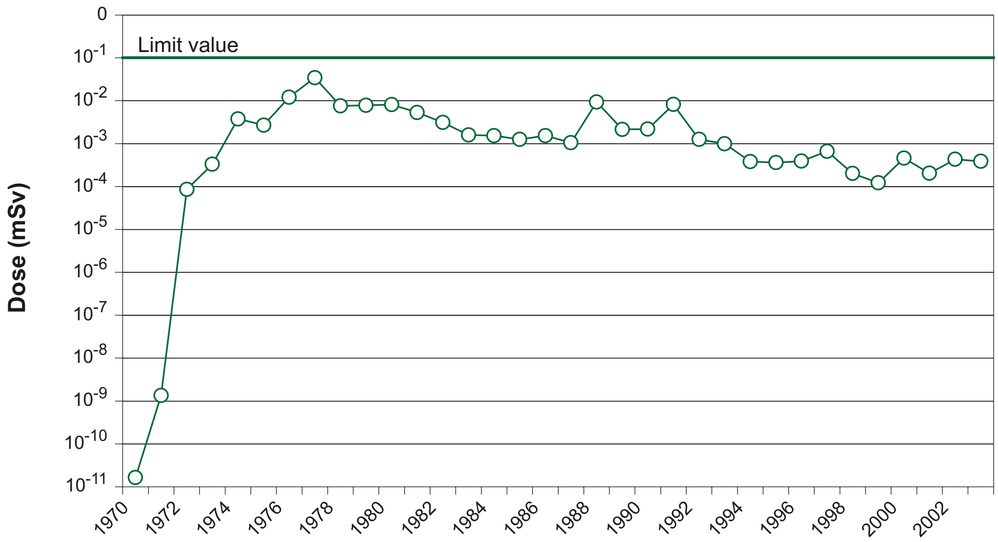


Figure 8-19. Dose to critical group from existing nuclear facilities in Oskarshamn.

8.1.5 Risk and safety issues

8.1.5.1 Environmental risks

In addition to expected effects and consequences during normal operation of the facility, environmental risks have also been studied /8-18/. By "risk" is meant the probability that an accident or mishap will occur and its impact on the recipient, i.e. how great consequences an accident can have on the specific site being studied.

During the operation of Clab, fire is the single biggest accident that can have environmental effects. However, the fire load is low and preparedness is high, so the consequences of a fire will be very limited. Other environmental risks concern ethanol spills during cleanup and diesel spills during filling of tanks and can be managed without major consequences for the environment.

Special environmental risks are associated with both overland and sea transport. Transportation of fuels and other goods involve risks of oil spills. On the work site (fenced-in area), there is preparedness for handling such an event, so the consequences are assessed to be small. The cleanup work is more difficult on public roads, with a risk of greater consequences depending on the accident location. The probability of an accident at sea with m/s Sigyn is very low and preparedness is very high, so the risk of environmental harm is less than for accidents with other cargo ships.

The risk of flooding due to higher sea levels in the future has been studied and is addressed in section 9.1.5.1. The risk is only reported for Clink, since flooding cannot occur until long after the encapsulation plant has been built.

8.1.5.2 Nuclear safety and radiation protection

Transport of spent nuclear fuel and nuclear waste

Safety in the transport of spent nuclear fuel and nuclear waste is guaranteed by special requirements on the transportation system where transport cask, ship and terminal vehicle comprise the most important components. The transport casks in particular guarantee high safety. The ability of the cask to withstand great stresses in connection with accidents is verified by tests and calculations. It must retain both its integrity and its radiation shielding properties when dropped from a height of nine metres onto an unyielding surface, when dropped from a height of one metre onto a sharp object, when subjected to 800°C for 30 minutes, and under a pressure equivalent to immersion under 200 metres of water for at least one hour /8-3/. Severe accidents during transport can thereby be handled without giving rise to any consequences for the environment.

Nuclear safety and radiation protection in Clab

Disturbances are events that can occur at some time during the lifetime of the facility. Examples of disturbances analyzed in the safety analysis report are component failure in cooling and handling systems, operator error, pressure loss and computer failure. The identified and analyzed disturbances are not expected to jeopardize the cooling of the fuel or lead to mechanical damage to the fuel cladding.

Mishaps are improbable events that are not expected to occur at any time during the lifetime of the facility. Examples of mishaps are prolonged loss of the makeup water supply to the storage pools, a large leak from the pools, a major fire or an earthquake.

The mishaps that have been identified and analyzed in the safety analysis report for Clab show very small releases and are not assessed to cause any serious consequences for the environment. Events with mechanical damage to fuel cause radioactive releases which, however, are well below the acceptance criteria. The calculated maximum individual dose occurs in connection with the mishap "dropped fuel storage canister". There is no specific Swedish regulatory requirement regarding the permissible radiological consequence for the environment for this type of event. The acceptance criterion for environmental dose, 50 mSv at a distance of one kilometre, is taken from American regulations for facilities equivalent to Clab. The environmental dose calculated to occur in conjunction with a mishap in Clab is lower than the acceptance criterion. The reason the calculated doses are so low is that nearly all gaseous fission products present in the fuel-clad gap decay before transport to Clab. In connection with other events, there is plenty of time (in most cases several days) to take appropriate steps so that releases of radionuclides can be avoided. In the event of an earthquake or other external impact on the facility, the fuel will remain intact.

8.2 Summarizing conclusions

In order to permit an overall assessment of the effects and consequences of the facility and the activity during continued operation, a summary is made here of the assessments that have been made for different aspects.

Clab is an existing facility that impacts the environment via discharges of hot water, noise, radioactive releases to air and water and non-radiological atmospheric emissions. However, the activity does not give rise to any appreciable negative consequences. See Table 8-8.

Table 8-8. Summary of effects and consequences for operation of Clab.

	Assessment
Natural environment	
Discharges to water	Operation of Clab entails that heated water is discharged to Hamnefjärden. The effluents from Clab comprise a fraction of the effluents from the nuclear power plant, at the same time as the hot water has certain positive effects on the ecosystem.
Landscape	Clab is mainly visible from the sea. However, the surrounding forest landscape provides a screen around the facility.
Residential environment and health	
Groundwater	The monitoring programme for Clab indicates a local limited impact on the groundwater and thereby no impact on private wells.
Noise	Existing noise levels around Clab lie below the legal limits for industrial noise and there is limited development around the facility.
Non-radiological atmospheric emissions	The biggest source of atmospheric emissions is the ship m/s Sigyn, which only uses public fairways for transport to and from Clab.
Radionuclide releases	Radionuclide releases lie far below the licensing calculations and established limit values for dose to critical group.
Risk and safety	
Non-radiological risks	The biggest single accident that has been identified as being able to cause environmental effects is fire. The consequences are assessed to be very limited, since the fire load is low and preparedness is high.
Radiological risks	Different scenarios that could lead to disturbances or mishaps have been studied. All show a calculated maximum dose to the individual that is below the acceptance criteria.

Integrated facility for interim storage and encapsulation (Clink)

9 Clink

SKB has chosen Simpevarp in Oskarshamn Municipality as the site for the encapsulation plant, since this makes it possible to exploit the personnel's experience of fuel handling at the same time as many of the existing systems and plant parts in Clab can be utilized for the encapsulation plant as well.

This chapter provides an account of the impact, effects and consequences of the integrated facility for interim storage and encapsulation (Clink) that is the subject of SKB's application. The account of the applied-for activity concerns its impact, effects and consequences during the construction phase for the encapsulation plant as well as the operating and decommissioning phase for the integrated facility, Clink. For the operating phase, a separate description is provided of the impact, effects and consequences of the encapsulation plant where relevant. Section 9.2 describes the considered alternative of a siting of the encapsulation plant in Forsmark.

The chapter also contains accounts of the impact, effects and consequences of shipments to and from the applied-for facility in Simpevarp and the considered alternative in Forsmark.

Information on decommissioning is very brief, since the long time horizon (around 2070) makes the assumptions uncertain.

9.1 Applied-for activities – Simpevarp

SKB is applying for a licence to build and operate an encapsulation plant and to locate it adjacent to Clab on the southwestern part of the Simpevarp peninsula, as well as to operate the two facilities as one integrated facility, Clink. Under the headings "Facility design" and "Description of activities" it is mainly the encapsulation plant and those systems that are common with Clab that are described. See Chapter 8 for information on the activities in Clab.

9.1.1 Facility design

The building in which encapsulation will be carried out will be built in three storeys below ground and seven storeys above ground. The outside dimensions of the building will be 75×90 metres, and the height of the tallest building part will be about 30 metres above the ground surface, see Figure 9-1. Virtually the entire building will be made of concrete.

The part of the facility that will be built on the ground surface will contain areas for process, service and transport. Visitors' areas will be built to enable parts of the process to be shown. The underground part of the facility will house a pool section whose lowest bottom will be 15 metres underground. The pools will be made of watertight concrete and lined with stainless steel. The pool section will be located above the deep rock caverns that hold Clab's pools.

Southwest of the encapsulation plant, a separate terminal building will be built in one level for transport casks and empty copper canisters. The arrangement of the buildings within the operations area for Clink is shown in Figure 9-2.

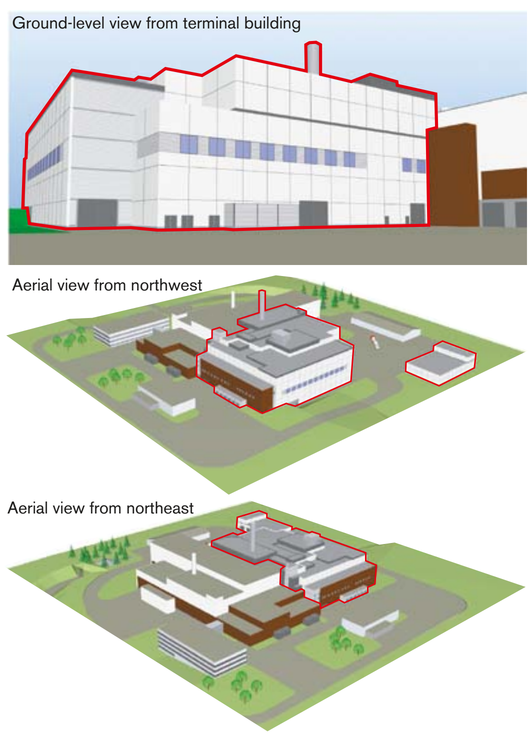


Figure 9-1. Design of the encapsulation plant when located adjacent to Clab. The red lines indicate the boundaries of the encapsulation building and the terminal building.

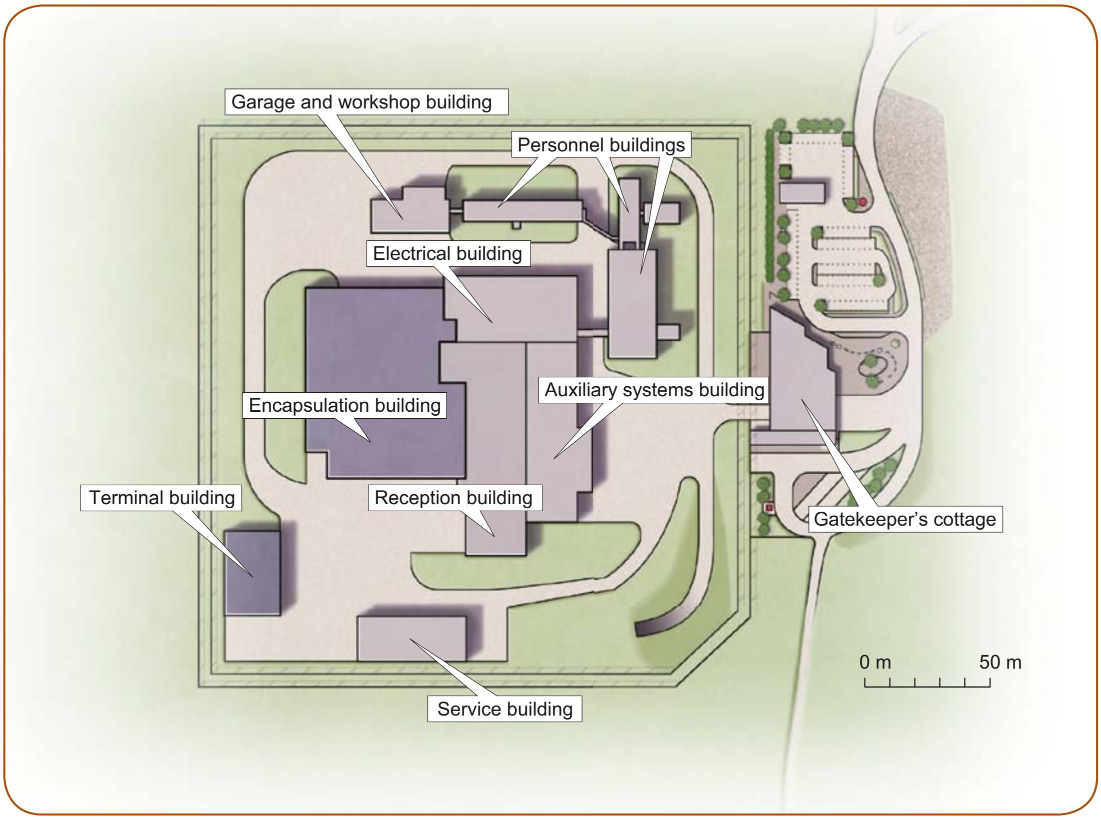


Figure 9-2. Arrangement of buildings inside the operations area for Clink.

The encapsulation plant is designed for a production capacity of 200 filled canisters per year, i.e. around one canister per work day /9-1/. The planned production rate is an average of about 150 canisters per year.

9.1.1.1 Common systems

When the two facilities are integrated, existing systems and functions in Clab will be co-utilized wherever possible. A number of systems in Clab will be extended and modified to comprise a part of the encapsulation plant as well. Monitoring and surveillance of common systems takes place from Clab's central control room. A number of other functions will also be common. Systems that supply the encapsulation plant with water and cooling are common with Clab, as are the systems that drain and treat water.

Treatment of water from controlled areas

Clab has a system for receiving and treating water from controlled areas (floor drainage and process water) so that it can be reused in the process or discharged to the cooling water channel, see section 8.1.1.1. These systems will also receive and treat water from controlled areas in the encapsulation plant.

Cooling system

The intake building for cooling water is located in Herrgloet, a sea bay south of Clab, see Figure 9-6. Surplus heat from the facility's pools is conducted to the system for cooling via an intermediate system to which the encapsulation plant will be connected. After having passed a heat exchanger in the facility, the heated sea water is conducted via an underground pipe to the cooling water outlet for the the nuclear power plant's reactor unit 1 and back into the sea.

Water supply and sanitary sewage

The encapsulation plant is connected via Clab to the nuclear power plant's water treatment plant for supply of deionized water (for use in controlled areas) as well as for tap water and fire extinguishing water. The water treatment plant takes its water from Lake Götemaren. The encapsulation plant is also connected to Clab's sanitary sewage system. Waste water is conducted to the nuclear power plant's treatment plant for treatment and is then discharged outside the sea bay of Hamnefjärden. If the reactors in the nuclear power plant are shut down, alternative solutions for water supply and waste water treatment may be found, since Clab's needs are small in relation to OKG's needs.

Heat

The heating system in the encapsulation plant constitutes a separate, closed system. However, heat from the storage pools in Clab is intended to be used for heating of the encapsulation plant /9-2/.

9.1.2 Description of activities

9.1.2.1 Construction phase

During the construction phase, a land area will need to be levelled by blasting and filling in order to create an establishment area. The establishment area will contain a site office, crew sheds, workshops, temporary storage areas and a parking lot and will be located west of the planned location of the encapsulation plant.

A deeper rock pit needs to be blasted for the encapsulation plant's pools. The pit will be situated immediately adjacent to Clab's surface part, and its bottom will be about 14 metres above the roof of the rock cavern in Clab. The distance between the rock pit and the fuel elevator shaft is about two metres. Preparations have been made at the fuel elevator in Clab to connect to a connecting pool. The fuel elevator can then be used to transport fuel from the storage pools to the encapsulation building.

During the construction phase, additional traffic will be dominated by removals of rock spoil and arrivals of concrete and materials. The rock volume that is blasted for the encapsulation plant is estimated at 24,000 cubic metres (solid rock), which can be compared with the rock volume of about 90,000 cubic metres that was blasted for Clab's other storage section, Clab 2. In calculating the number of heavy shipments it has been assumed that a truck smaller than 16 tonnes is used. Heavier vehicles could be used, especially for haulage of rock spoil, which would reduce the number of heavy shipments. Most of the heavy shipments are expected to take place during the first 3.5 years of the construction phase. It is assumed that most of the personnel will live in the nearby area during the construction period /9-2/. An estimate of the number of hauls during the different phases of the facility is shown in Table 9-1 /9-3/.

Table 9-1. Estimated total additional number of truck shipments per day and number of heavy shipments to and from the encapsulation plant during different phases.

	Construction phase stage 1 (year 0–3.5)	Construction phase stage 2 (year 3.5–7)	Operating phase	Decommissioning phase
Total additional shipments per day (round trip)[1]	170	70	70	30
Number of heavy shipments per day (round trip)[1]	90	30	15	10

[1] Assuming 230 working days per year (five working days a week).

9.1.2.2 Operating phase

Clab and the encapsulation plant will together function as an integrated facility, Clink. The siting of the encapsulation plant adjacent to Clab assumes that it is adapted to Clab in terms of operation and safety. Clab and the encapsulation plant will have a common operating organization. A total of about 130 persons will work in Clink.

The main activity during the operation of the encapsulation plant is to enclose spent nuclear fuel in tightly sealed copper canisters. The copper canisters, which are five metres long and have a diameter of about one metre, arrive ready-made at the encapsulation plant. The different steps in the encapsulation process are shown in Figure 9-3.

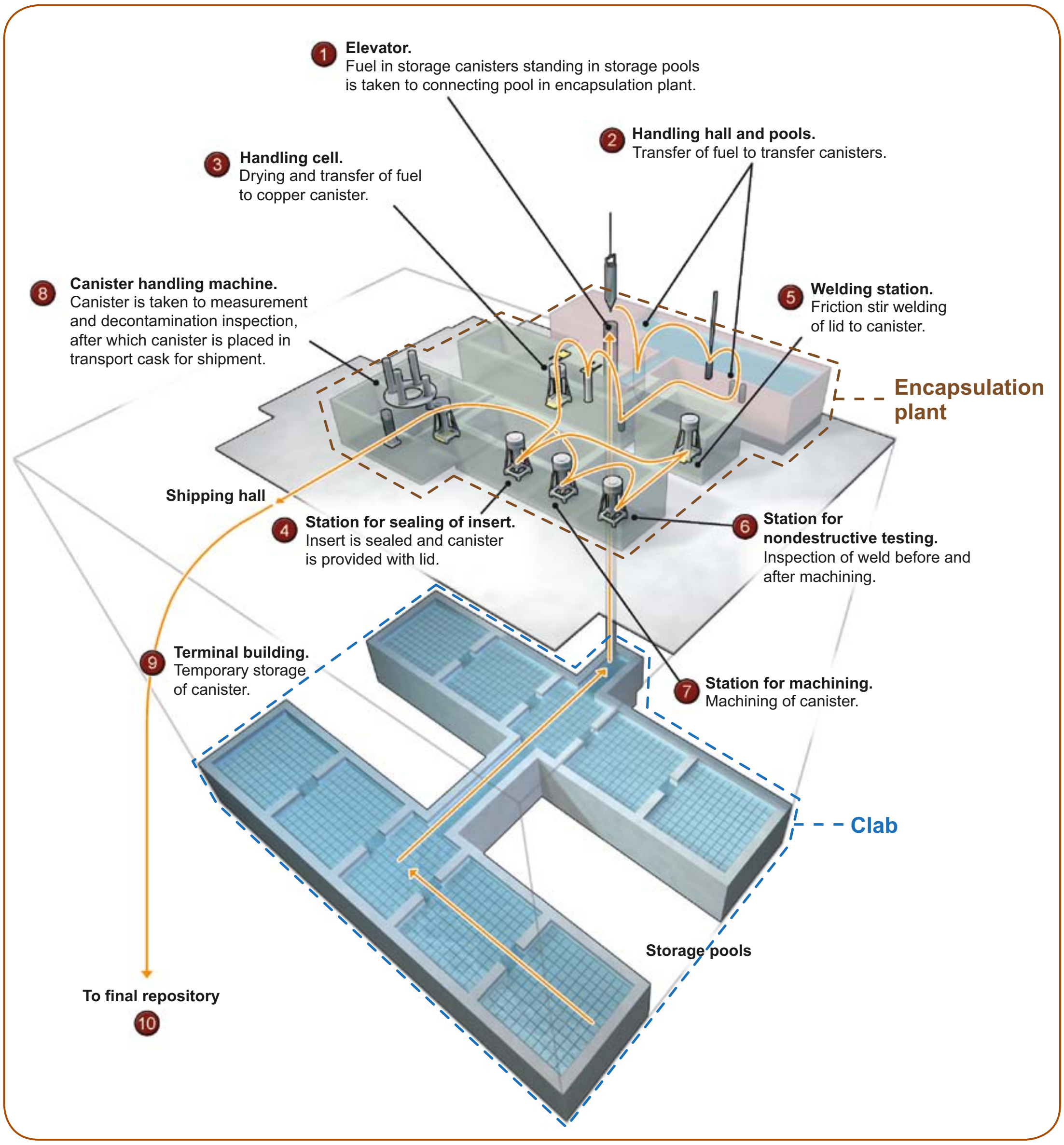


Figure 9-3. The different steps for handling of spent nuclear fuel in the encapsulation plant.

Before the spent nuclear fuel is taken into the encapsulation plant it has been interim-stored in Clab's pools to allow its radioactivity and heat output to decline. The selection of nuclear fuel for encapsulation is made based on the decay heat of the fuel assemblies and the permissible decay heat in each canister. The nuclear fuel is transported from the storage pools in Clab via the existing fuel elevator and is taken to the encapsulation plant's pools (1). The nuclear fuel is sorted in the handling pool (2). The fuel's decay heat can be measured in the pool. The fuel is then taken up out of the pool and put into a handling cell to dry and be placed in a copper canister (3). The insert in the canister is sealed and the air is replaced with inert gas (4). A lid is welded onto the canister (5). Friction stir welding is planned to be used for welding of the lid. The weld is inspected by nondestructive testing, for example radiographic and/or ultrasonic testing (6).

Irregularities on the surface of the canister are then machined off (7). Before the canister is placed in a transport cask it is inspected for surface contamination and cleaned if necessary (8). During the process the canister is moved in a remote-controlled transport frame between work stations in the plant where different steps are performed. During the entire process the canister is covered by a radiation shield. The end product is a filled copper canister placed in a transport cask and prepared for transport to the final repository, see Figure 9-4.

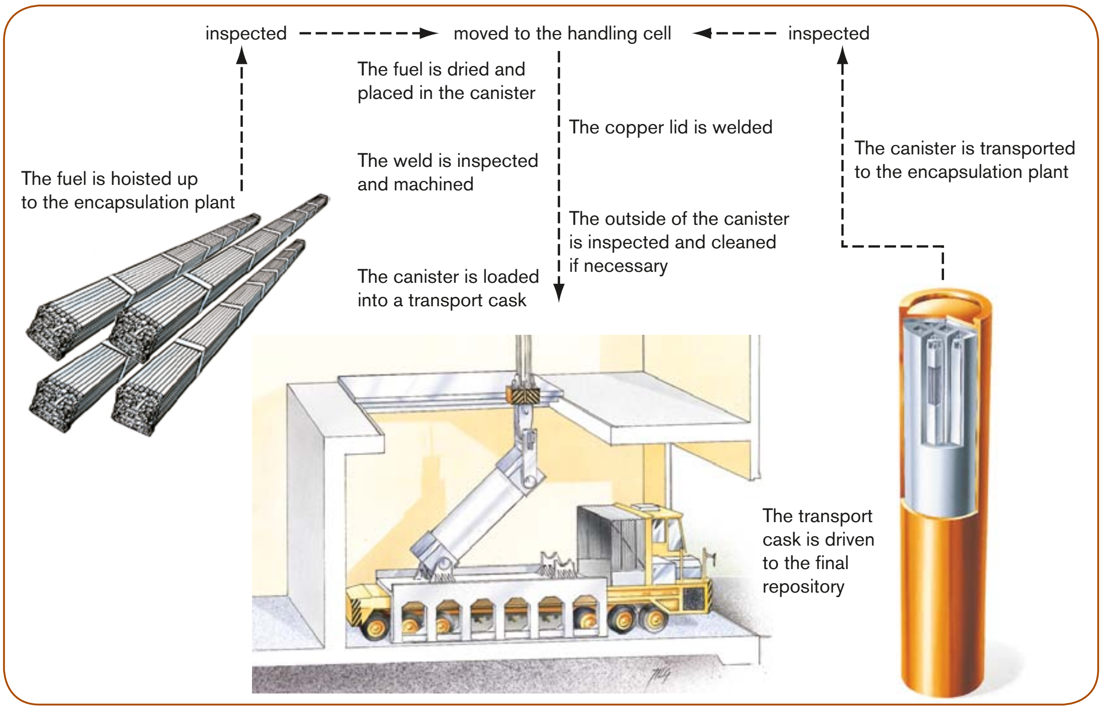


Figure 9-4. The filled copper canister is placed in a transport cask prior to transport to the final repository.

Transport of spent nuclear fuel

Canisters will be transported to the final repository in Forsmark by m/s Sigyn or an equivalent ship.

M/s Sigyn can be loaded with ten transport casks. Assuming a deposition rate of 150 canisters per year, the ship will make around 15 calls per year at the ports in Simpevarp and Forsmark for final disposal. More can be read about m/s Sigyn in section 8.1.2. There is in principle no difference between these shipments and today's shipments of spent nuclear fuel from the nuclear power plants to Clab. The only difference is that different transport casks are used for unencapsulated and encapsulated nuclear fuel. The transport cask is licensed to IAEA requirements for type B packages. The transport cask must be able to withstand stresses associated with accidents without losing its integrity or radiation shielding and be able to dissipate heat caused by fuel decay /9-4/. The canisters are then unloaded at the harbour in Forsmark by specially designed transport vehicles. A canister filled with spent fuel weighs about 27 tonnes. A filled transport cask with shock absorber weighs between 80 and 95 tonnes and the transport frame weighs around 17 tonnes, see Figure 9-5. Overland transport of spent nuclear fuel is done today by special slow-moving terminal vehicles with a payload capacity of 124 tonnes. They will be able to manage their future transport duties with ample margin.

Other transport

The traffic to and from Clink during the operating phase is expected to consist chiefly of 3,000–4,000 visitors per year, plus about 130 persons who commute daily to and from their place of work. There is already a visitor service at Clab today.

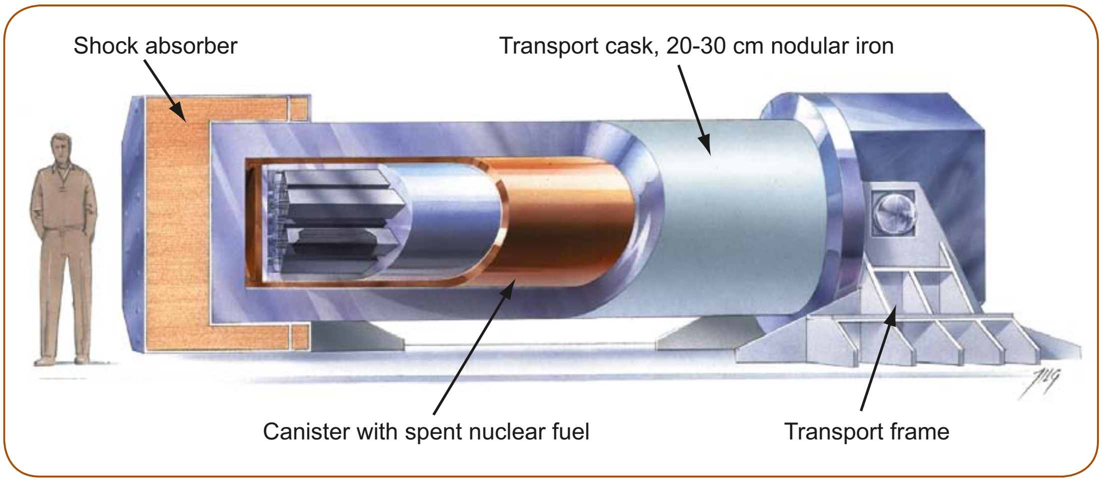


Figure 9-5. Canister transport cask and transport frame.

Fabrication of copper canisters requires a special canister factory. During the operating phase, empty canisters will therefore be transported from the canister factory to the encapsulation plant. The route used for transporting empty canisters will depend on where the canister factory is located. One possible location of the canister factory is adjacent to the existing canister laboratory in the harbour area in Oskarshamn. The estimated total additional number of road hauls during the operating phase is shown in Table 9-1.

9.1.2.3 Decommissioning phase

Clink will be decommissioned and dismantled when all spent nuclear fuel that has been interim-stored in the facility has been encapsulated and sent to the final repository and all core components have been hauled away for storage at the intended site. The timetable for decommissioning and dismantling is linked to when the last nuclear power plant is taken out of service as well as the availability of interim storage and final disposal facilities for radioactive waste. According to the latest reference scenario /9-1/, it is assumed that dismantling of the nuclear power plants will proceed until the 2050s, which means that dismantling of Clink could begin in around 2070. Dismantling is assumed to take between five and seven years. The facility can either be dismantled directly after all spent nuclear fuel has been encapsulated and left Clink, or dismantling can be deferred by placing the facility in so-called “safe store”. When the time for dismantling approaches, a more detailed alternative will be presented along with reasons for the chosen alternative.

A preliminary decommissioning plan has been prepared for the dismantling of Clink /9-5/. According to the plan, there are different possible alternatives for a decommissioning:

1. Decommissioning stops at the point where buildings and land are released from regulatory control for unrestricted use.
2. The facility is released from regulatory control and dismantled to about one metre below ground level. Cleared dismantling material is used for backfilling, mainly of the encapsulation plant’s underground parts. This must be done to permit unrestricted use of the land. The remaining cleared decommissioning waste is recycled and/or landfilled. Alternatively, the decommissioning waste can be deposited in Clab’s rock caverns.
3. The facility is decommissioned to green field, which means that all supplied material is removed. If the underground part needs to be backfilled, this is done with crushed rock.

Removal of decommissioning materials will dominate during the decommissioning phase. An estimate of the number of haul trips during the decommissioning phase is shown in Table 9-1. The facility will be dismantled some time after the Swedish nuclear power plants have been dismantled. This will make it possible to make use of experience and competence within the areas of nuclear safety, radiation protection, decontamination and decommissioning of nuclear facilities.

9.1.3 Impact

9.1.3.1 Land use

During the construction phase, approximately 28,000 square kilometres will be utilized for the future activity site for the encapsulation plant and the associated establishment area during the construction period, see Figure 9-6. The establishment area is planned to cover about 14,000 square metres in a forested area west of Clab. A temporary road for hauling construction materials will be built towards the north. The utilized land area will be felled, levelled and paved. The work entails blasting and infilling of the land area. The existing activity area for Clab will be extended about 50 metres to the west to provide room for the encapsulation plant. A new terminal building and secondary surfaces such as driving surfaces and safety zones will also be built. The access road to the encapsulation plant will be the same as the one used for Clab today.

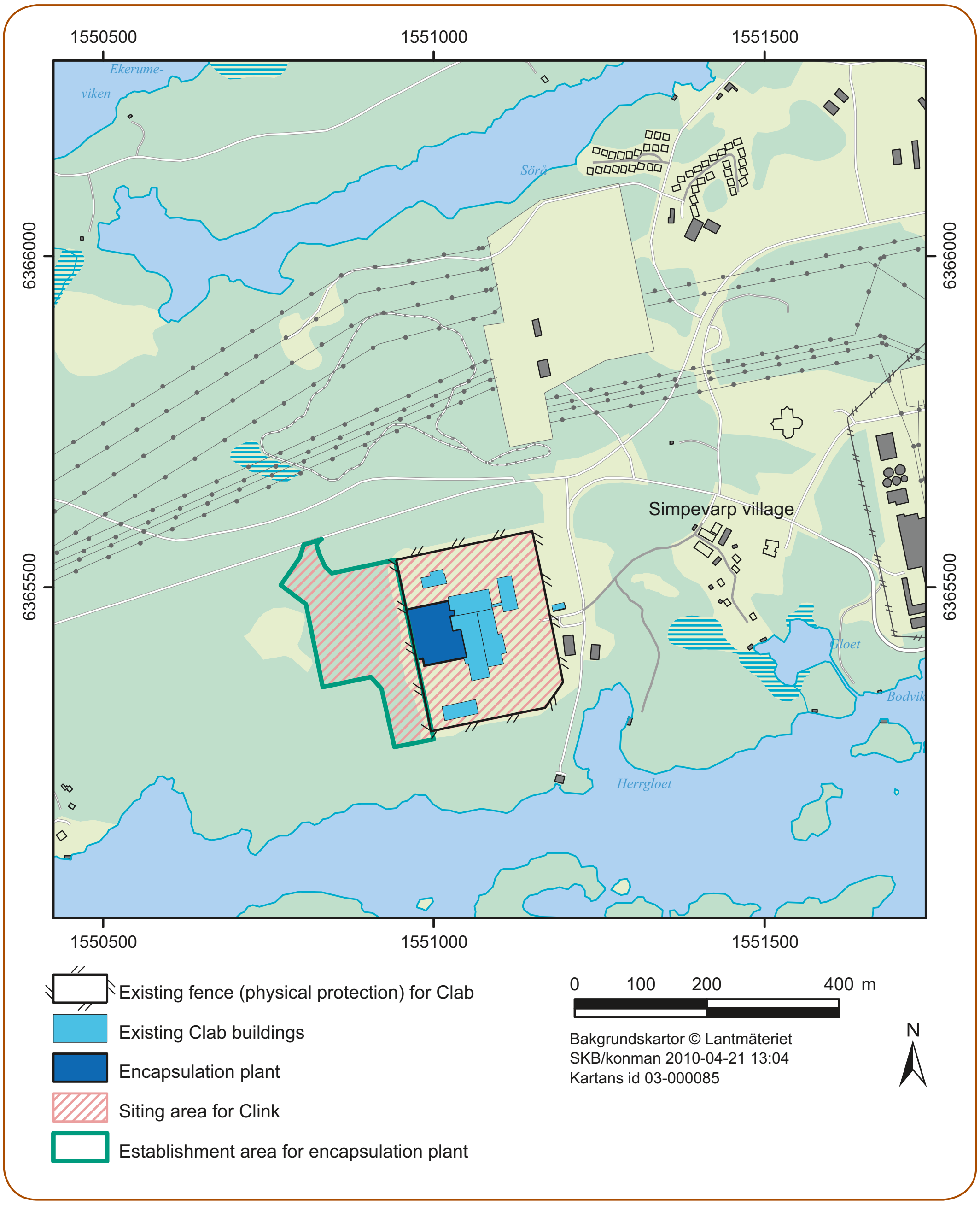


Figure 9-6. Siting area, including establishment area during the construction period.

The land areas that will be used temporarily will be restored as far as possible to their former natural state after the work is finished. The restoration can begin after about three years, when mainly interior work remains. To permit optimal restoration of the land, blasting of rock outcrops will be avoided if possible and irregularities will instead be levelled out by infilling. Exposed rock surfaces will be protected from the passage of tracked vehicles and old pine trees will be spared.

It is assessed that dismantling after the plant has been taken out of service will be able to be done within the surface occupied by the activity area.

9.1.3.2 Impact on groundwater level

Construction phase

Groundwater levels have been measured in boreholes around Clab since 1998 within the framework of the monitoring programme for construction of Clab 2 /9-6/. The measurements show changes in the groundwater level adjacent to the facility that can be traced to the construction of Clab's rock caverns. The encapsulation plant's rock pit will be located above the pools in Clab. The bottom of the pit for the encapsulation plant's underground parts will be located about 14 metres above the roof of the existing rock caverns. The possibility cannot be excluded that the rock pit will be built below the groundwater table. Construction of the encapsulation plant could entail an increase of groundwater inflow by an estimated ten percent compared with the present-day inflow into Clab's rock caverns. However, the positioning of the planned rock pit above the Clab 1 rock cavern means that the inflow into the encapsulation plant will be offset by reduced inflow into Clab. The estimates are reported in /9-7/.

The monitoring programme for Clab shows only local hydrogeological effects from the construction of Clab 2. Since the encapsulation plant's rock pit will be situated directly above the roof of the existing rock caverns, construction and operation of the encapsulation plant is assessed to entail only local effects on the groundwater level in the rock.

Operating phase

The impact on the groundwater level around Clab today will only change marginally during the operation of Clink. See the above description of impact during the construction phase.

Decommissioning phase

After dismantling of Clink, the groundwater level is expected to return to close to its original level. In view of the effective precipitation rate, excavated volume and affected surface area, this could take up to ten years /9-2/.

9.1.3.3 Noise and vibration

Construction phase

Truck haulage, heavy equipment, rock drilling, blasting, rock crushing (if applicable) and earthmoving by wheel loaders will cause noise and vibration during the construction phase. If noise in the frequency range below 200 hertz is dominant, it is perceived as low-frequency sound and can be more disturbing than "normal" noise. Normal noise is given in dBA, which entails that low-frequency sound is filtered away to some extent. The noise study /9-8/ notes that low-frequency noise can mainly be caused by rock crushers and heavy equipment.

Noise levels have been calculated for a scenario where mobile rock crushers and drilling rigs are in continuous operation simultaneously, see Figure 9-7. Noise propagation for the existing activity is shown at left in the figure.

Figure 9-7 shows that noise from the construction of the encapsulation plant will dominate in the area. The highest noise levels in relation to applicable guideline values will occur in the evening.

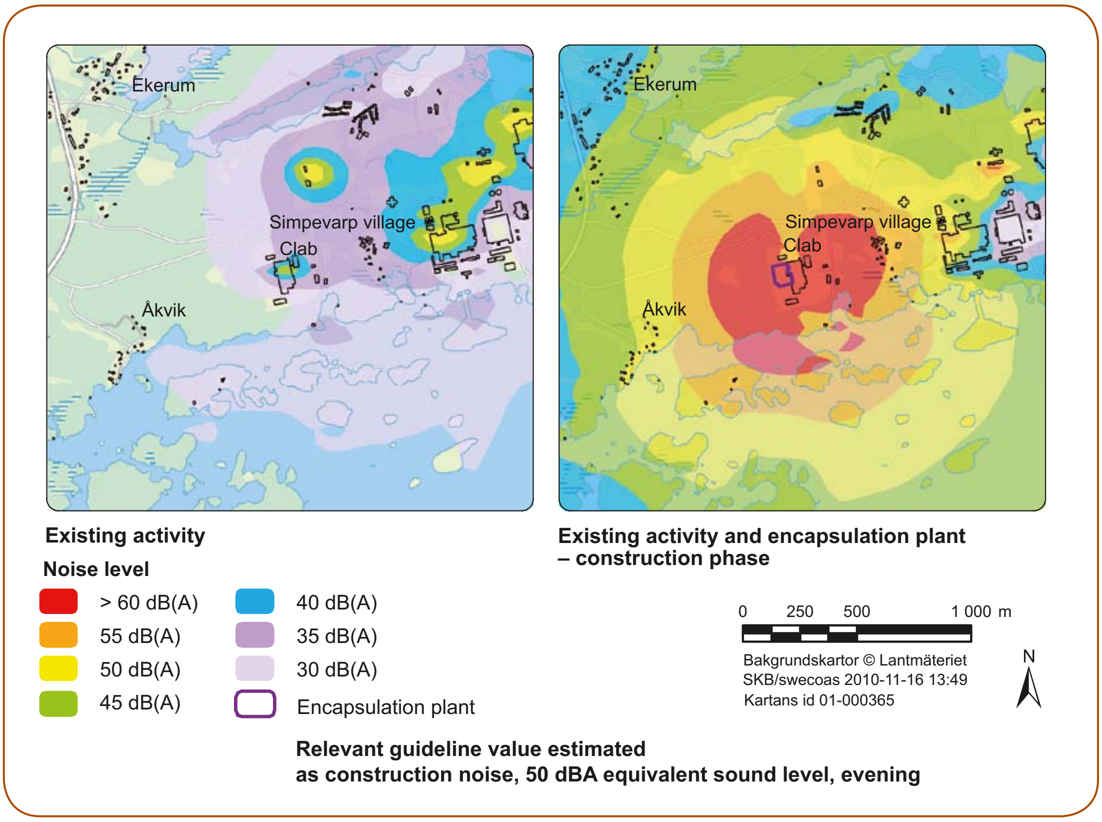


Figure 9-7. Equivalent sound level for existing activity (left) and combined with noise during construction of the encapsulation plant, evening (right).

The magnitude of the vibration caused by heavy traffic depends on the roughness of the roadway, vehicle weights, speed limits and foundation conditions. A sample calculation based on stony till and a road roughness of five centimetres (great roughness) is shown in Table 9-2 /9-2/.

Table 9-2. Sample calculation of vibration caused by heavy traffic.

Gross vehicle weight and speed	10 metres from road	50 metres from road
40 tonnes–70 km/h	0.5 mm/s	0.1 mm/s
60 tonnes–70 km/h	0.7 mm/s	0.2 mm/s

Blasting of rock for the encapsulation plant's pools will be done during the first part of the construction phase and proceed for an estimated three months. In view of the nearness to Clab, the charges will be relatively small. Blasting gives rise to both vibrations and air shock waves, i.e. a pressure change in the air that occurs in connection with rock blasting. Planning and execution of rock works will be governed by the caution required by the proximity of Clab's two rock caverns. In conjunction with the construction of Clab 2, the question of possible impact on the existing rock cavern was studied /9-9/. Experience is therefore available from the construction of Clab 2, which did not affect the stability or function of the existing facility. Pessimistic calculations show maximum vibration levels at nearby buildings of between 0.3 and 0.7 millimetres per second (mm/s), for which the limit values lie between 7 and 11 mm/s. Furthermore, most of the explosive charges will probably be smaller than assumed in the calculations. The calculations show values for air shock waves that are less than 50 Pascal (Pa), while the limit value is 500 Pa. This means that most rounds will not be audible at the nearby properties. Details on calculations of vibrations and air shock waves are given in /9-10/.

Operating phase

During the operating phase, ventilation fans will be the dominant noise source. Noise suppression measures are planned to meet applicable guideline values at the nearest housing. The activity inside the plant will not impact the surrounding environment. Figure 9-8 shows calculated noise levels from the encapsulation plant when the fans are located indoors. Noise propagation for the existing activity is shown at the left in the figure. The figure shows that noise levels at the nearest housing are below applicable guideline values. Nor are transport activities during the operating phase expected to cause any disturbing vibrations.

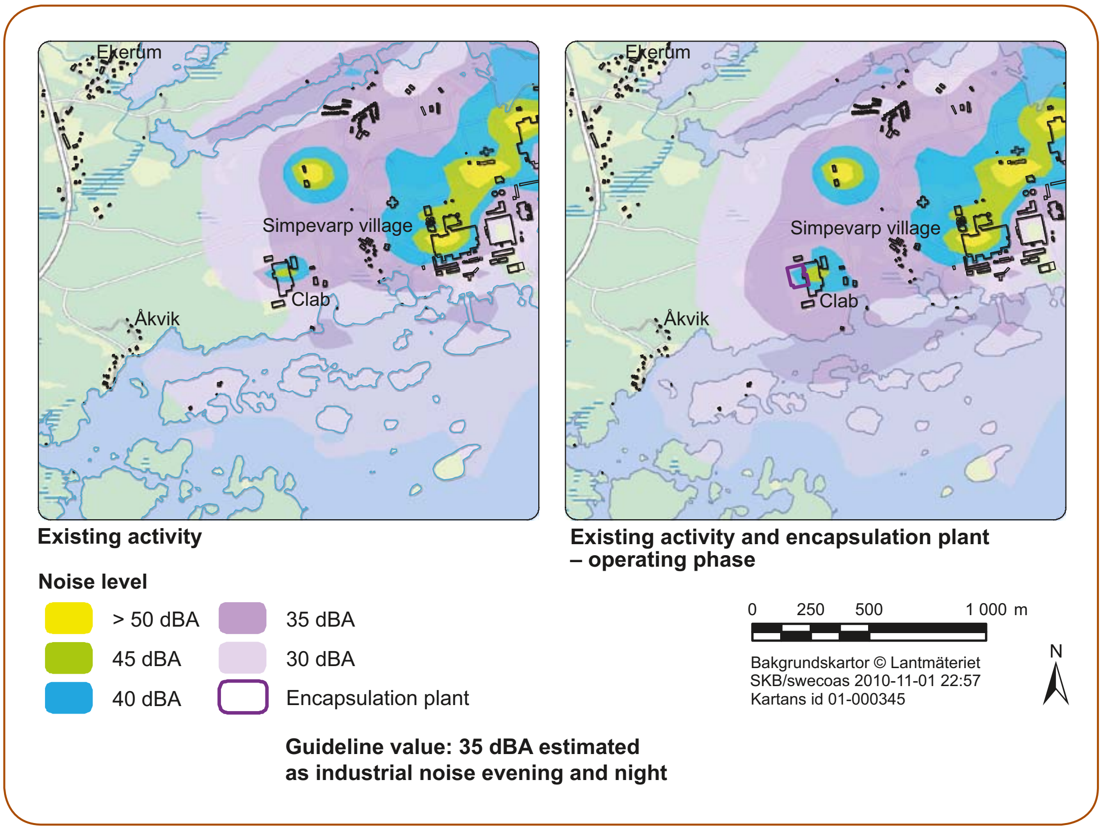


Figure 9-8. Equivalent sound level for existing activity (left) and combined with noise from the encapsulation plant during operation in the evening and at night (right).

Decommissioning phase

During the decommissioning phase, heavy equipment for dismantling, such as crushing of concrete, can lead to an increase in the noise levels. Haulage for removal of decommissioning materials also gives rise to noise. However, the number of hauls is expected to be much fewer than during the construction and operating phases. No noise calculations have been carried out for the decommissioning phase, since decommissioning lies far in the future.

9.1.3.4 Radiation and releases of radionuclides

Information on radioactivity and radiation is provided in section 3.4.

Construction phase

No radioactive substances are handled in the encapsulation plant during the construction phase.

Operating phase

The preliminary safety analysis report for Clink presents calculations of radioactive releases during normal operation and in connection with mishaps. The calculations are based on pessimistic assumptions, which means that the actual activity levels are expected to be much lower than the calculated levels. Radioactive releases during normal operation are described below, while radioactive releases during disturbances and mishaps are reported in section 9.1.5.2.

Radiation protection and radiation sources

The basic principle for radiation protection is often summarized by the acronym "ALARA" which stands for "As Low as Reasonably Achievable". The encapsulation plant's radiation protection will be designed using the best available technology, as required both in the Swedish Radiation Safety Authority's regulations and in the Environmental Code.

The radiation in the encapsulation plant mainly comes from the spent nuclear fuel and from the X-ray equipment in the station for nondestructive testing. Release of radioactivity within the encapsulation plant can only occur from the spent nuclear fuel to water in the plant's pools or to air in the plant's handling cell. All handling of the nuclear fuel takes place in isolated and radiation-shielded areas with controlled ventilation. Different areas are classified based on the risk of contamination and the radiation level. The classification of so-called "controlled areas" governs restrictions on access to the area. Once the fuel has been encapsulated it is no longer a source of airborne radioactivity, but radiation shielding is nevertheless required during its further handling. Before the nuclear fuel is taken into the encapsulation plant, its radioactivity has declined during interim storage in Clab. This means that the radioactivity that can be released per handled fuel assembly is much less in the encapsulation plant than in Clab.

The nuclear fuel that is handled has two different main sources of radioactivity that can be spread in the plant: activation products on the surface of the fuel assemblies (crud) and fission products inside the nuclear fuel. The latter can only be released from damaged fuel. The nuclides that dominate the emission of radioactivity from the crud and from the fission products are cobalt-60 (Co-60) and cesium-137 (Cs-137), respectively. Small amounts of other activation products, fission products and transuranics also occur.

Release of radioactivity in the plant

In the encapsulation plant, radioactivity can be released during normal operation, in conjunction with either handling in the encapsulation plant's pools or dry handling of the fuel.

In the pools, radioactivity is carried away from the fuel by the cooling and cleanup system, which is common with Clab, and is finally collected on filters and ion exchangers. This means that the quantity of collected radioactivity in the cleanup system is expected to increase. At the planned cleanup flow, maximum activity concentrations in the encapsulation plant's pools for Cs-137 and Co-60 are calculated to be $3.7 \cdot 10^7$ becquerels per cubic metre (Bq/m^3) and $1 \cdot 10^7$ Bq/m^3, respectively.

In connection with dry handling, radioactivity may be released by detachment of crud from the surface of the fuel assemblies. The largest quantity of crud will probably be released during drying of the fuel. Most of the released activity is expected to accompany the air flow and collect in the drying system's filters, while heavier particles remain and are collected when the system is decontaminated.

The ventilation system is designed so that the air flow always goes from areas with lower activity towards areas with expected higher activity. In areas where airborne radioactivity is expected, the ventilation system is equipped with filters that collect the airborne particles.

Dose to personnel

The personnel in the encapsulation plant will be exposed to radiation in connection with normal work duties and maintenance work. The collective dose to different personnel categories has been estimated based on experience from Clab, see Table 9-3. Fuel handling and handling of transport casks is of a somewhat greater scope in the encapsulation plant than in Clab, but this is compensated for by the fact that the activity of the fuel has declined during storage in Clab.

The predicted total collective dose to the personnel in Clink is estimated to be twice the mean value of the outcome for the collective dose at Clab during the period 1998–2007, or about 100 mmanSv per year.

The dose to personnel during the transport of spent nuclear fuel by m/s Sigyn will be negligible. Evaluation of the personnel's dosimeters have not shown any detectable doses in 25 years of measurements.

Table 9-3. Estimated collective dose to different personnel categories in the encapsulation plant, mmanSv for a normal year.

Cleanup	Mechanics	Operators/ Operation	Electricity/ instruments	Protection/ chemistry	Total
6.8	3.2	19.2	1.0	2.0	32.2

Releases of airborne radioactivity to the environment

Airborne releases from the encapsulation plant will occur via the plant's chimney and will be measured continuously with respect to alpha, beta and gamma activity. An estimate has been made of the annual airborne release based on experience from the operation of Clab. Releases to air are estimated to be completely dominated by the fission product krypton 85, followed by the activated corrosion product cobalt 60. Releases of krypton 85 are pessimistically calculated to amount to $5.3 \cdot 10^{13}$ Bq per year, which can be compared with the $5.6 \cdot 10^{11}$ Bq released per year from Clab (mean value between 1996 and 2009). In the same way, releases of cobalt 60 are pessimistically calculated to be $8.8 \cdot 10^{9}$ Bq per year. Equivalent releases from Clab are $1.6 \cdot 10^{7}$ Bq per year (mean value between 1996 and 2009).

Radioactive discharges via water to the environment

The encapsulation plant will not have any system of its own for water treatment but will be connected to Clab's cleanup system. From collection tanks the water is conducted to the discharge channel that opens out into Hamnefjärden. Activity levels are checked prior to each discharge, see Figure 9-9. Further treatment is done if necessary and the water is not discharged to Hamnefjärden until the limit values are met. Discharges to water are expected to increase when the encapsulation plant is in operation. The nuclides expected to dominate the discharges are tritium, cobalt 60 and cesium 137, the same ones that dominate the discharges from Clab.

Figure 9-9. Testing and discharge of water Clab.

Proposed measures to reduce discharges

A forecast shows that the radioactive discharges from Clink may be higher than today's discharges, in part because connection of the encapsulation plant will increase the load on Clab's cleanup system. A study has been made of possible ways to reduce the discharges /9-11/.

The study examines the biggest sources of radioactive discharge at Clab and the encapsulation plant. Different measures are proposed to limit the discharges where possible. Possible improvements in the form of new technology or methods for cleaning and reducing activity discharges to water from Clink have been studied. If all measures can be adopted, the discharges could be reduced by 95–99 percent.

When it comes to releases to air, the proposed measures focus on releases from the dry handling of spent nuclear fuel. A large point source for releases to air in the encapsulation plant is related to drying of fuel assemblies in the handling cell and related air handling systems. Releases of radionuclides to air can be reduced by raising the requirements for the filters that are used in the air cleaning systems.

Additional study and practical tests are required to determine whether the measures can be implemented in a manner that does not affect nuclear safety, radiation protection and waste management at the plant.

Decommissioning phase

After Clink has been taken out of service, no spent nuclear fuel will be left in the plant, which means that low radiation levels can be expected in the decommissioning phase. There is nothing to indicate that the dismantling of Clink should be more complicated than the dismantling of other nuclear facilities (e.g. nuclear power plants). On the contrary, it is assessed that dismantling can be carried out with low dose to the personnel and with a limited quantity of short- and long-lived radioactive waste /9-5/.

9.1.3.5 Impact on ecosystems of radionuclide releases

Radioactive releases to air and water from Clink will be spread to surrounding ecosystems. Impact on ecosystems has been studied for both normal operation and for mishaps and is reported in detail in /9-12/.

The study is based on data from Clink's preliminary safety analysis report. Both realistic and pessimistic calculations have been done for normal operation. Realistic calculations are based on data from the operation of Clab and extrapolated releases for the operation of Clink. Pessimistic calculations are based on release estimates used in designing the radiation protection for Clink. Effects and consequences during normal operation are reported in section 9.1.4.1.

Release data and release estimates have been used together with dispersion calculations to calculate nuclide-specific concentrations in different ecosystems in the area surrounding Simpevarp. The ecosystems that have been identified are forest, cultivated landscape, wetland, stream, lake, sea bay/archipelago and open sea. The locations of the different ecosystems, which have been selected based on where the highest concentrations are expected to occur after dispersion of nuclides in air and water, are shown in Figure 9-10.

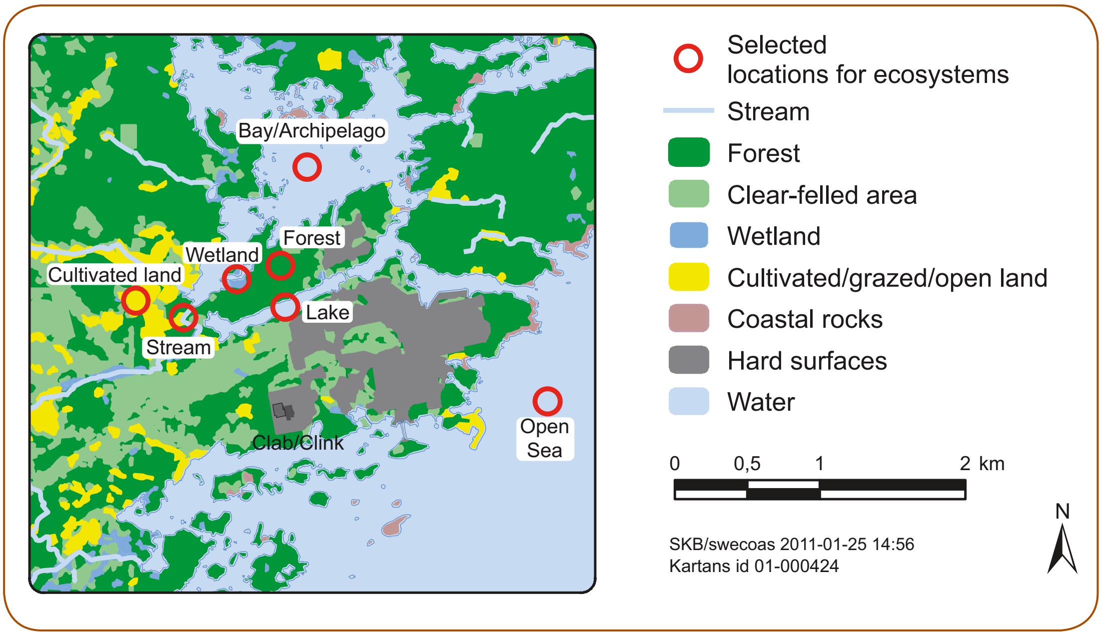


Figure 9-10. Selected locations for representative ecosystems in the environs around the Simpevarp peninsula.

Nuclide activity concentrations in terrestrial ecosystems have been calculated in air and soil, while the concentrations in aquatic ecosystems have been calculated in water and sediment. The concentrations are calculated to reach a maximum during Clink's final years of operation. The concentrations are used as input data for calculations of dose rates to animals and plants.

9.1.3.6 Non-radiological atmospheric emissions

The two most important sources of atmospheric emissions from the encapsulation plant and Clink are construction of the encapsulation plant and sea transport of fuel-filled canisters to the final repository during the operating phase.

Heavy equipment, trucks, buses and cars give rise to emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), exhaust particulate matter (PM_{exh}) and resuspended particulate matter (PM_{res}). A premise for the calculations has been that heavy equipment, trucks and buses run on diesel fuel of environmental class 1 while cars run on petrol. Emissions of sulphur oxides (SO_x) are in principle negligible, since diesel of environmental class 1 and 95 octane petrol are used as fuel.

Emissions from on- and off-site transport during all phases are shown in Table 9-4. By "on-site" is meant traffic and heavy equipment within the plant area, while "off-site" refers to traffic within a radius of 25 kilometres from the site. The years noted in the table are examples of typical years for the different phases of the project and are dependent on when SKB obtains a licence to build and operate the facility. This in turn means that the estimated impact may occur at another point in time, depending on how the project progresses. 2015 represents a year during the construction phase with higher intensity, while 2018 represents a year with lower intensity. 2030 represents the operating phase and 2075 the decommissioning phase /9-13/.

Table 9-4. Emissions from on- and off-site transport during the construction, operating and decommissioning phases (tonnes per year) for the encapsulation plant and Clink.

		2015	2018	2030	2075
NO_x	Encapsulation plant	1.8	0.8	0.06	0.03
	Clink	2.0	2.0	0.09	0.07
CO	Encapsulation plant	0.6	0.4	0.04	0.02
	Clink	0.7	0.5	0.07	0.05
HC	Encapsulation plant	0.1	0.06	0.004	0.002
	Clink	0.1	0.07	0.008	0.005
PM_{exh}	Encapsulation plant	0.03	0.02	0.0004	0.0002
	Clink	0.04	0.02	0.0007	0.0005
PM_{res}	Encapsulation plant	0.6	0.3	0.2	0.1
	Clink	0.8	0.5	0.4	0.3
FC	Encapsulation plant	140	87	34	18
	Clink	160	100	55	39
CO_2	Encapsulation plant	439	272	105	55
	Clink	504	334	171	121

Construction phase

The types of heavy equipment that give rise to the greatest carbon dioxide and NO_x emissions are mobile cranes and excavators. Emissions from sea transport of spent nuclear fuel to Clab during the construction phase of Clink are reported in Chapter 8.

In view of the nearness to Clab, blasting will be carried out with great caution; for example, smaller and denser charges than normal will be used. Dust from blasting is expected to be a minor problem. In order to limit emissions of dust and particulate matter, watering can be done in conjunction with blasting. Most of the dust and particulate matter is then bound by the water, which is then cleaned.

Operating phase

Most transport during the operating phase consists of off-site transport, such as transport of staff and visitors, waste and service transport and transport of copper waste.

There are diesel units for standby power at Clab for use in the event of a loss of off-site mains power. When the encapsulation plant is built, an additional diesel unit will be needed so that both facilities can be supplied with standby power. The diesel units, which run on low-sulphur diesel oil, are test-run at regular intervals, causing atmospheric emissions.

Sea transport of fuel-filled canisters to the final repository will be the predominant source of atmospheric emissions during the construction phase. Estimated emissions from sea transport based on 15 journeys between Clink in Simpevarp and the final repository in Forsmark are shown in Table 9-5. The calculations are based on a worst-case scenario without coordination with other shipments to and from SFR and the nuclear power plants, i.e. the ship travels back to Simpevarp carrying only empty transport casks. When a new ship is taken into service, atmospheric emissions will decrease, since the new ship will have better performance and be equipped with improved emissions control technology.

Table 9-5. Annual emissions from m/s Sigyn during transport of fuel-filled canisters.

Substance	Quantity (t/y)
CO_2	965
SO_2	0.3
NO_x	11
CO	0.2
HC	0.3

Decommissioning phase

The decommissioning phase for Clink will last about five to seven years. The uncertainty in the calculations is greatest for the decommissioning phase due to the long time perspective and possible technology development for vehicles and fuel.

9.1.3.7 Non-radiological effluents

Construction phase

Drainage water is generated during the construction phase in conjunction with blasting. The drainage water contains residues of nitrogen suspended matter from the blasting. It may also be contaminated with oil. The quantity of explosive that is consumed and the types of emissions are dependent on the geometry of the pits, the blasting method and what type of explosive is used. A spillage rate of four percent during blasting for the encapsulation plant gives 250 kg of additional nitrogen. Experience shows that about one-third of the nitrogen ends up in the drainage water, while the rest adheres to rock spoil or is emitted to the atmosphere /9-2/.

Since the encapsulation plant is located above Clab's rock caverns, where the groundwater is already lowered, the inflow of groundwater to the pits is expected to be very little. The quantity of drainage water can therefore mainly be traced to precipitation. Based on the surface area blasted out for the encapsulation plant and on statistics for annual precipitation in the area, the quantity of drainage water has been calculated to be three cubic metres per day (mean water volume). After treatment by oil separation and sedimentation, the drainage water is planned to be tested and then conducted to the existing stormwater system for Clab with outlet in Herrgloet, see Figure 9-11. A temporary treatment plant for drainage water can be assembled from containers for sedimentation of particulate pollutants and oil separation by flotation. The planned pond for stormwater management at Clab (see section 8.1.1.2) could also be utilized as a sedimentation pond, or a final treatment step, before the water is discharged into Herrgloet /9-14/.

Based on the precipitation rate, the quantity of stormwater generated from the surface area used during the construction phase has been calculated to be 12 cubic metres per day (mean water volume) /9-14/. The stormwater will be allowed to run off and infiltrate into the ground. Waste water is conducted to the existing waste water network and treated in the Oskarshamn nuclear power plant's treatment plant prior to being discharged into Hamnefjärden (See "Operating phase" below).

Figure 9-11. Aerial photo of Clab with the sea bay Herrgloet in the foreground.

Operating phase

The encapsulation plant will add new stormwater runoff surfaces in the form of roofs and paved surfaces. Roof runoff usually has low pollutant content and can be compared with ordinary rainwater. The quality of the water generated by the new paved surface depends on what activities are carried on there. There is little traffic around the encapsulation plant, so the stormwater is expected to have relatively low pollutant content.

Based on annual precipitation and the surface area occupied by the activity area for the encapsulation plant, the stormwater flow is estimated to be about 4,500 cubic metres per year, which means that the stormwater flow for Clink will be 27,500 cubic metres per year. Stormwater deriving from the establishment of the encapsulation plant will be managed according to the principles of stormwater best management practice. To as great an extent as possible, the stormwater will be reinfiltrated on site or next to paved surfaces, see Figure 9-12. The stormwater from the western part of Clab's main building is planned to be transferred to the encapsulation plant's system. An oil separator will be installed in connection with the parts where oil is handled. Drainage water from unmonitored underground parts of the plant can be diverted to Clab's stormwater pond at Herrgloet and thereby provide a steady flow of water, preventing stagnation and oxygen deficiency.

Waste water will be treated in the Oskarshamn Nuclear Power Plant's treatment plant before being discharged into Hamnefjärden. The quantity of waste water that will be discharged from the encapsulation plant is the same as the calculated water supply need of 1.5 cubic metres per day /9-2/. The total quantity of waste water generated at Clink will then be about 34 cubic metres per day. The encapsulation plant's contribution is assessed to be so small that it does not affect the effluent from the sewage treatment plant.

All of Clink will have a common cooling water system during the operating phase. The cooling water from Clink will be discharged into Hamnefjärden. Based on the design capacity and flow for Clab, cooling in the facility leads to a temperature increase of about seven degrees after the water has passed Clab. When the encapsulation plant is connected to Clab's cooling system, the cooling water temperature is expected to increase no more than one degree. This can be compared with the total heat energy from the 96 cubic metres per second discharged from the nuclear power plant (calculated after the power increase), which causes a temperature change of 12.5 degrees. The thermal energy from the encapsulation plant is estimated to be about one-thousandth of the thermal energy from the nuclear power plant /9-15/.

After shutdown of the reactors, Clink will account for all discharge of cooling water into Hamnefjärden. The heat output from Clink to Hamnefjärden will gradually decrease as the spent nuclear fuel is encapsulated and transported to the final repository.

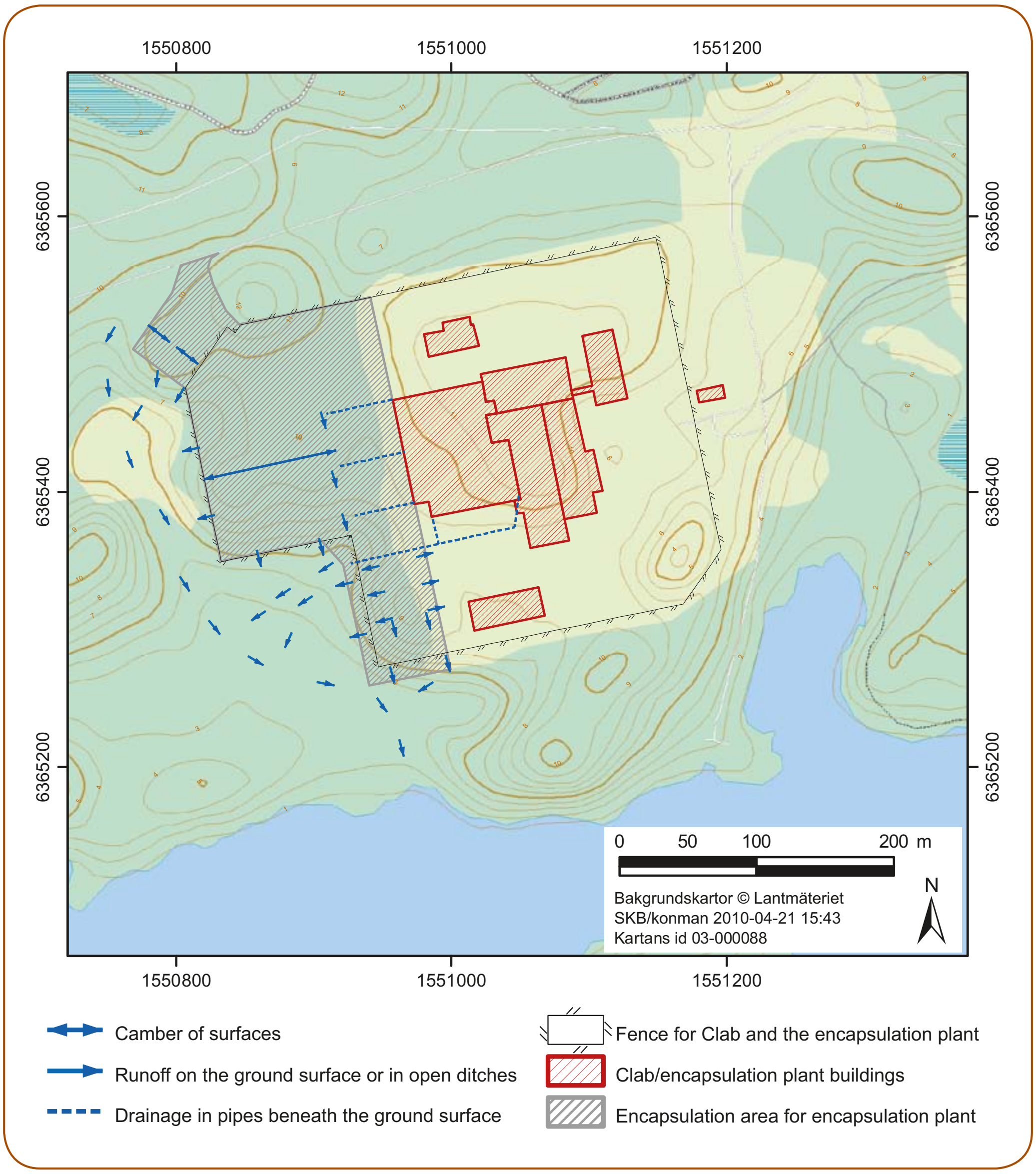


Figure 9-12. Proposed drainage principles for stormwater from the encapsulation plant.

Decommissioning phase

If the building is released from regulatory control and then used for other purposes or the site is paved over, stormwater will still have to be drained off, which can be done with the same solution as planned during the operating period. If the site is instead restored to green field, precipitation will infiltrate into the soil.

9.1.3.8 Light pollution

Construction phase

A good working environment will require functional work site lighting during the dark hours of the day. This need can be met by suitably designed and positioned light sources. This should be balanced against the requirement of low energy consumption. If the masts rise above the surrounding woods, the light can reach beyond the establishment area. The nearest housing is situated about 600 metres away and will probably not be affected by the lighting.

Operating phase

It is assumed that the lighting during the operating phase will be roughly like today with lighting poles along the fence around the area, the entrance road and the entry section.

Decommissioning phase

During the decommissioning phase, the area will be lit up by floodlights, just like during the construction phase.

9.1.3.9 Waste

Construction phase

It is assumed that building waste such as plastics, steel and paperboard will be produced during the construction phase, see Table 9-6. The quantity is estimated to be less than one percent of the material supplied /9-2/.

Table 9-6. Total waste quantities during the construction phase.

	Plastics	Boxboard	Insulation	Container-board	Steel	Sheet metal
(tonnes)	10	9	2	1,3	38	5

Operating phase

The goal of waste management is to minimize the quantity of waste. In order to manage the waste that will inevitably arise as efficiently as possible, waste management at the encapsulation plant will be coordinated with waste management at Clab. The current waste plan and procedures at Clab will be updated and replaced by common procedures for waste management at Clink. Waste is sorted and categorized to as great an extent as possible, which is important to minimize the quantity that needs to be transported to SFR.

Radioactive operational waste from the encapsulation plant consists mainly of waste from processes and maintenance. The kinds of waste that are created are the same kinds as those that occur at Clab. SKB has good operating experience from today's waste management, as evidenced by the low radiation doses resulting from waste management at Clab. Low-level waste is taken to a special near-surface repository and intermediate-level waste is embedded in cement in Clab's cement solidification plant. The solidified waste is then taken to SFR.

HEPA filters are used to clean air within controlled areas, and the consumption rate is estimated at 50 filters per year. Filters are also used in the encapsulation plant's ventilation chimney and in vacuum cleaning equipment in the handling cell. There are two alternative strategies for filter management: either the filters can be changed frequently and managed as low-level waste, or they can be changed less frequently and managed as intermediate-level waste. Filter management will be studied further within the framework of detailed design.

The quantity of radioactive waste disposed of in MLA (OKG near-surface repository for low-level waste in Simpevarp) is expected to be of the same order of magnitude as for Clab, i.e. about six tonnes per year. The total quantity for Clink will thereby be twelve tonnes per year. The waste consists of rags, protective equipment and packaging materials.

Reuse, recycling and clearance (release from regulatory control) of materials and components in the facility will be applied to as high a degree as possible. Approximately 250 kg of copper waste per canister will be generated during the operating phase by machining of the weld, which is about 30 percent of the weight of the lid. Based on a planned annual production of 150 canisters, the quantity of copper waste is expected to amount to 40 tonnes per year. After clearance, the copper waste can be melted down for recycling. The quantity of hazardous waste from m/s Sigyn (oil-containing bilge water called sludge) is estimated at about 30 tonnes.

Decommissioning phase

When Clink is decommissioned and dismantled, it will be possible to release most of the decommissioning waste from regulatory control. A smaller portion may have been radioactively contaminated and may need to be disposed of. The quantity of cleared concrete has been estimated at 298,000 tonnes and the quantity of contaminated concrete at 2,180 tonnes. The radioactive decommissioning waste will be sent to the final repository for long-lived low- and intermediate-level waste (SFL). The cleared decommissioning waste can be reused or be sent to a municipal landfill. An alternative may be to put the waste in Clab's rock caverns /9-5/.

9.1.3.10 Energy use

Construction phase

In the construction phase, energy is used for transportation and for operation of heavy equipment. Energy consumption has been calculated to be about 6.6 GWh for the entire construction phase, of which the heavy equipment accounts for about half. This is about 1.2 GWh per year.

The quantity of fuel, diesel environmental class 1, that will be consumed during the construction phase is calculated to be about 600 cubic metres /9-3/.

Operating phase

Energy consumption for transportation during the operating phase has been calculated to be about 0.5 GWh per year. Annual electricity use for the process in the encapsulation plant has been estimated at 4.5 GWh. This estimate is based on estimated figures on power needs and operating times for the process components. The calculated energy consumption for operation of fans, heat pump and chiller is 1.6 GWh per year. The total consumption of electrical energy in Clink is estimated at 21 GWh per year. By comparison it can be mentioned that the total energy use in Clab during the period 2003–2009 was on average 16–17 GWh per year /9-3/.

Heat for heating of the encapsulation plant can be extracted from the cooling water in Clab. Altogether about 4.3 GWh can be recovered per year, which covers the heating need. In the summertime, the encapsulation plant needs to be cooled indoors. The thermal energy that is removed from the plant and diverted to the sea is then estimated to be 0.2 GWh per year /9-2/.

Consumption of diesel for the standby power units is expected to be about 3 cubic metres per year. Fuel consumption for transport by m/s Sigyn from Clink to the final repository is estimated to be about 375 cubic metres of diesel per year.

Decommissioning phase

In the decommissioning phase, energy is consumed by transportation and operation of heavy equipment. Energy consumption has been calculated to be about 3 GWh for the entire decommissioning phase, of which the heavy equipment accounts for about 2.1 GWh. This is about 0.5 GWh per year /9-2/.

9.1.3.11 Water consumption

Construction phase

For water supply during the construction phase, the encapsulation plant will be connected to the existing water supply system in Clab (see "Operating phase" below).

Operating phase

The encapsulation plant's water needs are equivalent to those of normal office activities. With 30 employees, water consumption amounts to about 1.5 cubic metres per day or 550 cubic metres per year /9-2/. By comparison, total water consumption for Clab (both consumption and deionized water) during the period 2005 to 2009 was on average about 14,300 cubic metres per year.

Total annual water consumption for Clink is estimated to be about 16,000 cubic metres. The encapsulation plant will be connected to the existing water supply system at Clab, which is supplied from the nuclear power plant's water treatment plant. Raw water is taken from Lake Götemaren, about eight kilometres north-northwest of Simpevarp. The encapsulation plant will be connected to the existing extinguishing water system for Clab, which is supplied from the nuclear power plant's water treatment plant.

The quantity of cooling water that is withdrawn will increase only marginally when the encapsulation plant is connected to Clab.

Decommissioning phase

Tap water and extinguishing water will be needed during the decommissioning phase.

9.1.3.12 Resource consumption

It is estimated that approximately 44,000 tonnes of copper will be consumed in the encapsulation of the spent nuclear fuel over a 40–50-year period, which can be compared with the annual global production of copper of 15.5 million tonnes. Approximately 82,000 tonnes of iron will also be needed. The annual world production of iron is so great that this amount is only a very small fraction.

9.1.4 Effects and consequences

9.1.4.1 Natural environment

Land use and non-radiological impact

Consequences for the natural environment have been studied in several studies /9-16, 9-17/. The flat-rock pine forest that will be occupied by the encapsulation plant and the establishment area during the construction period consists of cultivated forest without high natural values today, see Figure 9-13. Single old pines have a future value, but the landscape type is common in the near-field and the region. Some small sedge fens risk disappearing, but the natural values associated with them are assessed to be limited and they only have a limited water-retaining function. There are no breeding sites for red-listed birds in the siting area, nor is the area assessed to be an important foraging or resting area. The utilization of the forested area is therefore assessed to entail insignificant consequences for the natural environment. The establishment area is planned to be restored after the construction phase. If this is done in such a manner that the flat-rock character of the area is preserved, the species associated with the environment will be able to recolonize the area. The consequences for these species will thereby be temporary.

The encapsulation plant's impact area impinges in part on the archipelagos of Västervik and Oskarshamn, which are of national interest. Criteria cited for the national interest are the archipelago landscape and rare ecosystem types in an essentially unaffected natural area with a rich flora and fauna. These values are not affected by the encapsulation plant. Nor are other protected natural areas located within the impact area assessed to be adversely affected by the encapsulation plant.

The activities at the encapsulation plant will give rise to noise, particularly during the construction period, in conjunction with blasting, transportation and rock crushing. The listed bird species believed to defend territories or breed within the impact area and along county road 743 have been studied in connection with bird inventories conducted between 2002 and 2004. One purpose of the study was to determine how these species are affected by noise from the drilling. The study does not show any noticeable negative consequences.

Besides breeding osprey, all known breeding sites are located far from the areas where disturbances can occur from the encapsulation plant. The facility is also located well outside of the extended disturbance zone of 500 metres considered to be warranted for osprey breeding. All in all, noise is expected to give rise to very small or no consequences for all listed bird species within the impact area, since the study shows that most species are not sensitive to noise. The consequences of vibrations for the fauna are assessed to be negligible. Many animals learn to live with such a disturbance as long as they are not directly threatened by it.

Figure 9-13. Part of the flat-rock pine forest at Clab occupied by the encapsulation plant.

The increased transport volume gives rise to greater atmospheric emissions. They are not expected to give rise to any negative consequences for the animal and plant life in the surrounding area. The creation of dust along transport roads has consequences for the vegetation alongside the road, but since there are no sensitive lichens, vascular plants or mosses alongside county road 743, the consequences are assessed to be negligible. Increased traffic causes increased road kills among animals. The relatively limited traffic increase caused by the encapsulation plant on county road 743 will probably not have any consequences for animals.

The encapsulation plant will be illuminated round the clock, and permanent lighting may have consequences for the insect fauna, which may in turn affect the bird fauna. In view of the fact that Clab and the Oskarshamn Nuclear Power Plant are currently illuminated, the illumination of the encapsulation plant is assessed to have negligible consequences for insect and bird life. Nor are there expected to be any noticeable consequences for the bats in the area.

Discharges of polluted or turbid water in the nearby sea bays could affect plant and animal life negatively. In view of planned measures for management of stormwater at Clink, the consequences for aquatic animals and plants are deemed to be small or non-existent. The change in temperature of the cooling water caused by the encapsulation plant is not assessed to have any noticeable consequences for animals and plants, since the temperature is already elevated today and the contribution from the encapsulation plant is marginal.

Sea transport of encapsulated nuclear fuel entails an additional 15 journeys between the ports of Simpevarp and Forsmark. Today about 20 to 30 journeys are made to Clab per year. M/s Sigyn makes at least 200 trips per year in the public fairways, and additional shipments are not expected to affect the bottoms or the animal and plant life in the waters around Forsmark Simpevarp /9-18/.

Radionuclide releases

Experience of effects and consequences of radiation for plants and animals are often limited to high radiation doses, and there is at present no limit value for the dose rate to animals and plants. However, studies of radiation effects at low radiation levels indicate that no detectable effects and consequences can be noted for animals and plants at dose rates less than 10 microgray per hour (µGy/h) /9-12/.

Contributions to the dose rate from Clink in connection with radioactive releases during normal operation have been calculated for a number of plant and animal species /9-12/. The choice of species is based on previous inventories and includes species that are protected or worthy of protection as well as species that perform a key function in the ecosystems, known as keystone species. Results from the dose calculations for keystones species are shown in Figure 9-14.

The dose calculations are based on a number of pessimistic assumptions. Among other things, it is assumed that the species in the area remain in the most exposed areas throughout their lifetime, whereas many animals, especially birds and mammals, move over much larger areas. Despite this, the calculated contribution from Clink to dose rates for species in the countryside around the Simpevarp peninsula lies below or far below 10 µGy/h. Radioactive releases from Clink during normal operation are thereby not expected to give rise to any consequences for the animals and plants in the area.

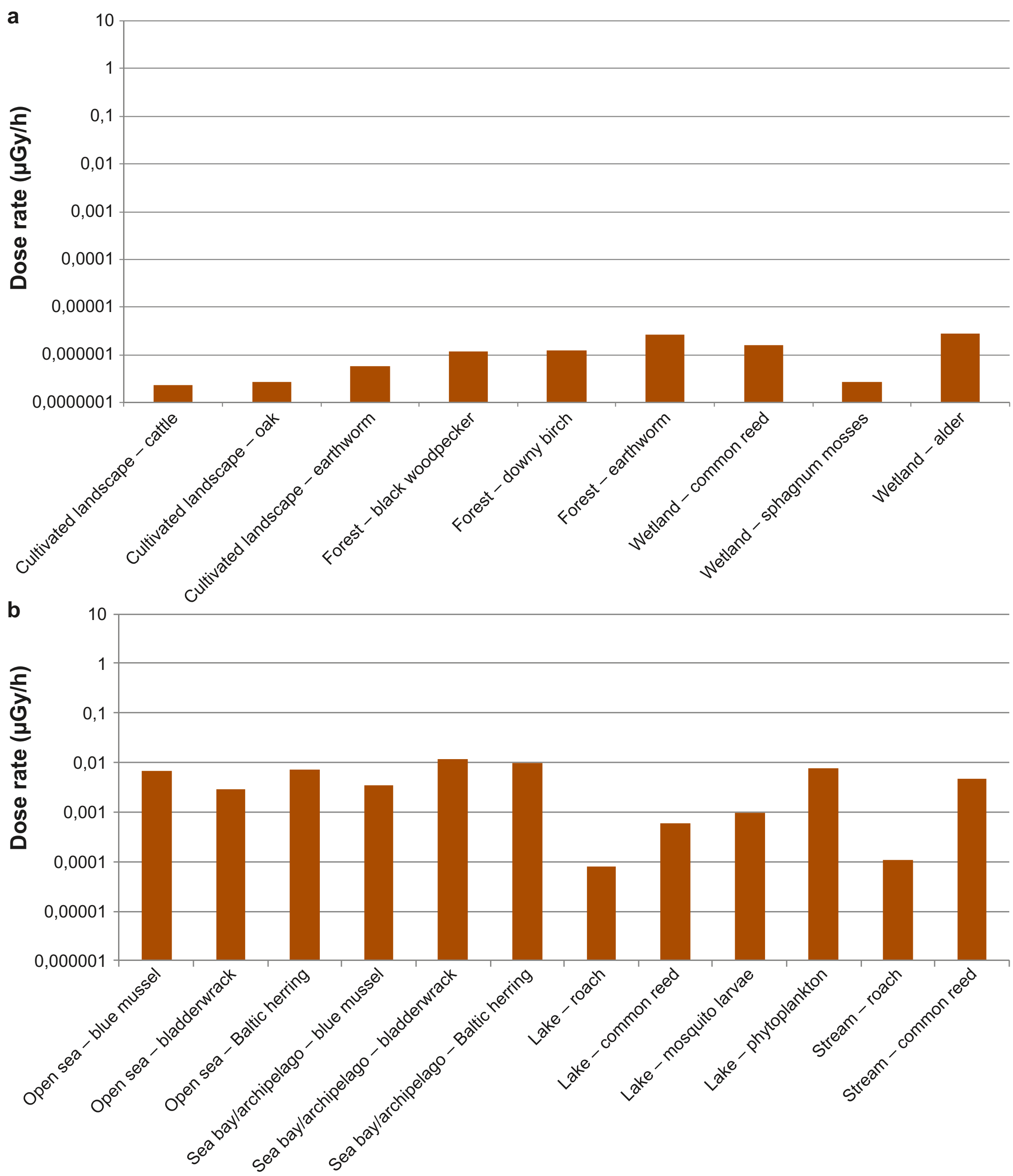


Figure 9-14. Calculated contribution from Clink (in normal operation) to dose rates for keystones species in different ecosystems. a) Terrestrial species b) Aquatic species.

9.1.4.2 Cultural environment

A cultural environment analysis has been carried out to determine the cultural heritage values that exist around Simpevarp and Laxemar /9-19/. The results of the analysis have served as a basis for determining what consequences the establishment of an encapsulation plant would have for the cultural environment and the landscape at Simpevarp. An archaeological survey has also been conducted in the affected area at Clab, in accordance with the Cultural Monuments Act /9-20/. Known archaeological remains, other historic remains and areas where concealed archaeological remains may exist are shown in Figure 9-15.

In view of the graves found in the area and the nearby Bronze Age cove, it is possible that prehistoric settlement sites may be affected. An establishment of the encapsulation plant will therefore probably entail some form of exploratory survey (stage 2 according to the Cultural Monuments Act etc.) in the area's western parts in order to determine whether concealed archaeological remains are affected. The known archaeological remains that could be affected by the establishment will have to undergo a preliminary investigation where their status and scientific value are determined. Otherwise, no prioritized cultural environment is affected by the encapsulation plant.

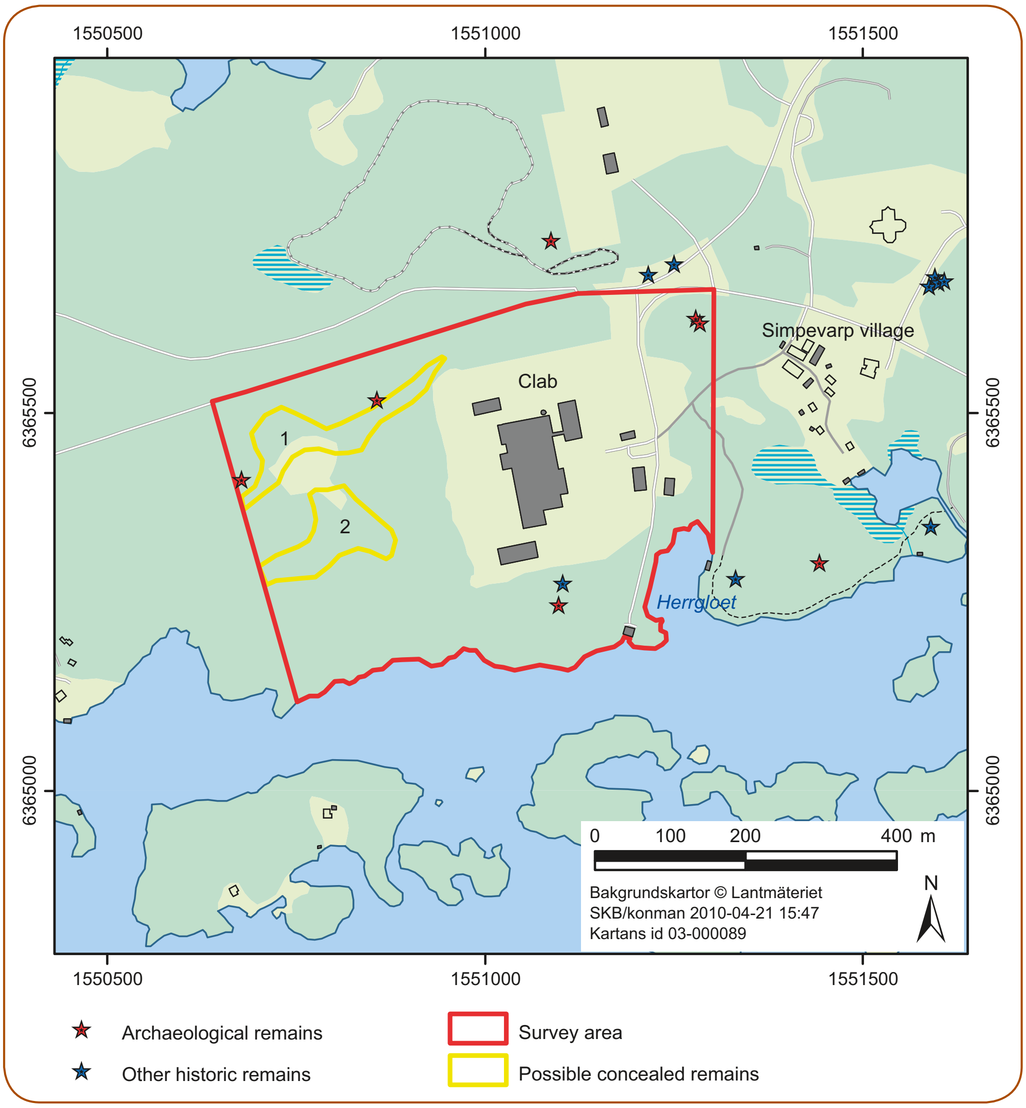


Figure 9-15. An archaeological survey has been conducted within the marked area. Stars indicate known archaeological remains and other historic remains. Areas 1 and 2 in the western part of the survey area are areas where it is assessed to be possible that concealed remains exist.

9.1.4.3 Landscape

Since there is already an established industrial environment on the Simpevarp peninsula, it is assessed that the encapsulation plant will not visually alter the character of the area. The encapsulation plant will mainly be built on land that is already included in the industrial area around Clab and will be integrated with Clab.

In order to assess the visual impact of the encapsulation plant on the landscape, a visibility analysis has been done showing from where in the landscape buildings in the operations area are visible. In addition to the topography, the vegetation, and particularly the forest, is of great importance for how visible the facility will be. Figure 9-16 shows two separate scenarios: one where the vegetation is retained and one where all forest, except that which is protected in e.g. nature reserves, has been felled. With today's vegetation, the facility is less visible than if the forest is felled. The maps show where the encapsulation plant's main building is visible in the landscape. The main building was chosen as the outlook point for the visibility analysis, since it is taller (about 30 metres) than existing Clab (25 metres) and thereby causes a greater visual impact on the landscape.

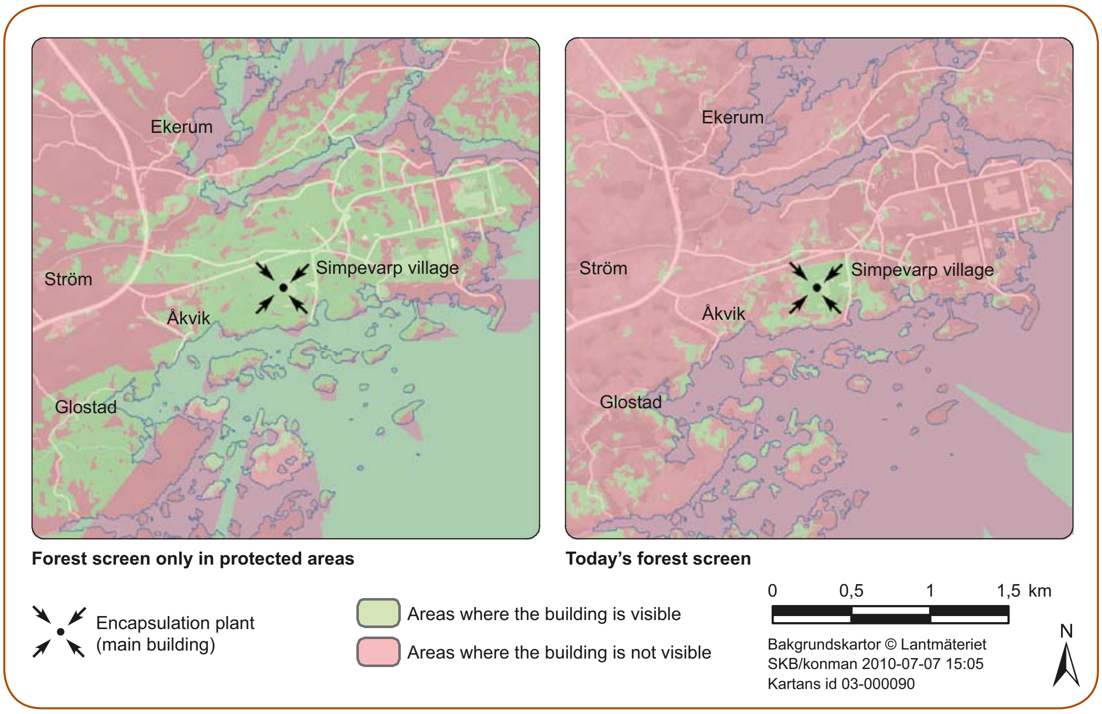


Figure 9-16. Visibility analysis for the encapsulation plant, where the plant's main building has been used as an outlook point. The map at the left shows the visibility of the building in the surrounding landscape when only protected forest has been retained, while the map at the right shows the same visibility analysis where today's vegetation has been retained.

Figure 9-17a and 9-17b. The left-hand picture shows the present-day view from the nature path southeast of Clab. The right-hand picture is a photomontage that includes the encapsulation plant and shows the same view after completion of the plant. Today's forest screen conceals most of the facility.

The two scenarios demonstrate the role of the forest in concealing the facility from the sea. The proportion of deciduous trees can also influence visibility in the wintertime. The forested shore area between the water and the facility will be preserved to as great an extent as possible. This forest screen with heights conceals Clab today from the southwest, from Strömsö. The landscape view for observers in the archipelago will therefore be largely unchanged from this direction. From the southeast, from Långskär and the marina, the forest screen is thinner and Clab is visible from the water. From this vantage point, the encapsulation plant will alter the building's silhouette, see Figures 9-17a and 9-17b.

9.1.4.4 Residential environment and health

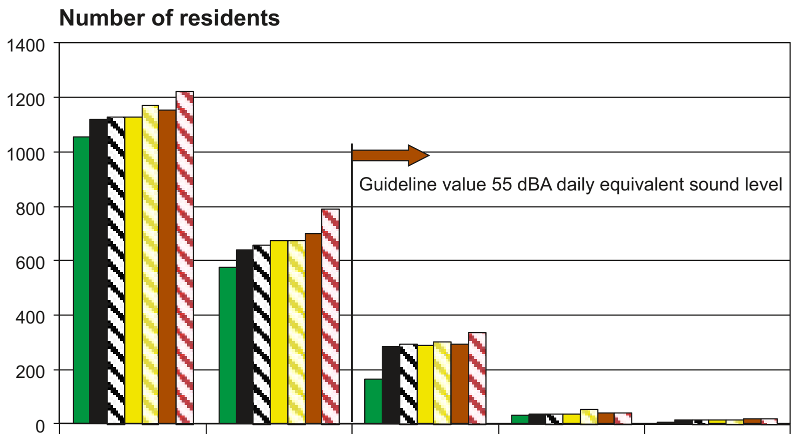
Noise and vibration

A noise survey has been done for the construction and operating phases /9-8/. As a result of noise from road transport, a maximum of 40 additional residents will be exposed to a daily equivalent sound level above the guideline value of 55 dBA if the encapsulation plant is built, see Figure 9-18. The number of events with maximum sound levels that occur during the passage of heavy vehicles will increase in proportion to the number of heavy vehicle passages. Transport-related health effects of the encapsulation plant, for example sleep problems, may occur to a small extent due to the increased number of heavy shipments.

During the construction phase with rock drilling and crushing, noise calculations show that noise levels at the closest housing will be below the guideline values without noise suppression measures having to be adopted. In the evening and and at night, noise barriers are needed around drilling equipment and mobile crushers so that the guideline values will not be exceeded. Guideline values for low-frequency sound indoors will not be exceeded for normally sound-insulated houses when the sound levels are low. With planned measures, no health consequences are expected to arise.

Vibration can give rise to comfort disturbances for people inside the buildings. Floor vibrations greater than 0.4 mm/s but less than 1.0 mm/s are deemed "moderately disturbing" according to SS 4604861 (Measurement and guidelines for the evaluation of comfort in buildings) /9-21/. Table 9-2 shows that the probability of disturbance is low, and since much lighter vehicles than those given in the table will be used for transport to and from the encapsulation plant, no appreciable vibration disturbances are expected to occur for residents along the transport routes.

Since the charges used in the blasting work for the encapsulation plant will be designed for vibration-sensitive equipment in Clab, the disturbance for nearby residents is expected to be limited.



Equivalent sound level	> 45 dBA	>50 dBA	>55 dBA	>60 dBA	>65 dBA
2006 current situation	1057	575	165	34	8
2015 zero alt.	1119	641	284	36	13
2015 extension Inka	1130	658	292	36	13
2018 zero alt.	1126	673	290	36	13
2018 extension Inka	1170	673	303	52	15
2030 zero alt.	1154	700	293	39	20
2030 operating phase Inka	1224	789	337	41	20

Figure 9-18. Number of residents exposed to equivalent sound level within different sound level intervals along the route between the facilities on the Simpevarp peninsula and the Port of Oskarshamn.

Radiation and releases of radionuclides

For nuclear facilities there is a requirement that the combined dose to the critical group from facilities in the same geographic area may not exceed 0.1 millisievert per year. The dose limit should therefore be applied jointly for the nuclear power plant and Clink. Releases of radioactivity from existing nuclear facilities, the nuclear power plant and Clab add up to less than one hundredth of the limit value.

The annual dose to the critical group as a result of radioactive releases to air has been estimated at $1 \cdot 10^{-6}$ millisievert for the encapsulation plant and $3 \cdot 10^{-6}$ for Clink as a mean value. A pessimistic forecast for radioactive releases to the receiving body of water for Clink, based on release statistics for Clab up to 2009, is shown in Table 9-7.

The combined contribution made by releases to both air and water from Clink to the dose to the critical group is thereby expected to be virtually negligible in relation to the limit value.

Table 9-7. Statistics and forecasts for dose to critical group from radioactive releases to water.

	Clab, mean value 2003–2009	Clab, mean value 1995–2007	Clink, pessimistic forecast
Dose [mSv/y]	$4 \cdot 10^{-7}$	$2 \cdot 10^{-6}$	$9 \cdot 10^{-4}$

Emissions of other substances to air

According to Oskarshamn Municipality's comprehensive plan, industrial emissions account for the greatest contribution of sulphur compounds to the atmosphere, while traffic accounts for the greatest contribution of nitrogen oxides in the municipality. Another major emission source is the increasing residential use of wood-fired heating.

A comparison with the expected emissions from heavy equipment, trucks and passenger cars show that these emissions contribute only marginally to total emissions in the county. Total emissions of nitrogen in Kalmar County in 1996 amounted to 10,343 tonnes of NO_x, which can be compared with the two tonnes per year at most that will be emitted by Clink. Total emissions of carbon dioxide from petrol and diesel combustion in 2000 amounted to 613,394 tonnes /9-22/, compared with a maximum of 504 tonnes per year for Clink with associated overland transport.

Dispersion calculations and calculated concentration contributions from Clink for both nitrogen oxides and particulates (PM_{10}) show very low concentrations /9-13/.

Atmospheric emissions from Clink, including from sea and overland transport, are not assessed to be great enough to pose a risk of exceeding atmospheric environmental quality standards. It is unlikely that the insignificant or very low contributions from overland transport would lead to any health consequences for the local populace. Sea transport to and from Clink takes place in the public fairways and is not assessed to make any significant contribution in relation to other traffic.

9.1.5 Risk and safety issues

9.1.5.1 Environmental risks

Aside from the nuclear activity, Clink can be regarded as an ordinary industrial plant. Different events during construction, operation and decommissioning can entail risks to property, third parties and the external environment. An environmental risk analysis has been done for all phases of the encapsulation plant /9-23/.

Construction phase

The environmental risks mainly occur during the construction phase and do not differ in most cases from the risks posed by any big construction project. No environmental risks have been identified for Clab due to construction of the encapsulation plant. The major risks are spills of oil, diesel or other substances on the construction site. Oil spills will be prevented by regular work site inspections of non-road mobile machinery and trucks. Diesel tanks are placed on paved surfaces and dyked-in and are equipped with overfilling and collision protection. If a spill should nevertheless occur, there will be preparedness for this on the work site, for example absorbents will be available.

Operating phase

The environmental risks decrease during the operating phase. What remains is mainly the risk of diesel and oil spills on the site or along the transport route for trucks or vehicles for canister transport. There are no sources of water supply along the transport route (county road 743). The general risk level is low along the route and precautionary measures have been adopted.

Oil spills can also occur in conjunction with accidents at sea. The probability that such an accident would occur with m/s Sigyn is low.

The risk of flooding due to high sea levels has been studied, since global climate change can lead to a rise in the sea level. A combination of calculations for the global sea level rise with future annual extremes due to temporary weather systems gives a maximum sea level at the Simpevarp peninsula in 2100 that is 341 centimetres higher than today's level /9-24/. Figure 9-19 shows where the coastline would be in the event of such an increase.

The map can be regarded as a worst-case scenario during the operating period and shows that only the intake building for cooling water will be affected and will be under water.

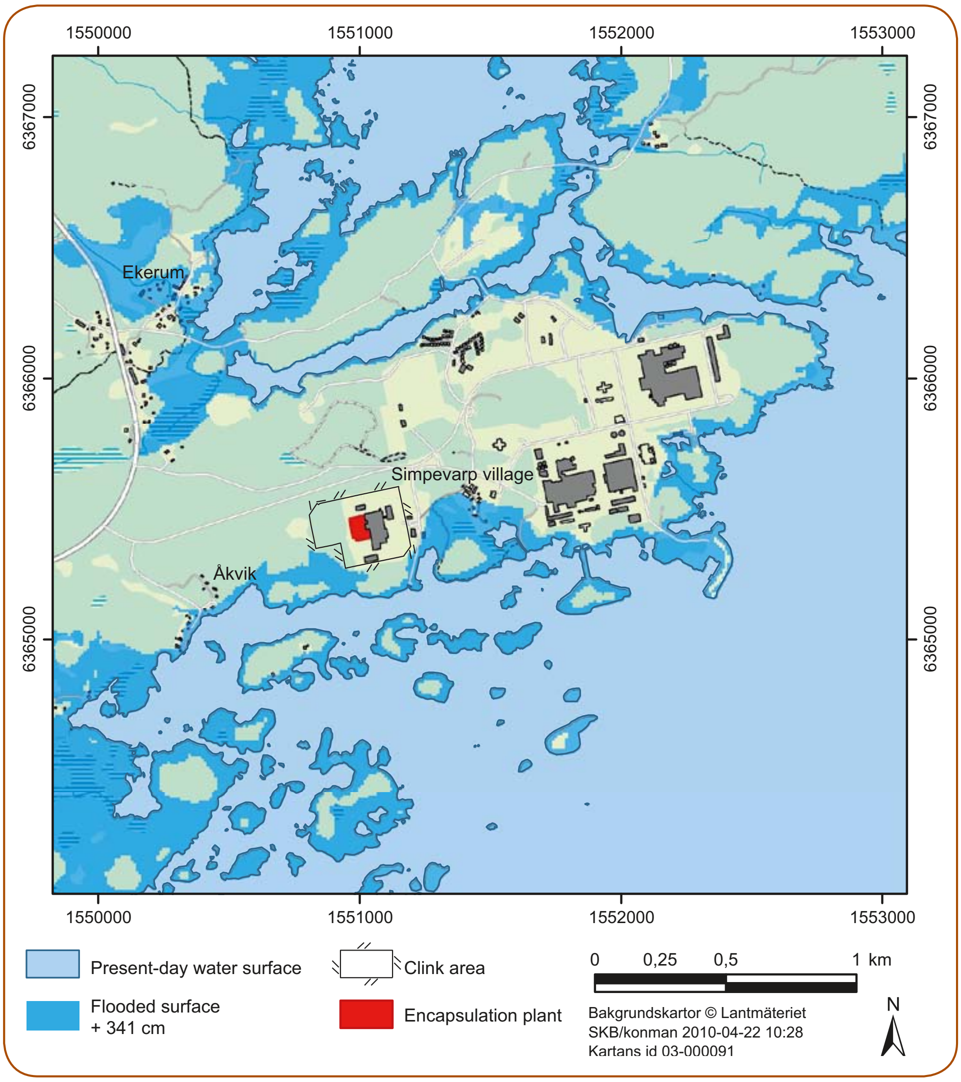


Figure 9-19. Area that risks being flooded in the event of an extreme sea level of +341 centimetres in Simpevarp in 2100.

Decommissioning phase

Decommissioning of Clink will give rise to environmental risks such as leaks/spills of hazardous substances and spills of acids used for decontamination /9-23/. The consequences can be limited by planned measures such as /9-5/:

- an inventory and cleanup of hazardous substances before decommissioning begins,
- use of existing systems and facilities for waste management in the nearby area wherever possible,
- creation of systems for management of other waste, such as cutting fluids.

There is no risk of flooding during the decommissioning phase.

9.1.5.2 Nuclear safety and radiation protection

Transport of spent nuclear fuel

Safety in the transport of spent nuclear fuel is guaranteed by special requirements on the transportation system where transport cask, ship and terminal vehicle comprise the most important components. The transport casks in particular guarantee high safety. The ability of the cask to withstand great stresses in connection with accidents is verified by tests and calculations. It must retain both its integrity and its radiation shielding properties when dropped from a height of nine metres onto an unyielding surface, when dropped from a height of one metre onto a sharp object, when subjected to 800°C for 30 minutes, and under a pressure equivalent to immersion under 200 metres of water for at least one hour. The transport casks can thereby withstand severe accidents without any consequences for the environment /9-4/.

Nuclear safety and radiation protection in the encapsulation plant

Radiological environmental impact in connection with disturbances and mishaps in the encapsulation plant is described below. The equivalent information for Clab is presented in section 8.1.5.2.

Disturbances are events that can occur at some time during the lifetime of the encapsulation plant. The disturbances may require the process to be stopped and the fuel to be returned to Clab, but they should not cause damage to the fuel or radiological consequences for the environment. Examples of disturbances that are analyzed in the preliminary safety analysis report are loss of power supply, component malfunction in processes and handling systems (for example loss of ventilation and loss of cooling in pools), operator error, water leakage and internal flooding, leakage of radioactivity, computer failure and limited fire.

Mishaps are unlikely events that are not expected to occur during the lifetime of the encapsulation plant, but that must be analyzed to demonstrate the ability of the plant to handle them with acceptable consequences for personnel and the environment. Mishaps that are analyzed in the preliminary safety analysis report are, for example, major fire, prolonged loss of cooling, major leakage from pools, various handling mishaps (e.g. dropped transfer canister or fuel assembly), earthquake and other external impact.

The environmental impact entailing a whole-body dose to a third party has been calculated for mishaps in the encapsulation plant. Calculations have been done for normal weather and two types of extreme weather: (A) low wind speed and unstable weather conditions, and (B) high wind speed and stable weather conditions. Type A results in high doses near the plant, while Type B results in dispersion of radioactivity over large areas. The dose for each weather type has been calculated for different distances: 200 metres, 500 metres, two kilometres, three kilometres and ten kilometres. A release height of 20 metres and a release time of one hour have been assumed in the calculations. The environmental impact has been calculated for dropped fuel elevator cage, dropped transfer canister and dropped copper canister. These three events have been used because they are types of mishaps that can give rise to the largest quantity of damaged fuel and can be regarded as umbrella cases for other mishaps in the encapsulation plant.

The largest whole-body dose is calculated to occur in extreme weather of type A at a distance of 200 metres from the facility. The whole-body dose was calculated under these conditions to be 0.00065 millisievert for dropped fuel elevator cage, 0.0029 millisievert for dropped transfer canister and 0.041 millisievert for dropped copper canister. The acceptance criterion for environmental dose for these types of events is 50 millisieverts, which is met with ample margin by all scenarios.

The impact on ecosystems in conjunction with mishaps has been calculated for the event "dropped copper canister or transfer canister", since this is assessed to give the largest release. Activity concentrations for the types of ecosystems that occur in the environs around the Simpevarp peninsula have been calculated for krypton-85, iodine-129, cesium-134 and cesium-137 and are reported in /9-12/.

9.2 Considered alternative – Forsmark

As an alternative to siting the encapsulation plant adjacent to Clab on the Simpevarp peninsula, SKB has studied a location near the nuclear power plant in Forsmark.

9.2.1 Facility design

A general description of the layout of the encapsulation plant for a location in Forsmark is provided here. For a more detailed description, see /9-25/. The considered site in Forsmark has been changed compared with what is presented in the report, but the technical solutions and layout of the buildings are not affected by this. The considered siting is presented in Figure 9-20.

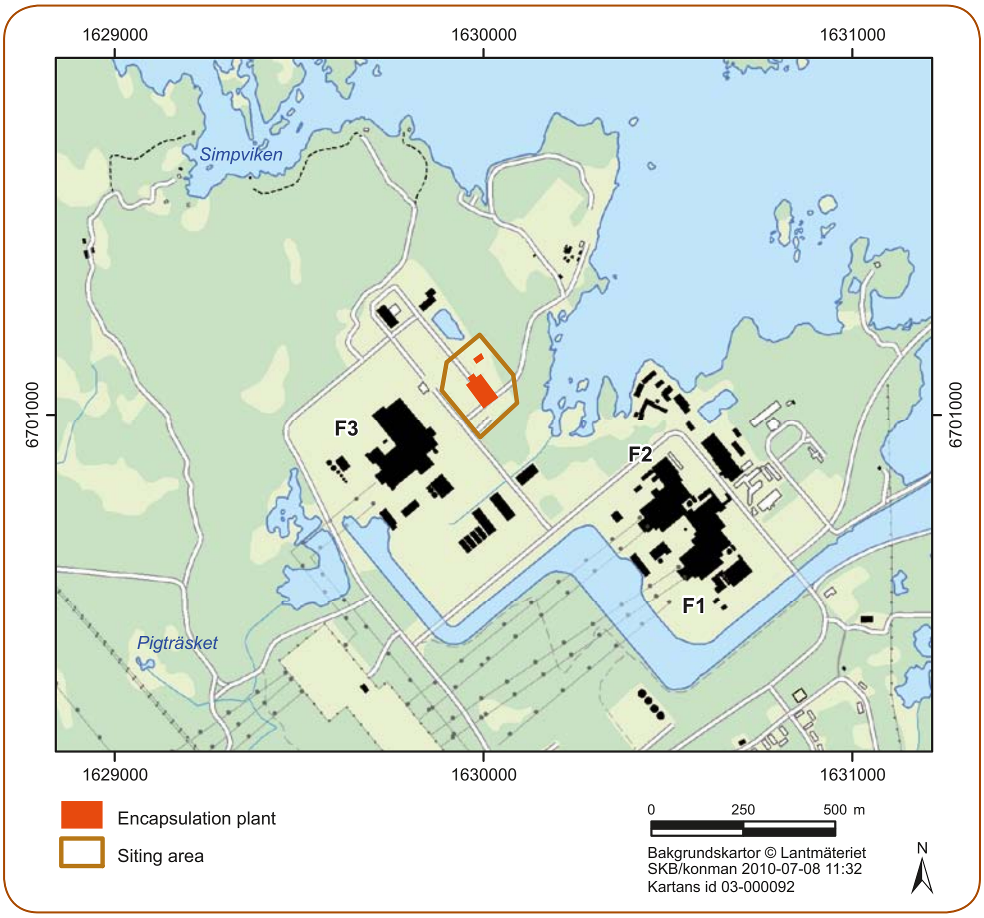


Figure 9-20. Siting of the encapsulation plant for the considered alternative in Forsmark.

The encapsulation plant consists of a main building that will house the encapsulation line and other equipment needed for operation, service and transportation. The plant will also contain a reception and an exhibition for visitors. The entire plant is located above ground. New infrastructure would be needed, but this has been coordinated with the nuclear power plant and the final repository. The encapsulation plant would be designed for the same production capacity and operating period as for the applied-for activity located adjacent to Clab.

9.2.1.1 Fuel handling

An important difference between an encapsulation plant at Clab and in Forsmark is the handling and preparation of the fuel prior to encapsulation. Fuel reception in Forsmark would be dry, and sorting and drying of the fuel, as well as verifying fuel measurements, would instead be done in Clab prior to transport to Forsmark. This means that parts of Clab would have to be rebuilt and provided with additional equipment.

9.2.1.2 Water supply and water managementg

For supply of tap water and deionized water (for use in controlled areas), the encapsulation plant could be connected to the existing water treatment plant that supplies the Forsmark nuclear power plant. Waste water could be treated in the Forsmark nuclear power plant's treatment plant prior to discharge in the cooling water channel and Asphällsfjärden.

9.2.2 Description of activities

9.2.2.1 Construction phase

Due to dry handling of the spent nuclear, no pools would be needed in the Forsmark alternative, and thereby no extensive blasting and crushing of rock. No extra surfaces besides the planned activity area would need to be occupied. Otherwise, construction is not expected to be different from the construction of an encapsulation plant adjacent to Clab.

9.2.2.2 Operating phase

Fuel reception at an encapsulation plant in Forsmark would be dry, without the need for water-filled pools.

Changes in Clab

Operation of Clab would not differ essentially from what has been described for the applied-for activity. In order to be able to sort and dry the fuel, and perform measurements on fuel assemblies prior to transport to Forsmark, certain changes would have to be made. Supplementary equipment can be installed in existing areas.

Handling and measurement of the fuel assemblies could take place in the component pool in Clab. For this it would have to be supplemented with new positions for storage canisters, and some equipment would have to be moved to another pool. A new handling machine and measurement equipment for gamma radiation would be needed. Drying equipment for drying of the spent nuclear fuel would be installed in an area connected to an existing cooldown cell.

The waste plant in Clab would need to be provided with equipment for receiving and handling the radioactive waste from the encapsulation plant.

Transport of spent nuclear fuel

Transport of unencapsulated spent nuclear fuel from Clab to the encapsulation plant would take place by sea and would not differ appreciably from today's fuel shipments between the nuclear power plants and Clab. The difference is that fuel that is shipped to encapsulation has decayed for several decades and therefore contains much smaller quantities of radionuclides and less decay heat (10–15 percent of the decay heat during fuel transport to Clab).

SKB's transportation system today includes ten transport casks for spent fuel assemblies. The same or similar casks as those used for fuel shipments to Clab can be used for shipments from Clab. The planned average rate of deposition is about 150 canisters per year. The equivalent quantity of fuel assemblies will be then transported to the encapsulation plant. This corresponds to some twenty shipments by m/s Sigyn. The number of additional shipments to and from the harbour in Forsmark is expected to be lower, thanks to the fact that they can be coordinated with other shipments to be made during the same period.

The overland shipments that would be required with the given assumptions are:

- transport casks with unencapsulated fuel from Clab to the harbour in Simpevarp,
- transport casks with unencapsulated fuel from the harbour in Forsmark to the encapsulation plant,
- transport casks with encapsulated fuel from the encapsulation plant to the final repository in Forsmark.

The two types of transport casks that would be needed (for unencapsulated and encapsulated fuel) would be of similar size and handleability. They can be transported by the same type of vehicle.

The distances in question are about two kilometres from the harbour in Simpevarp and about four kilometres from the harbour in Forsmark.

Other transport

Other transport to and from the encapsulation plant would mainly go on the access road to the nuclear power plant and on national road 76. The current volume of traffic on national road 76 is about 2,000 vehicles per day (annual mean value), while the equivalent volume of traffic between the town of Forsmark and the nuclear power plant is about 850 vehicles per day.

The total volume of traffic will be greater during the operating phase at an encapsulation plant in Forsmark compared with a plant at Clab. This is because personnel can be co-utilized if the facilities are built next to each other, which means fewer additional commuting trips. There will be slightly fewer heavy goods shipments during the construction phase in Forsmark than in Oskarshamn, due to the fact that no pools are built, which would require removal of rock spoil, see Table 9-8.

Table 9-8. Estimated total additional number of truck shipments to and from an encapsulation plant in Forsmark during different phases.

	Construction phase stage 1 (year 0–3.5)	Construction phase stage 2 (year 3.5–7)	Operating phase	Decommissioning phase
Total additional shipments per day (round trip)[1]	150	70	120	30
Number of heavy shipments per day (round trip)[1]	30	14	12	10

[1] Assuming 230 work days per year (five work days per week).

9.2.2.3 Decommissioning

A preliminary decommissioning plan prepared for the encapsulation plant describes the dismantling work for a facility located in Forsmark /9-26/.

Dismantling of the encapsulation plant and Clab would coincide in time, since they are dependent on each other. A preliminary decommissioning plan has been prepared for the dismantling of Clab /9-27/.

9.2.3 Impact

9.2.3.1 Land use

The encapsulation plant can be located within the nuclear power plant's existing activity area next to reactor unit 3, see Figure 9-21. The site covers approximately 30,000 square metres plus a parking lot of 40×100 metres. The area currently consists of a gravel field with shrubs plus asphalt surfaces. The remaining land that would need to be utilized during the construction, operation and decommissioning phases is existing industrial land.

Figure 9-21. Reactor unit 3 in Forsmark, where the red oval shows the area considered for a siting of the encapsulation plant.

9.2.3.2 Impact on groundwater level

No underground facilities are planned in Forsmark. There would therefore be no impact on the groundwater level during any of the phases: construction, operating or decommissioning.

9.2.3.3 Noise and vibration

Noisy work operations would occur during the construction phase, but since the whole plant would be located above ground there we be no need for extensive rock blasting, drilling or crushing. The noise calculations that have been done show that the noise would be lower than the guideline values.

The vibration levels would not change due to traffic, since there are already heavy shipments on the roads in the area.

As in the case of the encapsulation plant at Clab, ventilation fans would be the dominant noise sources during the operating phase. Noise suppression measures for fans can be adopted to meet the guideline values.

9.2.3.4 Radiation and releases of radionuclides

Construction phase

No radioactive materials would be handled during the construction phase.

Operating phase

The work done in Clab prior to the transport of encapsulated nuclear fuel to Forsmark do not result in any difference in radioactive releases compared to if the work is instead done in an encapsulation plant at Clab. The same operations (measurement, sorting and drying) are performed and the same cleanup systems and discharge points are utilized. No radioactive releases take place to the environment during the transport of unencapsulated nuclear fuel to Forsmark.

In an encapsulation plant in Forsmark, the nuclear fuel would be handled dry, which means that radioactivity would mainly be released to air and not to water. Airborne radioactivity mainly arises in the handling cell and in the station for change of atmosphere and tightness testing. The ventilation system would be designed in the same way as in the encapsulation plant at Clab with the same type of cleaning system.

Decommissioning phase

According to the decommissioning plan that applies for both sitings, decommissioning can be done with a low dose to personnel /9-26/.

9.2.3.5 Non-radiological atmospheric emissions

No calculations of emission levels have been done for the alternative of siting the encapsulation plant in Forsmark. By comparing the number of shipments and assumed driving distances with the assumptions made for the emission calculations for the encapsulation plant at Clab, a rough idea can be obtained of the emission levels /9-13/.

Construction phase

There will be fewer shipments during the construction phase in comparison with the applied-for activity at Clab. In particular there will be fewer heavy shipments since no underground facility will be built. Furthermore, the building volume will be slightly smaller, which means that the number of shipments of building materials to an encapsulation plant in Forsmark will be slightly fewer. Since no blasting will be done, there will be no emissions of nitrogen either. The overall result is lower atmospheric emissions during the construction phase than what can be expected if the encapsulation plant is built at Clab.

Operating phase

Most transport during the operating phase consists of off-site transport such as personnel, visitor and service transport. If the encapsulation plant were to be located in Forsmark, there will be more commuting trips since a new organization has to be built up for operation of the encapsulation plant. Roughly the same transport distance is assumed as for the encapsulation plant at Clab (30 kilometres) in order to include trips from Östhammar and Öregrund. Since the number of commuting trips will increase, car emissions will be greater for an encapsulation plant in Forsmark.

An additional type of transport that does not exist for the the applied-for activity with an encapsulation plant at Clab is transport of unencapsulated fuel from Clab to Forsmark. With an encapsulation plant at Clab, however, shipments of encapsulated fuel will take place, with the same type of ship and to roughly the same extent. Emissions at sea would therefore be equivalent.

The process in the facility gives rise to very low atmospheric emissions.

9.2.3.6 Non-radiological effluents

Construction phase

The stormwater that arises in the construction phase may contain oil and particulates. Based on figures for annual precipitation and the size of the occupied surface, the quantity of stormwater has been calculated to be about 17 cubic metres per day. A combination of different solutions has been proposed for stormwater management. Some of the stormwater can be infiltrated on site or diverted to surrounding forest land for infiltration. The waste water can be treated in the Forsmark nuclear power plant's treatment plant before being discharged to Öregrundsgrepen.

Operating phase

During the operating phase, stormwater will come from roof surfaces and lightly trafficked surfaces with expected low pollutant content. The flow has been estimated to be the same as during the construction phase, about 17 cubic metres per day. Stormwater management would be the same as during the construction phase.

9.2.3.7 Light pollution

The construction work would be carried out for the most part in the daytime, as for the applied-for activity. The facility would probably be illuminated in the same way as the nuclear power plant.

9.2.3.8 Waste

The waste quantities that can arise during the construction and operating phases are roughly the same as the estimated quantities for an encapsulation plant at Clab. A floor drainage system would have to be built for treatment of liquid radioactive waste. Liquid waste remaining after treatment can be collected in drums for transport to Clab. Maximum output is estimated at one 200-litre drum per working day /9-25/.

The quantity of decommissioning waste generated during dismantling of the encapsulation plant would be less if it were located in Forsmark, since the building volume is smaller. The quantity of cleared concrete has been estimated at 70,000 tonnes, while the quantity of contaminated concrete has been estimated at 1,400 tonnes. However, more decommissioning waste will be generated by the dismantling of Clab compared with the applied-for alternative, since some modifications and additional equipment will be needed there /9-26/.

9.2.3.9 Energy use

Energy use during the construction and decommissioning phases is estimated to be 80 percent of the calculated energy use for an encapsulation plant at Clab. This is because the building volume in Forsmark is about 80 percent of the building volume at Clab /9-28/.

Energy use during the operating phase is assessed to be the same regardless of which site is selected. Cooling water from the nuclear power plant can be used for heating of the encapsulation plant.

9.2.3.10 Water consumption

Figured on the basis of a workforce of 75–80 persons, water consumption is about five cubic metres per day /9-28/, which is more than for an encapsulation plant at Clab, where the workforce is planned to be smaller. A smaller quantity of deionized water will be used, since no pool would be built in the encapsulation plant in Forsmark.

9.2.4 Effects and consequences

9.2.4.1 Natural environment

Since the area for the considered siting in Forsmark does not have any high natural values and is located on already occupied industrial land, siting the encapsulation plant there would have no or small consequences for the natural environment. Regardless of whether the encapsulation plant is located at Clab in Oskarshamn or in Forsmark, it will be located in an area that bears strong traces of industrial activity.

The studied red-listed bird species within the impact area have a stable population and are not appreciably affected by noise from test drilling for the final repository /9-29/. Since the noise from the encapsulation plant would be limited, there are not expected to be any negative consequences for the area's bird life.

The increased transport volume would give rise to greater atmospheric emissions. They are not expected to have any negative consequences for the animal and plant life in the surrounding area. There are no known sensitive lichens, mosses or vascular plants along the transport routes.

All discharges to water would be treated, and it is assessed that there would be no or small consequences for aquatic animals and plants.

9.2.4.2 Cultural environment and landscape

Since the considered siting is located in a young land area, and moreover in an existing industrial area where earthworks have already been done, no archaeological remains would be affected. Nor are there any other historic remains in or near the area, aside from the remains of a fishing camp south of the cooling water channel. These remains would not be affected by siting of the encapsulation plant at Forsmark.

In order to preserve the various landscape characters within the Forsmark area, new nuclear activity should be sited adjacent to the existing industrial area. Since it has been proposed that the encapsulation plant should be located next to reactor unit 3, the visual consequences for the landscape would be small. From the sea side, the facility would be concealed behind the existing forest screen or be overshadowed by the silhouette of unit 3.

9.2.4.3 Residential environment and health

Noise and vibration

A noise survey has been done for the construction and operating phases for an encapsulation plant in Forsmark /9-30/. The survey does not show any appreciable difference in noise from the facility or from transport activities compared with an encapsulation plant at Clab.

A siting at Forsmark would entail more commuting trips during the operating phase than a siting at Clab, since it is possible to co-utilize personnel at Clab. However, there would be no rock blasting or crushing during the construction phase and no disturbing vibrations would arise.

Calculations of construction noise show that the guideline values would be met at all housing. As far as transport during the construction phase is concerned, the number of residents exposed to a sound level above the guideline value is roughly the same as for the zero alternative in the same year. Most transport during the operating phase consists of personnel transport (commuting). Applicable guideline values can be met for all residents.

Radiation and releases of radionuclides

For nuclear facilities there is a requirement that the combined dose to the critical group from facilities in the same geographic area may not exceed 0.1 millisievert per year. The mean value of dose to critical group in Forsmark is about 1/500th of the applicable limit value. Based on the dose calculated for the encapsulation plant at Clab, the dose from an encapsulation plant in Forsmark is expected to be virtually negligible in relation to the limit value and the contribution from other nuclear facilities in the area.

Non-radiological atmospheric emissions

Atmospheric emissions from traffic and industry in Östhammar Municipality are limited. It is clear from the municipality's comprehensive plan that the traffic intensity is not so high anywhere that hazardous levels of air pollution occur, despite the fact that the municipality's inhabitants are highly dependent on the car as a means of transportation /9-31/. The Stockholm – Uppsala County Air Quality Management Association's forecast for nitrogen oxide levels in Östhammar Municipality in 2006 show that the levels were well below the environmental quality standards at all locations in the municipality /9-32/.

No calculations have been done for emissions that would be caused by an encapsulation plant in Forsmark. A comparison can be made with expected levels from establishment of the encapsulation plant at Clab, where calculations have been made of future concentrations and dispersion. These calculations, where emissions from Clab are also included, show a virtually non-existent contribution that does not contribute to exceeding the environmental quality standards /9-13/.

9.2.5 Risk and safety issues

9.2.5.1 Environmental risk analysis

Of the identified risks, some may be dependent on where the encapsulation plant is sited. The main risks are associated with transport. The risk of environmental impact due to oil leakage from road tankers is site-dependent. This is partly because the probability of an accident occurring is dependent on traffic and distances, and partly because the consequence is dependent on the presence of water supply sources and sensitive fauna. No significant differences between studied sitings have been identified in the environmental risk analysis /9-23/.

9.2.5.2 Nuclear safety and radiation protection

The requirements on an encapsulation plant in Forsmark when it comes to safety and radiation protection are the same as for the encapsulation plant at Clab. The facilities are assessed to be equivalent with respect to radiological risks. However, siting of the encapsulation plant in Forsmark would involve additional off-site transport of unencapsulated nuclear fuel. This transport would take place in the same way as today's transport of spent nuclear fuel from the nuclear power plants Clab.

The safety analysis report for the transportation system includes, in addition to a description of the system, an account of safety with respect to radiation and radioactive releases. No risks of harm to the citizenry or the environment have been identified that would require additional safety measures beyond those already adopted. The most important safety measure is the use of transport casks that meet the IAEA's requirements for Type B packages. This entails that the casks are completely tight and very resistant to stresses both during normal operation and in the event of an accident. The specially built ship, the monitoring systems and the administrative procedures also contribute to the safety of the shipments. No events during normal operation or possible accident scenarios could cause releases of radioactive substances from the transport cask.

The transport casks are designed to provide good radiation shielding. The radiation levels outside the cask are always checked prior to departure. Existing rules ensure that the load can be handled by the transport personnel without requiring any additional radiation protection measures.

The system for monitoring and physical protection in conjunction with sea transport works the same regardless of the type of cargo. Overland transport by terminal vehicles is also surrounded by safety measures against accidents and sabotage.

The risks of environmental impact associated with transport of spent nuclear fuel are already low today, mainly thanks to the strong, tight transport casks. The fuel that is shipped to encapsulation has decayed for several decades and thereby contains much less radioactivity and emits less decay heat (10–15 percent of the heat output during fuel transport to Clab).

9.3 Summarizing conclusions

In order to clarify the differences between the applied-for activity and the considered alternative, a summary is made here of the conclusions that have been arrived at in the assessment of effects and consequences for the encapsulation plant. The considered siting in Forsmark is compared to the applied-for siting at Clab in Oskarshamn. For a summary of effects and consequences for the integrated Clink facility, see Chapter 12.

Regardless of whether the encapsulation plant is located at Clab or in Forsmark, it will be located in an area that bears strong traces of industrial activity. At Clab, some of the forested area adjacent to the present-day activity area will be utilized, but since no high natural values have been found, the consequences for the natural environment are assessed to be small. At Clab there are also some historical remains that may have to be removed, but the overall consequences for the cultural environment and the landscape are assessed to be small. In Forsmark, the encapsulation plant occupies almost only industrial land, aside from a strip of forest a few metres deep.

The transport volume is estimated to be greater during the operating phase for a siting at Forsmark, while more noisy work operations (rock drilling and crushing) will be required in the construction of an encapsulation plant at Clab. Emissions to air mainly result from transport activities and are assessed to be low regardless of siting. In view of the fact that noise levels at the nearest housing will be lower than guideline values for noise during both construction and operation of the facility, there will be no significant impact on the residential environment. Red-listed species, mainly birds, occur on both sites within areas that may be affected by noise.

Sea transport is necessary regardless of the siting of the encapsulation plant, and the same route will be used in both cases. This means that atmospheric emissions from sea transport will be the same regardless of the siting of the encapsulation plant. The only difference is that a siting of the encapsulation plant in Forsmark entails sea transport of unencapsulated fuel between Clab and the encapsulation plant, while a siting at Clab instead entails sea transport of encapsulated fuel to the final repository. Transport of unencapsulated spent nuclear fuel is planned to be done in the same way as today's transport of spent nuclear fuel between the nuclear power plants and Clab. No risks that would require additional safety measures beyond those already adopted have been identified in the safety analysis report for the existing transportation system. Most of the non-radiological risks are probably not dependent on the siting either.

Since no significant consequences or differences in terms of risks have been identified, the two sites are assessed to be equivalent from an environmental and health viewpoint. The advantage of a siting at Clab is that the personnel's experience of fuel handling can be taken advantage of at the same time as SKB can utilize the existing systems and plant parts in Clab for the encapsulation plant as well. The above summary is also shown in Table 9-9.

Table 9-9. Compilation of effects and consequences of a siting of the encapsulation plant in Oskarshamn versus Forsmark.

	Siting at Clab in Oskarshamn	Siting in Forsmark
Natural environment Natural environment	Part of a forested area adjacent to Clab is utilized; otherwise the facility is contained within the existing industrial area. No high natural values have been found. Red-listed species, mainly birds, occur within areas that may be affected by noise. Experience from SKB's test drilling shows that the birds are affected very little by the disturbance.	Only industrial land is utilized. As with the alternative at Clab, there are red-listed species, mainly birds, within the impact area. Experience from SKB's test drilling shows that the birds are affected very little by the disturbance.
Groundwater	Blasting is required for the pool. The groundwater is projected to be affected to a very small extent.	No pool and no blasting is needed. The groundwater will therefore not be affected.
Cultural environment and landscape	Part of a forested area adjacent to Clab is utilized. Some historical remains that may have to be removed. The overall consequences for the cultural environment and the landscape are assessed to be small.	Only industrial land is utilized; no consequences have been identified.
Residential environment and health Noise	Transportation, noisy work operations during the construction phase and ventilation fans during operation contribute to noise. It should be possible to comply with applicable guideline values if noise barriers are used in the evening and at night. Another 40 residents along the transport routes may be exposed to noise levels above the guideline value for traffic noise.	There are fewer noise sources during the construction phase compared with the alternative at Clab, but there is more transport activity during the operating phase. Guideline values for noise are met, with the exception of traffic noise during the construction phase, since an additional property along the transport route is exposed to noise levels above the guideline value for traffic noise.
Non-radiological atmospheric emissions	Transportation and heavy equipment give rise to atmospheric emissions. In view of the existing air pollution situation and calculated emissions, there is not assessed to be any risk that environmental quality standards will be exceeded.	There is more transport activity during the operating phase compared with the alternative at Clab. In view of the existing air pollution situation and the size of the emissions calculated for the alternative at Clab, the emissions are not assessed to be so great that there is a risk that environmental quality standards will be exceeded.
Radiation and releases of radionuclides	The dose to critical group at the nuclear facilities on the Simpevarp peninsula is well below the legal limit. The activity quantities contributed by the encapsulation plant are virtually negligible. Dose limits to personnel are met with good margin.	The dose to critical group at the nuclear facilities in Forsmark is well below the legal limit. The activity quantities contributed by the encapsulation plant are virtually negligible. Dose limits to personnel are complied with.
Risk and safety Non-radiological risks	Non-radiological risks occur mainly in the construction phase and do not differ from the risks associated with any large construction project.	Most of the non-radiological risks that have been identified are not site-dependent.
Radiological risks	Various mishaps have been analyzed. Calculations of environmental impact show that the acceptance criteria for environmental dose are met in conjunction with mishaps in the encapsulation plant.	The facilities are assessed to be equivalent with respect to radiological risks. The additional sea transport of spent nuclear fuel is done in the same way as today's transport between the nuclear power plants and Clab. No transport-related risks have been identified that would require additional safety measures beyond those already adopted.

Final repository for spent nuclear fuel

10 Final repository

SKB has selected Forsmark as the site for the final repository for spent nuclear fuel. The choice has stood between Forsmark in Östhammar Municipality and Laxemar in Oskarshamn Municipality. What decided the choice is that Forsmark is assessed to offer better prospects for achieving long-term safety. The decisive factors in the choice of a site are nuclear safety and radiation protection.

This chapter discusses the impact, effects and consequences of the construction, operation and decommissioning of the final repository. The impact, effects and consequences of transport to and from the facility are also examined. These aspects are described for both the applied-for activity, which is a final repository in Forsmark, and the considered alternative, a final repository in Laxemar.

The decommissioning phase has been studied at a more general level, owing to the fact that decommissioning lies far in the future, entailing great uncertainties.

10.1 Applied-for activities – Forsmark

SKB is applying for a licence to site the final repository in Forsmark, near the nuclear power plant and SFR, see approximate location in Figure 10-1.

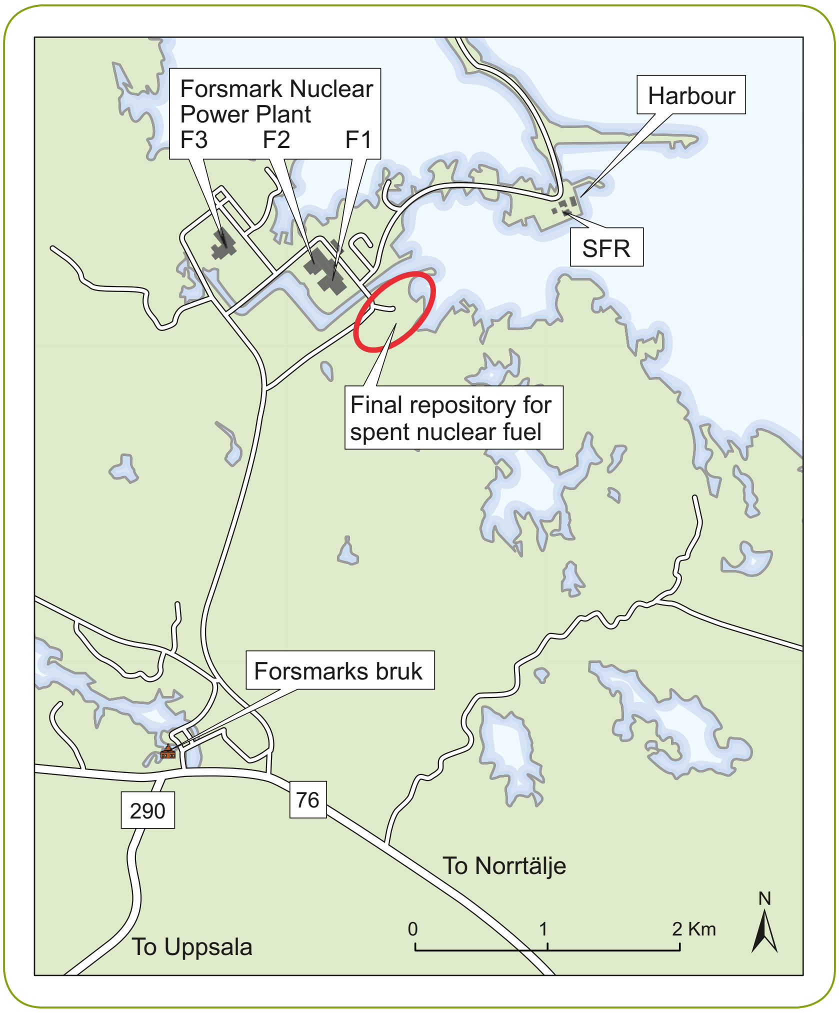


Figure 10-1. Approximate location of the final repository.

10.1.1 Facility design

The final repository will consist of a surface part and an underground part, see Figure 10-2. The vital functions on the surface for the operation of the facility will be gathered within the operations area. This consists in part of a guarded area, the inner operations area, where the spent nuclear fuel is handled and there is a connection to the underground part. The materials that will be used for buffer, backfilling and closure will be stored and treated in the other part, the outer operations area. The surface part of the facility also includes the external parts, a rock heap and ventilation stations.

The underground part will consist of a central area and a repository area. The central area will include underground openings with functions for the operation of the underground part. It is connected with the operations area on the surface via a spiral ramp and a number of shafts. The ramp will be used to transport canisters with spent nuclear fuel and other heavy or bulky materials. The shafts will be used to transport excavated rock, buffer, backfill and personnel, as well as for ventilation. The repository area is the tunnel system where the canisters are deposited. The repository tunnels will be built out as they are needed.

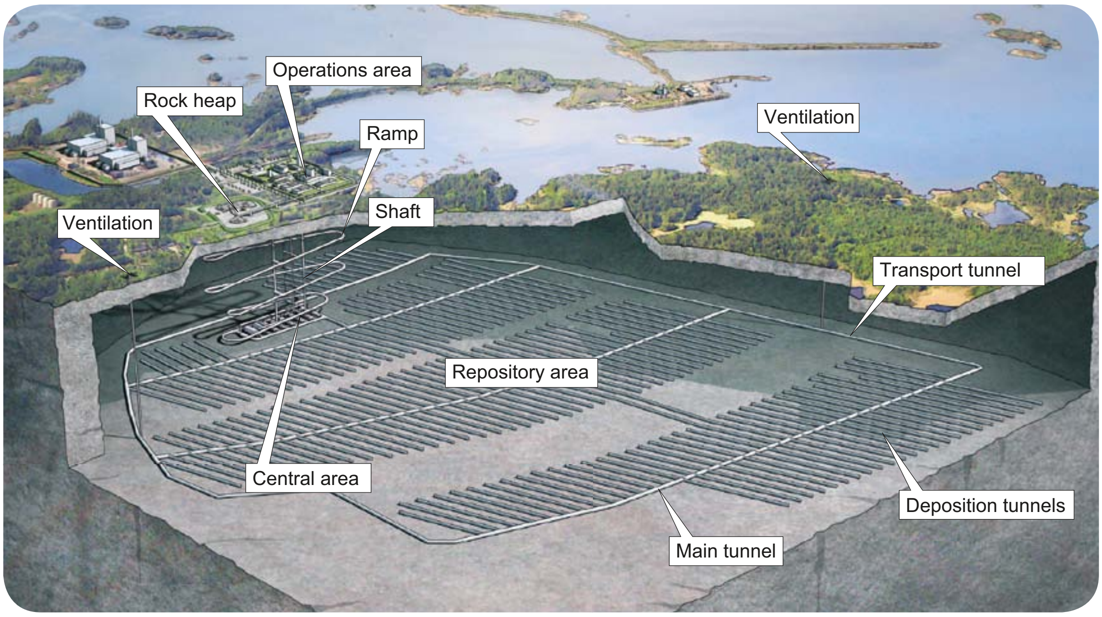


Figure 10-2. The final repository, consisting of an above-ground or surface part and an underground part.

10.1.1.1 Surface part

Figure 10-3 shows a site plan of the final repository's surface part.

The outer operations area will contain the production plant for buffer and backfill and a number of buildings intended for operating functions, service and maintenance, and personnel. No nuclear activity takes place here, and the area is therefore designed as a conventional, fenced-in industrial area.

The outer operations area will contain the following buildings:

- The administration building with office workstations for the facility's administrative activities. The building will house a reception and entrance control to the outer operations area.
- The production building, where bentonite buffer and backfill will be manufactured.
- The reception building with reception, transloading and interim storage of bentonite delivered to the facility.

- The geology building with areas for the measurements and analyses of the rock performed during detailed characterization.
- The workshop building with areas for service and repair of vehicles and machinery as well as facility maintenance.
- The storage building, where different kinds of consumable supplies used in the facility will be stored.
- The electrical building, which will contain switchgear for power supply to the facility.
- The heating plant, which will supply heat to the facility.

The conveyor for rock spoil will also pass through the outer operations area before continuing to the rock heap.

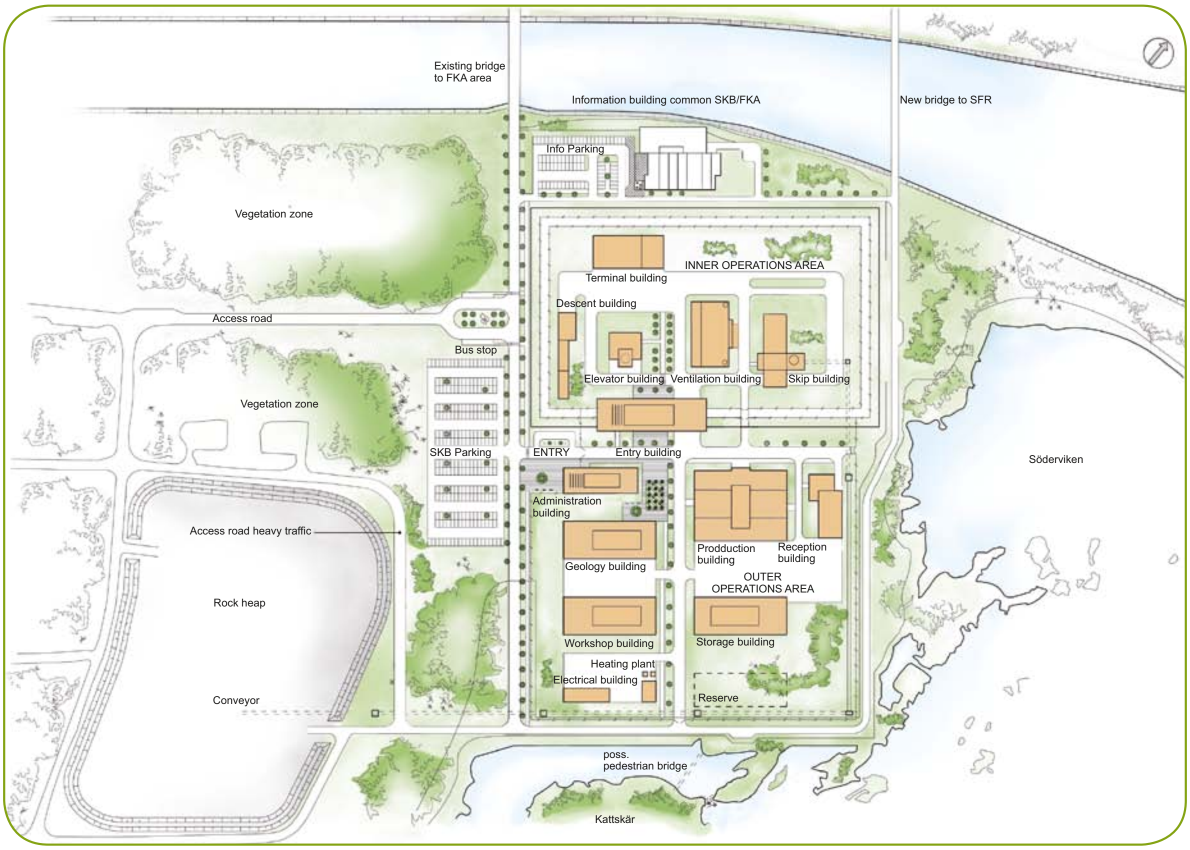


Figure 10-3. Site plan of the final repository's operations area.

The inner operations area will contain the buildings that contain accesses to the facility's underground part and will therefore be a guarded area subject to special requirements on area protection and entry and exit procedures, see Figure 10-4. The inner operations area will contain the following buildings:

- The entrance building, which is the building where all passage into and out of the inner operations area will take place. This includes people, goods and vehicles.
- The descent building, which shelters the portal to the ramp to the underground part from the elements.
- The elevator building, which will have a connection to the underground part via the elevator shaft for passenger transport.
- The ventilation building, which will house equipment for underground ventilation as well as equipment for power supply and heat recovery.

- The skip building with the rock hoist (the skip). The skip will be used for transport of rock spoil, buffer and backfill material. The skip building will have a connection to the underground part via the skip shaft. A conveyor will carry rock spoil out of the skip building.
- The terminal building, where transport casks containing canisters of spent nuclear fuel will be held before being transported down to the underground part.

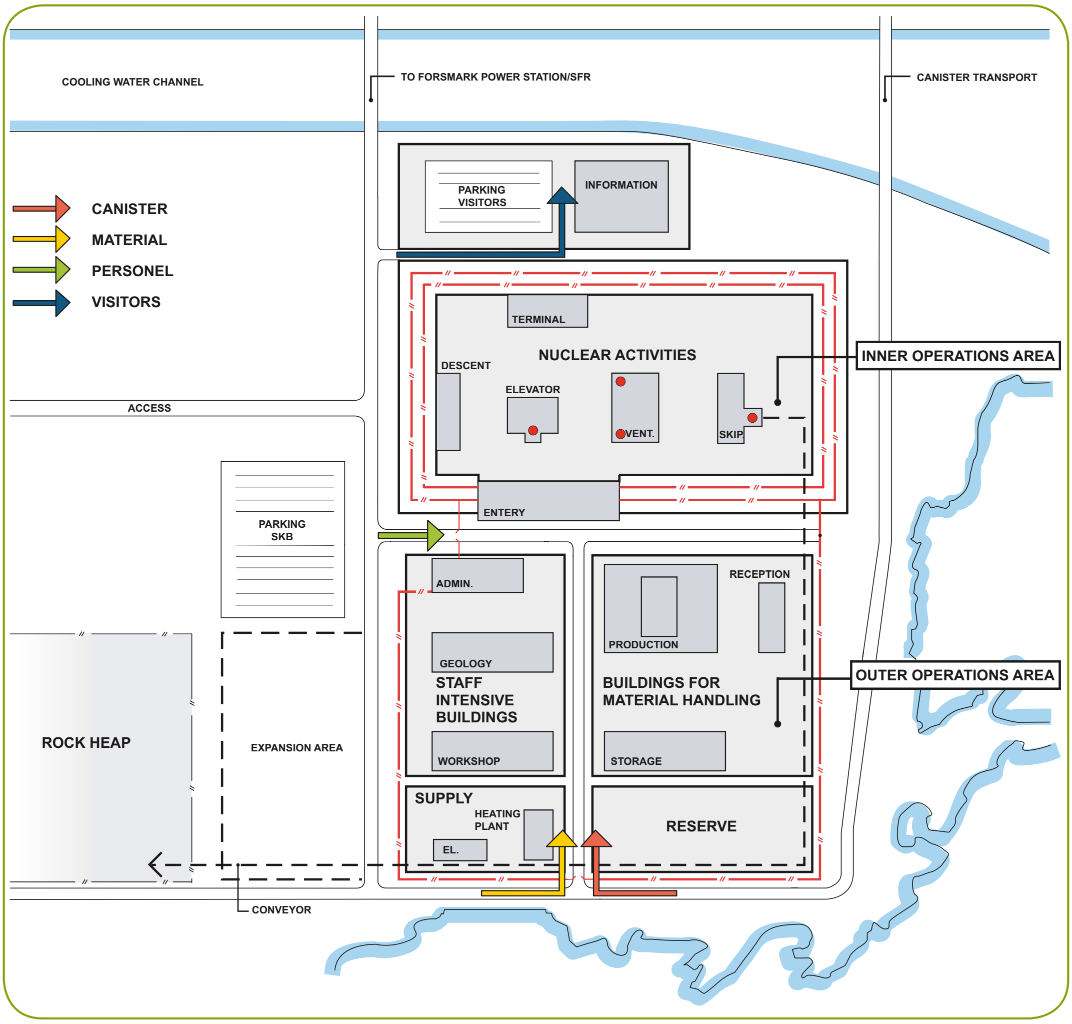


Figure 10-4. Operations area, schematic plan.

The following facility parts will be situated outside of the operations area:

- The rock heap, where excavated rock spoil will be kept until it can be sold. It will be located on the site of the present-day barracks village.
- The ventilation stations, whose purpose is to vent exhaust air from the repository area. They are connected by shaft to the underground part and comprise a guarded area.
- The information building, which will probably be situated close to the operations area. Visitors are received here.

Treatment plants will also be located outside the operations area to purify different types of contaminated water at the final repository. Waste water from toilets, showers, kitchens and other wet areas in the operations area will be collected and conducted to FKA's sewage treatment plant for treatment. Since the final repository will be located on the site where the sewage treatment plant is located today, a new treatment plant will be built west of the barracks village. Sedimentation ponds for leachate from the rock heap will be built on the area for the rock heap. Furthermore, a broad irrigation area and a collection pond for leachate will be built southwest of the rock heap and Lake Tjärnpussen, located next to the barracks village, see Figure 10-5.

The entrance for motor vehicle traffic will be the present-day access road to the power plant, which will be modified for connection to the operations area. A new link between the final repository and SFR will also be built in the form of a bridge over the cooling water channel. The new bridge will mainly be used for canister transport from the port in Forsmark to the final repository and for rock haulage during the construction of SFR. The new bridge will be built over the cooling water channel further east (closer to SFR) than the present-day bridge. The bridge is planned for two lanes and a pedestrian and cycle path. Due to the length of the bridge, about 90 metres, at least one intermediate pier in the water is needed.

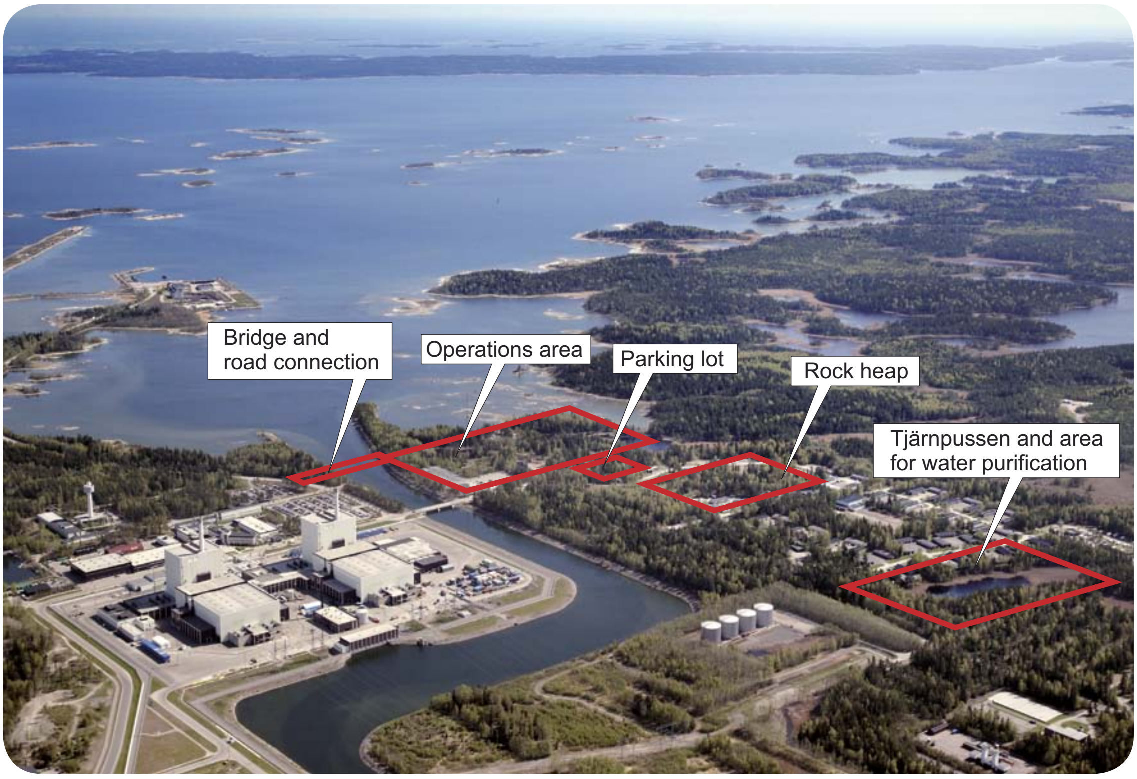


Figure 10-5. Placement of the final repository and changes in existing infrastructure.

10.1.1.2 Underground part

The underground part is included in its entirety in the nuclear facility. The underground part will consist of shaft, ramp, central area and repository area.

The central area will be located directly beneath the inner operations area in the surface part, see Figure 10-6. It will consist of a number of parallel halls with different functions for the underground part's operation. The halls will be connected by tunnels on both sides, which serve as the transport routes through the central area. In the central portion, a through pedestrian tunnel and a service tunnel will connect with the bottom of the skip shaft.

There will be transport tunnels between the central area and the repository area. Canisters of spent nuclear fuel, buffer and backfill will be transported to the repository area, and rock spoil will be hauled back and hoisted to the ground surface in the skip. For ventilation of the central area, there will be two longitudinal ventilation tunnels, one for supply air and one for exhaust air, connected to the top of each hall. The ventilation shaft from the surface part connects to these tunnels.

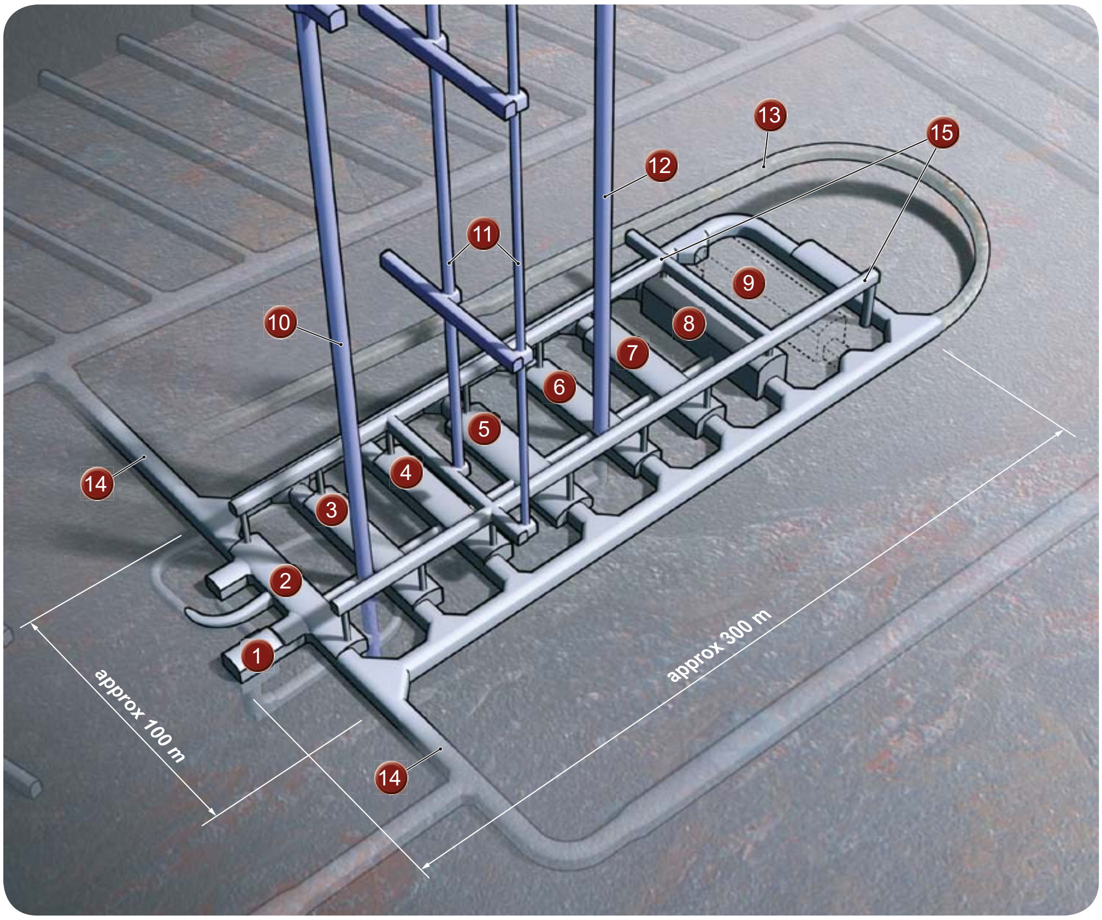


Figure 10-6. The different parts of the central area 1. Rock loading station 2. Rock hall 3. Skip hall 4. Electrical hall 5. Vehicle hall 6. Elevator hall 7. Storage and workshop hall 8. Transloading hall 9. Extra space 10. Skip shaft 11. Ventilation shaft 12. Elevator shaft 13. Ramp 14. Transport tunnels 15. Ventilation tunnels.

The repository area, where the canisters of spent nuclear fuel will be deposited, will be an extensive area of tunnels, see Figure 10-7. The repository area will extend to the southeast from the central area. The repository area and ramp are supplied with air via the overlying supply air tunnel.

Within the repository area there are fracture zones where deposition of canisters cannot be done. The layout of the repository area is based on the results of the site investigations and has been divided into several deposition areas. The area must have room for 6,000 canisters, including reserve space to compensate for loss of deposition positions due to local rock conditions. A deposition hole is only used if it meets the requirements stipulated in the safety analysis report /10-1/.

There will be several different types of tunnels in the repository area:

- Transport tunnels, which go from the central area to the first deposition area, and between the different deposition areas.
- Main tunnels, which are the through tunnels in the repository area from which the deposition tunnels emanate.
- Deposition tunnels, which are the tunnels where deposition of canisters of spent nuclear fuel takes place. The canisters are deposited in vertical deposition holes bored in the floor of the deposition tunnels.

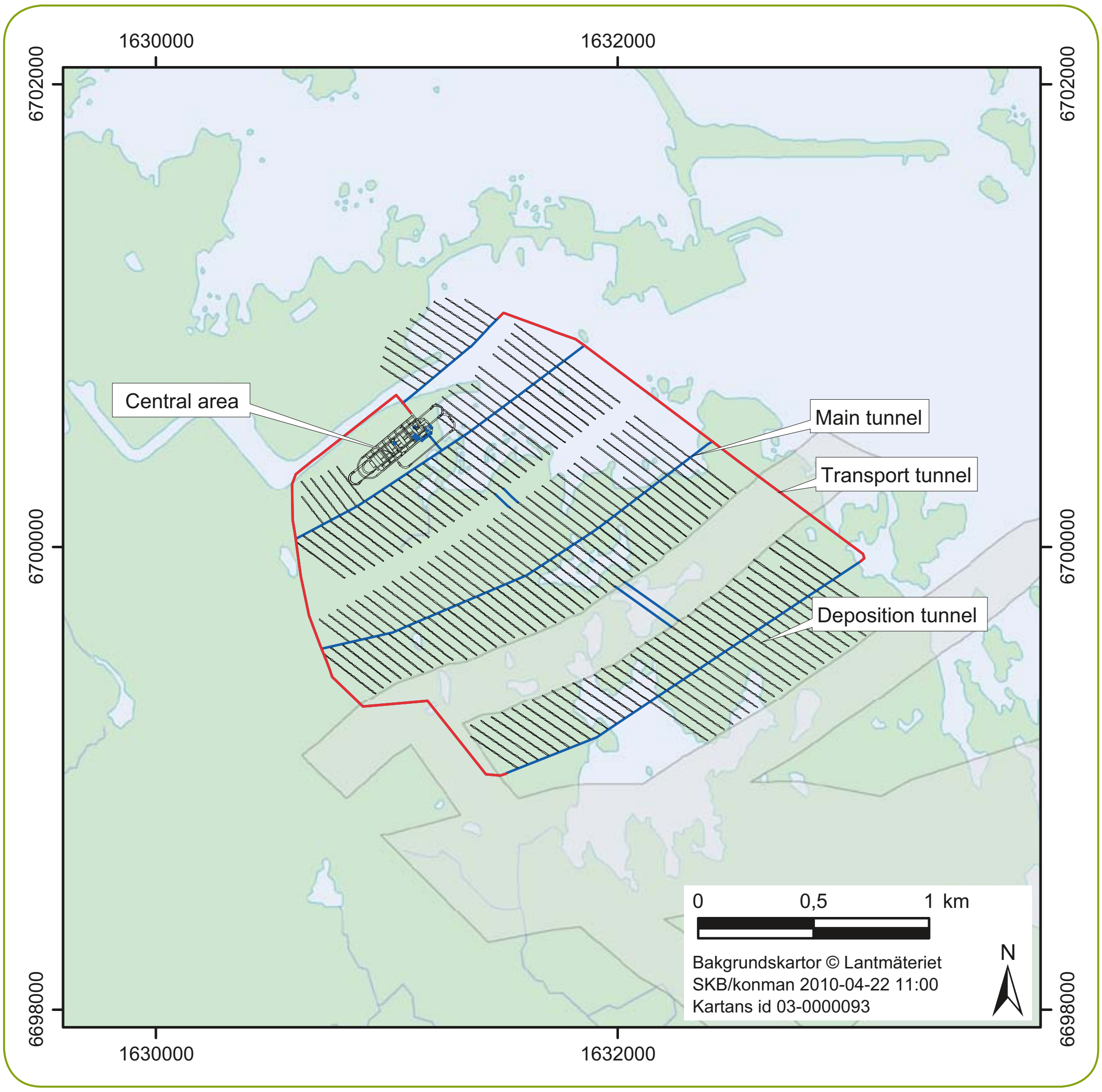


Figure 10-7. Extent of repository area.

10.1.2 Description of activities

10.1.2.1 Construction phase

The construction phase is estimated to take seven years and is concluded with integrated testing, which tests that the whole final repository functions as planned, organizationally as well as technically. The integrated testing is followed by an application to the Swedish Radiation Safety Authority for a licence for trial operation.

The following tasks will be carried out during the first part of the construction phase (see Figure 10-8):

- A building site is established and surfaces for sheds and parking are prepared.
- The land in the inner operations area and parts of the outer operations area is filled in.
- The descent building, geology building and information building are built.
- The rock heap is established.
- A bridge is built over the cooling water channel.

The following rock works will be carried out:

- Investigation of the rock by means of boreholes and measurements.
- Blasting of the skip shaft and raise boring of parts of the elevator shaft and the ventilation shaft.
- Blasting of the rock hall and the rock loading station.
- Blasting of about three kilometres of the ramp.

Approximately 190,000 cubic metres of rock will be excavated during the first half of the construction phase. This is equivalent to a total of about 500,000 tonnes or 55,000 cubic metres (150,000 tonnes) per year. The shot rock consists of surface rock and tunnel rock in pieces sized 0–500 millimetres. The tunnel rock will be hauled by articulated hauler to the surface. Parts of the rock spoil excavated during the first year will be used for infilling in the operations area. Initially, material will also have to be brought in from the outside for infilling. For this purpose, SKB plans to use rock spoil deposited along the pier at SFR when it was built. An estimated volume of 50,000–60,000 cubic metres can be taken from there, which is deemed sufficient until SKB excavates its own rock spoil. During the construction period it will also be necessary to make road material for the final repository's ramp and openings, but rock spoil will also be used for foundations of surfaces and facilities above ground /10-2/. In order meet the need for different types of rock materials, a mobile crusher will be set up near the surface facilities. Crushing will be done as needed.

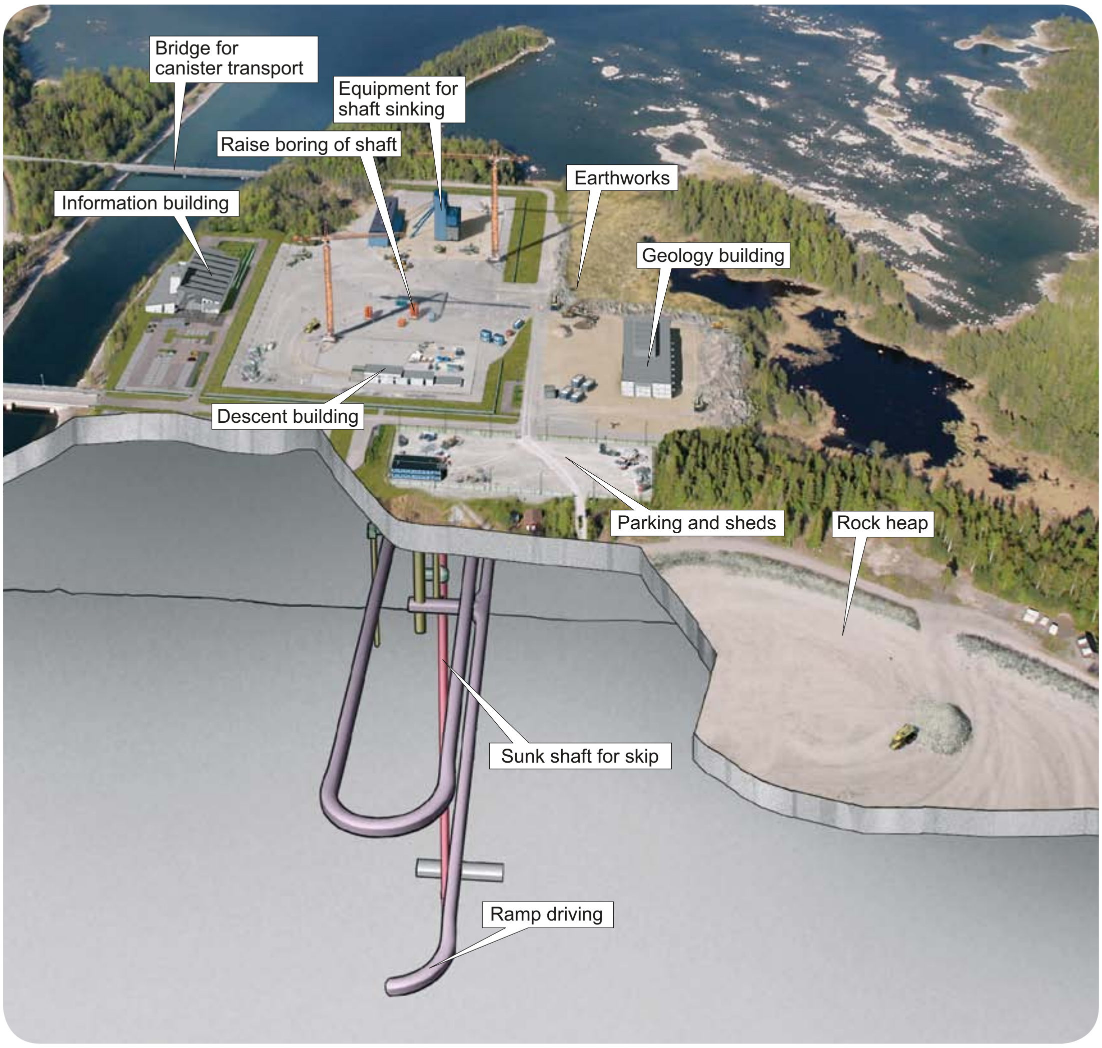


Figure 10-8. Activity year 2.

During the second part of the construction phase the activity will intensify. The following tasks are planned for years 4–7, see Figures 10-9 and 10-10:

- The remaining portions of the outer operations area are filled in.
- All surface buildings are built and the physical protection is extended.
- The rock spoil conveyor is set up.
- The leachate treatment system is built.
- The rock heap is established.

The following rock works will be carried out:
- Shafts and ramp are finished.
- The central area is blasted and finished.
- Driving of transport tunnels and main tunnels in the repository area.
- Driving of deposition tunnels and boring of deposition holes are begun.

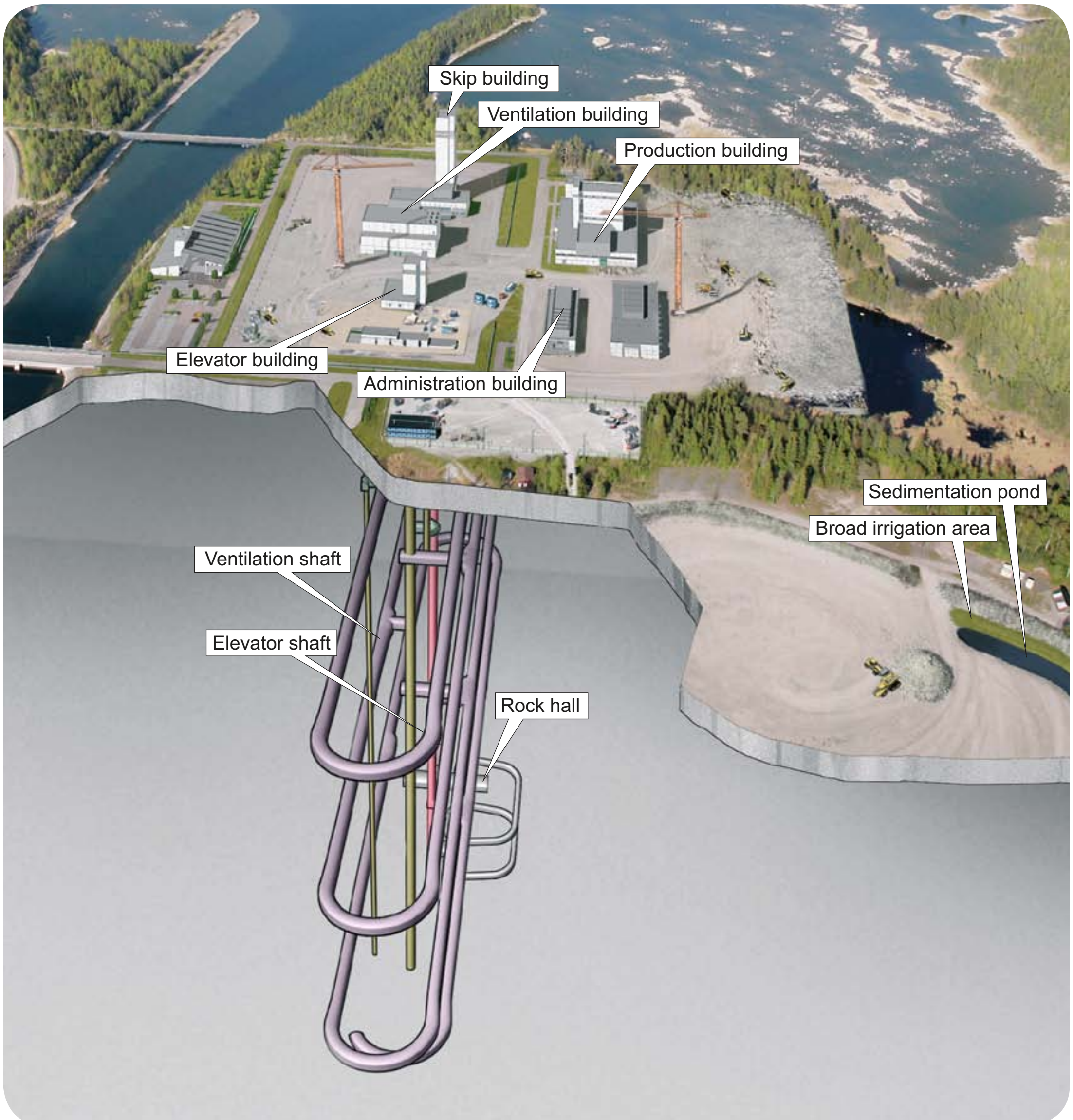


Figure 10-9. Activity year 4.

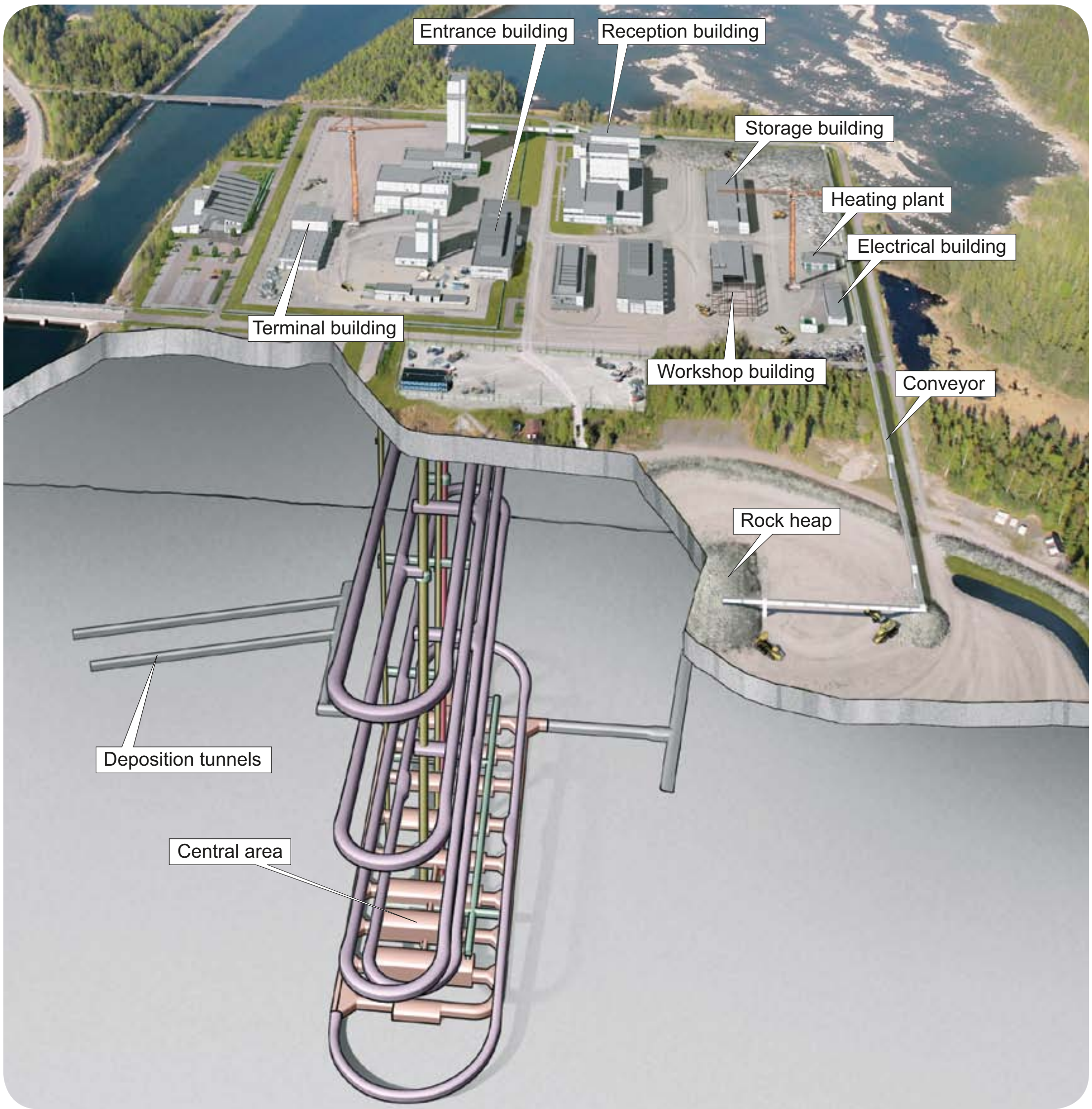


Figure 10-10. Activity year 6.

During the second part of the construction phase, the skip will be finished and put into operation. This means that rock extraction can increase sharply and will amount to around 1.1 million tonnes. Prior to being hauled up in the skip, excavated rock spoil will be crushed in the crusher at repository level. Altogether during the construction phase, about 1.6 million tonnes of rock spoil will be blasted and transported to the ground surface.

At the end of the construction phase, all systems and equipment will be installed, after which commissioning and integrated testing can begin. About 300–400 persons are expected to be employed in the facility at the end of the construction phase /10-3/.

Detailed characterization will be carried out throughout the construction phase, both from underground openings and from the ground surface.

Water management

The activity at the final repository will give rise to contaminated water that needs to be managed. The different water flows are waste water from sanitary areas, drainage water from the underground facility, leachate from the rock heap and stormwater, distributed as shown in Table 10-1 /10-4/. The flow of drainage water is based on results from the sub-appendix on water operations /10-5/.

During the construction phase it will take time before certain systems are built and commissioned, which will require temporary solutions before water management can take place as described below.

Table 10-1. Water flows during the construction phase.

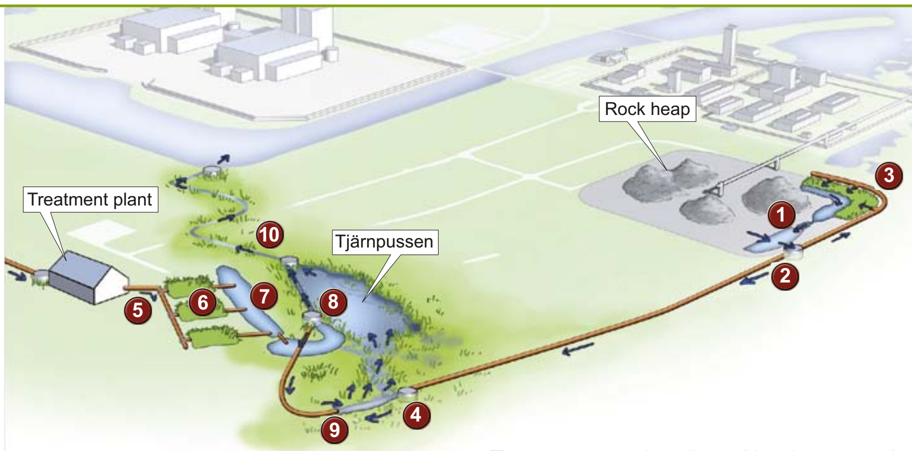
	Flow, m^3/day	Phosphorus, kg/y	Nitrogen, t/y	Nitrogen, annual mean concentration mg/l	Salt
Sanitary waste water	40*	130	0.9	75	–
Drainage water	900–1,700	–	0.7–3.3	1.1–10	Some
Leachate	50	–	1.1–4.5	60–260	–
Stormwater	90** 0***	< 10** < 5***	–	–	–

* Max. daily flow.
** Means that principles of stormwater best management practice are not applied.
*** Means that principles of stormwater best management practice are applied.

Sanitary waste water comes from toilets, showers and other wet areas in the operations area. The purpose of waste water treatment is to prevent the spread of disease, reduce the discharge of nutrients and pollutants to receiving bodies of water and reintroduce nutrients to productive land. The waste water from the operations area will be collected and piped to FKA's treatment plant for treatment. The waste water from the underground facility will be collected in tanks which are then driven to the treatment plant. The establishment of the operations area at Söderviken means that FKA's existing sewage treatment plant must be moved. The new sewage treatment plant is designed with enough capacity to treat waste water from the final repository /10-4/.

Treatment of drainage water (sedimentation and oil separation) will involve temporary solutions until the central area is finished. Drainage water is discharged into the northern, deeper part of Söderviken. Towards the end of the construction phase, drainage water will be managed in the manner described during the operating phase.

Leachate from the rock heap will contain oil, particles and nitrogen. The first two contaminants will be separated by treatment in sedimentation ponds within the rock heap area. Nitrogen removal will be accomplished by diverting the leachate to a broad irrigation area that is also located within the rock heap area. The water is recirculated between the sedimentation pond, the broad irrigation area and the pump sump several times before being discharged into Lake Tjärnpussen for further nitrogen removal, see Figure 10-11.



1. Leachate from the rock heap is collected in a sedimentation and flow equalization pond at the rock heap.

2-3. The leachate is conducted to a pump sump (2) and pumped to a broad irrigation area (3) for nitrogen removal by nitrification, i.e. oxidation of ammonia to nitrates. The pumping to the broad irrigation area is pulsed. The leachate is recirculated several times between the sedimentation pond, the broad irrigation area and the sump.

4. The leachate is pumped from the sump to the fen area at Tjärnpussen.

5-6. Waste water from the treatment plant (5) undergoes aftertreatment in pulse fens (6).

7. The waste water is collected in a larger pond for final treatment

8. Effluent waste water is conducted from the final treatment pond to a discharge well for testing. After the discharge point, the treated waste water is conducted past Tjärnpussen via a bypass ditch.

9. From the discharge well it is also possible to pump a partial stream of effluent waste water to the outlet for treated leachate and enrich the water with phosphorus for optimal nitrogen reduction.

10. Treated leachate and waste water are discharged from Tjärnpussen via an extraction well for regulation and testing to a ditch that opens out into the cooling water channel.

Figure 10-11. Illustration showing treatment of leachate and aftertreatment of waste water.

From Lake Tjärnpussen the water will continue through natural discharge and runoff pathways to the cooling water channel. The quantity of leachate during the construction and operating phases is estimated to be about 50 cubic metres per day, with surges when the leachate arises as a result of rain and snow melting.

The stormwater that is formed during establishment of the operations area is planned to be managed according to the principle of stormwater best management practice. This entails that infiltration surfaces are created, that the formation of stormwater is restricted and that stormwater runoff is delayed, at the same time as contaminants are trapped in the soil instead of being discharged to the recipient. The principles of stormwater best management practice are described in greater detail in section 12.4.1.4. When these principles are applied there is no stormwater flow that needs to be drained from the facility.

Extinguishing water can result from fire extinguishing. The water will be mixed with drainage water underground. It will thereby undergo sedimentation before being discharged into Söderviken.

On-site transport

Transport has been divided into on-site and off-site transport. By on-site transport is meant transport within the operations area and underground, as well as the limited transport flow related to the rock heap and ventilation stations.

In the transport study done by SKB /10-2/, the on-site transport activity in the construction phase has been estimated for the vehicles' total driving distance or total running time, see Table 10-2.

Table 10-2. Estimated on-site transport (heavy equipment) during the construction phase, total for seven years.

	Total running time (h)	Total driving distance (km)
Tree harvesting machine	40	
Bulldozer	600	
Excavator	5,100	
Backhoe loader	400	
Wheel loader	15,450	
Articulated hauler, 10 m³	4,000	43,900
Vibratory roller	1,050	
Aerial platform	5,800	
Service vehicles	11,600	59,700
Mobile crusher	300	
Mobile crane	12,600	
Forklift	1,000	
Concrete mixing truck, 5 m³		43,300
Concrete pump	900	
Articulated hauler, 20 m³		145,500
Scaling machine	3,600	
Explosives transport		11,700
Truck, 10 m³		38,000
Asphalt paver		600

Off-site transport

Off-site transport activities have also been estimated in the transport study /10-2/. By "off-site transport" is meant transport between the final repository and a start or end point located off site. Off-site transport will comprise rock spoil, building materials, service, personnel and visitors. The number of transport trips is specified in the descriptions of these types of transport. Haulage of a load of rock spoil generates two transport trips: one with a full truck away from the facility and the other with an empty truck back to the facility.

Construction of the final repository will yield a surplus of rock spoil. The rock spoil that is not needed for the facility will be sold. At today's market value it is profitable to transport crushed rock products about 50 kilometres by road before the transport costs become too high. It is assessed that transport by truck and local sale of surplus rock spoil is the most realistic alternative for the final repository, in part because it offers flexibility over time. Shipping-out by barge via the Port of Forsmark cannot be ruled out entirely, but the harbour and the fairway are not intended for such transport and the scope of such shipments will therefore be limited.

Table 10-3 shows the number of shipments of rock material during the construction phase to and from the final repository. The transport frequency assumes that the entire rock volume is sold on the market and that the rock is hauled away by a truck with a payload of 25 tonnes. It is further assumed that the number of work days per year is 200.

The table also shows material transport and service transport trips divided into light and heavy vehicles. The greatest number of transport trips is for transport of personnel and visitors. The number of commuting journeys assumes 1.3 persons per car.

Table 10-3. Estimated number of trips to and from the final repository. Vehicle trips per day during the construction phase.

Type of transport	Number of vehicle trips per day, mean
Cars	600
Light shipments < 3.5 tonnes	30
Heavy shipments > 3.5 tonnes (excl. rock spoil)	35
Heavy shipments > 3.5 tonnes (rock spoil)	75

The transport activities that are generated around the final repository will be distributed among the roads in the region. Certain assumptions have been made regarding the end points of the transport trips to enable the traffic effects to be quantified. It is assumed that all transport trips from the facility go south on national road 76 and that no trips go north on national road 76 towards Lövstabruk/Gävle or west on county road 290 towards Österbybruk. The assumptions are based on today's commuting from FKA, 90 percent of which goes south on national road 76. Table 10-4 shows the predicted traffic flow for the typical years 2015 and 2018, as well as estimated additional bulk shipments and other construction and passenger traffic for the reported road sections, see Figure 10-12. Traffic on the roads without the final repository has been calculated based on the Swedish Road Administration's forecast of future traffic /10-6/.

Table 10-4. Estimated traffic quantities (vehicle trips per day) at four points in the region. The figures after the road sections refer to the numbering in Figure 10-12.

	Typical year 2015			Typical year 2018		
	Traffic forecast without final repository	Rock shipments from the final repository	Additional car and other traffic	Traffic forecast without final repository	Rock shipments from the final repository	Additional car and other traffic
National road 76 Johannisfors (1)	2,069	60	612	2,136	86	1,056
National road 76 Börstil (2)	6,139	44	200	6,335	57	500
National road 76 Harg (3)	1,686	9	50	1,746	23	50
County road 288 Rasbo (4)	8,687	9	50	8,964	23	100

Since the transport study was conducted, the need of rock shipments has been slightly revised. These changes entail that the number of rock shipments during the typical year 2015 is about twelve percent lower than the figures reported in the study, while those for the typical years 2018 and 2030 are around twelve percent higher. The number of rock shipments in Tables 10-3 and 10-4 is based on the new figures /10-7/.

Figure 10-12. Road sections where estimated traffic volumes from the final repository are reported.

10.1.2.2 Operating phase

The operating phase will be divided into trial operation and routine operation. Trial operation will be commenced when the Swedish Radiation Safety Authority has granted a licence for trial operation and approved the updated safety analysis report. Trial operation is concluded when the Authority has issued a licence for routine operation.

Trial operation is a type of test period where the entire facility is run and all activities are conducted but at a slower pace than during routine operation, see Figure 10-13. During trial operation the activity is evaluated. The deposition rate will be progressively increased during the trial operation phase to approach the rate that will prevail during routine operation.

When SKB has received permission from the Swedish Radiation Safety Authority, routine operation of the facility can start. This will last around 45 years and some 240 persons are expected to be employed in the facility during this phase. During routine operation the whole facility is run, including all handling and transport equipment. The main activities will be:

- Detailed characterization.
- Excavation of new deposition tunnels.
- Deposition of canisters.
- Backfilling and plugging of deposition tunnels.
- Manufacture of buffer and backfill.

Deposition tasks include preparations for deposition, placement of buffer in deposition hole, deposition of canister, plus backfilling and plugging of the deposition tunnel. When a deposition tunnel has been backfilled completely, it is plugged by casting a concrete plug in the mouth of the deposition tunnel. Rock work includes activities required for excavation of tunnels and boring of deposition holes, including preparations and detailed characterization, and has a duration of about 40 years. Rock work and deposition are separated so they will not affect each other. The average deposition rate is planned to be about 150 canisters per year.

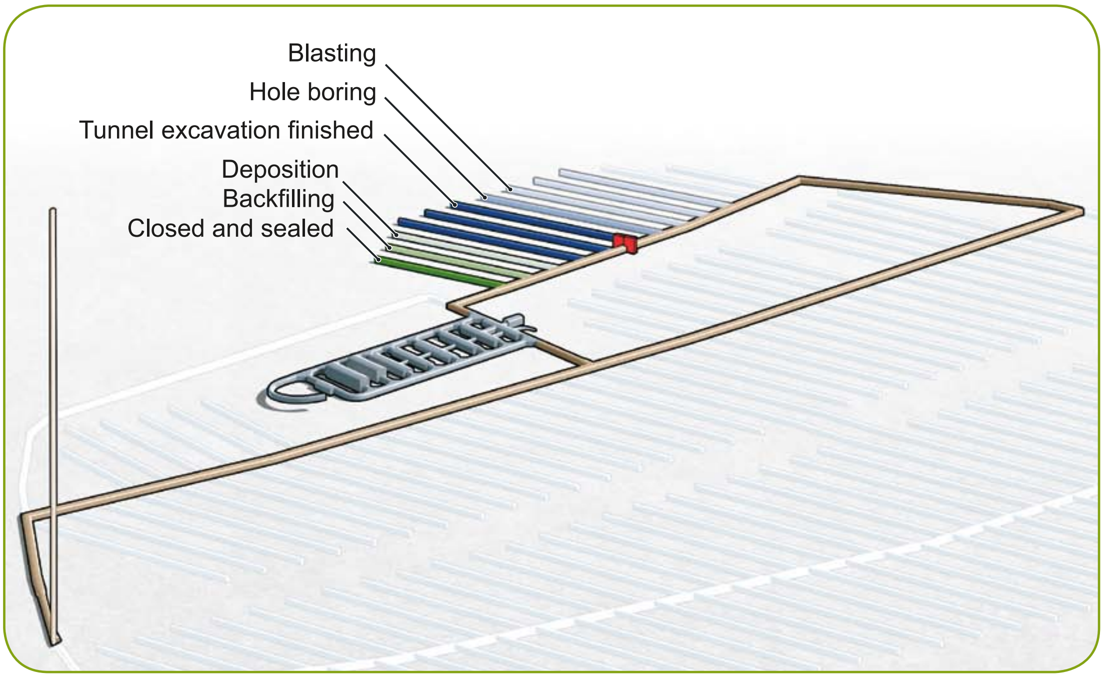


Figure 10-13. The repository area on transition to routine operation.

The repository area thus gradually grows in size during the operating phase. At the same time as new deposition tunnels are excavated, tunnels where deposition has already occurred will be backfilled and sealed. This means that only parts of the repository area will be open at the same time.

Production of crushed rock proceeds at an even pace during the operating phase. Rock production during the operating phase is estimated at about 120,000 tonnes per year or a total of about 4.8 million tonnes /10-8/. The surplus is not assessed to be so great that it will be difficult to find a market for the rock spoil in the municipality or the region. However, the rock spoil may be stored on the rock heap for some time prior to use.

The material SKB intends to use for buffer and backfill is bentonite. Bentonite is a clay that swells in contact with water, which makes it difficult for water to penetrate. The buffer consists of bentonite that has been compacted to blocks, rings and pellets in the production building. The backfill for the deposition tunnels consists of compacted bentonite blocks, in combination with bentonite pellets for filling of gaps in deposition holes and deposition tunnels /10-8/.

Water management

Water management will be the same as during the operating phase and the latter part of the construction phase. Table 10-5 shows the distribution between the different water flows during the operating phase /10-4, 10-5/.

Table 10-5. Water flows during the operating phase.

	Flow, m^3/day	Phosphorus, kg/y	Nitrogen, t/y	Nitrogen, annual mean concentration mg/l	Salt
Sanitary waste water	20*	65	0.6	67	–
Drainage water	1,700–3,500	–	0.4–1.7	0.3–2.8	Yes
Leachate	50	–	0.6–2.3	30–140	–
Stormwater	90** 0***	8**	–	–	–

* Max. daily flow.
** Means that principles of stormwater best management practice are not applied.
*** Means that principles of stormwater best management practice are applied.

During the operating phase, drainage water will be pumped from the final repository in stages of about 100 metres, where each pump stage is preceded by sedimentation. Oil will be separated in pools underground, see Figure 10-14. Next to the hoisting site for the drainage water, the water will pass a heat exchanger for recovery of heat, which will be used to heat the supply air in the underground facility. If necessary, the pH of the drainage water will also be adjusted before being discharged into Söderviken.

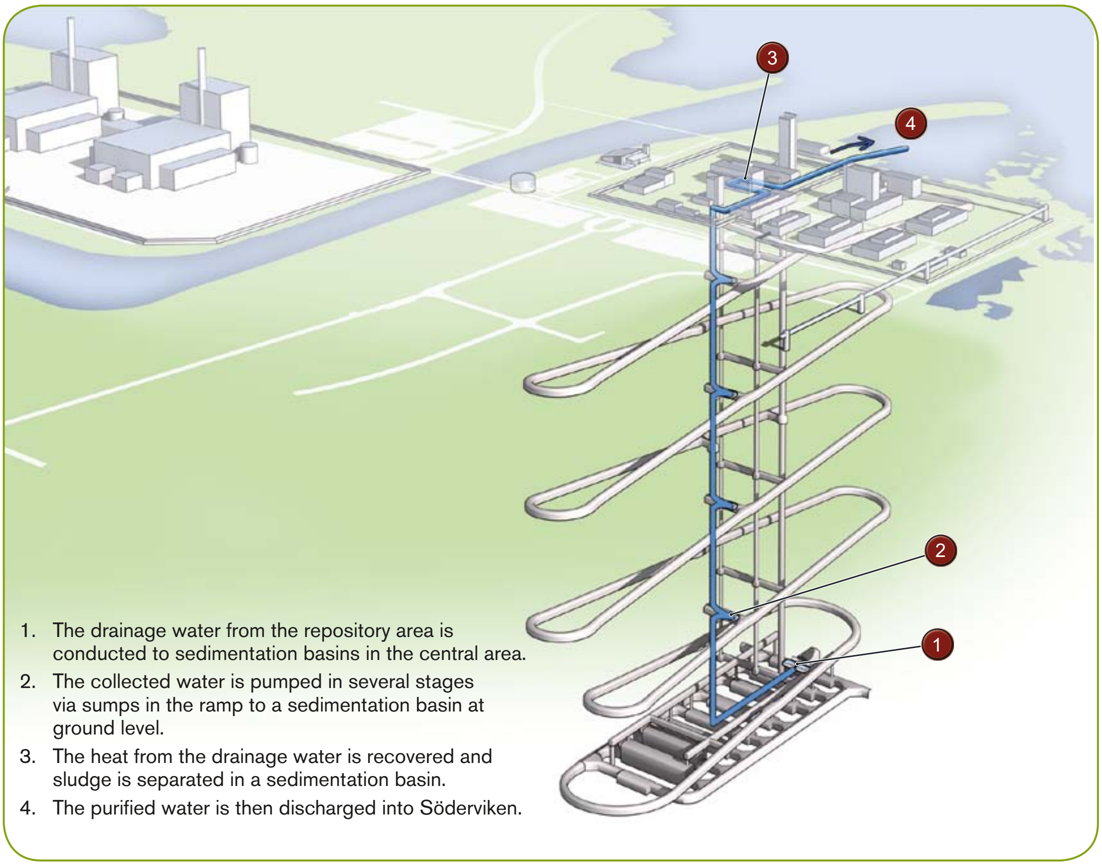


Figure 10-14. Management of the drainage water.

Transport of spent nuclear fuel

Encapsulated spent nuclear fuel is planned to be transported by m/s Sigyn, or an equivalent ship, from the encapsulation plant in Simpevarp to the harbour at Forsmark, and from there by terminal vehicle to the terminal building located within the final repository's inner operations area, see 9.1.2.2. The canisters will be transported to the transloading hall at repository level via the ramp. This is done by a special vehicle developed for this purpose. In the transloading hall, the canister is transferred to the deposition machine, which carries the canister to the deposition tunnel. The canister will lie protected in the transport cask during all transport, except when being carried by the deposition machine. It is then protected by a radiation-shielding tube.

On-site transport

Many of the work operations carried out during the final repository's construction phase will continue during the operating phase. A larger portion of the work will be done underground. Transport of buffer and backfill material, as well as canisters for deposition, are additional work operations compared with the construction phase. Table 10-6 presents an estimate of the on-site transport volume per year during the facility's operating time /10-2/.

Table 10-6. Estimated transport volume for heavy equipment during the operating phase.

Operating phase	Total running time (h/y)	Total driving distance (km/y)
Articulated hauler, 20 m³		10,400
Explosives transport		3,800
Scaling machine	600	
Excavator	1,100	
Aerial platform	3,000	
Concrete mixing truck, 5 m³		3,400
Truck, 10 m³		16,100
Front loader	300	
Vibratory roller	300	
Service vehicles, passenger transport		15,100
Service vehicles, goods transport		87,100
Transport of bentonite blocks		4,100
Deposition machine		450
Forklift	2,300	
Tractor, freight containers with backfill material		9,100
Concrete pump	50	

The transport volume per year will be lower during the facility's operating phase than during its construction phase. Owing to the length of the operating phase, the total traffic volume will nevertheless be greater during the operating phase than during the construction phase.

Off-site transport

The total number of off-site transport trips will decrease during the final repository's operating phase compared with the construction phase due to the fact that the quantities of rock spoil to be transported are smaller. Shipments of buffer and backfill material add to the total transport volume in this phase. Just like during the construction phase, it is assumed that surplus rock can be sold on the market.

Bentonite consumption is estimated at 50,000 tonnes per year /10-8/. Suitable bentonite is not available in Sweden, so the material has to be imported from e.g. southern Europe, the USA or India. The choice of supplier depends on a number of factors and will be made when the operating phase begins. At present, the best alternative is assessed to be that the bentonite is delivered by ship to the Port of Hargshamn for further transport to the final repository by truck.

SKB plans to use the Port of Hargshamn for bulk handling. The Port of Hargshamn is well suited to that type of handling, while the Port of Forsmark is not as suitable today /10-2/. The Port of Hargshamn also has facilities for storage of bentonite. The Port of Hargshamn has been described in Chapter 7 about site conditions. In order for goods receiving to work, certain changes must be made in the port /10-9/. The existing quay may have to be lengthened and a port yard with warehouses may have to be built for receiving and storing bentonite and clay. The quay can best be lengthened at the eastern end, where bulk goods are currently handled. Such a change can be implemented under the port's current licence.

Just like during the construction phase, most of the transport trips will be for passenger transport. In the transport study, it is estimated that passenger trips constitute 82 percent of the total number of transport trips. The number of employees and contractors will, however, be fewer than during the construction phase, at the same time as the number of visitors can be expected to increase. Table 10-7 shows the estimated number of road transport trips to and from the final repository during the operating phase /10-7/. It has been assumed that 60 cars and two buses with visitors will arrive at the final repository per day during the operating phase.

Table 10-7. Estimated number of road transport trips during the final repository's operating phase.

Type of transport	Number of vehicle trips per day
Cars	500
Light shipments < 3.5 tonnes	20
Heavy shipments > 3.5 tonnes (rock spoil)	50
Heavy shipments > 3.5 tonnes (bentonite)	20
Heavy shipments > 3.5 tonnes (other)	20

Table 10-8 shows a compilation of the predicted traffic flow for typical year 2030, as well as the estimated additional bulk shipments and other construction and passenger traffic for the reported road sections /10-7/.

It is assumed in Table 10-8 that all transport to and from the final repository drives south on national road 76 and passes through Johannisfors. The greatest relative increase in traffic volumes on this road is expected to occur between Forsmark and the turn-off to Öregrund. In reality, the traffic increase will presumably be somewhat less since some commuting can be expected to go north. Today about ten percent of the commuting from FKA goes north on national road 76.

Table 10-8. Estimated traffic in 2030, vehicle trips per day.

	Operating phase			
	Traffic forecast without final repository	Rock transport from final repository	Additional passenger and other traffic	Bentonite transport
National road 76 Johannisfors	2,385	48	549	20
National road 76 Börstil	7,066	48	200	20
National road 76 Harg	1,960	13	30	0
County road 288 Rasbo	9,997	7	40	0

10.1.2.3 Decommissioning phase

When all spent nuclear fuel has been disposed of and SKB has obtained permission from the authorities for closure, closure of the facility will commence. How closure is to be carried out has not yet been determined, since it lies far in the future. SKB's current strategy is as follows /10-8/:

- The main tunnels and transport tunnels are backfilled in the same way as the deposition tunnels, with blocks and pellets of compacted bentonite.
- The central area is filled with crushed rock.
- The lower part of the shafts and the ramp is backfilled with bentonite and the upper part with crushed rock.
- The upper part of the shafts and the ramp is filled with compacted coarse crushed rock.

When the underground part has been closed, decommissioning of the surface part's buildings and other facility parts remains. Other possible alternatives are:

- All buildings are dismantled and the land is restored to green field. Some type of indication is provided on the ground surface that this is the site of the final repository.
- The operations area is transformed into a tourist destination where the visitors are reminded of the existence of the final repository and can get information on its historical background. All buildings are dismantled, with the exception of the information building. The land area is otherwise restored to green field.
- The buildings that may be used for other purposes, for example small industrial enterprises, are preserved. Other buildings are dismantled and new buildings are built on the site. In this way it is possible to make use of the existing infrastructure, buildings, roads etc., which can be modified for other activities by relatively simple measures /10-3/.

The traffic quantities during the decommissioning phase are difficult to estimate. It is uncertain how the land around the final repository will be used after closure, but if the site is to be restored, all buildings and facilities must be dismantled and the material hauled away from the site. In that case, the transport activities will be of roughly the same scope as during the initial part of the construction phase.

10.1.3 Impact

10.1.3.1 Land use

The final repository's operations area will be located in the existing industrial area in Forsmark, at Söderviken. FKA's waste water treatment plant, office barracks with parking, a communications mast and storage areas are currently located on the site. Otherwise the area consists of forest land and water areas, see Figure 10-15. Existing installations will need to be moved prior to establishment of the the final repository.

Figure 10-15. Siting of the activity.

Construction phase

The final repository will be extended gradually both above and below ground. In the initial part of the construction phase, large parts of the operations area will be filled to their final level with rock and soil. This means that the ponds that exist in the area will be filled in. The existing access road to FKA will be rebuilt to some extent. A parking lot will be built on the east side of the road to FKA, along with a new road between the parking lot and the operations area. Following the construction phase, parts of the existing barracks village will also be dismantled to make room for the rock heap, among other things. The recently refurbished temporary housing in the southwest part of the village will probably be preserved, at least during the construction phase.

As rock spoil is removed from the underground work, the rock heap will be established and gradually grow. The rock heap will cover about 40,000 square metres during the construction phase. A new road and a new conveyor will be built to the rock heap. A new bridge will also be built over the cooling water channel further east (closer to SFR) than the present-day bridge. A ventilation station will be built southwest of the operations area for ventilation of the underground part. It will occupy about 3,000 square metres.

Figure 10-16 shows the finished facility. Figure 10-17 shows what land areas will be used for the different surface parts of the facility.

Figure 10-16. Photomontage of the finished facility.

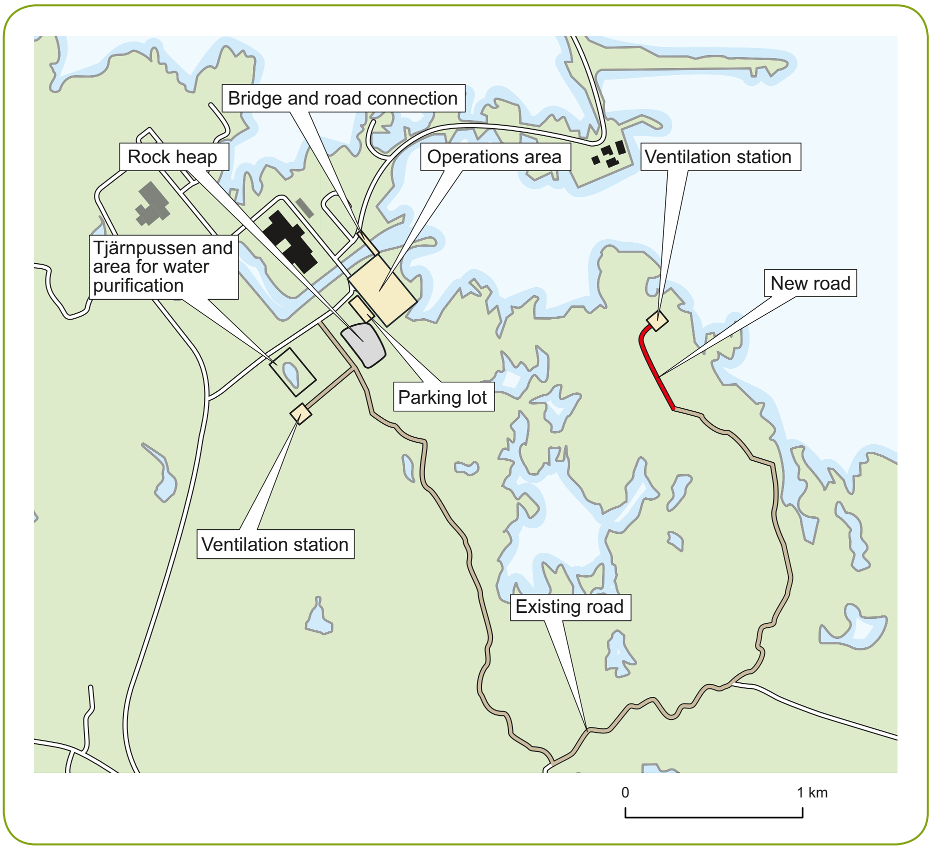


Figure 10-17. Land areas used for the activity. The eastern ventilation station and the road to it will not be added until in the operating phase. The locations of the ventilation stations are preliminary and subject to change in the light of additional knowledge on rock conditions.

Water treatment plants will be built west of the rock heap, see Figure 10-17. A broad irrigation area of about 2,000 square metres and a collection pond of about the same size will be built for purification of leachate from the rock heap. See schematic illustration in Figure 10-11.

The surfaces in the southern and eastern part of the operations area will not be used until the end of the construction phase. The final repository's surface facility, including the outer and inner operations areas, will occupy a surface area of about 70,000 square metres when finished. Underground, the central area will occupy a surface area of about 3,000 square metres. Most of the surfaces needed to build the facility are located within the future operations area, and the size of temporarily utilized surfaces is limited.

Operating phase

Most of the surfaces needed for the final repository will be utilized already during the construction phase. Impact will therefore be limited during the operating phase.

The repository area underground will be built progressively during the operating phase, and when fully built-out will occupy a surface area estimated at three to four square kilometres at a depth of 470 metres /10-8/. Another ventilation station will be built northeast of Bolundsfjärden. A new road will be built from the existing logging road to the ventilation station. This road will take the form of a small logging road. The road can be routed to avoid impact on sensitive ecosystems.

Decommissioning phase

No new surfaces will need to be occupied during the decommissioning phase. Several different alternatives for handling the surface part's buildings and other facility parts are possible. For example, all buildings could be dismantled and the land restored to green field, or the site and the buildings could be used for other purposes. See also Chapter 10.1.2.3.

10.1.3.2 Impact on groundwater level

Groundwater will flow into all of the final repository's underground openings as long as some part of the facility is kept open, i.e. during the construction, operating and decommissioning phases. The inflow will be collected in the facility and pumped to the ground surface for further handling. The size of this groundwater inflow will depend on the depth and geometry of the facility, the hydraulic conductivity (permeability) of the rock and the sealing measures undertaken /10-10/. The facility will be designed and adapted to avoid, wherever possible, major water water-conducting fracture zones in the rock, but wherever water-conducting fractures or fracture zones nevertheless have to be passed during construction, sealing (grouting) may be necessary in order to reduce the inflow. Different methods and grouts can be used to create a zone with lower hydraulic conductivity /10-11/. Completely preventing inflow is not possible, however, since grouting can never make the rock completely watertight. The descent ramp through the near-surface, highly conductive part of the rock is expected to require extensive sealing measures. At greater depth, however, the rock is very tight, requiring less sealing.

Inflow into the final repository will lower the groundwater pressure in the rock, which can lead to groundwater lowering in the area. This groundwater lowering will decline with the distance from the facility and will occur at greater distances mainly along fracture zones in contact with the facility. The groundwater lowering (drawdown) and the area affected, the "impact area", is therefore largely determined by the hydraulic properties and geometry of such fracture zones.

Lowering of the groundwater table can only occur where uninterrupted fractures and fracture zones lead from the deeper parts of the rock up to the upper part of the rock and the soil layers /10-10/. Due to the interaction between groundwater in soil and surface water, lowering of the groundwater table can reduce the outflow of groundwater. This can in turn affect water levels in wetlands and water flows in streams. Wetlands that are mainly fed by outflowing groundwater (for example headwaters) are particularly sensitive. This sensitivity is less for lakes and wetlands that are completely or mainly fed via streams (if the flow in these streams is not itself affected by the final repository), precipitation or meltwater that runs off on exposed rock and other impervious ground surfaces.

Extensive model analyses have been done to calculate the changes in groundwater pressure in the rock and the lowering of the groundwater table in the area, and for different scenarios with regard to sealing measures. Analysis methods and results are described in greater detail in /10-5/.

Groundwater lowering during construction and operating phases

Detailed calculations of groundwater lowering are presented in /10-5/. Modelling has sometimes been done for a case when the entire final repository is assumed to be open simultaneously. In reality, the build-out strategy means that no more than half of the deposition tunnels within a deposition area are open at the same time. See Figure 10-18 for an illustration of the strategy for blasting, deposition and backfilling.

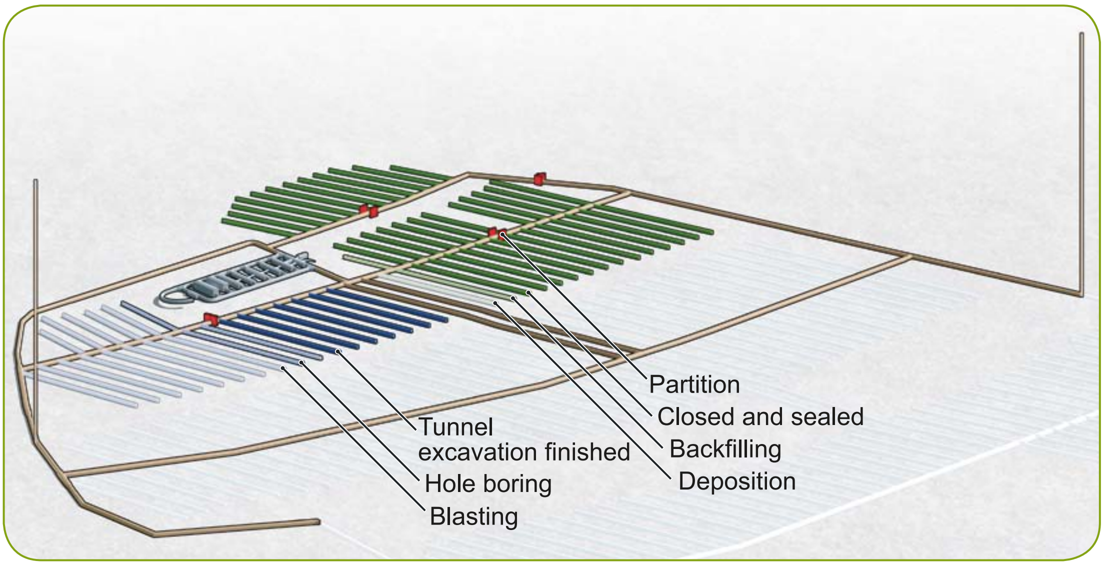


Figure 10-18. Illustration of principle of parallel blasting, deposition and backfilling of deposition tunnels along a main tunnel.

The calculation results reported here comprise a "worst case", since the whole final repository is assumed to be open at the same time. What varies in the reported calculations is the degree of sealing (how successfully the rock around the facility has been sealed). Table 10-9 shows the size of the impact area for different sealing alternatives and different drawdown limits. The "worst case" has been used for the impact assessment (conductivity of grouting, K_{grout}, = 10^{-7} metres per second). The table shows variations in the size of the impact area, depending on the conductivity of the grouting.

Table 10-9. Impact area (square kilometres) for lowering of groundwater table (drawdown). The calculations pertain to a hypothetical case with the whole repository open at the same time.

Hydraulic conductivity in the grouted zone, K_{grout} (m/s)	Maximum drawdown (metres)	Size of impact area (square kilometres)			
		Drawdown limit 0.1 metre	Drawdown limit 0.3 metre	Drawdown limit 0.5 metre	Drawdown limit 1 metre
10^{-7}	16.5	2.45	1.38	1.05	0.69
10^{-8}	9.2	1.96	1.05	0.72	0.47
10^{-9}	3.9	1.20	0.64	0.40	0.24

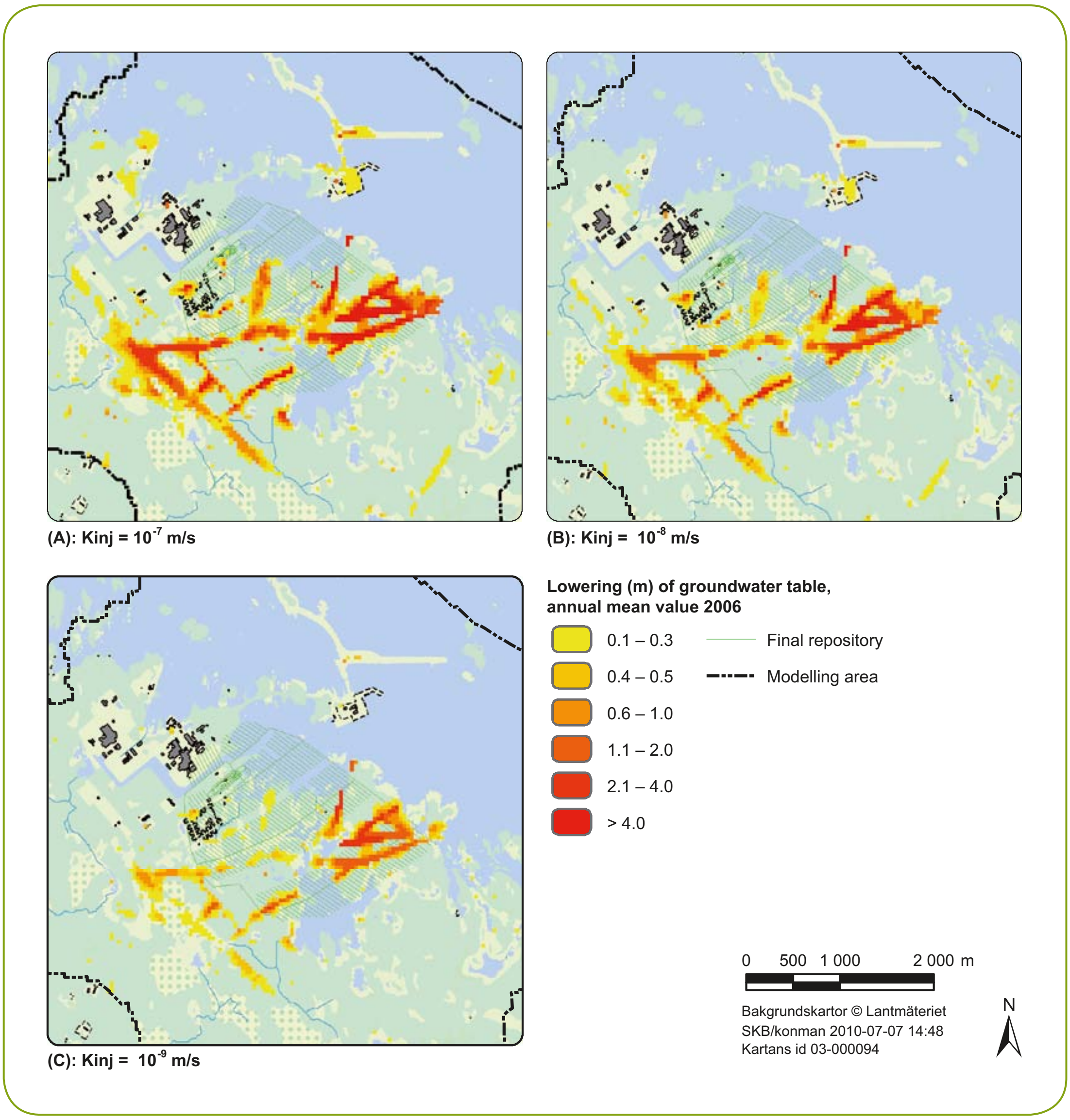


*Figure 10-19. Annual mean value for lowering of the groundwater table for 2006. The calculation pertains to a hypothetical case with the whole repository open at the same time. The calculation assumes a hydraulic conductivity in the areas where the rock is sealed by grouting of $K_{grout} = 10^{-7}$ m/s (A), $K_{grout} = 10^{-8}$ m/s (**B**), and $K_{grout} = 10^{-9}$ m/s (**C**).*

Figure 10-19 shows the lowering of the groundwater table for three different values of the hydraulic conductivity, K_{grout}. The three cases are K_{grout} = 10^{-7} m/s in Figure 10-19 (A), K_{grout} = 10^{-8} m/s in Figure 10-19 (B) and K_{grout} = 10^{-9} m/s in Figure 10-19 (C). A conductivity of 10^{-7} m/s can be regarded as pessimistic, since it has been deemed possible to achieve K_{grout} = 10^{-8} m/s, while K_{grout} = 10^{-9} m/s could be achieved in certain parts of the facility if necessary /10-11/. The year 2006 has been used as a typical year in the calculations, since it was a relatively normal (although slightly dry) year in Forsmark from a meteorological standpoint, with an accumulated precipitation of 539 millimetres.

The maps show that the shape and extent of the impact area is similar in the different sealing cases (different K_{grout}), with a number of zones running in an east-west and north-south direction above the repository, and within the areas around the cooling water channel. This provides some certainty in the assessment of which areas run a risk of being affected by the diversion of groundwater. The shape of the impact area for groundwater lowering can be explained by the rock's hydrogeological properties, above all the distribution of vertical and horizontal fracture zones in the rock. In the upper part of the rock there are gently dipping, nearly horizontal fractures with high horizontal permeability where the groundwater can flow at roughly the same level in the rock. In these fractures, a change in groundwater pressure can be spread out horizontally. At certain places, the gently dipping fractures meet steeply dipping deformation zones (structures with high vertical permeability, where the groundwater can flow upward or downward in the rock). This means that changes in groundwater pressure in the rock give rise to a lowering of the groundwater table, particularly in the limited areas where the steeply dipping deformation zones are in contact with the upper part of the rock and the soil layers. These principles are illustrated in Figure 10-20.

It is the impact area from Figure 10-19 (A) that has been used as a basis for a description of the consequences of groundwater diversion in Chapter 10.1.4.1.

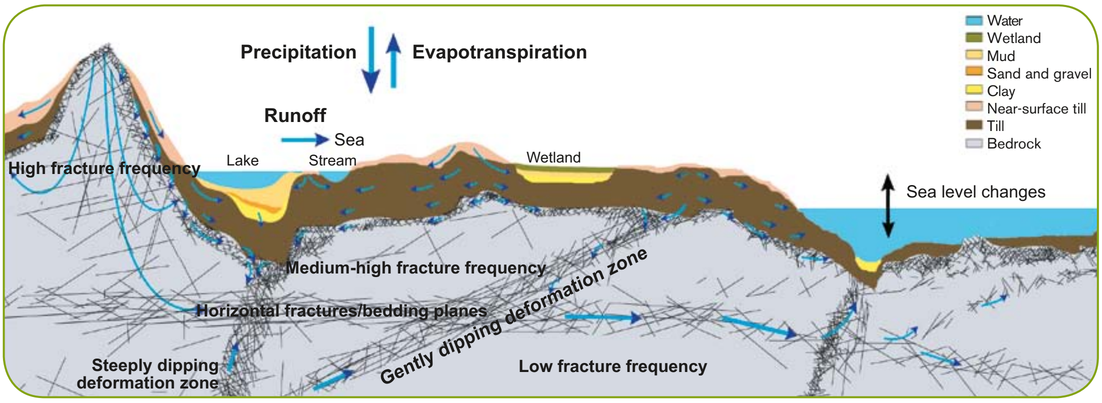


Figure 10-20. Illustration of the hydrogeological conditions in the upper parts (about 150 metres) of the rock in Forsmark. According to the illustration, there is a network in this part of the rock that consists of gently dipping fracture zones with high horizontal permeability and fracture zones with high vertical permeability.

Post-closure recovery of the groundwater table

During the decommissioning phase, the facility will be backfilled and closed. At this point, the diversion of the groundwater from the facility will cease. The recovery sequence when inflow into the repository decreases can be likened to a mirror image of the lowering sequence. By using the impact area for lowering of the groundwater table as a reference, the modelling shows that the impact area is reduced to about one-third after one year and to about one-twentieth just over two years after the inflow into the repository has decreased considerably or ceased completely. A comparison between the lowering and recovery sequences shows that the recovery sequence can proceed slightly faster than the lowering sequence.

10.1.3.3 Noise

The dominant noise source in Forsmark today is a static converter station at Dannebo. The activity at the nuclear power plant and the traffic on the roads in the area also give rise to noise.

The impact of both facility noise and transport noise is reported for the different phases of the project. Facility noise consists of noise from the activities in the final repository's operations area, while transport noise originates from off-site transport.

Since the noise study /10-12/ was done, the forecast for the number of rock shipments has changed. However, the changes are deemed to not affect the equivalent noise levels.

Construction phase

Infilling, earthmoving, drilling and blasting, rock handling, transport, rock crushing, foundation work, ventilation and building construction are examples of civil engineering works that will give rise to noise in the area around the final repository.

Blasting will give rise to short-duration noise. It will occur a few times a day and will not affect the equivalent sound level to any appreciable extent. Blasting on the ground surface will last for about six months.

Besides blasting, rock crushing is the task that will cause the most noise. This is therefore the activity that determines the noise level in the daytime and in the evening. If rock spoil is also extracted from the pier at SFR, rock crushing may also need to be done alongside the pier. However, the resultant noise level is not expected to be so high that it affects either the nearest housing, the planned short-term housing at Igelgrundet, or the bird sanctuary east of SFR. At nighttime, heavy vehicle transport will be the activity in the operations area that causes the highest noise levels. When the work has reached repository depth and the skip and central area are completed, rock spoil can be crushed underground and hauled up by the skip for further transport via conveyor to the rock heap for interim storage or removal by truck. The skip will comprise a new source of noise during the second half of the construction phase. During limited periods it may be necessary to split large shot rocks on the ground surface. Such rock breaking can cause high noise levels.

Structure-borne sound can be caused by e.g. drilling prior to tunnel blasting rounds. Structure-borne sound is sound that is propagated via solid material in the form of vibration. Structure-borne sound can be propagated to buildings founded directly on rock and can be perceived at a distance of 100–200 metres from the source. The nearest building, the existing barracks village, is located about 150 metres from the drilling work. Parts of this village will be demolished during the construction phase, however. Other buildings are located more than 400 metres from the nearest blast hole drilling, so structure-borne sound is not expected to reach audible levels (25–30 dBA) in these buildings.

The sound levels from drilling on the surface have been estimated to be about 50 dBA at the nearest housing, which is the planned short-term housing at Igelgrundet.

The highest noise levels in relation to guideline values – 50 dBA for construction noise in the evening and 35 dBA for industrial noise in the evening and at night – will occur in the evening, see Figure 10-21.

In order to limit this noise, rock crushing on the ground surface, loading and haulage of rock spoil from the rock heap, and superficial blasting work should be avoided at night.

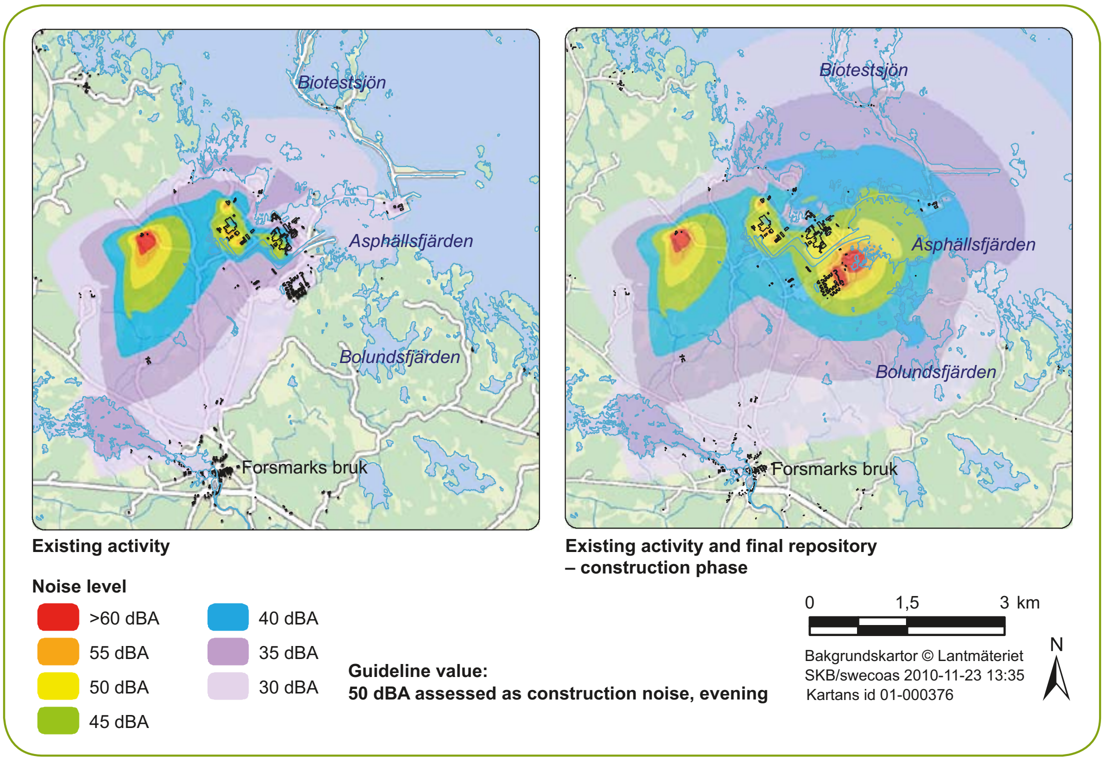


Figure 10-21. Existing noise, evening and night (at left), and existing noise combined with noise from construction of the final repository, evening (at right).

The noise levels from off-site transport have been calculated for the situation without a final repository (called the zero alternative in Figure 10-22) as well as for the build-out alternative and are fully reported in /10-12/. The traffic volumes from the final repository are calculated to be greatest during the latter part of the construction phase, and the figures represent the typical year 2018. Figure 10-22 shows examples of the noise levels for a road section at Norrskedika where most of the haulage traffic from the final repository will pass, at the same time as the housing is located near national road 76. Most of the transport activities will take place during the daytime. The figure shows a marginal increase in the noise levels caused by SKB's activity.

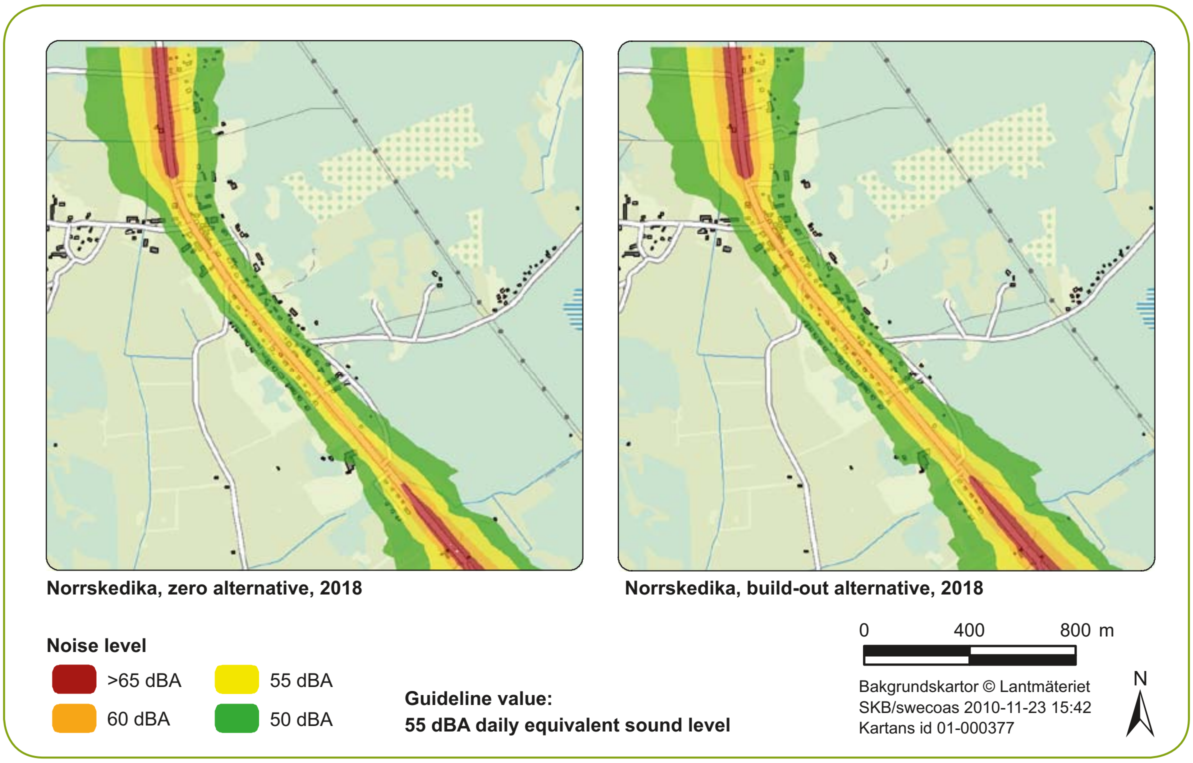


Figure 10-22. Noise from road traffic in Norrskedika, with and without the final repository.

Operating phase

The tasks that are expected to cause the most noise during the operating phase are operation of the skip, use of heavy vehicles on the work site, and rock handling at the rock heap. Mobile crushers may be used during the daytime, in campaigns. Outside the operations area, sound is also produced by evacuation fans at ventilation stations. However, these will probably be located at repository level, which mitigates the noise. The calculations are based on sound data shown in Table 10-10, given as sound power level in dBA or dBC next to the sound source. The letters A and C refer to different scales, where C is used for impulse noise and gives greater weight to low frequencies, which in the case of A are filtered out to some extent.

Table 10-10. Typical sound data for sources during the operating phase. Equivalent sound level given as sound power level in dBA and dBC, respectively. The sound levels are given at the source.

Source	dBA	dBC
Skip	111	114
Mobile crusher	118	127
Rock heap	103	119
– Wheel loader		
– Excavator	98	119
– Falling stone (from conveyor belt)	111	112
Conveyor belt – 10 m	86	97
Fans	87	95
Truck	107	112

Figure 10-23 shows noise levels for evenings and nights for the existing activity in the area as well as existing noise levels combined with the contribution from the final repository during the operating phase for evenings and nights.

Table 10-10 shows that in the case of several of the noise sources, low-frequency noise, measured in dBC, will dominate. This is the case for e.g. wheel loader, excavator and rock crusher. If the difference in sound level between dBA and dBC is greater than about 15, the sound can be perceived as more disturbing than is indicated by the dBA level. Figure 10-24 shows noise from wheel loader, excavator and mobile crusher in dBA (at left) and in dBC (at right). In the right picture in Figure 10-24, the boundary between green and yellow indicates 55 dBC (40+15, which is equal to the guideline value plus the difference between dBA and dBC). In the left picture, the equivalent sound level is given in dBA, where the boundary between green and yellow indicates 40 dBA.

The figures show that the range for 55 dBC will be slightly greater than the range for 40 dBA. On the other hand, the range for 50 dBC will be much greater than the range for 35 dBA. This means that if the mobile crusher is in operation in the evening and at night, there is a greater risk of disturbance than if it is running during the daytime.

Decommissioning phase

Calculations have not been made of noise levels during the decommissioning phase. The noise levels are determined by what methods are used for dismantling and whether all facilities or only parts will be decommissioned. To a great extent, the noise levels will be equivalent to the levels during the construction phase.

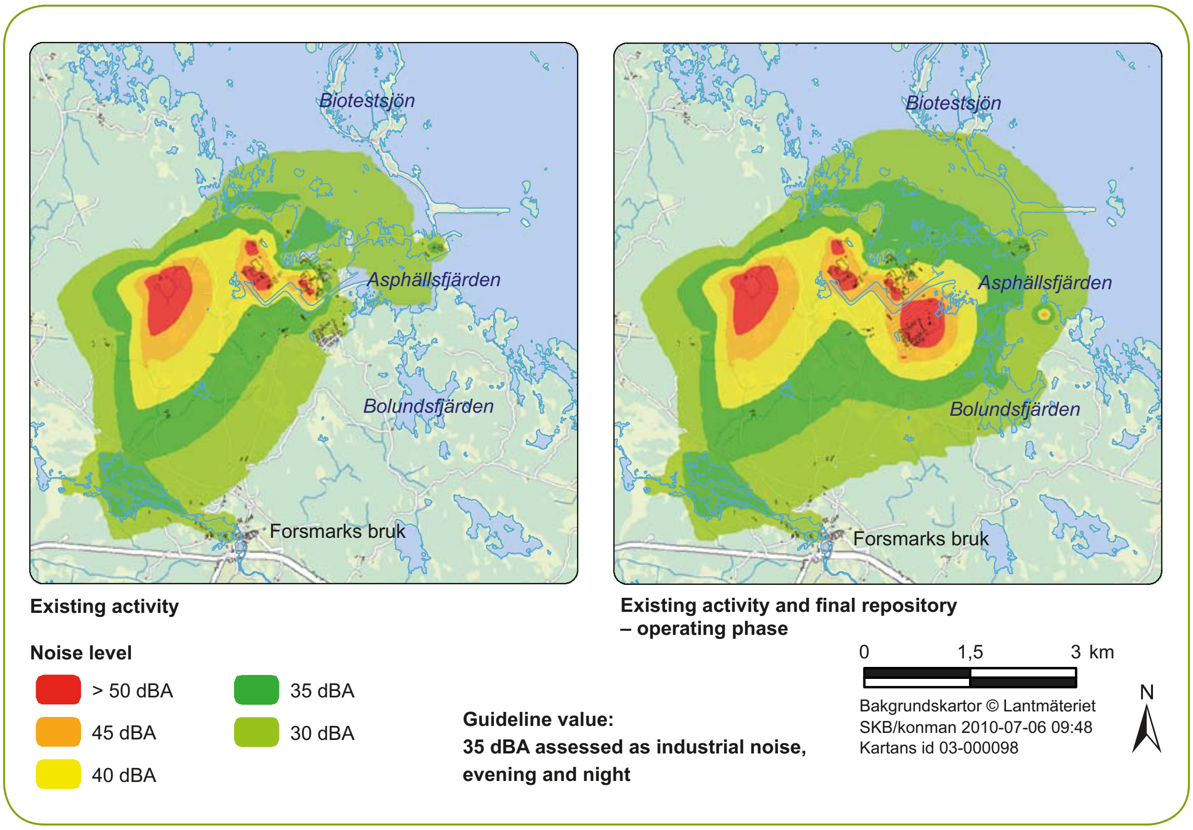


Figure 10-23. Existing noise, evening and night, (at left) and existing noise combined with noise from the final repository, evening and night, during the operating phase (at right).

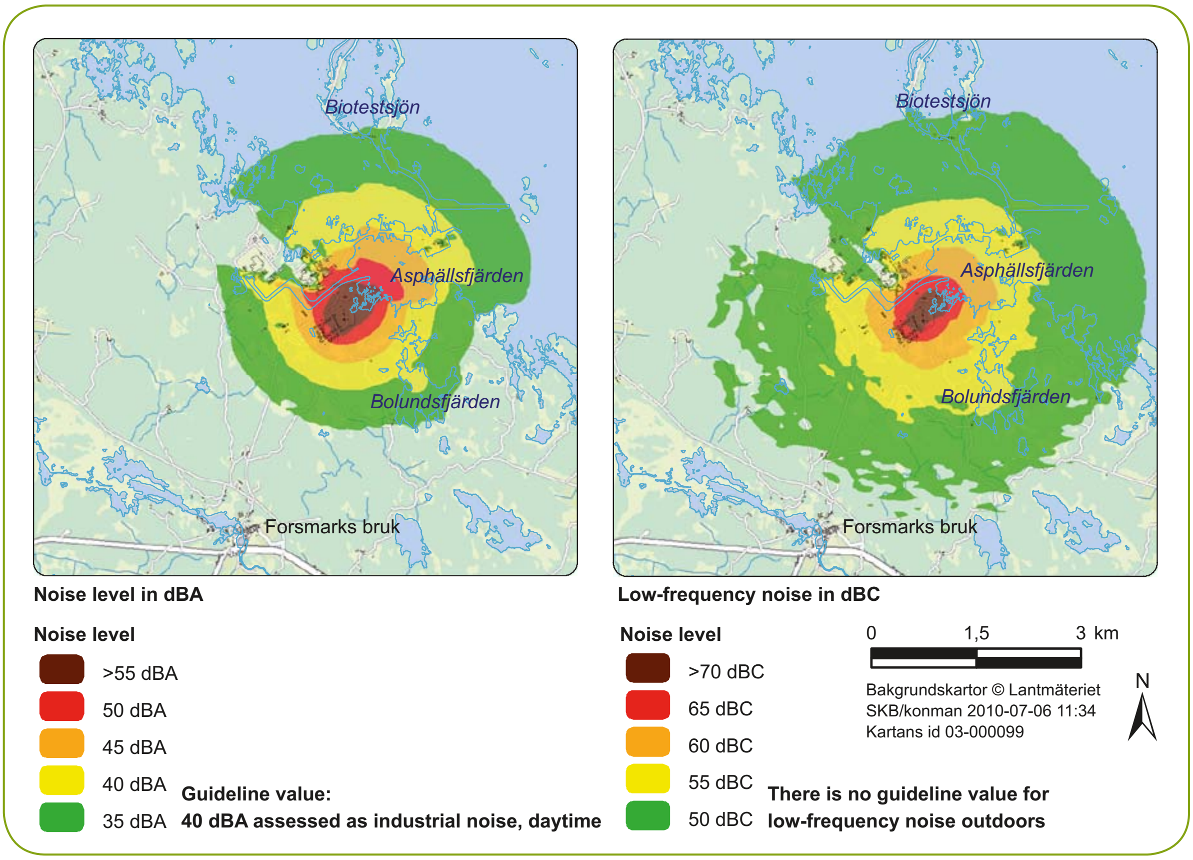


Figure 10-24. Noise level in dBA from wheel loader, excavator and mobile crusher (at left) and low-frequency noise in dBC from wheel loader, excavator and mobile crusher (at right).

10.1.3.4 Vibrations

Vibrations occur as a result of blasting at the final repository and heavy transport to and from the facility.

A study has been conducted where vibrations and air shock waves generated by the activity at the final repository were calculated and possible effects were preliminarily evaluated /10-13/. The risk of impact on the existing activity is described in section 10.1.5.2.

Construction phase

Vibrations will mainly arise as a result of blasting, above and below ground, in the operations area for the final repository. The blasting may also give rise to air shock waves.

Above-ground blasting will be carried out during a limited part of the construction phase when foundations are being laid for some of the buildings in the facility's operations area. The underground blasting is expected to cause lower vibration levels than the above-ground blasting, but will on the other hand continue throughout the construction phase. The impact on the surface will decline with time, however, since the depth to the driving faces gradually increases. Blasting for the foundation of the production building and for driving of the accesses (ramp and shafts) is expected to cause the highest vibration levels.

There is no permanent housing within the impact distance from the blasting. The closest vacation homes are located more than two kilometres from the operations area and the above-ground blasts. In a late phase of the build-out of the final repository (the operating phase), the distance from the blasts on repository level to the vacation homes will be at least about 600 metres.

A new housing complex is planned at Igelgrundet, on the north side of the cooling water channel. The distances from the blasts to the buildings in this complex will be at most about 500 metres.

With few exceptions, the distances to the planned blasts are thus 500 metres or more. At such great distances, the impact is generally limited.

A possible source of vibrations, aside from the blasts, is heavy transport to and from the final repository. The additional transport volume does not affect the vibration levels along the transport roads, since heavy transport already occurs on these roads. Vibrations will occur more frequently, however, since the traffic will increase. Vibrations from heavy traffic seldom cause damage to buildings, but can cause disturbances to people in nearby buildings. The degree of impact depends on such factors as road quality and what kind of foundations the buildings have. National road 76 between Forsmark and Hargshamn has a smooth roadway, and nearby buildings are founded on rock or firm soil material. This is advantageous and means that the vibration levels from traffic will be very limited. A reference measurement performed in housing on national road 76 in Norrskedika confirmed very low vibration levels.

Operating phase

During the operating phase, more or less daily blasting will be a part of the normal operating activity for many years. All blasting will take place at repository level, however, about 470 metres underground. The vibration will be felt on the ground surface directly above the rounds, but the distances are so great that environmental impact is expected to be minimal.

There will be fewer transport runs during the operating phase than during the construction phase. Vibration resulting from the traffic to and from the final repository will therefore occur less frequently, but the vibration levels will be the same.

Decommissioning phase

During the decommissioning phase, the underground works are not expected to give rise to any vibrations near the facility. Vibrations can arise during the dismantling of surface buildings, depending on what dismantling method is used, but they decline rapidly at distances greater than a few tens of metres. The vibrations will therefore be much lower during the decommissioning phase than during the construction phase.

Vibration levels from road transport are determined by the transport volume and the future status of the roads, but the frequency of vibrations caused by traffic to and from the final repository may be similar to that during the construction phase.

10.1.3.5 Radiation and releases of radionuclides

This chapter describes both naturally occurring radionuclides and radiation and those that can come from the spent nuclear fuel. Information on radioactivity and radiation is provided in section 3.4.

Radioactive substances are present naturally in the rock in most Swedish hard rock facilities, partly in the form of radon and its decay products, radon daughters. Radon in hard rock facilities is emitted from rock surfaces, crushed rock in tunnels and rock caverns, and from inflowing groundwater. Radon concentrations in mines and underground structures can be high, especially if the rock's uranium content is high. Adequate ventilation is the main means of controlling the radon concentration in underground facilities. This is also true of the final repository in its various phases.

Besides radon from the final repository that is vented out with the ventilation air, radon will be emitted from the rock heap, to which it is brought with the rock spoil. Radon will also be emitted with the water that is discharged from the facility. Radon concentration is measured in units of becquerels per cubic metre of air (Bq/m^3) or per litre of water (Bq/l).

Construction phase

During the construction phase, radionuclide releases and radiation will only be caused by the natural radioactivity present in the rock, mainly in the form of radon and radon daughters. The radon levels are primarily an occupational safety issue, since radon levels are higher in the facility's underground parts than outside the facility. The legal limit for the atmospheric concentration of radon in indoor spaces, which includes finished underground openings, is 400 Bq/m^3. The legal limit for radon exposure in openings where rock work is under way is 2,500,000 Bqh/m^3 per year, which is equivalent to an annual mean value of radon concentration in the air of 1,500 Bq/m^3. The ventilation system in the final repository will be designed for larger air flows than the minimum flows required to keep the radon concentration below the limit values. During the construction phase, the radon contribution from the final repository is estimated to be 1–8 Bq/m^3 and from the rock heap 1–16 Bq/m^3, where the higher figure represents a rock heap of maximum size. Under realistic conditions, the radon contribution to the surrounding air from the final repository and the rock heap will be less than 6 Bq/m^3. This can be compared to a normal original concentration of radon in the atmosphere of 10 Bq/m^3. As long as the air is not completely stationary around the rock heap and the ventilation openings, no impact is expected on the radon concentration in the outdoor air around the final repository /10-14/.

Water released from the facility will mainly come from the rock. The effluent mainly contains substances from the rock, including a certain quantity of radon plus certain residual products from blasting. Most of the radon in the effluent is emitted to the air in the final repository's underground parts before the water reaches the discharge pipe /10-15/.

Operating phase

During the operating phase, canisters of spent nuclear fuel will be deposited in the final repository. A design premise for the canister is that it must keep both radionuclides and the alpha and beta particles that are generated by radioactive decay contained. This radiation will therefore not escape from the canisters. The spent nuclear fuel also emits gamma and neutron radiation as it decays, only some of which is shielded by the canister. The canister itself thus emits gamma and neutron radiation to an extent that requires radiation protection during handling, but no radionuclides are released from the canister. Neither gamma radiation nor neutrons will reach beyond the facility.

The smallest amount of radioactivity that will be handled in the final repository is that present in the canister. The facility is designed so that the canister will remain intact throughout the operating phase, and the radioactivity that is present inside the canister will be kept contained in it. Due to decay, however, the radioactivity in the canister will decline with time. The largest quantity of radioactivity that is planned to be handled simultaneously in the facility is the radioactivity contained in thirteen canisters, since that is the number of canisters handled simultaneously: ten canisters standing in transport casks in the terminal building, one in transit above ground or in the ramp, one in the transloading hall and one in the deposition process. Deposited canisters are not counted among those being handled in the final repository, since they are covered by bentonite blocks and thereby have no impact on the environment.

Radiation protection and radiation shielding

During all transport outside the final repository and before the transloading hall, the canister will be enclosed in a transport cask that acts as a radiation shield and limits radiation to the environment. In the transloading hall's radiation-shielded transloading cell, the canister is transferred from the transport cask to the deposition machine. The deposition machine's radiation-shielding tube encloses the canister and prevents radiation from escaping.

During transloading to the deposition machine and the deposition process, the canister will be a radiation source. During deposition, a radiation shielding hatch will be used when the canister is placed in the deposition hole, until the buffer blocks have been placed over the canister. This provides radiation protection during deposition /10-15/. The radiation shielding is intended to protect those who work in the final repository, since the gamma and neutron radiation does not have enough range to reach outside the facility.

Dose to personnel

Personnel who work in the final repository can be exposed to radiation, since the canister will be a radiation source and the naturally occurring radon in the facility will emit radiation. Individual dose and collective dose in normal operation with minor disturbances have therefore been calculated.

The calculations of individual and collective dose have been made with pessimistic assumptions, and the actual radiation doses will probably be lower. The individual dose to a maximally exposed individual for deposition of one canister is calculated to be 0.08 mSv, and if the same individual performs the same task for all canisters deposited in a year (150 canisters) this adds up to 12 mSv. The collective dose for deposition of a canister has been calculated to be 0.3 mmanSv, while the collective dose for deposition in a year is 46 mmanSv. The calculated radiation doses include the radiation dose from the natural background radiation (radiation dose from radon) present in the facility /10-15/.

Radiation doses from radon will be limited by ventilation in the same way as in the construction phase.

If a mishap (described in section 10.1.5.2) occurs, all work must be interrupted, the different tasks must be planned and radiation shielding must be provided. A dose budget must also be prepared for the tasks that will have to be performed. This budget must then be approved by the Swedish Radiation Safety Authority before the work of dealing with the event can begin /10-15/.

Radionuclide releases

The canisters with the spent nuclear fuel do not release any radionuclides. To ensure than no free radioactivity or contamination are brought into the facility via the transport equipment and transport of the canister, the inside and outside of the transport cask will be checked for radioactive contamination in the transloading hall. The air in the transport cask will also be checked with respect to radioactivity. If the transport cask is contaminated, it is returned together with the canister to the encapsulation plant.

Radon present naturally in the final repository will be evacuated via the ventilation air and the drainage water. Radon will be emitted to air from rock heap during the operating phase as well.

The radon contribution from the facility during the operating phase will be of roughly the same magnitude as during the construction phase.

Decommissioning phase

There will not be any radionuclide releases from the canisters. Radon release and dose to personnel from radon during the decommissioning phase has not been closely studied. The ventilation system will be designed so that no limit values are exceeded during the decommissioning phase either.

10.1.3.6 Non-radiological atmospheric emissions

The final repository will cause air pollution by direct emissions via vehicle exhaust pipes, dusting and resuspension of already deposited substances as a result of construction or transport activities. Blasting also generates emissions of explosion gases. The principal air pollutants that arise in connection with the repository activity (not counting ship transport) are nitrogen oxides (NO_x), carbon dioxide (CO_2), particulate matter (PM), hydrocarbons (HC) and carbon monoxide (CO).

The account of atmospheric emissions has been divided into emission quantities and concentrations. By "emission quantities" is meant the quantities of pollutants that are released via the vehicles' exhaust pipes. Emission quantities are reported in tonnes per year. The concentrations are reported as annual mean concentration in milligrams per cubic metre (mg/m^3) and show how SKB's activities contribute to the concentration of air pollutants in the area.

In order to calculate the emission quantities, vehicle types and transport volumes have been taken from the transport study published by SKB /10-2/. The average driving distance for off-site transport is assumed to be 25 kilometres per one-way trip. The methodology for calculating emission quantities and complete calculations are presented in /10-16/. Since the study /10-16/ was done, the predicted number of rock shipments has changed. This does not result in any significant changes in atmospheric emissions, however.

Construction phase

Table 10-11 shows total emissions from on-site and off-site transport to and from the final repository for the typical years 2015 and 2018 /10-16/. These emissions are compared with the total emissions in Uppsala County in 2006 /10-17/.

Emissions of all substances will be greatest during the second half of the construction phase, when civil engineering and transport activities are most intensive, but will not contribute noticeably to the total emissions in the county.

In order to determine the contribution to local air pollution concentrations, dispersion calculations have been done for emissions from on-site and off-site transport and for activities above and below ground. Dispersion calculations have been done for nitrogen dioxide and particulate matter for the typical year 2018. There are environmental quality standards for these substances. The dispersion calculations for the final repository include on-site transport and activities at the rock heap. The contribution from rock handling (dusting) is based on measurements at an existing facility with rock handling. Figure 10-25 shows the concentration contribution of particulate matter (PM10) and the concentration contribution of nitrogen oxides (NO_x).

Table 10-11. Emissions from road transport to and from the final repository in the typical years 2015 and 2018 (tonnes per year) compared with total emissions in Uppsala County in 2006.

	Final repository 2015	Final repository 2018	Uppsala County 2006
NO_x	3	4	3 800
CO_2	1,200	1,600	1,062,000
PM10	2	4	1,500

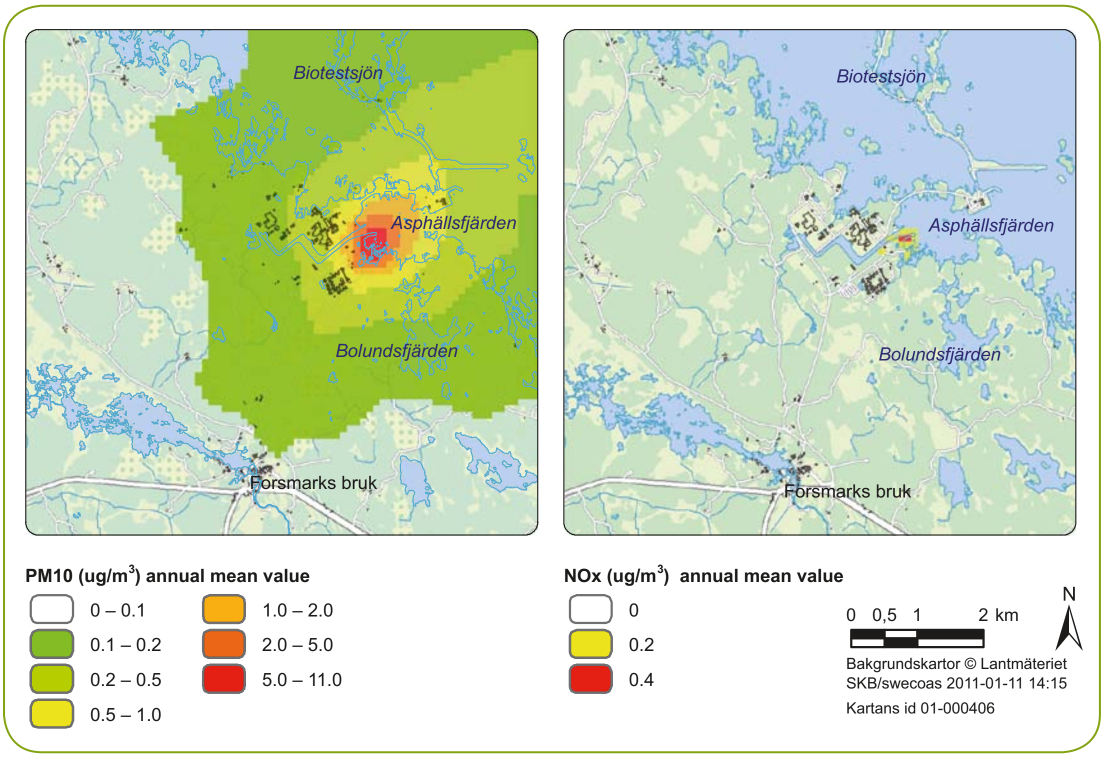


Figure 10-25. Concentration contribution in 2018 of PM_{10} annual mean concentration (at left) and concentration contribution in 2018 of NO_x annual mean concentration (at right).

Dispersion calculations have also been done for off-site transport to and from the final repository for a road section at Norrskedika, where most of the traffic from the facility will pass, at the same time as the housing is located near national road 76. Since the traffic will be most intensive during the latter part of the construction phase, dispersion calculations have been done for 2018. The calculations show that SKB's contribution of both PM10 and NO_2 of 0.5 microgram per cubic metre (µg/m^3) will not disperse beyond 20 metres from the road. Dispersion maps for national road 76 through Norrskedika are shown in report /10-16/.

The deposition of nitrogen has been calculated for the area around the final repository. The calculations show that SKB's activities contribute a small portion of the nitrogen deposition in the three nearby Natura 2000 sites and in the Forsmark-Kallrigafjärden area of national interest. According to /10-16/, the deposition from the activities at the facility will amount to less than 0.00001 gram per square metre (g/m^2) and year, which is less than 0.002 percent of the background load.

Operating phase

Activities during the operating phase will be similar from year to year, which means that emissions will be the same during the entire operating period, provided that the assumptions concerning exhaust emissions control, engines and fuels that have been made for the typical year 2030 remain valid. Report /10-16/ presents a study of possible future scenarios for development of vehicles and fuels, and the emission calculations for 2030 are based on this study. Annual emissions of all studied substances will be lower during the operating phase than during the construction phase.

The dispersion calculations have also been done for the operating phase in 2030. The concentrations from the work at the final repository and along the off-site transport routes are expected to be lower in 2030 than in 2018. This is attributable to less intensive rock work and thereby fewer transport trips during the operating phase. Dispersion maps for the final repository and for national road 76 through Norrskedika are shown in report /10-16/. Emissions from ship transport are described in section 8.1.3.5.

The deposition of nitrogen from activities at the facility will amount to less than 0.00001 g/m^2 during the operating phase as well, which is less than 0.002 percent of the background load.

Decommissioning phase

Transport emissions during the decommissioning phase are estimated to be at roughly the same level as during the operating phase, but dispersion calculations have not been done for the decommissioning phase since the uncertainties for this phase are too great. The uncertainties stem mainly from development of new fuels, but also development of new vehicles. Nor have calculations been made of the deposition contribution of nitrogen.

10.1.3.7 Non-radiological effluents

Construction phase

During the first part of the construction phase, the technical solutions for water management will be temporary, only to be converted to permanent solutions during the second half of the construction phase.

Waste water

The waste water from the operations area will be collected and piped to FKA's sewage treatment plant for treatment. Purified water from the sewage treatment plant will be discharged to the cooling water channel and out into the Biotest Basin after having passed the nuclear power plant to cool the reactors. Before the purified cooling water is discharged into the cooling water channel, part of the stream can be diverted via Lake Tjärnpussen in order to optimize the after-treatment of leachate from the rock heap. The addition of water from the final repository will not alter the impact on the receiving body of water /10-4/.

Drainage water

During the construction phase, the drainage water will mainly consist of groundwater inflow to the ramp and central area, but also of water used for drilling, blasting and earthmoving. In addition to nitrogen, the drainage water will also contain cement residues, oil residues and other contaminants from work vehicles and heavy equipment. The salinity in the drainage water is assessed to be roughly the same as in the Baltic Sea outside Forsmark /10-4/.

The nitrogen concentrations in the drainage water will be so low (below 5 mg/l) that treatment is not necessary. The drainage water passes sedimentation basins before being discharged into the northern, deeper part of Söderviken, see Figure 10-26 /10-4/. However, the discharges of drainage water will give rise to changes in the concentration of nitrogen in Asphällsfjärden and in Söderviken, which increases primary production (plankton, algae, vascular plants etc.). Owing to the low phosphorus concentrations in the receiving waters and the rapid dilution that will occur, however, the impact will be limited /10-18/.

Figure 10-26. Planned location (yellow circle) for discharge of drainage water into Söderviken.

Leachate

Leachate from the rock heap consists of precipitation and meltwater and will mainly be contaminated with nitrogen. The nitrogen will probably be leached out of the rock spoil relatively quickly, which may lead to great variations in the nitrogen content of the leachate. The leachate will have to be purified, since the nitrogen concentrations in the leachate are so high as to be toxic to aquatic organisms /10-4/.

Nitrogen removal will take place on a broad irrigation area at the rock heap and in Lake Tjärnpussen. In order to avoid flooding, and to increase purification capacity, the normal water level in Lake Tjärnpussen will be raised and some flow regulation is planned. The current maximum water level can be maintained or lowered slightly. Lowering reduces the risk of flooding of valuable forest and fen areas. Water treatment will raise the nutrient content of the water in Lake Tjärnpussen /10-4/.

Extinguishing water

Fire extinguishing, if necessary, will give rise to extinguishing water. The extinguishing water may contain soot particles and other particulate matter. The water will be discharged into Söderviken after having passed sedimentation basins.

Stormwater

Since stormwater will be managed locally within the operations area, generation of stormwater will be limited and stormwater runoff will be delayed, at the same time as pollutants will be retained in the soil instead of being discharged to receiving waters.

The stormwater in the operations area mainly contains inert dirt particles such as silicon dust and other material from crushed rock. These particles are not toxic but can nevertheless have negative effects on nearby aquatic environments via turbidity and sedimentation on underwater vegetation and bottoms. The stormwater will also be polluted by heavy metals, organic pollutants and and nutrients. These pollutants result from increased erosion in connection with logging as well as earthmoving and excavating work. The pollutants also come from exhaust gases and lubricating oils, as well as wear of tyres, roadways and brake pads. Transboundary air pollution also contributes to pollution of stormwater /10-4/. The stormwater flow shown in Table 10-1 occurs during the latter part of the construction phase when buildings and paved surfaces have been built. The flows will be lower in the beginning of the construction phase.

Unless measures are undertaken, it is estimated that phosphorus discharges could amount to about nine kilograms per year. Discharges of zinc would amount to about eight kilograms per year, while discharges of oil would be about 80 kilograms per year. If measures are adopted, these amounts will be reduced and the discharge values will be close to the background values for runoff in the area /10-4/.

Operating phase

Water management will be the same as during the operating phase and the latter part of the construction phase. The water in the operating phase will, however, have slightly different flows and pollutant contents. The leachate's nitrogen content will decrease compared with the construction phase, since the greatest amounts of nitrogen have already been leached out. The drainage water flow will increase compared with the construction phase, since groundwater inflow from the deposition tunnels will be added, at the same time as the nitrogen content of the water decreases due to reduced quantities of explosives.

Decommissioning phase

Water management during the decommissioning phase has not been studied, but in principle both water quantities and pollutant content will decrease during the decommissioning phase. The water stream with the longest duration is the waste water flow from the use of sanitary rooms. The waste water will probably be treated in the sewage treatment plant at the site using the technology available at that time.

10.1.3.8 Light pollution

Lighting during the different phases of the final repository will be chosen with regard to the working environment, safety, the surrounding landscape and nearby residents. The lighting should be adapted to the activity. Some work areas may require stronger lighting.

Construction phase

A good working environment requires functional work site lighting during the dark hours of the day. This need can be met by suitably designed and positioned light sources. This should be balanced against the requirement of low energy consumption.

Operating phase

The outdoor lighting for the facility's roads and open spaces will be traditional short lighting poles. Slightly taller poles are planned along the access road. One or more lighting masts will be used at the rock heap. In order to prevent light from spreading beyond the operations area, the lighting will be aimed and shielded as much as possible. Tree screens will be preserved wherever possible.

The lighting concept will be further studied in the design of the facility.

Decommissioning phase

Work site lighting during the decommissioning phase is expected to be similar to that during the construction phase.

10.1.3.9 Waste

Numerous goods and products will be used during construction, operation and decommissioning of the final repository. Some of these goods and products produce waste that must be managed. SKB's objective is to minimize the waste quantities. This objective will be achieved by a combination of good facility design and choice of materials, which can also contribute to efficient sorting of materials when the facilities are dismantled or demolished.

Waste is divided into hazardous and non-hazardous waste. Hazardous waste is managed separately from other waste and is kept in dumpsters pending collection. Before the facility has been designed in detail, only a rough assessment of the waste quantities is possible.

Construction phase

It is estimated that 50 tonnes of hazardous waste and 1,100 tonnes of other waste will arise during the construction phase /10-8/.

Operating phase

Since the activity is fairly constant over time, the waste quantities are not expected to vary from year to year during the operating phase. Hazardous waste is calculated to amount to 5 tonnes per year or just over 200 tonnes altogether and other waste to 120 tonnes per year or 5,400 tonnes altogether /10-8/.

The estimated waste quantities are based on the assumption that the machines are properly maintained and cared for. Due to advances in technology and an ambition to optimize capacity throughout the operating phase, it is likely that vehicles, machines, computers and other technically advanced equipment will have to be replaced several times during the operating period. This equipment becomes waste at the end of its service life.

Decommissioning phase

Dismantling and remediation measures on the ground surface will depend on future wishes and requirements. Contaminated materials may comprise an additional fraction during the decommissioning phase. In this case the contamination may have occurred on areas above and below the surface where vehicles have stood and chemicals have been handled. Contaminated materials may constitute hazardous waste that must be managed when the final repository is to be decommissioned.

Hazardous waste is calculated to amount to about 240 tonnes, contaminated materials to at most 100,000 tonnes and other waste to about 42,000 tonnes /10-19/.

10.1.3.10 Energy use

In order to reduce energy use, the entire final repository will be designed so that heat is recovered from the exhaust air and the drainage water. Ventilation accounts for a large portion of the energy use and will therefore be demand-controlled, which means that it can be reduced when there is no activity in an area.

Construction phase

Electric power will be needed for heating of buildings, lighting, ventilation, drainage, machinery and elevators. It is estimated that a total of about 60 gigawatt-hours (GWh) will be used during the construction phase. To this must be added consumption of diesel oil for vehicles, machinery and heating, estimated at a total of about 640 cubic metres /10-8/.

Energy use is reduced by using the skip for vertical transport of rock spoil during the latter part of the construction phase, instead of hauling rock spoil on the ramp.

Operating phase

More vehicles and machines will be used in the operating phase than in the construction phase. Electricity use during the entire operating phase is estimated to be 1,100 GWh or about 25 GWh per year. Diesel consumption for vehicles and machines is estimated at just over 100 cubic metres per year or a total of 4,500 cubic metres/10-8/.

Energy use will be reduced during the operating phase as well by use of the skip for vertical transport of rock spoil, buffer and backfill.

Decommissioning phase

Electrical energy is required during the decommissioning phase as well. It is estimated that 100 GWh of electricity and 2,600 cubic metres of diesel will be consumed /10-20/.

10.1.3.11 Water consumption

The activities at the final repository will consume water during all phases. Water will be used in toilets, sinks, kitchenettes, wash basins and showers as well as at sanitary installations in the underground part of the facility. Water will also be used for drilling, blasting and excavating. Consumption of water for drilling, blasting and earthmoving is estimated at about 0.15 cubic metre per cubic metre of solid rock, which is normal for a rock works contract of this size. The figures on water consumption are taken from /10-5/.

Construction phase

Water consumption will vary during the construction phase depending on the intensity of the rock excavation work. Water consumption in sanitary rooms and for rock works for the whole period is estimated at about 170,000 cubic metres.

Operating phase

Water consumption during the operating phase is estimated at about 15,000 cubic metres per year and about 680,000 cubic metres altogether.

Decommissioning phase

Water consumption will be less during the decommissioning phase than during the construction and operating phases, since there is no rock work. Water will be consumed in sanitary rooms as long as people are working within the area. Water consumption during the decommissioning phase is estimated at 3,000 cubic metres per year a total of 39,000 cubic metres for the entire period.

10.1.3.12 Handling of rock spoil and resource consumption

Construction phase

The ramp and shafts, the central area and parts of the deposition area will be excavated during the construction phase. Handling of rock spoil is described in section 10.1.2 "Description of activities". A total of about 1.6 million tonnes of rock spoil will be produced /10-8/. Some of the rock spoil will be reused in the facility during the construction phase, but most is surplus that can be disposed of on the open market. It is assumed that much of the rock spoil can be used locally or regionally.

Rock spoil will also be needed during the construction phase to fill in the ponds in the operations area, for example. The volume to be filled in is 180,000–200,000 cubic metres, see /10-21/. If the material has a density of about two tonnes per cubic metre, this means that 350,000–400,000 tonnes is needed for fill in the operations area.

Operating phase

Excavation of rock continues during the operating phase, albeit on a smaller scale than in the construction phase, when all tunnels in the repository area will be excavated. This work is expected to generate about 120,000 tonnes of rock spoil per year, which is equivalent to about 4.8 million tonnes altogether. Backfilling of the deposition tunnels with bentonite in the form of blocks and pellets is also begun during the operating phase. It is estimated that approximately 50,000 tonnes of bentonite per year, or a total of 2.3 million tonnes, will be consumed for backfill and buffer /10-8/. Total global production in 2007 was 15.7 million tonnes.

The deposition holes will have a slot at the top edge. This enables the cross-section of the deposition tunnels to be reduced, which means that the quantity of excavated rock, and thereby the need for backfill material, is reduced.

Decommissioning phase

During the decommissioning of the final repository, the main and transport tunnels will be closed, along with the central area, ramp and shafts for transport and ventilation. It has not yet been decided which materials will be used for closure, but candidates are bentonite, clay and crushed rock. One proposed closure concept entails backfilling the main and transport tunnels with blocks and pellets of bentonite in the same way as the deposition tunnels, while the central area is backfilled with crushed rock. Shafts and ramp are backfilled with bentonite and crushed rock /10-8/.

An assessment of how much material is consumed will be made at a later stage, since decommissioning lies so far in the future.

10.1.4 Effects and consequences

10.1.4.1 Natural environment

Land use

Land will be utilized for the surface part of the final repository. Most of this land is industrial land with limited natural values, but land located near the shore of Söderviken with high natural values will also be included. The main reason for the high natural values attributed to this land is the occurrence of the pool frog, see Figure 10-27. Three ponds, in two of which the pool frog has been observed, will be filled in. The consequences of land use for the area's natural values are reported in /10-18/.

The pool frog has been encountered in seven ponds in the investigation area for the natural value inventory, and the establishment of the operations area could have severe negative consequences for the species unless measures are adopted. Each pond is important for the local pool frog population.

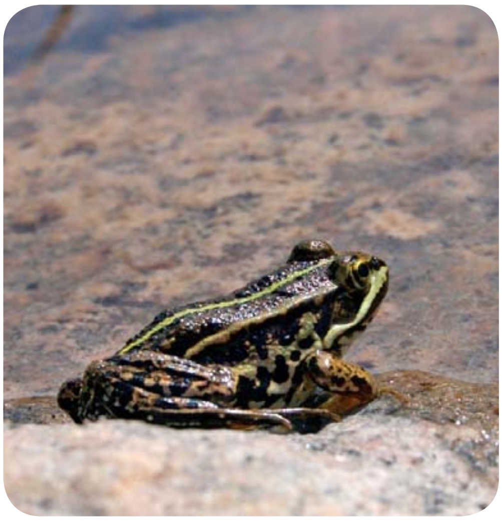


Figure 10-27. Pool frog at a pond in the Forsmark area.

Since the final repository will alter living conditions for the pool frog, SKB will apply for an exemption from the Species Protection Ordinance and draft a proposal for how to compensate for the loss of pool frog habitat. SKB plans to do this by creating new ponds in suitable settings. With the planned compensatory measures, establishment of the surface part of the final repository is not expected to entail any negative consequences for the local pool frog population. The application for an exemption from the Species Protection Ordinance will include a detailed account of the impact of the facility on species included in the Ordinance, as well as planned compensatory measures to minimize this impact.

The plant for treatment of leachate from the rock heap represents a new encroachment in the natural environment, see Figure 10-28. A rich fen of regional interest next to Lake Tjärnpussen could be affected. The assessment is that the protective measures for handling and treatment of leachate will entail limited consequences for Lake Tjärnpussen and surrounding environments, at the same time as they reduce SKB's discharges to water and resulting effects on aquatic environments. Discharge of drainage water to Söderviken can be expected to have limited effects in the bay and in Asphällsfjärden. Nitrogen residues in the drainage water could cause increased growth of underwater vegetation. However, the nitrogen concentrations are low (below five mg/l) and SKB intends to discharge the drainage water into the deeper part of Söderviken, which is in direct contact with Asphällsfjärden and the cooling water channel intake. This results in great dilution of the drainage water. Furthermore, phosphorus will quickly become the limiting factor for vegetation growth.

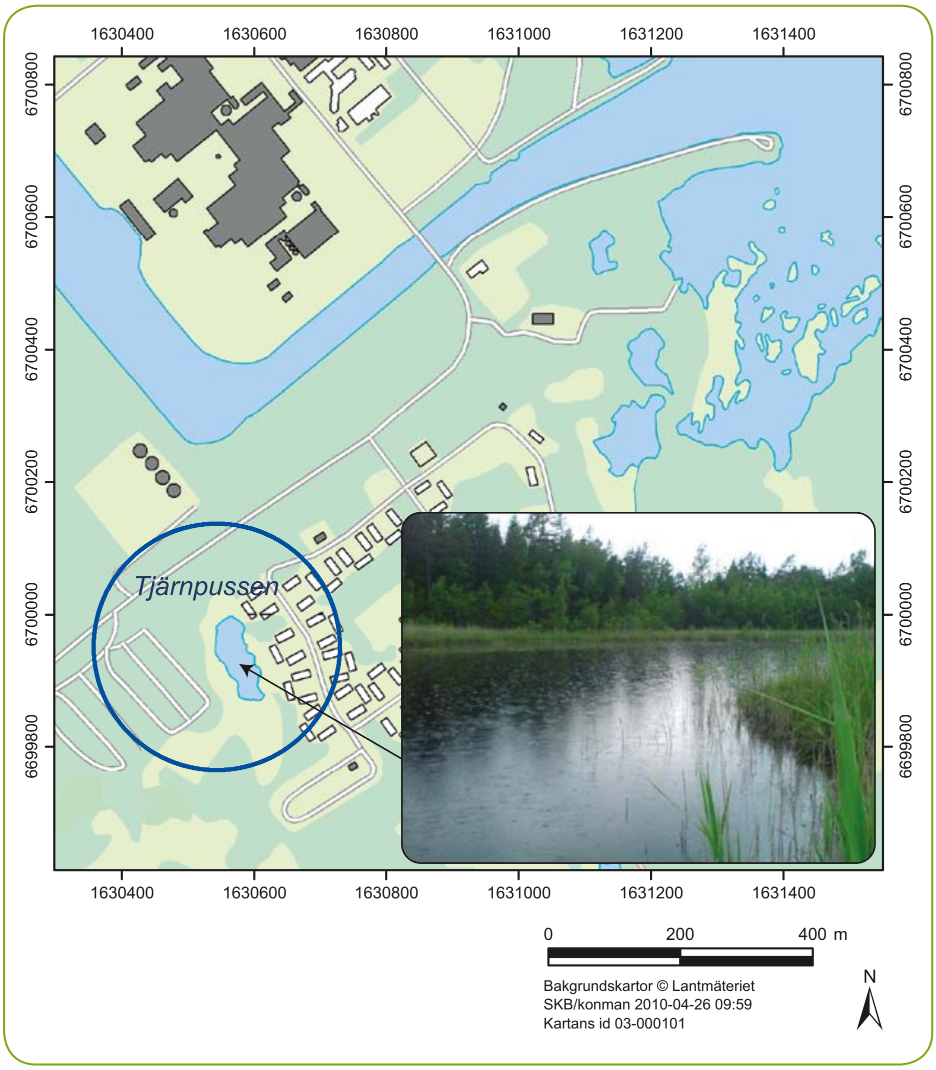


Figure 10-28. Map showing Tjärnpussen Lake and photo of part of the water area. Ponds harbouring pool frogs can be seen in the northeast quadrant of the map.

In view of this, and the fact that the receiving waters are assessed to be relatively resilient, the consequences for the aquatic environment are considered to be small.

A ventilation station is planned to be built approximately 1.5 kilometres east of the operations area. The impact area for the ventilation station contains herb-rich mixed coniferous forests of regional interest, plus a rich fen of national interest. The road to the ventilation station may affect surrounding rich fen environments if no preventive measures are taken. A simple preventive measure could be to build a permeable road embankment so that local surface water and groundwater flows are not affected.

The area around Forsmark has a rich bird life, but SKB's land use is not expected to impact any areas with bird fauna worthy of protection. Breeding birds can, however, be disturbed by people who come near their nests.

Figure 10-29 shows the consequences for the natural environment of land use if no preventive measures are adopted.

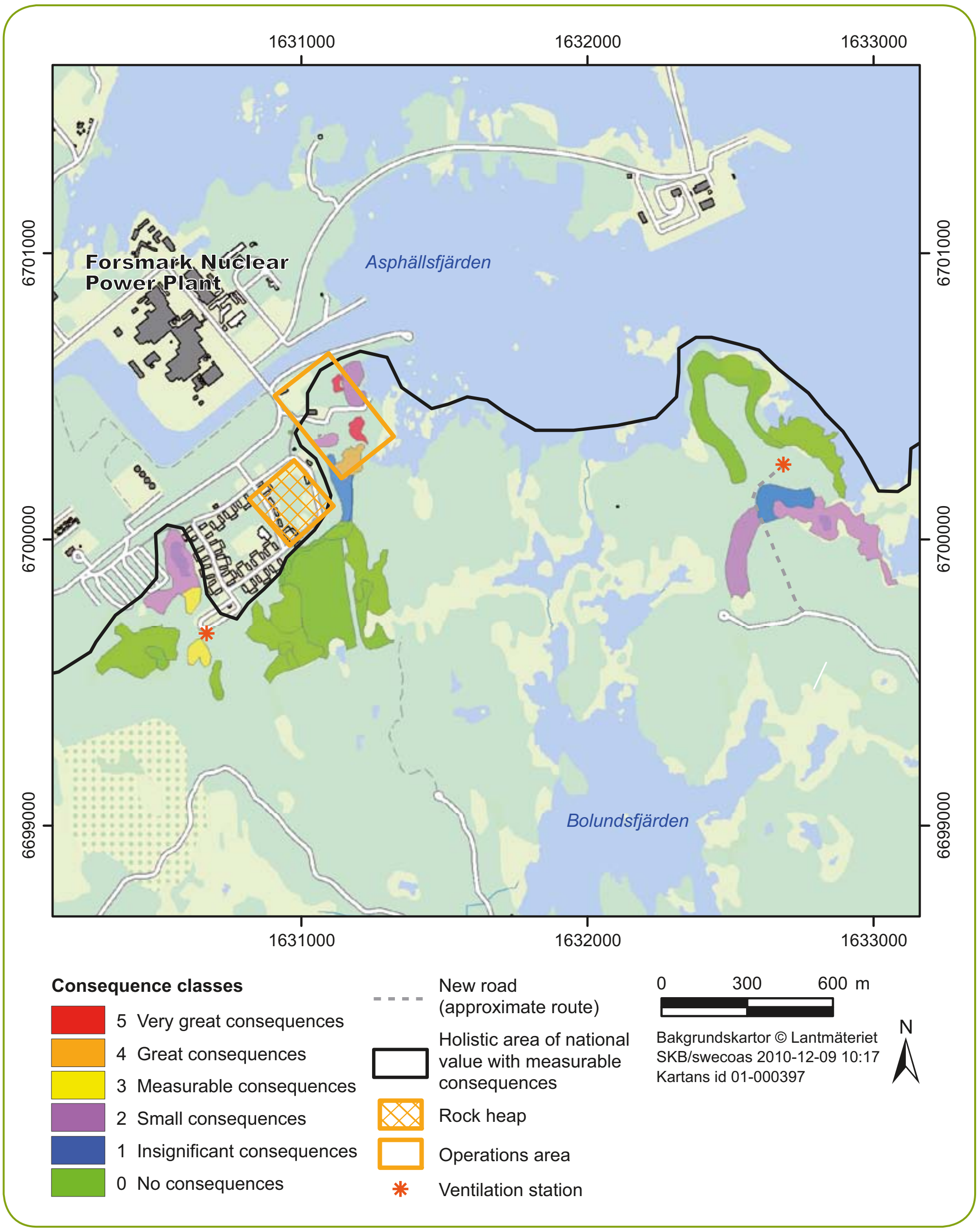


Figure 10-29. Map showing consequences for the natural attractions that may be affected by SKB's land use.

Groundwater lowering

The groundwater lowering (drawdown) that occurs during the construction and operating phases for the final repository may entail consequences for surrounding natural areas.

The sensitivity of the natural values to changes in the groundwater level is decisive for any consequences. The Forsmark area is characterized by wetlands, fenlands and ponds with high natural values. A prerequisite for the preservation of fen and pond environments in low-lying terrain is a high groundwater table. Most inventoried wetlands in Forsmark are assessed to be sensitive to a lowering of the groundwater table, see Figure 10-30.

Figure 10-30. Shallow pond and surrounding rich fen that may be sensitive to a groundwater lowering.

Even moderate drawdowns of less than a decimetre cause a change in the vegetation towards drier types, and in the long run invasion by shrubs and trees. During their reproductive period, the pool frog and other amphibians are particularly sensitive to drying-out of the ponds. Investigations of soil layers and sediments beneath the wetlands and the ponds shows relatively varying conditions /10-22/. Several of the wetlands and ponds contain larger or smaller segments of impervious sediments such as clay and mud, but often parts of the bottoms consist of till. The lakes Bolundsfjärden and Norra Bassängen are important nursery grounds for fish, and a lowering of the lake level could adversely affect fish migration. The area also contains a number of valuable woodland habitats with herb-rich calcareous coniferous forests. These woodlands and have varying moisture conditions and groundwater levels, but are dominated by healthy to moist conditions. The forests' natural values are less sensitive to groundwater lowering, since the natural values are mainly determined by the age and management of the forest.

Roughly half of the approximately 70 identified valuable wetland sites, ponds and surface waters within the investigation area will be affected by the calculated groundwater lowering due to the fact that they are located within the "finger-like" zones where a lowering of the groundwater has been predicted, see Figure 10-31. Another fifteen or so sites will be affected by a changed groundwater balance due to the fact that they are located immediately adjacent to the impact area for groundwater lowering. The calculations of the scope of the groundwater lowering are based on a "worst case" scenario where the whole repository is open at the same time and the hydraulic conductivity to the tunnels is assumed to be 10^{-7} metres per second. The areas where the groundwater lowering is calculated to be 0.1 metre or more are considered to be impacted.

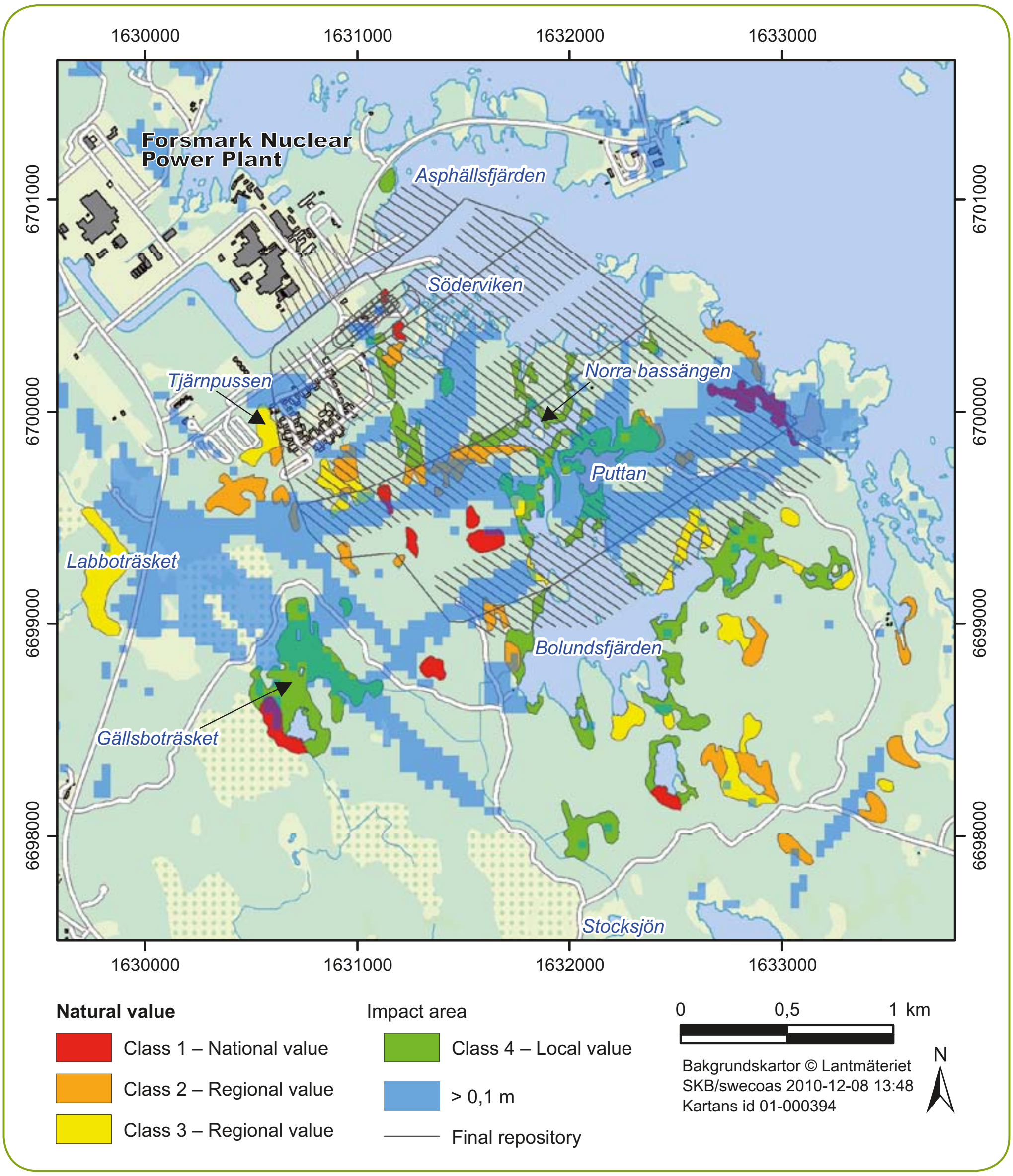


Figure 10-31. Predicted impact area for lowering of the groundwater table, plus identified and natural value-classified wetland sites. The impact area pertains to a hypothetical case with the whole repository open at the same time and a hydraulic conductivity (K_{grout}) of no more than 10^{-7} m/s.

The sites affected by the calculated groundwater lowering under these conditions have been investigated based on each site's natural values and sensitivity to groundwater impact and how great the calculated groundwater lowering will be on the site. Seven of the ten highest classified wetland sites (national value) in the investigation area are located within or next to the impact area. Groundwater drawdown is assessed to entail very great consequences for two sites (of national interest), great consequences for 15 sites and noticeable consequences for eight sites if no measures are adopted.

The rich fen and the ponds exhibit great biodiversity. Several red-listed and protected species may be affected by a groundwater lowering. Species such as pool frog, fen orchid, flea sedge and Geyer's whorl snail are dependent on wet environments. If no measures are taken, it is assumed that modelled groundwater lowering can lead to great negative consequences. The consequences of groundwater lowering for the natural environment according to the worst case scenario and without any preventive measures being adopted are shown in Figure 10-32.

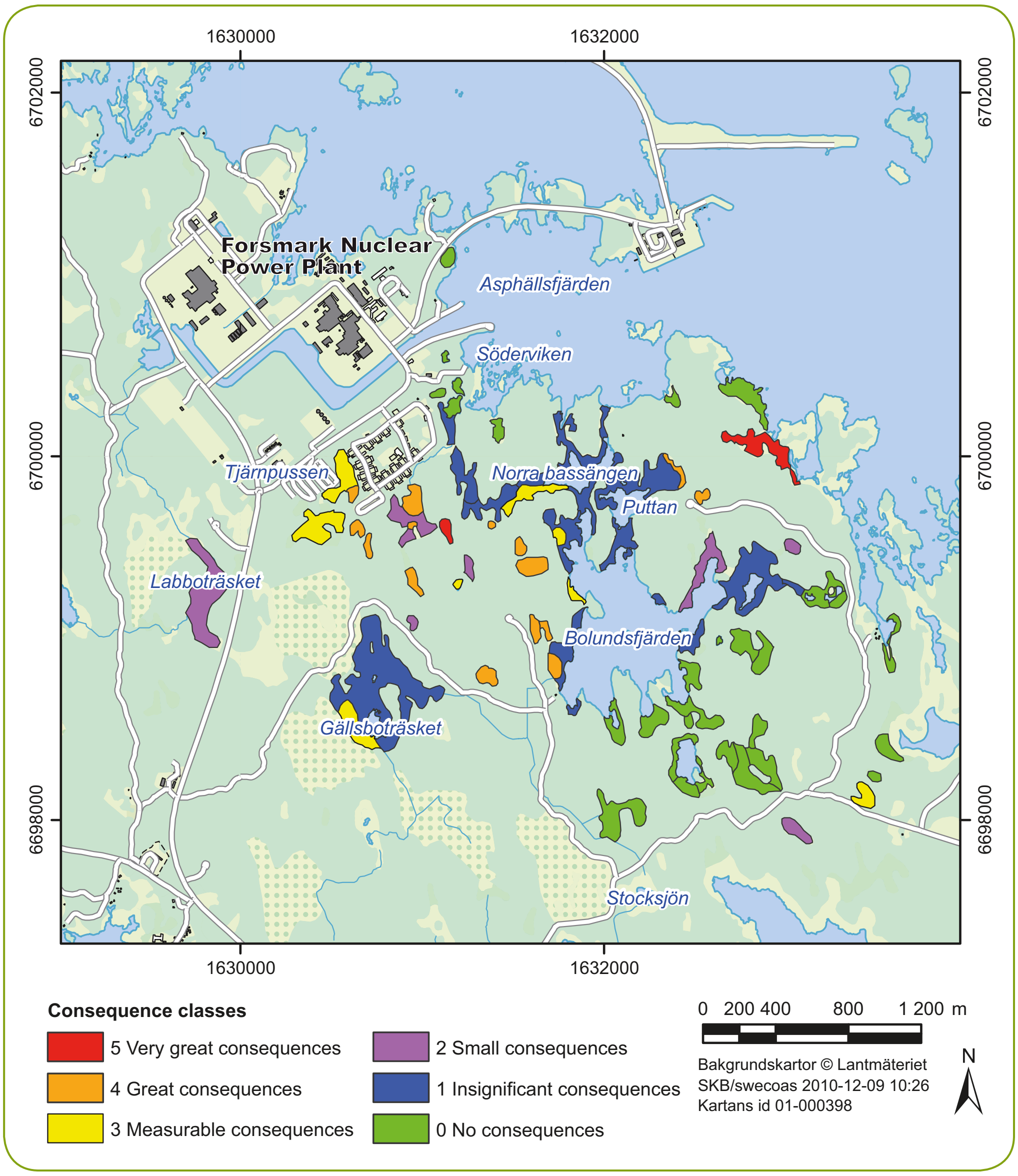


Figure 10-32. Assessment of consequences for natural value-classified wetland sites, based on modelled groundwater lowering at an assumed hydraulic conductivity of 10^{-7} m/s.

Owing to the possible negative consequences of groundwater lowering, a preparedness for consequence-mitigating measures is planned for the most sensitive or valuable natural attractions (see section 12.4.1.3). One measure that is planned is supplying water to valuable rich fens and calcareous ponds (with pool frog and/or fen orchid) that run the greatest risk of being affected by a groundwater lowering. Local infiltration of water creates an artificial groundwater table so that the superficial groundwater will not fall below normal levels. Damage to natural values can thereby be avoided, see Figure 10-33.

Another measure that is planned is management of wetlands with high natural values and/or wetlands that risk being affected by groundwater lowering. If suitable management measures are adopted in good time, the consequences for these environments can be mitigated.

Groundwater diversion is expected to give rise to a very small lowering of the water level in the lakes Bolundsfjärden and Norra Bassängen and is not expected to affect the importance of the lakes as nursery grounds for fish.

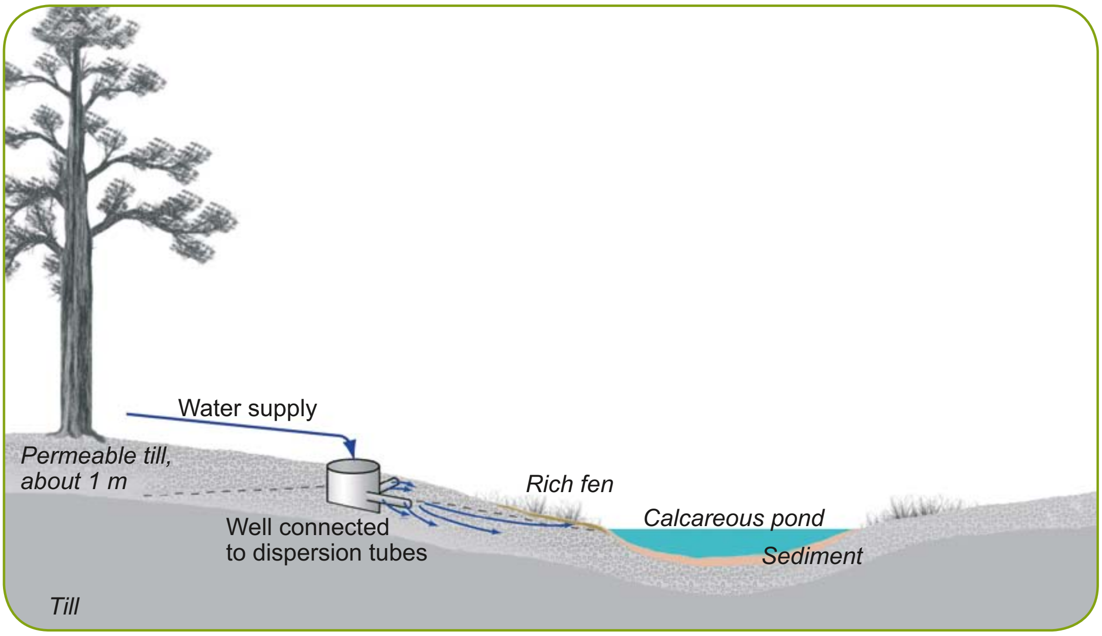


Figure 10-33. Schematic illustration of supply of water to rich fen in order to maintain the water level.

A groundwater lowering could lead to noticeable negative consequences for some ten or so forest sites that harbour species associated with the wetter woodland areas. No preventive or consequence-mitigating measures aimed at individual sites are planned for these environments. On the other hand, SKB plans to apply conservation-oriented management of woodland areas with high natural values, which also contributes to mitigating the consequences of groundwater lowering.

For more details on impact assessment and proposed measures, see /10-5/ and /10-23/.

10.1.4.2 Recreation and outdoor activities

The area around the planned final repository has low value for recreation and outdoor activities, according to the assessment model used in /10-24/ and is mainly used by nearby residents. The area does have moderate value for birdwatching, however. The area nearest the nuclear power plant is currently disturbed by noise from the activity at the nuclear power plant, traffic and the static converter station. Further away from the nuclear power plant and from the major roads, however, the environs are relatively undisturbed by human activity and offer good potential for relaxation and enjoyment of nature. The greatest impact which the final repository will have on outdoor activities in the area consists of noise and an increased human presence. Areas where expectations of experiencing peace and quiet are higher are generally more sensitive to noise disturbances.

Construction phase

The noise levels east and south of the nuclear power plant will increase during the construction period due to the activity at the final repository. The noise levels will be particularly high to the east and south during periods when the mobile crusher is being used in the rock heap. The noise levels north and west of the nuclear power plant will only be marginally affected. Since the area around the nuclear power plant is already exposed to elevated noise levels today, the area's value for recreation and outdoor activities will not change due to the final repository activity, so the consequences will be small.

The noise levels around Forsmarks bruk, which is of national interest for the cultural environment, will increase as a result of the transport activity generated by the final repository, which will have some impact on the recreational values at Forsmarks bruk and the surrounding area. The consequences of this are assessed to be small, however.

The planned facilities entail a small change in existing hunting grounds, and noise disturbances could possibly affect hunting. The contribution made by the facility to an increase in traffic-related wildlife accidents is assessed as insignificant, which means that hunting is not affected. The final repository will probably entail little or no measurable impact on the general behaviour of wildlife, which means no consequences for hunting /10-17, 10-21/.

Increased human movement in the area resulting from the various activities at the final repository may be experienced as disturbing in a tranquil and quiet environment. This particularly affects the recreational experience of people in the woods and fields, such as mushroom pickers, bird watchers and orienteerers. The increase in traffic may also lead to increased insecurity.

Nor will accessibility for canoeing, boating, skating or fishing be affected to any significant extent by the increase in ship traffic. The accessibility of the Biotest Basin will depend on whether the road to SFR will remain open to the public. This will in turn depend on how extensive the requirements on physical protection will be for the nuclear power plant and the final repository. Current plans call for the road to SFR to be kept open to the public.

In summary, the final repository is not assessed to give rise to any appreciable impact on, or any great consequences for, recreation and outdoor activities.

Operating phase

Since rock crushing can occur during the operating phase too, the noise levels around the final repository will be at roughly the same level as during the construction phase. However, crushing will be done in campaigns during a few weeks per year, and during the intervening periods the noise levels around the facility will be slightly lower than during the construction phase, which is advantageous for outdoor activities.

During the operating phase the guideline values for external industrial noise may be applied to the activities at the final repository. The guideline values for external industrial noise within areas planned for recreational accommodation and outdoor activities are 40 dBA in the daytime and 35 dBA in the evening and at night. The area around the final repository is included in an area of national interest for outdoor activities in accordance with Chap. 4, Secs. 2 and 4 of the Environmental Code, but is also zoned for industry in a detailed development plan. During the periods when the mobile crusher is being used within the rock heap, the surface area exposed to noise levels above 35 dBA increases from about eight square kilometres to about 13 square kilometres. Most of the additional area lies east of the nuclear power plant, where the value for recreation and outdoor activities is low, see Figure 10-34.

During the operating phase a second ventilation station will give rise to noise, land use and an increased human presence. The ventilation station causes limited noise and land encroachment, and the consequences for outdoor activities are therefore assessed to be small.

In summary, the overall consequences for recreational and outdoor activity values are assessed to be roughly equivalent to those during the construction phase.

Decommissioning phase

No new land needs to be occupied and noise levels can be expected to be more or less unchanged from previous phases. The assessment is therefore that the consequences for recreation and outdoor activities do not change during the decommissioning phase.

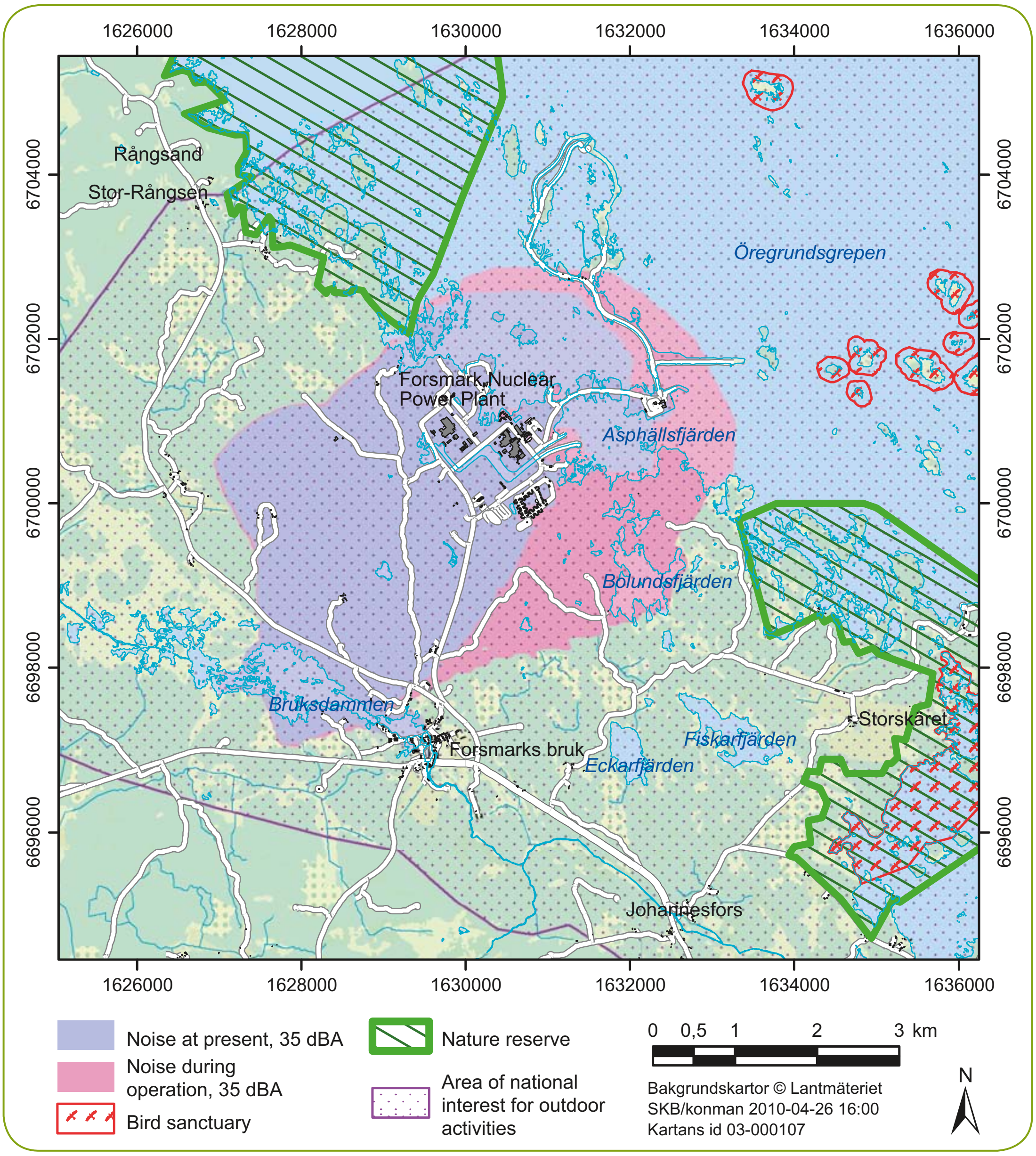


Figure 10-34. Range for noise over 35 dBA at present and when the final repository is in operation. Transport noise is not included.

10.1.4.3 Cultural environment

Construction phase

A cultural environment analysis, stage 1 of an archaeological survey and an in-depth inspection of Söderviken have been carried out in order to assess cultural values in the area /10-25/. The findings show that the Söderviken area does not harbour any particular cultural heritage values and is separated from valuable cultural environments. No fixed archaeological remains are affected by the siting area. There are a couple of historical remains near the siting area and near the ventilation stations, but it is assessed that they can all be exempted in the event of development. Furthermore, there is assessed to be a very small probability that concealed underground remains might be affected. In view of this, the consequences for the cultural environment are assessed to be non-existent or small.

The most valuable historical remains and environments are around Forsmarks bruk, situated about five kilometres south of Söderviken. The mill town is relatively well preserved, but its direct link to the surrounding countryside has been weakened by national road 76 to the south and the entrance road to the nuclear power plant to the north. Forsmarks bruk is both a low-protection historic landmark and an area of national interest and regional interest for cultural heritage preservation. The final repository is assessed to have some impact on the historic landmark and the national interest site of Forsmarks bruk owing to increased traffic. There is noise impact due to traffic already today, mainly from national road 76. The additional sound has some negative consequences in the form of a less peaceful experience of parts of the area. Since the noise change is so small, however, the consequences for the cultural environment are assessed to be small /10-25/.

Operating phase

The cultural environment is mainly affected by the establishment of the industrial area and its impact on the surrounding cultural landscape. This impact occurs already during the construction phase, and the impact during the operating phase will be largely unchanged. The risk of encountering archaeological remains in connection with the construction of the ventilation station is assessed to be very small. The consequences for the cultural environment are thereby assessed to be small.

Decommissioning phase

The consequences for the cultural environment during the decommissioning phase are assessed to be small, since no new land surfaces are occupied and the area is already exposed to noise disturbance.

10.1.4.4 Landscape

Construction phase

The landscape will be altered during the initial phase of construction, since most of the land surfaces needed for the operation of the facility will be occupied. Construction of buildings within the operations area will continue throughout the construction phase but will be completed prior to the operating phase.

In the landscape analysis that has been done /10-26/, the area around the nuclear power plant is described as a lake-rich forest landscape dominated by low-lying coniferous forest extending all the way to the coast, with many watercourses and wetlands. As a result, the croplands are small with irregular shapes and lie scattered in the landscape, often in small asymmetrical pockets in the bouldery till. Large contiguous croplands are only found around Forsmarks bruk and at Storskäret. The area in question is flat with small elevation differences. The higher parts of the landscape consist of hills or wave-washed bouldery till.

The area has a modern industrial character today with large-scale buildings that stand in stark contrast to the surrounding forest and coast landscape. The three power plant buildings form large landmarks and are very dominant in the area. The industrial area adjacent to the reactor units is characterized by large, functional paved surfaces, rubble fills, straight wide roads at right angles and fenced enclosures.

The planned facility will above all affect the forest landscape, which is highly resilient, and the outskirts of the lake-rich forest landscape.

The facility will be designed to fit in with the existing buildings, see Figure 10-35. The planned operations area will strengthen the character of the industrial area and be surrounded by the low-lying coniferous forest. The highest buildings will be the skip building (around 50 metres in height) and the production building (around 35 metres in height). Both of these buildings will be lower than the nuclear power plants' reactor units. The final repository will be visible from the water, but the nuclear power plant will dominate from this vantage point as well, see Figure 10-36.

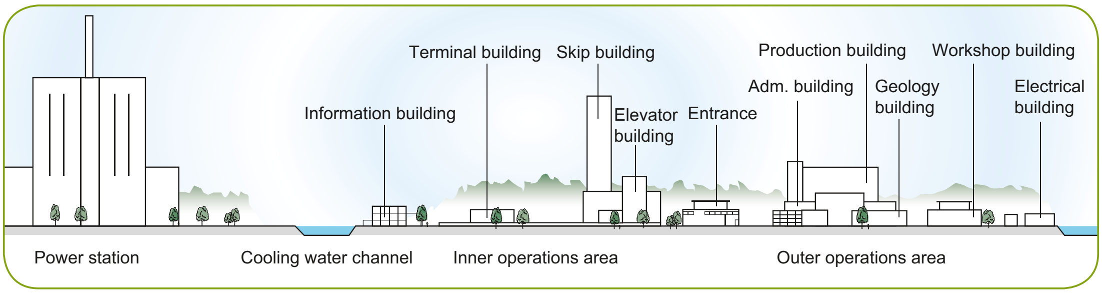


Figure 10-35. The final repository's surface part consists of low office and storage buildings, plus a few higher buildings, of which the skip building is the highest.

Figure 10-36. Photomontage of the planned final repository and the nuclear power plant (at right), viewed from the SFR site.

In order to assess the final repository's visual impact on the landscape, a visibility analysis has been carried out. The results of the visibility analysis show from where the buildings in the operations area are visible. Besides the topography, the vegetation is of great importance for how visible the facility will be. Figure 10-37 therefore shows two separate scenarios: one where the vegetation is retained and one where all forest, except that which is protected in e.g. Nature 2000 sites, has been felled. With today's vegetation, the facility is less visible than if the forest is felled. The pictures show from where the production building is visible in the landscape. Most of the operations area will be lower than the production building. The skip building, the tallest building, will be a relatively slender and light building, making it more difficult to distinguish against the sky. In both scenarios, the final repository will mainly be visible from the sea.

The rock heap has a local visual impact on the landscape and will mainly be visible from the nearby road. The rock heap will not be higher than nearby trees. A vegetation-covered earth embankment is planned around the rock heap. Viewed from the water, the rock heap will be obscured by the buildings in the planned facility.

In order to limit the visual impact on the landscape, which is characterized by contrasting landscape types, the final repository will be built in an area which is already affected by other industrial facilities. The visual consequences for the landscape are thereby assessed to be small. The operations area on the surface will, however, lie close to the coastline, and great care will be taken in designing the facility.

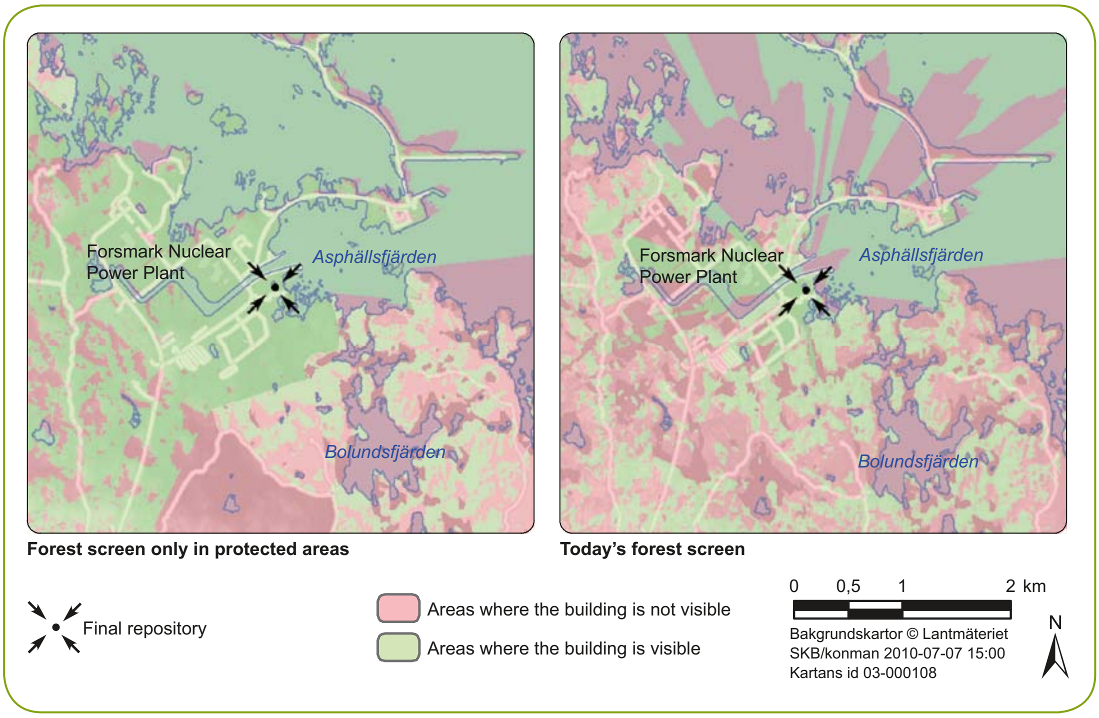


Figure 10-37. At a height of 33 metres, the production building's tower is visible in the green areas. The left map shows visibility with maximum trees felled (all trees felled except in protected areas), while the right picture shows visibility with today's vegetation.

Operating phase

When the operating phase begins, all buildings within the operations area are completed and the visual impact on the landscape does not change. The ventilation stations that are built have a marginal visual impact on landscape, since they are built in forest areas where they are not visible at a distance.

It is not known how the site will be utilized if the nuclear power plant is taken out of service. If it is used for some kind of energy production in the future as well, the consequences for the landscape will be unchanged. If the nuclear power plant is instead decommissioned and dismantled, the final repository will be a much more noticeable feature in the landscape.

Decommissioning phase

As the final repository's surface facilities are dismantled, the visual impact on the landscape will diminish. How great the consequences of decommissioning will be depends on whether certain buildings will be saved and whether surrounding areas will be restored to green field or another enterprise will be established on the site.

10.1.4.5 Residential environment and health

Noise

The information on noise has been taken from the noise study that has been done /10-12/. Since the study was completed, the need for rock shipments has been slightly revised. Due to these changes, the figures on rock shipments during the initial part of the construction phase is about twelve percent lower than the figures on which the study is based, while they are about twelve percent higher for the latter part of the construction phase and the operating phase. The assessment is that this change will not affect the equivalent noise levels or the number of residents exposed to noise levels above the guideline values. Nor is the number of residents exposed to maximum noise levels above the guideline values affected.

Construction phase

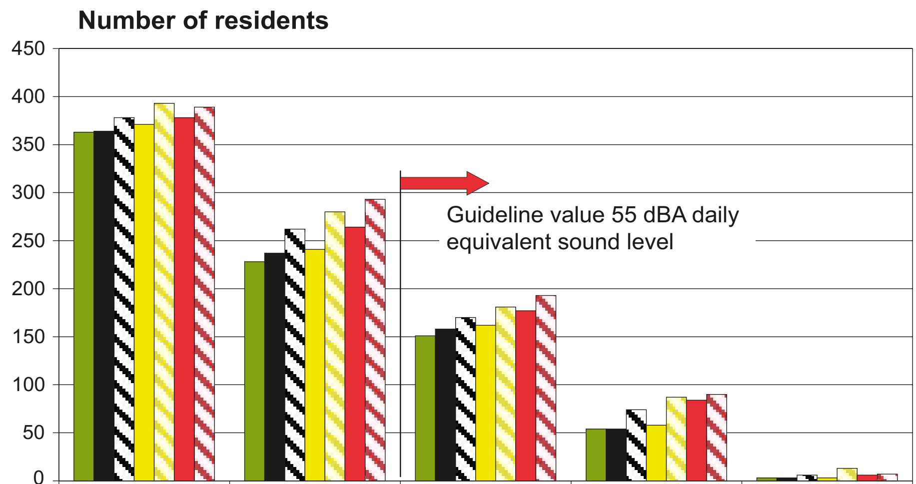
The civil engineering works will cause the noise levels in the environs to increase. During the construction phase, no permanent residents around the final repository will be affected by equivalent levels above 50 dBA in the evening, which is the guideline value for construction noise. The long construction period warrants assessing the noise from the activity as industrial noise. The guideline values are not exceeded even if the noise from the activity is assessed as industrial noise, since no permanent residents will be affected by equivalent levels above 35 dBA in the daytime, which is the guideline value for vacation home areas. It is also the lowest guideline value stipulated for noise from both construction activity and industrial activity. The assessment is therefore that the noise from the activity at the final repository will not give rise to noticeable health effects for permanent residents.

Housing for temporary accommodation is planned at Igelgrundet. There are no guideline values for noise for temporary residents, but the sound levels at the temporary housing is calculated to be lower than existing guideline values for construction noise at permanent and secondary residences.

The guideline values for structure-borne sound are the same as for the airborne noise. Preliminary results show that based on the relatively great distances between surrounding properties and the final repository, structure-borne sound from underground works is not assessed to give rise to audible sound levels (above 25–30 dBA) in any properties.

The road traffic noise along national road 76 is already perceived as disturbing by the residents along the road. The additional transport volume from the final repository will not increase the noise along the transport routes. The noise levels will increase most nearest the facility and decrease with the distance from the facility. South of Börstil, transport related to the activity at the final repository will not change the noise level more than marginally. The number of residents exposed to sound levels above 45 dBA today and in the typical years 2015, 2018 and 2030 (the operating phase) with and without the final repository is shown in Figure 10-38.

The distance from the transport route at which the equivalent sound level has been attenuated to 55 dBA is estimated to increase by 15 metres in 2018 compared with the situation without a final repository. This means that the number of residents exposed to road traffic noise above 55 dBA will increase by about ten in 2015 and about 20 in 2018. The additional properties are located above all in Johannisfors, Norrskedika and Börstil. Measures to reduce the road traffic noise along these sections can be considered, but responsibility for this rests with the Swedish Transport Administration (formerly the Swedish Road Administration).



Equivalent sound level	> 45 dBA	>50 dBA	>55 dBA	>60 dBA	>65 dBA
2006 current situation	363	228	151	54	3
2015 zero alt.	364	237	158	54	3
2015 build-out	378	262	170	74	6
2018 zero alt.	371	241	162	58	3
2018 build-out	393	280	181	87	13
2030 zero alt.	378	264	177	84	6
2030 operating phase	389	293	193	90	7

Figure 10-38. Number of residents along the section from Forsmark to the Port of Hargshamn exposed to equivalent sound level in different sound intervals.

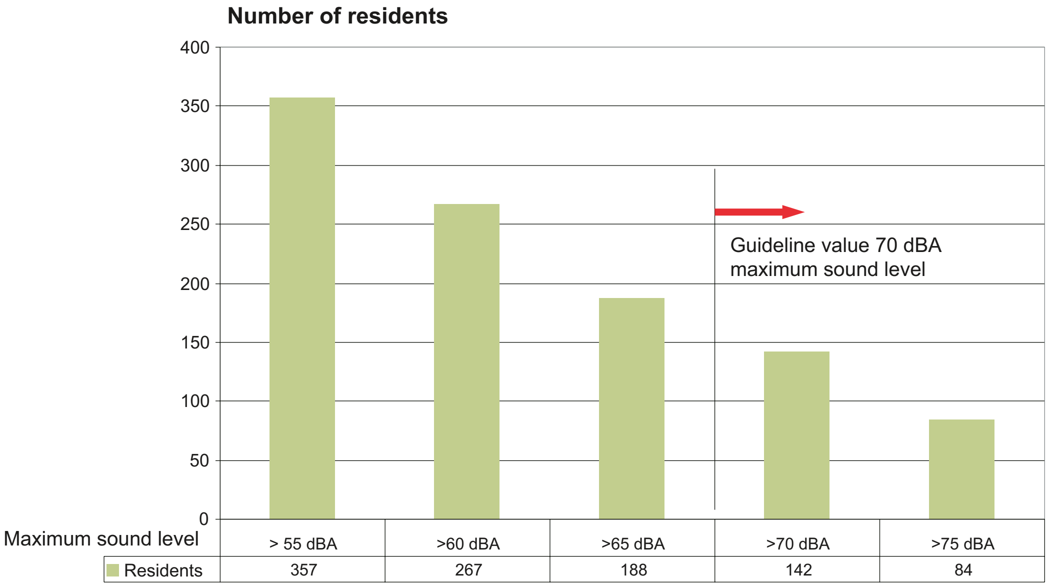


Figure 10-39. Number of residents exposed to maximum sound level within different sound level intervals along the transport routes.

The maximum sound level is independent of the different phases of the work, so the number of residents exposed to a maximum sound level above the guideline value does not change, see Figure 10-39. Since heavy traffic occurs on the roads today, the figure also applies to the current situation.

Guideline values for noise are not based on health risks but on the degree to which people can be expected to be disturbed. For example, 30–35 percent of a group are disturbed, and approximately ten percent are very disturbed, by road traffic noise when the noise level is on a par with the guideline value for permanent residences (55 dB).

Without a final repository, it is estimated that more than 50 persons will be annoyed by traffic noise in the more densely built-up areas along the section Forsmark–Hargshamn in 2018. Approximately 20 of these persons are expected to experience the disturbance as severe. During the construction of the final repository, another five persons are expected to experience severe disturbance due to the increased number of transport trips.

Physiological impact on the cardiovascular system has been linked to higher noise levels. Among residents aged 45–70 years who are exposed to more than 55 dBA during a ten-year period, the expected risk increase for both high blood pressure and more serious heart disease can be estimated at 10–40 percent. This may be of importance primarily for persons with high blood pressure, which afflicts 40 percent of the individuals in the specified age interval when milder forms are also included. It can be assumed that some ten or so persons in this age group will be exposed to levels above or equal to 55 dB in connection with the peak in transport volume to and from the final repository in the typical year 2018. However, this will only contribute to one or two cases of high blood pressure.

Sleeping problems are a particularly serious effect of noise exposure. An important causal factor is recurrent noise peaks levels at night. However, no increase in heavy transport is planned during evenings and nights, so sleeping difficulties should not increase compared with the situation without a final repository.

A couple of schools are exposed to transport noise today, one of which is exposed to facade noise levels above 55 dBA. The final repository will not have any impact on school activities.

Operating phase

Operation of the skip, use of heavy vehicles on the work site and rock handling on the rock heap are the noisiest tasks. No residents will be affected by equivalent levels above 35 dBA (guideline value for industrial noise during the evening in recreation areas) or above 40 dBA (guideline value for industrial noise in the daytime in vacation home areas).

A mobile crusher, which mainly produces low-frequency noise, may also be used in campaigns. Low-frequency noise can be experienced as more disturbing than "normal" noise. If the mobile crusher is running both in the daytime and during evenings and nights, there is a greater probability that it will cause disturbance in the evening and at night. But the level will not be so high that the guideline value for low-frequency noise indoors at a permanent residence will be exceeded in a normally insulated house.

The assessment is that the situation for permanent residents in the area will not differ from that during the construction phase. The sound level at the temporary housing will be lower than during the construction phase, and no health consequences are expected due to the noise from the facility.

The number of transport trips during the operating phase as a consequence of SKB's activity is fewer than during the most intensive part of the construction phase. Fewer residents will be exposed to sound levels above 55 dBA due to transport to and from the final repository (16 during the operating phase compared with 19 during the latter part of the construction phase). The number of persons who consider themselves to be severely disturbed by noise from SKB's transport activities is expected to decline by one or two compared with the construction phase /10-12/.

The expected risk increase for high blood pressure and serious heart disease is at the same level as during the construction phase.

Schools will be exposed to traffic noise to the same extent as during the construction phase.

Decommissioning phase

Noise arising during the decommissioning phase has not been studied closely, since this phase is considered to lie too far in the future to permit prediction of what the vehicle fleet will look like. However, the transport quantity is assessed to be of the same magnitude as during the construction phase.

Vibrations

Information on vibrations has been taken from the vibration study /10-13/.

Construction phase

At the nuclear power plant's closest parts, unit 1 (F1) and the office buildings, the vibrations may be noticeable when the blasting is at its closest. They will not be experienced as unpleasant, however. There are no nearby residents within a distance of two kilometres of the surface blasting, so there is no risk of health consequences for residents.

The vibration levels along the roads in the Forsmark area will not change due to the final repository activity. The number of occasions with high vibration levels will, however, increase due to the increased number of heavy shipments. There is no standard for how limit values should be calculated with respect to traffic vibrations, but SS 02 52 11 (Guidance levels and measuring of vibrations in buildings originating from piling, sheet-piling, excavating and packing) /10-27/ is considered to provide a satisfactory basis for assessment. Limit values for buildings according to /10-27/ vary from three to five mm/s or more. In the case of buildings within five metres of national road 76, the vibration levels from heavy transport may amount to 1.5 mm/s at the foundation level. There is therefore no risk of damage. The number of buildings that are situated very near national road 76 (5–10 metres) is also few.

Aside from damage to buildings, vibration can give rise to comfort disturbances for people inside the buildings. Floor vibrations greater than 0.4 mm/s but less than 1.0 mm/s are deemed "moderately disturbing" according to SS 460 48 61 (Measurement and guidelines for the evaluation of comfort in buildings) /10-28/. The assessment is that the vibration levels could amount to 0.4–0.5 mm/s in an isolated building, which could be experienced as moderately disturbing. There is no risk of health consequences, however.

Operating phase

During the operating phase, all blasting will be done at repository depth, so the risk of health consequences for nearby residents is assessed to be minimal. The vibrations will only be noticeable to persons above the rounds, and the air shock waves are not assessed to be audible.

Since there are fewer heavy shipments during the operating phase than during the construction phase, the consequences for the residential environment along the transport routes due to vibrations are assessed to be less than during the construction phase.

Decommissioning phase

The vibration levels are assessed to be so low that no consequences can be expected.

Water supply

Groundwater diversion from the final repository is assessed to lead to very limited consequences for private water supplies in the Forsmark area. In a worst case, groundwater diversion could lead to some reduction in the capacity of three drilled wells. One of these three wells has not been located, however, despite assistance from the property owner (FKA). The consequences for the wells in the form of impaired capacity and/or water quality are expected to be marginal, if any.

Radiation and releases of radionuclides

Construction phase

Radon emission in underground facilities is so great that there is always a risk that the exposure will constitute a health risk. Adequate ventilation is the primary means of limiting the radon concentration. The ventilation system will be designed for much greater air flows than the minimum flows required to keep the radon concentration below the limit values /10-14/ and no health consequences are expected.

Operating phase

For the operating phase as well, the ventilation system will be designed for much greater air flows than are required to keep the radon concentration below the Swedish Work Environment Authority's limit values. The canisters of spent nuclear fuel do not release any radionuclides.

A person who passes a ventilation station where the air from the final repository is vented will receive roughly the same radiation dose as a person in the facility, since the concentration in the exhaust air is the same as the concentration in the air in the facility. It is calculated that the radiation exposure of a person who spends one hour at the facility is 0.006 mSv. By comparison, it can be mentioned that the radon gas concentration in the air in newly built houses may not exceed 200 Bq/m^3, which is equivalent to about 2 mSv/year. So in order to reach a radiation dose from the final repository that exceeds what is permitted in a newly built house, a person must spend many days near the facility's ventilation station /10-14/. No health consequences are therefore expected due to radiation exposure outside the ventilation stations.

The facility is designed so that the radiation dose to personnel will comply with SSM's regulations. SSM's radiation protection rules limit the effective whole-body dose in radiological work to 100 mSv during five consecutive years. There are also annual limits, which are presented in Table 10-12.

According to SSM's regulations, a more restrictive design-basis dose should also be established, if possible. If the same individual should carry out all depositions during one year (150 canisters), this

Table 10-12. Dose limits for persons working with ionizing radiation.

Highest dose per year/mSv	
Effective dose	50
Equivalent dose to eye lens	150
Equivalent dose to skin	500
Equivalent dose to extremities	500

corresponds to a dose of 12 mSv, which is in compliance with the above regulations. The calculation of 12 mSv is carried out with pessimistic assumptions, and the same individual will presumably not carry out all depositions during one year, which means that the individual dose will probably be lower in reality. Remote control of certain tasks will also be considered in order to reduce the dose load.

Decommissioning phase

The radiation dose to personnel is assessed to be lower than during the operating phase, since no canisters are handled and all deposition tunnels are sealed. No calculations of radon concentration have been done for the decommissioning phase.

Non-radiological atmospheric emissions

Since the air study /10-16/ was conducted, the prediction of the number of rock shipments has changed. This does not result in any significant changes in atmospheric emissions.

Construction phase

Tables 10-13 and 10-14 compare emissions from the repository activity and from transport to and from the final repository with relevant environmental quality standards (EQS) and environmental targets. The levels are given for Norrskedika, where most of the transport trips to and from the facility will pass and where the residences are located close to the road. This is also the area that gets the highest concentrations, even compared with calculations for residential areas closer to the final repository.

Table 10-13. Calculated concentration contributions of NO_2 from the final repository at Norrskedika during the construction phase, and estimated background concentrations compared with EQS and interim target.

NO_2 Norrskedika (µg/m³)	Traffic without SKB	Regional background	Final repository construction phase	Total concentration construction phase	EQS	Interim target 2010
Annual mean concentration	2	About 2	< 0.25	About 5	40	20
98 percentile day	6	About 8	< 0.5	About 14	60	–
98 percentile hour	10	–	< 0.5	–	90	60

Table 10-14. Calculated concentration contributions of PM10 from the final repository at Norrskedika during the construction phase, and estimated background concentrations compared with EQS and interim target.

PM10 Norrskedika (µg/m³)	Traffic without SKB	Regional background	Final repository construction phase	Total concentration construction phase	EQS	Interim target 2010	Generation target 2020
Annual mean concentration	1	12	< 0.25	About 13	40	20	15
90 percentile day	4–6	19	< 0.5	About 25	50	35	30
98 percentile day	6–8	30	1	About 38	30*	–	–

* Upper evaluation threshold.

The background concentrations are much higher than the contribution from SKB's activity. The background concentrations consist to a great extent of transboundary pollution from industry in other countries. In the case of particulate matter, natural contributions from e.g. plant pollen comprise a large portion. It has been assumed in the calculations that the background concentrations in the area do not change from current levels.

The calculations show that environmental quality standards for air will not be exceeded. An environmental quality standard for a 98-percentile day is lacking for PM10, so Table 10-14 gives the upper evaluation threshold instead. The background concentrations are close to the upper evaluation threshold, but this does not mean that the environmental quality standard is exceeded, just that the level must be checked.

The fact that environmental quality standards for particulate matter and nitrogen dioxide will not be exceeded does not necessarily mean that the risk of health impact can be completely ruled out. However, the background concentrations of nitrogen dioxide are very low, and the insignificant addition made by SKB's activity will lie below the levels that have shown increased risk of health effects in some studies. The additional particulate matter concentration at the most affected permanent residences entail 0.1–1.0 percent increased risk of being hospitalized with heart or lung problems (health outcome). Only twelve permanent residences and seven secondary residences will be affected by the increase, so it is not statistically relevant to calculate the number of additional health outcomes.

Operating phase

The concentration contribution from the final repository does not change between the construction and operating phases. For transport to and from the final repository it is expected to decrease slightly compared with the construction phase, see Tables 10-15 and 10-16.

Table 10-15. Calculated concentration contributions of NO_2 from the final repository at Norrskedika during the the operating phase, and estimated background concentrations compared with EQS and interim target.

NO_2 Norrskedika (µg/m³)	Traffic without SKB	Regional background	Final repository operating phase	Total concentration operating phase	EQS	Interim target 2010
Annual mean concentration	< 0.5	About 2	< 0.1	About 2	40	20
98 percentile day	1	About 8	< 0.25	About 9	60	–
98 percentile hour	2	–	< 0.25	–	90	60

Table 10-16. Calculated concentration contributions of PM10 from the final repository at Norrskedika during the operating phase. The table also shows estimated background concentrations as well as EQS and environmental targets.

PM10 Norrskedika (µg/m³)	Traffic without SKB	Regional background	Final repository operating phase	Total concentration operating phase	EQS	Interim target 2010	Generation target 2020
Annual mean concentration	1	12	< 0.25	About 13	40	20	15
90 percentile day	4	19	< 0.5	About 24	50	35	30
98 percentile day	6	30	0.5	About 36	30*	–	–

* Upper evaluation threshold.

Nor are environmental quality standards for air expected to be exceeded during the operating phase. It is, however, calculated that even the background levels of PM10 will be close to the evaluation threshold, but this does not mean that the environmental quality standard is exceeded, just that the level must be checked.

The concentrations of nitrogen dioxide and particulate matter around the final repository will be roughly the same as during the construction phase.

Decommissioning phase

Dispersion calculations have not been done for the decommissioning phase, but emissions during dismantling of the facility will not be lower than during the construction phase. Since the concentrations will be low during the construction phase, no health consequences can be expected.

10.1.5 Risk and safety issues during construction and operation

Risk and safety for the final repository and its environs during construction and operation are described in this section.

10.1.5.1 Environmental risks

Along with expected effects and consequences during normal operation of the facility, environmental risks have also been studied /10-29/. Risk is a combination of the probability of an accident and the scope of the damage that would be caused by the accident. The scope of the damage is closely related to the sensitivity of the recipient.

Construction phase

One environmental risk that has been identified is an inflow of water into the final repository's underground parts that is greater than expected and can affect the sensitive natural values in the area. Another environmental risk is that valuable environments and species have been overlooked, despite the extensive investigations that have been conducted, and may be harmed. These two risks are managed, however, in part by making pessimistic assumptions in calculations of inflow, and in part by the fact that SKB will maintain a preparedness for damage-mitigating measures in the form of infiltration of water in sensitive environments.

Another environmental risk during the construction phase is spillage of fuels, hydraulic oils or other chemicals. The probability of such spills occurring is high, but the consequences can be mitigated by preventive measures such as dyking-in and collection pads where e.g. fuel tanks are set up. Events that can prevent water treatment from working as planned have also been identified, for example excessive inflows to the treatment plant or flooding. The consequence is emissions of higher nitrogen concentrations in particular than planned. The likelihood of such events occurring is moderate, and the assessed consequence is time-limited environmental damage.

Particular environmental risks are associated with overland transport. Construction of the final repository requires transport of fuels, hydraulic oils and other chemicals. There is preparedness in the operations area for managing spills, and the consequences are therefore considered to be small. If spills occur outside the operations area in Forsmark, the consequences are assessed to be great, since the natural environment is sensitive. Spills on public roads make the cleanup work more difficult, with a risk of greater consequences depending on the accident location.

Operating phase

The environmental risks for the final repository decrease during the operating phase, but the risks of spillage of fuels, hydraulic oils or other chemicals still exist, as do some of the risks that water treatment will not work as planned.

Transportation will give rise to environmental risks similar to those during the construction phase. The operating phase also involves shipments of canisters of spent nuclear fuel by m/s Sigyn or a similar ship. The environmental risks associated with these shipments are described in Chapter 9.1.5.1.

A special environmental risk is rising sea levels, due to global warming. As a result of sea level rise, very high temporary water levels can occur that could cause flooding in the operations area and rock heap. Research on future sea levels is intensive and associated with great uncertainties. The report that has been published /10-30/ therefore uses three different predictions of sea level rise in order to estimate the sea level rise in a hundred years. The predictions are based on a combination of many processes (meltwater from glaciers, land uplift, extreme weather conditions, ocean currents and others) of varying geographic extent (local, regional and global). The hypothesis is that these processes can coincide during the chosen time period (up to 2100) and result in extreme levels.

Based on the three predictions, three very high water levels have been calculated: +175 centimetres, +254 centimetres and +316 centimetres in the height system RH 70. These levels have been assumed to occur temporarily during a relatively short period and are thus not the normal

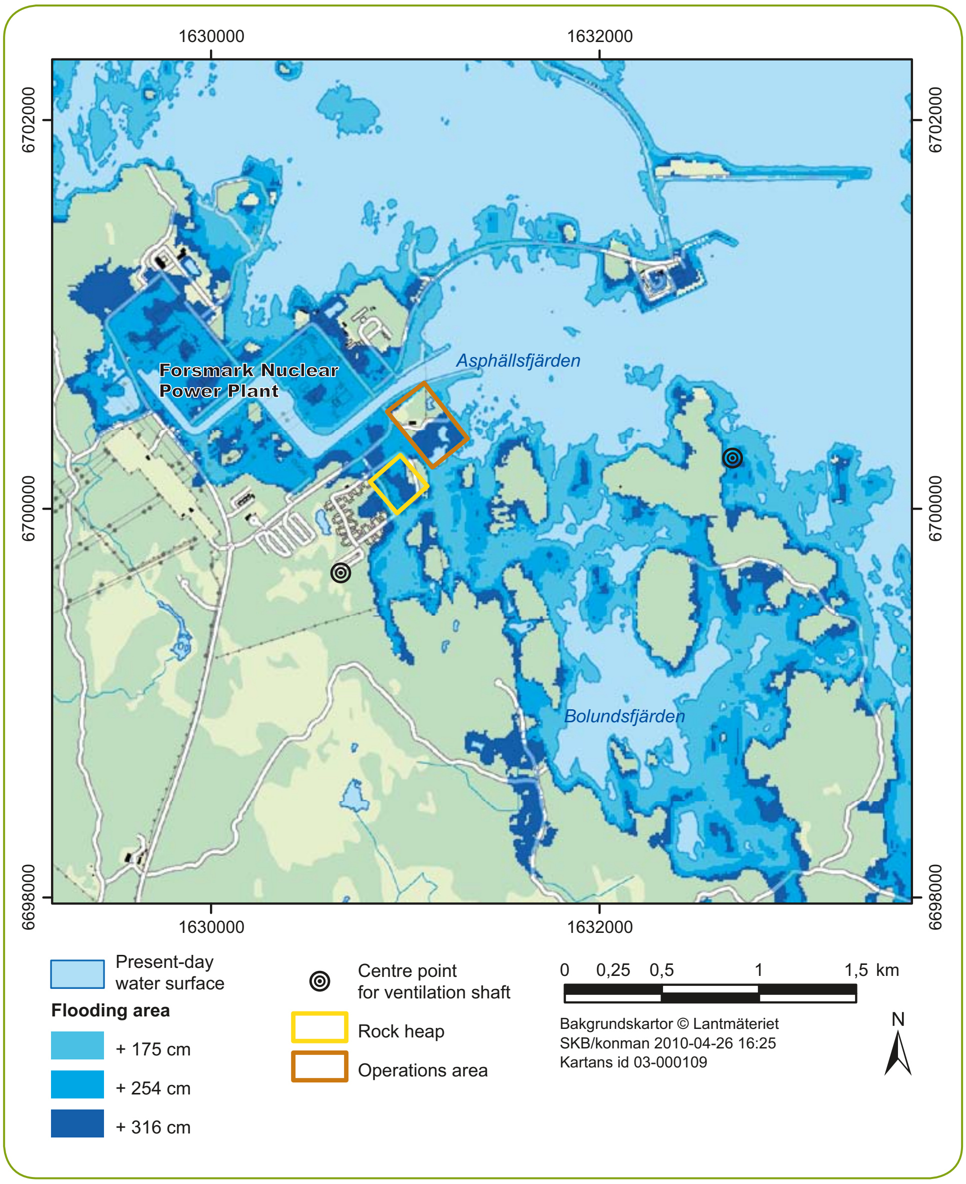


Figure 10-40. Very high water level in 2100 according to three different predictions, plus operations area, rock heap and ventilation station. The map shows the situation when the outer operations area is filled to +300 and the inner operations area to +350 centimetres.

sea level in 2100. For example, the third prediction of +316 centimetres is an extreme scenario that will probably be limited by other processes. The prediction has nevertheless been used as a basis for the final repository's design premises. The year 2100 was determined in order to be sure to include the highest expected shoreline during the operating lifetime of the final repository.

As shown in Figure 10-40, the facility has been designed to withstand extreme water levels. The land level for the outer operations area will be raised to +300 centimetres and for the inner operations area to +350 centimetres. This means, for example, that shafts and access tunnels leading down to the repository will be protected against flooding according to all scenarios. If flooding should nevertheless affect the work of backfilling a deposition tunnel, it may be necessary to redo the backfilling. Flooding is not assessed to lead to any radiological consequences, however.

The lowest level for other facility parts has been determined with a view to the consequences of possible flooding. Less important facility parts can, for example, be allowed to be lower than the outer operations area.

Flooding of parts of the facility could result in contamination of the sea with pollutants from the facility. From the operations area, contaminants could also be spread by the water to the surrounding land and sea.

Decommissioning phase

The greatest environmental risk associated with the decommissioning of the final repository is assessed to be leakage and/or fire caused by incorrect handling of fuel tanks /10-29/. Risks due to spills can be reduced by:

- inventory and cleanup of hazardous substances prior to decommissioning,
- utilization of conventional facilities for waste management in the nearby area,
- creation of systems for management of other waste /10-19/.

The environmental risks to which transport gives rise in the decommissioning phase are assessed to be comparable to the risks during the construction phase.

When decommissioning begins, the deposition tunnels are already closed. However, closure of other openings can be affected by flooding. This does not lead to any radiological consequences, however.

10.1.5.2 Risk of impact on existing activity

Of the nuclear power plant's three units, unit 1 (F1) lies closest to the planned final repository. The distance from the surface blasting rounds to F1 will be about 450 metres, and from the closest underground blasting rounds (the ramp) about 300 metres. Adjacent to the nuclear power plant are switchgears, transformers, oil tanks, water reservoir, water treatment plant, sewage treatment plant, meteorology mast and a number of office buildings. The sewage treatment plant and the meteorology mast are located within the planned operations area for the final repository and will be replaced with new plants at a different location prior to the start of construction. The nearest object in relation to the final repository will then be an oil line that is now longer in use, situated about 250 metres from the nearest surface blasting round and about 100 metres from the nearest underground blasting round. The nearest office buildings are situated at a distance of about 400 metres from the blasts. The SFR facility is located too far away to be appreciably affected by vibrations.

SKB and FKA have initiated an inventory that will provide a better basis for ensuring that vibrations and air shock waves cannot cause unacceptable consequences for FKA's activity. The purposes of the investigation programme are to:

- Identify installations and equipment that may be particularly sensitive to vibrations or air shock waves. This includes turbines and relays and other electrical components.
- Where necessary, propose measures to minimize the impact on identified equipment and installations. Examples of possible measures are vibration isolation or replacement of components deemed to be particularly sensitive.
- Propose limit values and restrictions for vibration levels wherever possible.

Based on the information available today, the assessment is made that there is no risk of damage to the nuclear power plant's buildings, since the expected oscillation rates are less than 2 mm/s. This can be compared with calculated limits of 8–12 mm/s /10-13/. Limit values for vibration-sensitive equipment and installations will be determined at a later stage. In view of the fact that the expected acceleration levels are less than about one metre per second squared (m/s^2), the preliminary assessment is that there will be no damage or disturbances. The inventories will also clarify whether any installation or equipment requires action before the blasting work begins. Beyond this, the intention is that special procedures will be applied during the nuclear power plant's refuelling outages. The procedures may, for example, entail temporary blasting interruptions or load relief or barring of turbine shafts.

There is no risk that the air shock waves that are generated will damage buildings. The expected air shock wave pressures are less than 200–300 pascals (Pa), which can be compared with the limit value of 500 Pa for reflected pressure. Aside from vibrations, blasting on the surface always entails some risk of flyrock. The relatively great distances between the blasting sites and surrounding roads, buildings and facilities entails limited risks of flyrock, but protective measures will nevertheless be taken. In general, the environs are protected from blasting impact by means of controlled blasting. Furthermore, the blasts will be planned so that the blast direction is away from nearby roads, buildings and other places where people are present. Blasting methods and precautionary measures, for example use of blasting mats, will be determined at a later stage.

10.1.5.3 Nuclear safety during operation

The final repository is designed to permit handling of canisters from the receiving position to final placement in the intended deposition hole with high reliability and safety. The facility, its systems and components, are designed to withstand malfunctions and internal and external loads. Building parts, systems, components and devices are classified on the basis of their importance for the facility's safety and are designed, manufactured, installed and tested to meet requirements commensurate with their safety-related importance. In order to verify that the facility meets all safety requirements and design premises, an analysis is made in Chapter 8 of the safety analysis report for the operation of the final repository of how the facility copes with possible disturbances and mishaps and what radiological impact can be caused to the environs by a disturbance or mishap /10-31/.

The facility and its equipment are designed so that the canister will withstand all events in normal operation as well as disturbances and mishaps without the canister's copper shell being breached. As a result, no radioactive release can occur in the final repository provided that the facility, its equipment, the transport cask and the canister meet the acceptance criteria.

A disturbance is an undesirable event that can be expected to occur during the lifetime of the facility at a frequency of more than 0.01 time per year. The disturbances to the final repository have been divided into disturbances that can:

- Lead to radiological consequences due to radioactivity release, for example damage to the transport cask or canister due to collision with rock, limited fire, or loss of external power.
- Cause damage to barriers during the operating period, for example a lifting or handling disturbance that causes minor external damage to the canister or the buffer, or limited flooding.
- Give rise to an individual dose (radiation dose to personnel), for example ventilation malfunction, canister getting stuck in unshielded position, or improper opening of radiation protection.

A mishap is an event that is not expected to occur during the lifetime of the facility but which must nevertheless be analyzed in order to demonstrate the ability of the facility to handle it with acceptable consequences. A mishap has a lower frequency than a disturbance and occurs between 0.01 and 0.000001 times per year. Mishaps are divided into events that can:

- Lead to radiological consequences due to radioactive release, for example fire, lifting or handling mishap, collision, earthquake or rock slide.
- Cause damage to barriers during the operating period, for example the presence of prohibited chemical substances, high water flows in a deposition hole or deposition tunnel that are not discovered, defects in a canister or buffer, wrong bentonite grade, defects in the rock, extensive flooding or extreme weather conditions.
- Give rise to an individual dose (radiation dose to personnel), for example a canister getting stuck in the transport cask or the deposition machine's radiation shielding tube during transfer and deposition.

The results of the safety assessment /10-31/ show that disturbances and mishaps can lead to an increased individual dose to personnel. Furthermore, disturbances and mishaps could have consequences for the engineered barriers if no action is taken, since a disturbance or mishap may necessitate replacement of the barriers or abandonment of a deposition hole. When the barriers are replaced or a deposition hole is abandoned, a reversible process is followed entailing that the canister must be handled again. The radiation from the canister may then lead to an increase in the individual dose to personnel in the final repository. Neither disturbances nor mishaps will lead to a release of radioactive material from the canister, since the integrity of the canister is preserved. The types of mishaps and disturbances that lead to replacement of the engineered barriers or abandonment of a deposition hole have no impact on long-term safety. The purpose of the preliminary safety analysis report is to predict wherever possible the disturbances and mishaps that might occur. Provided that all types of mishaps and disturbances have been identified in the safety assessment and that they are discovered and handled properly if they occur, long-term safety will not be affected by disturbances or mishaps during operation.

If an event should occur in any of the nearby nuclear power reactors that leads to a nuclear accident, i.e. a large release of radionuclides to the environs, it may be necessary to stop or curtail the operation of the final repository for a certain period. Conditions do not exist in the final repository that could give rise to any rapid sequences of events that could damage the canisters in such a way that radionuclides are released either in the facility or to the environs. Furthermore, the leaktight copper canisters with spent nuclear fuel are in turn placed in deposition holes or transport casks, so a curtailment in the operation of the facility would not affect their safety. Before the final repository returns to normal operation, it is checked that various components and systems are ready for operation and that the working environment complies with the relevant requirements.

10.1.6 Post-closure safety

The long-term post-closure safety of a final repository according to the KBS-3 method has been assessed on a number of occasions since the first report was published in 1983. The previous safety assessment, SR-Can /10-32/, was published in 2006 and was a preparation for SR-Site /10-33/, the safety report that now serves as a basis for, and is attached to, the applications for licences to build and operate the final repository. SR-Can was reviewed by SKI and SSI (now Swedish Radiation Safety Authority, SSM) with the aid of national and international experts. The review resulted in comments and viewpoints that have been integrated in SR-Site.

According to the Act on Nuclear Activities (SFS 1984:3), nuclear activities shall be conducted in such a manner that the requirements on safety are met. SSM's regulations SSMFS 2008:21 contain detailed provisions regarding the design required for safety. According to SSM's general recommendations for the regulations, safety should be interpreted as "the ability of a repository to prevent the dispersion of radioactive substances". According to the regulations, this shall be done by a system of engineered and natural barriers which shall contain, prevent and retard the dispersion of radioactive substances. The geological formation at the repository site can, according to the general recommendations for the regulations, constitute a natural barrier which can both isolate the nuclear waste from the environment on the ground surface and hinder human intrusion. The site and depth of the repository should be chosen so that the geological formation provides sufficiently stable and favourable conditions to ensure that the repository barriers perform as intended over a sufficiently long period of time.

SSM's regulations SSMFS 2008:37 also contain provisions regarding what protective capability the final repository should have. An important requirement is the authority's risk criterion. It entails that the annual risk of cancer or hereditary effects from radiation doses caused by releases from the final repository may not exceed one in a million for those individuals who are exposed to the greatest risks. In simplified terms, this is equivalent to saying that people in the vicinity of the repository may not be exposed to radiation doses that exceed approximately one-hundredth of the natural background radiation in Sweden.

The guidelines on SSMFS 2008:37 state that the time scale for a safety assessment for a final repository for spent nuclear fuel should cover a period of one million years after closure. A detailed risk analysis is required for the first thousand years after closure. The guidelines also state that the risk criterion is applicable up to about 100,000 years after closure. For the period after 100,000 years, calculated risks can be used as one of several indicators to discuss the repository's protective capability. After about 100,000 years, the radiotoxicity of the spent nuclear fuel is comparable to that of the natural uranium ore used to produce the fuel.

The purpose of SR-Site is to investigate whether the KBS-3 method, with the chosen reference design on the selected site in Forsmark, fulfils SSM's risk criterion, and to serve as a basis for further development of the repository's design. The assessment is based on the reference design of the repository and the site descriptive model, which describes the site's geological, rock mechanical, thermal, hydrogeological and geochemical properties as well as the properties of the surface system and the rock's transport properties.

10.1.6.1 Methodology

The primary safety function of the final repository is to contain the spent nuclear fuel in copper canisters during the entire assessment period. If a canister should be damaged, the secondary safety function of the repository is to retard any releases from the repository so that they do not cause unacceptable consequences.

The repository system – consisting of the deposited spent nuclear fuel, the barriers (canister and buffer), the surrounding rock and the biosphere adjacent to the final repository – will evolve with time. The future state of the system will depend on:

- the initial state, i.e. the state when it has just been built,
- internal thermal, hydraulic, mechanical and chemical processes in the repository system over time,
- external processes acting on the system.

Internal processes include e.g. decay of radioactive material, which liberates energy from the fuel in the form of heat to the engineered barriers and the bedrock. Groundwater movements and chemical processes that affect the barriers and the composition of the groundwater are other examples. External processes include the future climate and climate changes, which can cause e.g. glaciations and shoreline displacement. Future human actions may also affect the repository. In order to investigate how the repository system will evolve, the methodology used in SR-Can has been further developed for SR-Site. It includes the following steps:

1. Identification of factors of importance (FEP processing)
All factors to be included in the analysis are identified. Experience from earlier safety assessments is used, together with KBS-3-specific and international databases of relevant features, events and processes (FEPs) influencing long-term safety. A catalogue is prepared which lists and describes the factors to be addressed in SR-Site.

2. Description of the initial state
The initial state of the system is described based on the design specifications for the KBS-3 repository, a descriptive model of the repository site and a site-specific layout of the repository. The initial state of the fuel and the engineered components refers to conditions immediately after deposition. The initial state of the geosphere and the biosphere refers to the natural conditions prior to excavation.

3. Description of external conditions
Factors related to external conditions are divided into three categories: "climate related issues", "large-scale geological processes and effects" and "future human actions". Climate-related issues in particular are of great importance in the evaluation of the repository's safety.

4. Description of processes
Identification and handling of known processes in the repository that are of importance for the long-term evolution of the repository system is a key element in the safety assessment. It is based on previous assessments and on the FEP screening in step 1. Certain processes are assessed as being of sufficiently little importance to be excluded, while others are studied with mathematical models. The results of such model studies serve as a basis for the description of the long-term evolution of the repository system.

5. Definition of safety functions, safety funcion indicators and safety function indicator criteria
In this step, the system's safety functions are described, along with how they can be evaluated with a set of indicators that are in principle measurable or calculable properties of the canister, buffer, backfill and rock. An important safety function of the buffer is to prevent advective transport, i.e. transport of solutes with flowing water, between the groundwater and the canister. An example of a safety function indicator for this function is the buffer's swelling pressure, since a high swelling pressure (more than one megapascal) guarantees that advective transport is prevented.

6. Compilation of input data
A structured procedure is used to select data for model studies of the evolution of the final repository and dose calculations.

7. Definition and analysis of reference evolution
A reference evolution, i.e. a probable future evolution of the repository system, is defined and analyzed. First the system's ability to contain the spent fuel over time is analyzed. This analysis describes the general evolution of the system, and an evaluation of the safety functions is made. If the evolution leads to a breach of the fuel's isolation, the retarding capacity of the final repository and its environs is analyzed and dose consequences are calculated. The reference evolution is described in greater detail in section 10.1.6.2.

8. Selection of scenarios
A comprehensive main scenario is defined in accordance with SSM's regulations SSMFS 2008:21. The main scenario is based entirely on the reference evolution analyzed in step 7. The evolution of the repository system involves many uncertainties that are difficult to take into consideration and cover in the reference evolution/main scenario. A number of additional scenarios are therefore also studied in order to ensure that all uncertainties are covered when the repository's safety is evaluated. The choice of additional scenarios is based on a systematic analysis of what might threaten the repository's safety functions as defined in step 5. The set of selected scenarios also includes scenarios that are mentioned explicitly in applicable regulations, such as human intrusion.

9. Analysis of selected scenarios
The main scenario is analyzed primarily by referring to the reference evolution in step 7. Additional scenarios are analyzed by focusing on factors that could lead to situations in which the safety function in question is not maintained. In most cases, these analyses are carried out by comparison with the evolution for the main scenario. For these scenarios, as for the main scenario, a risk contribution is estimated. The results of the scenario analysis are described in greater detail in section 10.1.6.3.

10. Additional analyses and supportive arguments
In this step, a number of additional analyses required to complete the safety assessment are carried out, including analyses required to show that the best available technique has been used. A review is also made of which arguments for safety can be taken from observations of natural phenomena of long duration, such as naturally occurring metallic copper and formations of bentonite clay that have been stable for a long time in repository-like environments.

11. Conclusions
This step includes compilation of the results from the various scenario analyses, conclusions regarding safety in relation to regulatory criteria and feedback with regard to design premises, repository design, continued detailed site characterization and SKB's RD&D programme.

10.1.6.2 Reference evolution

A reference evolution for the final repository, which covers the entire assessment period of a million years, is studied to gain an understanding of the overall evolution of the repository and to provide a basis for scenario selection and scenario analyses. The objective is to describe a probable evolution of the repository system over time.

Two cases of the reference evolution have been analyzed:

- A base case, where it is assumed that the external conditions during the first glacial cycle of 120,000 years are similar to those that prevailed during the most recent cycle, the Weichselian. After that it is assumed that seven repetitions of the same glacial cycle cover the entire assessment period of a million years.
- A global warming variant, where it is assumed that the future climate during the initial 50,000 years will be heavily influenced by anthropogenic emissions of greenhouse gases.

Base case

The analysis is carried out in four periods: the final repository's construction and operating phases, the first temperate period after closure, the first glacial cycle and the period following the first glacial cycle. The course of events resulting from internal processes in the repository and external processes acting on the repository is studied within each period.

Construction and operating phases

The course of events during this period is dominated by the construction and operation of the final repository, which distinguishes it from subsequent periods, which essentially are driven by naturally occurring processes. The period lasts for about 60 years. The focus of the analyses is whether construction and operation can affect post-closure safety, and they show that construction and operation do not affect post-closure safety for those canisters that have already been deposited. The rock excavation for building deposition tunnels causes blast damage in tunnel walls and floors. This damage, and the resulting "excavation-damaged zone", is, however, very limited and of little importance for safety. Large inflows of water into deposition holes and deposition tunnels could damage the buffer and the backfill before they have become water-saturated and swelled, but this damage is limited to acceptable levels by only accepting deposition holes and deposition tunnels with limited water inflows.

The initial period of temperate climate after closure

Climate variations in Sweden during the past 1,000–2,000 years have been small. It is assumed in the base case of the reference evolution that variations in temperature and precipitation during the first 1,000 years after closure will also be relatively small and follow the pattern of natural climate variations. Temperate conditions are assumed to prevail in Forsmark up until about the year 10,000. Shoreline displacement will continue throughout this period, but at a gradually diminishing rate. Around the year 3,000, the strait at Öregrund will be cut off and Öregrundsgrepen will be transformed into a bay. Around the year 5,000, the coastline will have receded to about five kilometres from the repository, many straits in the archipelago are expected to be cut off, and a number of lakes will be isolated from the sea. Many lakes are small and shallow and are expected to fill in and be transformed into mires within 2,000–6,000 years. Around the year 10,000, the assessment is that most of the lakes in the area will have been filled in and only a few large, deep lakes near Gräsö island will be left.

The repository's host rock and the water-filled tunnels will become water-saturated after closure, and the subsequent evolution of the rock is characterized by a return to the natural, unperturbed state prior to the start of construction. Water saturation of the rock and the deposition tunnels is estimated to take several hundred years. The water saturation time for the buffer will vary greatly between different deposition holes and is estimated to amount to a thousand years or so at most. In parallel with the water saturation process, the repository will be heated by the decay heat in the spent nuclear fuel. The calculated maximum temperature on the surface of the copper canister (about 90 degrees) and on the inner surface of the buffer (about 80 degrees) will be reached after ten or so years. The temperature of the buffer should be below 100 degrees, which is achieved with good margin.

The first glacial cycle

This period extends by definition up until 120,000 years after closure, since a repetition of the latest glacial cycle is assumed. It is characterized by periods of permafrost and glacial conditions, with intervening periods of temperate climate, and is studied by means of modelled reconstruction of the conditions during the last glacial cycle. The repository is mainly affected by climate-related processes, such as the growth of ice sheets and permafrost, and by shoreline displacement, while the climate as such on the ground surface is of less importance. A large earthquake, greater than magnitude 5, could occur in the vicinity of the repository, but the probability of this is low.

The period after the first glacial cycle

The further evolution of the repository system is analyzed by assuming seven more repetitions of the 120,000-year-long Weichselian glaciation. The same phenomena are expected to occur as during the first glacial cycle. During the coming million years, two earthquakes greater than magnitude 5 are statistically expected to occur in the vicinity of the repository.

Global warming variant

In the global warming variant, a temperate climate is assumed to prevail for 50,000 years before the relatively mild start of the base variant of the next glacial cycle ensues. There are great variations in temperature and precipitation during this temperate period. At the beginning of the period, both temperature and precipitation are higher than today's conditions due to global warming, but gradually decrease.

Results of the analysis of the reference evolution

After each period in the analysis of the reference evolution, the different safety functions of the repository are evaluated. The results show that for most of the 6,000 deposition holes, all safety functions are preserved, which also means that the canisters remain intact so that the spent fuel remains contained.

However, in a million-year perspective there are two eventualities for which the possibility of canister damage cannot be entirely ruled out.

One concerns the possibility that the buffer is eroded when it is exposed to dilute groundwater, either after long periods of temperate climate or under glacial conditions. If enough buffer is eroded in a deposition hole, the buffer's ability to counteract the flow of groundwater through the hole is compromised. The canister then becomes more vulnerable to corrosion by sulphides in the groundwater. In the unlikely combination of a deposition hole with high groundwater flow and the highest sulphide concentrations that occur in the repository environment, canister damage cannot be ruled out. Such damage could occur, with low probability, after hundreds of thousands of years. The quantitative analyses show that on average, less than one of the 6,000 canisters could be damaged as a result of such a process after a million years.

The other eventuality involves canister damage as a result of major earthquakes in the vicinity of the repository. Major earthquakes can, for physical reasons, only occur in large fracture zones, and canisters are not deposited in such zones. Major earthquakes can, however, lead to so-called secondary movements in individual fractures, and if a large fracture of this kind intersects a deposition hole, the canister may be damaged by a secondary movement. The analyses show that the probability of a single canister being damaged among the 6,000 canisters after a million years is less than one in ten. Several pessimistic simplifications have been made in this analysis, where the available body of data has not permitted a detailed quantitative analysis.

10.1.6.3 The scenarios

Selection of scenarios

The reference evolution serves as a basis for a main scenario that is expected to provide a reasonable picture of how the repository might evolve. The main scenario is based entirely on the reference evolution. Just as in the case of the reference evolution, there are two variants of the main scenario: a base variant and a global warming variant. A number of critical questions pertaining to the safety of the repository are analyzed in a series of additional scenarios:

- Can the buffer freeze?
- Can the buffer disappear due to erosion?
- Can the buffer clay be transformed into a material with unfavourable properties?
- Can the canister corrode apart?
- Can the canister be damaged by the pressure from the swelling bentonite clay and by the groundwater pressure at repository depth?
- Can the canister be damaged by earthquakes?

Each of these questions is being studied in a separate scenario to determine whether the conditions can become less favourable than in the main scenario and what the consequences might then be in the form of dose to man and biota (the flora and fauna in an area). The goal is to ensure that all uncertainties that were not dealt with in the main scenario are considered. If the assessment is that a scenario could possibly occur, the consequences of that scenario are included in a risk summary for the repository. Otherwise it is regarded as a residual scenario. The total risk is then compared with SSM's risk criterion.

The buffer scenarios are analyzed first, and every case of negative impact on the buffer that cannot be ruled out is then included in the analyses of the canister. In order to obtain a complete picture of possible sequences of events and risks, additional combinations of scenarios must also be studied.

Analysis of ability to contain the spent nuclear fuel

The results of the analyses of the different scenarios in terms of the repository's ability to contain the spent nuclear fuel are summarized below.

Buffer freezing: This was ruled out in the main scenario, since the buffer freezes at a temperature of –4°C or lower, which even with pessimistic assumptions is never reached at repository depth. The conclusion drawn from the analyses in the buffer freezing scenario as well is that freezing can be ruled out, even with the extreme assumptions concerning the future climate.

Loss of buffer: Loss of buffer by erosion cannot be ruled out in the main scenario, where advective conditions arise in a number of deposition positions over a period of a million years. The additional analyses of all factors that affect buffer erosion showed that the possible scope of buffer loss can vary within somewhat wider limits than in the reference evolution. This result was propagated to the analysis of canister damage as a result of corrosion.

Buffer transformation: The special minerals of which the buffer clay is composed can be altered at high temperatures. There is also a risk that the buffer can be damaged at high pHs. The analyses of possible causes of harmful elevated temperature or elevated pH in the buffer led to the conclusion that this cannot be ruled out, and that harmful alteration of the buffer is therefore regarded as a residual scenario. The situation with an altered buffer is therefore not further dealt with in the analysis of the canister scenarios.

Canister failure due to corrosion: Canister failure due to corrosion can occur in the main scenario when the buffer is eroded. Analyses of corrosion when the buffer is intact showed that none of these mechanisms threaten the canister during the million-year period covered by the analysis. The additional analyses in the corrosion scenario of canister corrosion in combination with buffer loss showed a somewhat greater extent of canister damage compared with the results in the reference evolution. The evaluation of the uncertainties surrounding this sequence of events also shows that a possible outcome would be that the extent of erosion is very small and that no canisters are damaged. Additional knowledge concerning the erosion process could therefore lead to exclusion of the phenomenon in future safety assessments. SR-Site evaluates the consequences of both a) canister damage of the same extent as in the reference evolution and b) the greatest possible extent of canister damage given the uncertainties surrounding the erosion phenomenon. In the former case the calculated average number of damaged canisters after a million years is between 0.1 and 0.7, in the latter case about twice as high. The results of the analysis of the consequences of these extents of canister damage are presented in section 10.1.6.4 below.

Canister failure as a result of the pressure from the groundwater and the bentonite clay: In order to determine whether the canisters could be damaged due to the pressure in the repository, the canister's design pressure must be compared with the sum of the maximum pressure from the swelling bentonite and the maximum groundwater pressure. Canister damage as a result of high pressures was ruled out in the main scenario, and additional analyses of e.g. thicker ice sheets than in the reference evolution showed that such damage can be ruled out.

Canister failure due to earthquake: Canister damage due to earthquake has low probability in the reference evolution. Additional analyses of factors that affect the extent of such canister damage that were carried out in the earthquake scenario showed that the extent of damage assumed in the reference evolution can be regarded as pessimistic. The results of the analysis of the consequences of such canister damage are presented in section 10.6.1.4 below.

Future human actions: The repository can be affected by different types of future human actions. In accordance with SSM's regulations, SR-Site only deals with inadvertent intrusions. They are regarded as residual scenarios that are not included in the risk summation. Following a methodical survey of different cases, the following cases were analyzed: Unintentional penetration of a canister in connection with rock drilling; an unsealed investigation borehole, an abandoned unsealed repository, a tunnel in the upper parts of the bedrock above the repository and exploitation of potential mineral resources in the vicinity of Forsmark.

All scenarios have also been analyzed in the light of the global warming variant of the reference evolution. The above conclusions also apply for the climate evolution in the global warming variant.

Analysis of ability to retard releases

If the primary safety function of containing the radionuclides in the repository cannot be preserved, the secondary safety function enters into play: retarding any releases of radionuclides from the repository. An analysis of the ability to retard releases is performed in the form of calculations of the doses and risks to which individuals in the vicinity of the repository can be exposed, and most thoroughly for the scenarios where canister damage cannot be ruled out.

During the long period of time that has been analyzed, the biosphere will change dramatically, above all due to future climate changes with periods of permafrost and glacial conditions. The highest radiation doses are expected during periods of temperate climate. Due to expected future climate changes, the site is expected to be covered by ice for long periods, leading to lower groundwater flows and considerable dilution of any releases from the repository. It is also possible that radionuclides will accumulate in the bottom sediments, leading to consequences in the form of delayed radiation doses. This also means that the consequences of a prolonged release may be greater.

In order to analyze how the final repository fulfils SSM's risk criterion, the doses to a representative individual in the group exposed to the greatest risk are calculated. The most exposed group is defined as a group of people who maximally exploit and are exposed to an ecosystem of a given size. All potential exposure pathways have been included, for example ingestion of contaminated food and contaminated water, inhalation of contaminated air and external radiation from contaminated areas. The doses have been calculated with pessimistic assumptions and therefore give pessimistic dose estimates. It is, for example, assumed that the individuals in the group obtain all food and all water from the most contaminated area and spend all their time in the area.

Doses to biota are also calculated to show whether possible releases can affect the external environment. The focus is mainly on species currently present in the Forsmark area. A dose rate of 10 micrograys per hour (µGy/h) is used in the calculations as a limit value for detectable effects on biota.

10.1.6.4 Conclusions

Fulfilment of the risk criterion

The scenario analyses show that canister failure during the first 1,000 years can be ruled out, with the exception of a minimal probability of damage due to earthquake. The probability of such canister failure is calculated pessimistically to be one in forty thousand. Statistically, this means that only one canister failure due to earthquake would occur in a thousand-year period in 40,000 final repositories, each with 6,000 canisters.

During the period up to a million years after closure, canister failure could occur due to either copper corrosion caused by sulphide in the groundwater, if the protective buffer has eroded, or earthquake. With pessimistic assumptions concerning buffer erosion, copper corrosion and radionuclide transport, the radiological risk from erosion/corrosion is judged to be non-existent for tens of thousands of years after closure, at most a hundredth of the risk limit over a period of 100,000 years, and approximately one-tenth of the risk limit over a million years, see Figure 10-41. The risk caused by canister failure due to earthquake is less than one-hundredth of the risk limit over a hundred thousand years and less than one-tenth of the risk limit over a million years. The total risk for a final repository in Forsmark lies well below SSM's risk criterion, even over a million years, and the central conclusion in SR-Site is therefore that a long-term safe KBS-3 repository can be built in Forsmark. Figure 10-41 shows the calculation cases that give the highest risk for the earthquake scenario and for the corrosion scenario, plus the sum of these.

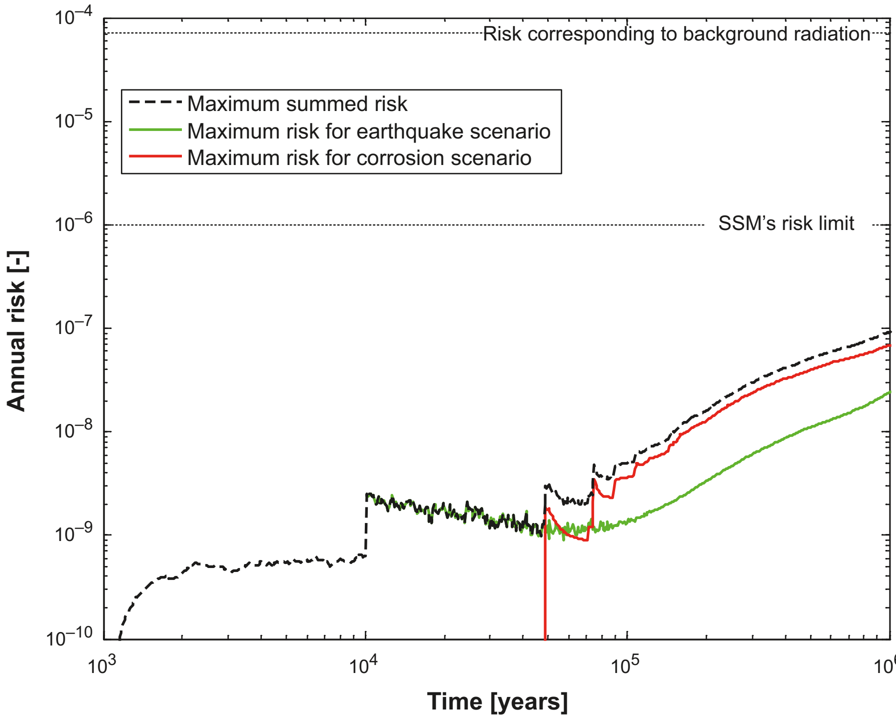


Figure 10-41. The overall risk picture in SR-Site. The figure shows the calculation cases that give the highest risk for the earthquake scenario and for the corrosion scenario, plus the sum of these. Since the sum curve lies below the risk limit during the whole million-year period, the conclusion is that SSM's risk criterion is fulfilled for a KBS-3 repository in Forsmark.

Doses to biota

The calculations of doses to biota show that the highest dose rates are obtained for the corrosion scenario. However, the dose rates are far below the limit value 10 µGy/h, and the assessment is therefore that releases of radionuclides will not give rise to any biological effects on species in the area.

Fulfilment of other regulatory requirements

As mentioned above, in addition to the risk criterion there are a number of other regulatory requirements on e.g. the design of a repository with a multiple barrier system, selection of a site with favourable properties for long-term safety, and the contents of the safety analysis report with regard to e.g. scenarios and handling of uncertainties. Appendix A of the SR-Site main report presents the regulations SSMFS 2008:21 and 2008:37 with associated general recommendations, and it is also indicated there where in the SR-Site report each relevant part of the regulations is dealt with. The assessment is that all requirements that are relevant to the safety assessment are met.

Confidence in the results

Confidence in the results of SR-Site is assessed to be sufficient for them to serve as a basis for a decision regarding the applications. In summary, the following contributes to confidence in the results:

- The knowledge of the rock and of the surface conditions in Forsmark that has been obtained from the site investigation is sufficient to assess long-term safety. The rock has favourable properties for long-term safety, and no remaining questions that need to be answered in order to demonstrate long-term safety have been identified.
- The reference design, with specific and practically feasible production and inspection methods, results in an initial state of a repository in Forsmark favourable to long-term safety. The design can be further optimized when it is further developed.
- The scientific understanding of issues of importance for long-term safety resulting from decades of research in the nuclear fuel programmes of Sweden and other countries and from international cooperation is reassuring.
- A complete assessment of issues of relevance to long-term safety has been carried out in SR-Site. The assessment has been carried out with a methodology where, for example, pessimistic assumptions are used when the data are associated with uncertainties.

Documented procedures for quality assurance have been employed in determining the initial state, developing the site description and analyzing long-term safety. The procedures include independent peer review.

10.1.7 Chemically toxic risks from deposited spent nuclear fuel

In addition to radiological risks associated with the radioactive substances that will be present in the final repository, certain non-radioactive substances can also be toxic to man and the environment if they reach the biosphere in high concentrations. An assessment has been made of the risks to human health and the environment posed by non-radioactive substances in the spent nuclear fuel and the canister containing the fuel, i.e. copper, steel and nodular iron, as well as the actual fuel matrix /10-34/.

The assessment is based on the composition of the spent nuclear fuel when it is deposited in the final repository, about 40 years after it has been taken out of the reactor.

The assessment has been carried out in two stages. In the first stage, those substances that require large quantities of water for dilution to harmless concentrations were identified. The next stage focused on the substances that require the largest quantities of water. In general, pessimistic assumptions were used to avoid underestimating the potential risks.

In the first stage it is assumed that a canister with its contents, including fuel, is dissolved instantaneously in water and that its entire contents come to a single receiving body (well, lake, watercourse or sea bay).

The water volumes that are needed for dilution to a harmless concentration according to set criteria are compared with the flux of water in the receiving bodies in question. The results show that relatively limited volumes of water are required for dilution. For example, if a canister with contents should be completely dissolved, the annual flux of water through a well in the Forsmark area is sufficient to dilute most substances to concentrations below the drinking water standard. The substances which were the focus of further calculations were copper and uranium as well as e.g. nickel, chromium, iron, copper and manganese.

The second stage was based on the model calculations for damaged canisters that were done in the previous safety assessment, SR-Can. In order for corrosion of the insert, fuel box and other components in the canister, as well as dissolution of the spent nuclear fuel, to occur, the copper shell must be damaged. Based on the assumptions made in SR-Can, possible concentrations of the various substances in the groundwater at repository level were calculated. Even without taking into account dilution, the concentrations are below the drinking water standards and the environmental risk-based concentration criteria for all substances from the copper shell and the steel and nodular iron insert, except copper. It has been calculated that the copper concentrations in water at repository level could be of the same order of magnitude as the environmental risk-based criterion for sea water, but less than the average concentration of copper in the sea water outside Forsmark. The assessment is thereby that no risk of potential harm to human health and the environment is posed by non-radioactive substances present in spent nuclear fuel and the canister on deposition.

The evaluation shows that the maximum concentration of uranium can be expected to be 0.02–0.2 microgram per litre (μg/l), depending on type of receiving water. These concentrations are below the concentration criteria for uranium. Other substances in the fuel have maximum concentrations that are at least 100 times lower.

In summary, even with pessimistic assumptions, the concentrations in the receiving waters will be far below the concentration criteria, indicating that health and environmental risks are improbable.

10.2 Considered alternative – Laxemar

In an effort to find the most suitable site for the final repository, Laxemar in Oskarshamn Municipality has been investigated to the same level of detail as Forsmark since 2004. The factors that decided the choice in favour of Forsmark are presented in the appendix on site selection /10-35/.

During the long and thorough selection process, other environmental factors have also been investigated in Laxemar. The consequences of the alternative of siting a final repository in Laxemar near the nuclear power plant on the Simpevarp peninsula are presented here in general terms, see Figure 10-42. The considered facility and its environmental impact are described in comparison with the final repository in Forsmark.

Information on a possible decommissioning phase in Laxemar has not been included in the description, since the long time left until decommissioning (in around 2070) makes the assumptions highly uncertain. The difference compared with the assessments made for the decommissioning phase in Forsmark are also small, with the exception of backfilling of the final repository, where about a million more tonnes of backfill material would have been required in Laxemar than in Forsmark.

10.2.1 Facility design

The final repository in Laxemar would have had a similar layout to the repository in Forsmark, with a surface part consisting of an inner and an outer operations area plus an underground part consisting of a central area and a repository area, see Figure 10-43. The layout differs slightly between the sites due to differences in geology and external environment. The facility's underground repository area would have been larger in Laxemar than in Forsmark. The main reason is that the thermal conductivity of the rock is lower in Laxemar and that the canisters therefore have to be spaced farther apart.

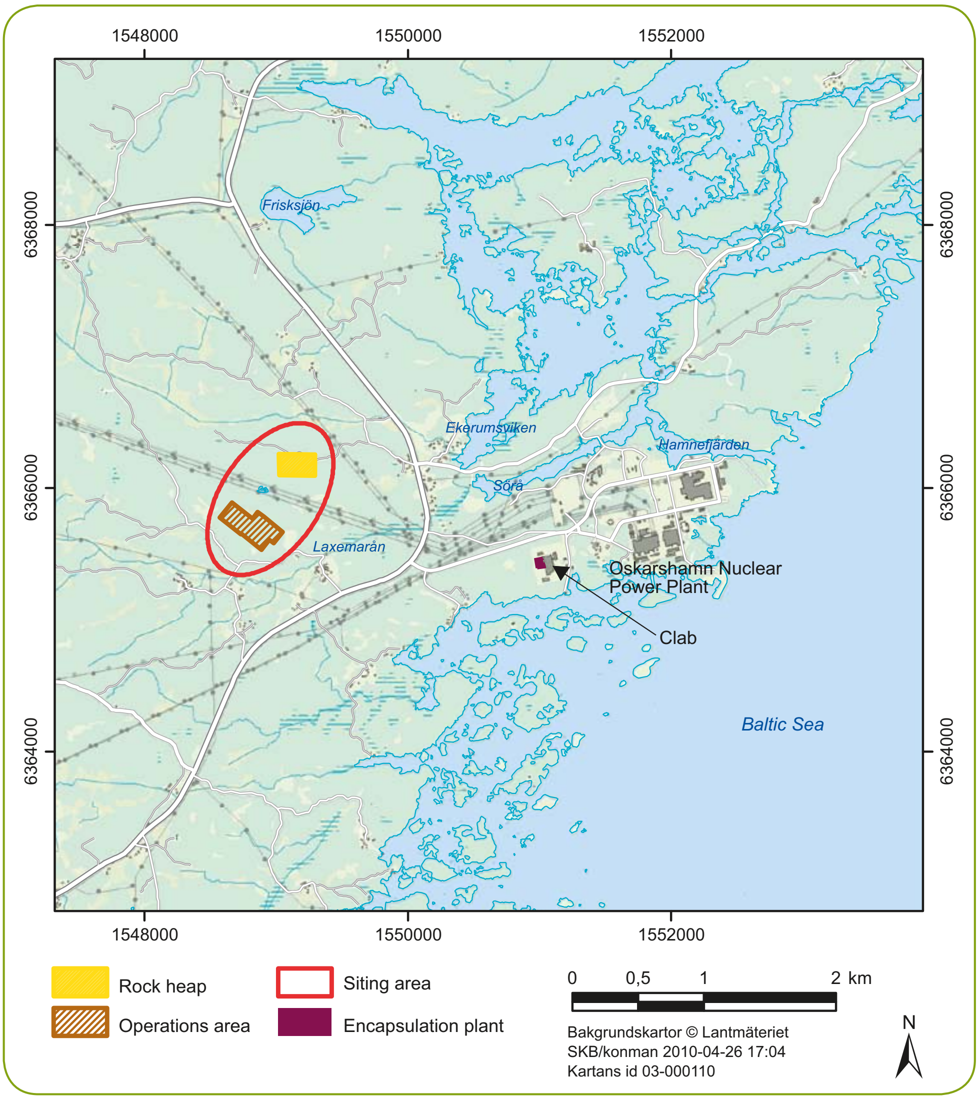


Figure 10-42. Approximate location for the considered alternative, a final repository in Laxemar.

The surface facility was planned to be located in an undeveloped area on the southern side of a large power line corridor in Laxemar. There is no nearby coast or large-scale industry as in Forsmark. There are more homes in the immediate area in Laxemar than in Forsmark. The differences in the immediate environment influence the interior disposition of the facilities and the external form of the buildings, see Figure 10-44.

Table 10-17 summarizes the size of the final repository sited in Laxemar compared with one in Forsmark.

Table 10-17. Comparison between a final repository in Laxemar and in Forsmark.

	Laxemar	Forsmark
Size of above-ground operations area (total outer and inner)	75,000 m²	70,000 m²
Size of repository area	5–6 km²	3–4 km²
Depth of repository area	–510 m	–470 m
Size of rock heap	40,000 m²	40,000 m²
Height of rock heap	~15 m at most ~10 m	~15 m at most ~10 m most likely
Tallest building	45 m	50 m

Figure 10-43. The underground part of the final repository in the studied siting at Laxemar.

Figure 10-44. Photomontage of the surface part of the final repository in Laxemar.

10.2.2 Description of activities

The activities at a final repository in Laxemar would be the same as in Forsmark. The differences are above all in transport quantities, since the amount of rock extracted would have been greater in Laxemar than in Forsmark.

10.2.2.1 Construction phase

The final repository would be built in a similar manner to the repository in Forsmark, as described in Chapter 10.1.2.1.

The activity in Laxemar would also give rise to contaminated water in the form of waste water, leachate, stormwater and drainage water with water streams of the same size as in Forsmark. Water treatment would take place according to the same principles as in Forsmark. The waste water from the operations area would be collected and piped to OKG's sewage treatment plant, which has the necessary treatment capacity.

The final repository in Laxemar was planned to be located slightly deeper under ground and occupy a larger surface area than the repository in Forsmark, which means that larger rock volumes would have to be excavated. The quantity of rock spoil is estimated at about 200,000 tonnes per year, or a total of about 1.7 million tonnes, which is roughly 100,000 tonnes more than in Forsmark /10-36/.The larger volume of excavated rock means more shipments of rock from the facility. The number of shipments during the second half of the construction phase has been estimated to be about ten more per day in Laxemar than in Forsmark (100 versus 90). During the first half of the construction phase, the number of shipments is the same for both sites (60 per day).

Work journeys, material shipments and service transport trips are of the same order of magnitude as in Forsmark. Transport to and from a final repository in Laxemar is described in report /10-37/.

10.2.2.2 Operating phase

The operation of the facility in Laxemar would be the same as that of the facility in Forsmark, as described in section 10.1.2.2.

During the operating phase, it is mainly water quantities and transport volumes that differ between Laxemar and Forsmark. It is calculated that there would be at least twice as much drainage water in the operating phase as in Forsmark. The actual handling of spoil materials is similar, but the quantities would be greater in Laxemar.

Planned rock excavation is expected to yield about 175,000 tonnes of rock spoil per year in Laxemar, which is about 55,000 tonnes more per year than in Forsmark /10-36/. This would amount to a total of about seven million tonnes of rock spoil during the time the rock excavation work is in progress. Backfilling of the deposition tunnels with bentonite in the form of blocks and pellets also begins during the operating phase.

Nuclear fuel would be transported by terminal vehicles from the encapsulation plant to the terminal building in the inner operations area. Aside from short moves within the operations areas, nuclear fuel would be transported by road, about 2.5 kilometres from Simpevarp to Laxemar.

10.2.2.3 Ports

The existing port in Simpevarp could be used for the final repository activity without extensive investments. In addition to widening and deepening of the channel and construction of breakwaters, a new port yard and a new quay would be needed. The port in Oskarshamn is, however, well suited for imports of bentonite and clay, but for environmental reasons it is less well suited for shipping-out of rock material /10-37/.

10.2.3 Impact

10.2.3.1 Land use

Slightly more land would have been needed in Laxemar than in Forsmark. The final repository's operations area was planned to be located separately from the nuclear power plant on the Simpevarp peninsula and other industrial development, see Figure 10-45. The site consists of undeveloped land with a small meadow and a mix of coniferous and deciduous trees.

The location of the facility in the midst of an undeveloped area would have entailed that a new service road would have to be built, since the existing road system from the south is not of the required standard. The final repository's surface parts would have included the same functions as in Forsmark, but their layout would have been slightly different to suit the site. The operations area and the rock heap would occupy roughly the same surface areas as in Forsmark.

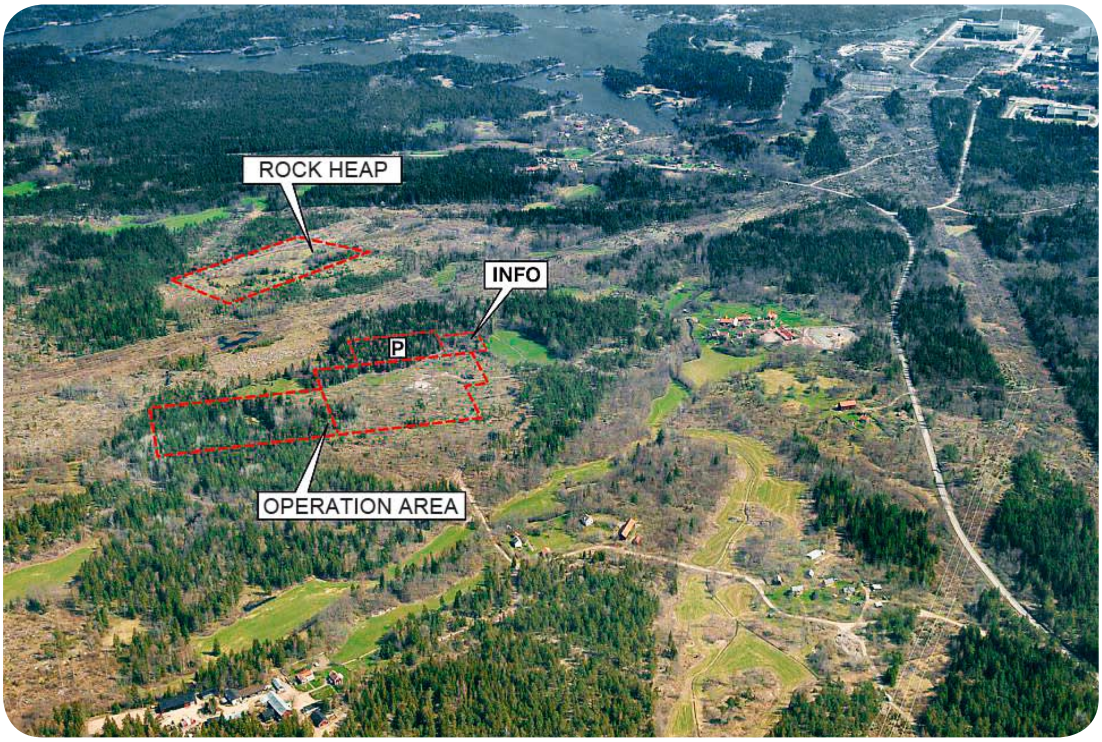


Figure 10-45. Location of the final repository. Clab and the nuclear power plant can be seen in the background.

Contaminated leachate from the rock heap has to be purified. This could have been done in a planned broad irrigation facility adjacent to the rock heap and in a fenland below the broad irrigation facility.

10.2.3.2 Impact on groundwater level

The groundwater flow rate within the area and its impact on the groundwater level has been the subject of extensive modelling efforts. The impact on the groundwater is important to analyze in order to assess the possible consequences for the surface ecosystem. Detailed information on diversion of groundwater, impact on groundwater levels and the methods used for the hydrogeological study in Laxemar is provided in /10-38/.

The inflow of groundwater into a final repository in Laxemar during the construction phase could be of the same magnitude as to the the final repository in Forsmark. The impact area for lowering of the groundwater table would, however, be larger during this phase compared with in Forsmark.

Inflow into the facility during the operating phase would be at least twice as great as in Forsmark. The size of the area affected by a lowering of the groundwater table is calculated to be about ten times larger in Laxemar than in Forsmark. Based on the same scenario as for Forsmark (the whole repository is open at the same time and a drawdown limit of 0.1 metre for the areas considered to be impacted), the impact area is calculated to be about 20 square kilometres compared with two square kilometres for Forsmark.

The difference between Laxemar and Forsmark in terms of impact on the groundwater table is partly attributable to the fact that the average distance between water-conducting fractures at a depth of 500 metres is about 10 metres in Laxemar, while the equivalent distance in Forsmark is more than 100 metres. This means that the groundwater flow through the repository, and thereby the inflow of water into the tunnel system, is greater in Laxemar than in Forsmark.

Another difference is that the occurrence of water-conducting fractures is relatively homogeneous all the way to the surface, which in turn makes the impact area for groundwater lowering circular in shape compared with the elongated shape of the impact area in Forsmark.

10.2.3.3 Noise

Blasting, rock crushing and drilling are the tasks that cause the highest sound levels during the construction phase /10-39/. This is true for both Laxemar and Forsmark. The sound from blasting is of short duration, will occur one or two times per day and will not appreciably affect the equivalent sound level. Blasting can cause structure-borne sound, but the assessment is that such sound will not amount to audible levels in surrounding housing in Laxemar either /10-40/. The sound level from above-ground drilling at the nearest building has been calculated to be about 5 dBA higher in Laxemar than in Forsmark (55 dBA). Equivalent noise levels during the construction phase and the operating phase are shown in Figure 10-46.

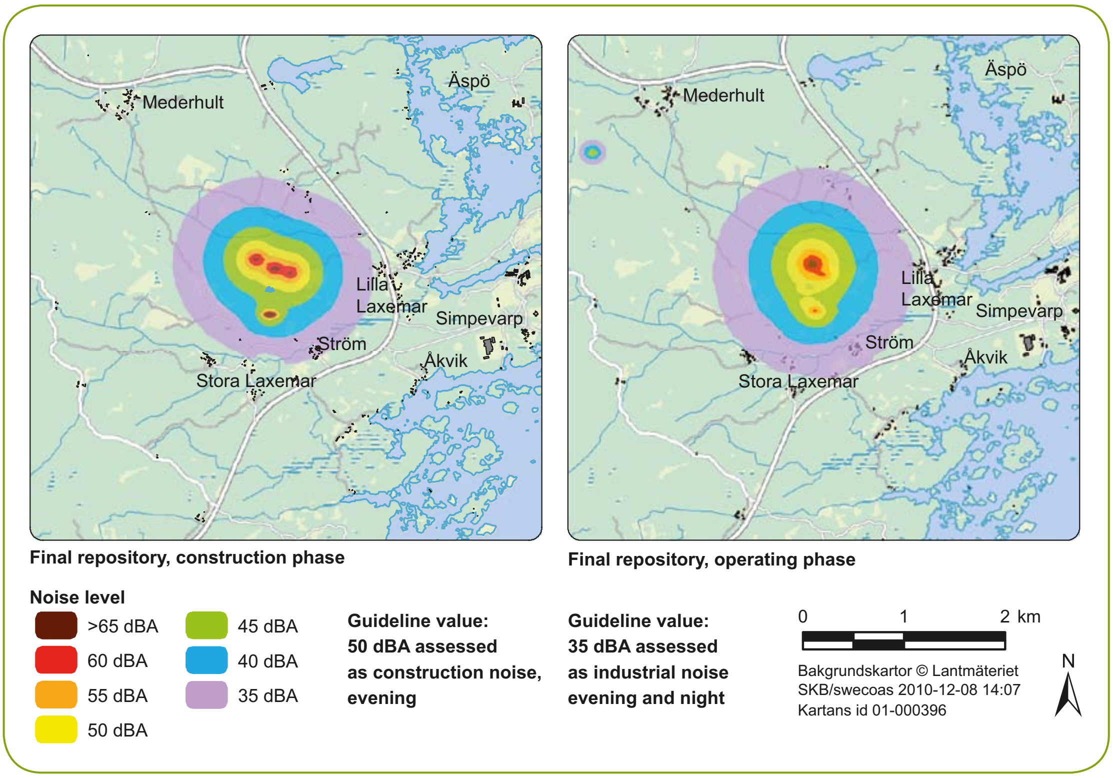


Figure 10-46. Noise in the evening during the construction phase (at left) and noise in the evening and at night during the operating phase (at right).

The tasks that are expected to cause the most noise during the operating phase are operation of the skip, use of heavy vehicles within the work site, and rock handling at the rock heap. Sound from evacuation fans also contributes to increased noise. The noise expected to be caused by a final repository has been calculated for both Laxemar and Forsmark. Sound data for the two sites are equivalent.

10.2.3.4 Vibrations

The assessment is that the vibration levels in Laxemar and Forsmark do not differ significantly. There are fewer vibration-sensitive facilities in the vicinity of the final repository in Laxemar than in Forsmark. The vibration levels from blasting have been assessed to be so low that no buildings, installations or equipment in Laxemar with environs would have been affected.

Heavy shipments may cause vibrations along the transport routes. Such vibrations may be experienced as disturbing by residents along the routes. The vibration levels would not be changed as a consequence of the traffic to and from a final repository, since heavy transport already occurs today on the roads in the area /10-40/.

10.2.3.5 Radiation and releases of radionuclides

Radionuclides, mainly radon, would occur naturally in the considered final repository in Laxemar. These radionuclides give rise to some radiation in the same way as in a facility in Forsmark. During the operating phase of a final repository, radiation-emitting canisters of spent nuclear fuel are deposited.

The number of canisters deposited does not differ between the considered alternative and a final repository in Forsmark. What distinguishes the two sites in terms of radioactivity and radiation is above all the natural radon concentration in the rock.

Construction phase

Generally speaking, the radon concentrations in a final repository in Laxemar would be much higher than in the repository in Forsmark. The ventilation requirement would thereby also be greater in Laxemar so that the radon concentration in the facility would comply with the Swedish Work Environment Authority's limit values. Radon would also have been discharged with water from the facility, and just as in Forsmark the radon would have disappeared via deaeration before the water reached the discharge pipe.

Operating phase

There are no releases of radionuclides from the canisters of spent nuclear fuel that have been deposited in the final repository. Shielding-off of gamma and neutron radiation from the canister is done in the same way as in Forsmark, and the dose to personnel would be the same at both sites /10-14, 10-15/.

10.2.3.6 Non-radiological atmospheric emissions

Construction phase

Emissions from on-site transport are the same for both sites. Nor do emissions from off-site transport during the first part of the construction phase, represented by the year 2015, differ from those in Forsmark. During the second part of the construction phase, emissions from off-site transport would be slightly higher in Laxemar due to a larger number of material shipments. The differences are small; the increase in the calculated emissions is between two and ten percent.

The background concentrations of both nitrogen oxides (NO_x) and particulate matter (PM10) in the environs around Laxemar are on the same level as in the environs around Forsmark. The concentration contributions of nitrogen oxides from the final repository together with Clink in Laxemar-Simpevarp are calculated to be the same as in Forsmark, while the concentration contributions of particulate matter are calculated to be slightly lower. Calculations have only been done for the concentration contributions from both the final repository and Clink, but the contributions from Clink are assessed to be very small.

The deposition of nitrogen from a final repository in Laxemar would be less than 0.002 percent of the background load, which is comparable to the situation in Forsmark.

Operating phase

In the same way as in Forsmark, emissions from on-site and off-site transport at the final repository in Laxemar have been calculated for the year 2030. The emissions have been calculated to be marginally greater in Laxemar, with the exception of carbon dioxide (CO_2), which is calculated to be slightly lower.

Dispersion calculations have been done which show that the concentrations of nitrogen dioxide (NO_2) and particulate matter from the final repository and from transport along the off-site transport routes are expected to be lower in 2030 than in 2018. It is assumed that development of fuels and engines will lead to lower emissions. The calculations include the contribution from the encapsulation plant, which is small. SKB's contribution to the particulate matter concentrations has been calculated to be slightly higher in Laxemar than in Forsmark. Dispersion maps are presented in /10-41/.

10.2.3.7 Non-radiological effluents

The same type of water streams would arise in Laxemar as in Forsmark as a result of the activity at the final repository: waste water, drainage water from rock caverns, leachate from the rock heap and stormwater from the operations area. The volume of the water streams would be roughly the same as in Forsmark, with the exception of drainage water, whose volume would be at least twice as great during the operating phase as for the final repository in Forsmark. Drainage water would be treated in the same way as in Forsmark. The waste water from the operations area will be collected and piped to OKG's sewage treatment plant for treatment.

Just as in Forsmark, oil, particulate matter and nitrogen are removed from the leachate in Laxemar by means of sedimentation and nitrogen reduction in fenland. The assessment is that about 25 percent of the nitrogen, or about 0.5 tonne, remains after treatment in the fenland /10-42/.

Stormwater can be managed locally within the operations area. The same type of measures as in Forsmark would be used. This entails retardation of stormwater runoff so that impurities are retained in the soil instead of being discharged to the receiving water.

10.2.3.8 Light pollution

Lighting during the final repository's different phases would be chosen according to the same principles as in Forsmark.

10.2.3.9 Waste

Management of waste in the considered alternative does not differ from waste management in Forsmark.

The assessment is that as much hazardous and other waste would arise in Laxemar as in Forsmark during the construction phase (50 versus 1,100 tonnes) /10-43/.

Repository activity is relatively constant over time on both sites, which means that the waste quantities do not vary over the years during the operating phase. Just as in the construction phase, the waste quantities are assessed to be roughly the same as in Forsmark: about 5 tonnes of hazardous waste per year or more than 200 tonnes altogether, and 130 tonnes of other waste per year or 5,800 tonnes altogether /10-43/.

10.2.3.10 Energy use

Since a repository in Laxemar would be larger than in Forsmark, more electrical energy would be required to excavate and handle rock spoil. The higher water throughflow in Laxemar also means that more electrical energy would be required to pump drainage water. Otherwise, power supply, energy uses and conservation methods are the same as in Forsmark.

As much electrical energy would be required during the construction phase in Laxemar as in Forsmark, about 60 GWh. Diesel consumption in vehicles and machinery would be the same on both sites.

Electrical energy use during the operating phase would be roughly the same as in Forsmark, while diesel consumption would be higher /10-43/.

10.2.3.11 Water consumption

The activity at a final repository consumes water in all phases. The need for water would be as great per cubic metre of rock as in Forsmark (about 0.15 cubic metre of water per cubic metre of solid rock).

Since the repository area has been calculated to be bigger in Laxemar than in Forsmark, water consumption would also be greater. A total of approximately 200,000 cubic metres of water would be consumed in Laxemar during the construction phase, which is more than in Forsmark.

Water consumption would be about 20,000 cubic metres per year during the operating phase, for a total of about 800,000 cubic metres /10-43/. In Forsmark, the amount is calculated to be about 15,000 cubic metres per year, for a total of about 680,000 cubic metres.

10.2.3.12 Handling of rock spoil and resource consumption

Handling of rock spoil would not differ from that in Forsmark, but the quantity would be greater in Laxemar. The following figures are taken from early underground design-basis data. Further design work has shown that more rock volume is required to accommodate the underground part of the final repository, which means that more rock spoil will be produced and more bentonite will be required for backfilling.

The quantity of rock spoil in Laxemar has been estimated at more than 200,000 tonnes per year, for a total of about 1.7 million tonnes of rock spoil during the construction phase (about 100,000 tonnes more than in Forsmark) /10-36/. Most of the rock spoil would be sold on the market.

Rock excavation continues during the operating phase, although on a smaller scale than during the construction phase. This work would give rise to about 175,000 tonnes of rock spoil per year in Laxemar. The equivalent annual amount in Forsmark is about 120,000 tonnes. Over the 40 years the rock excavation work would continue, some 7 million tonnes of rock spoil would be produced in Laxemar. The equivalent figure for the final repository in Forsmark is about 4.8 million tonnes. Backfilling of the deposition tunnels with bentonite in the form of blocks and pellets is also begun during the operating phase. It is estimated that approximately 76,000 tonnes of bentonite per year, or a total of 3.4 million tonnes, will be consumed for backfill and buffer /10-36/. The equivalent figure in Forsmark is about 2.3 million tonnes.

10.2.4 Effects and consequences

10.2.4.1 Natural environment

Land use

An undeveloped land area would be used for the surface part of the final repository in Laxemar. The area's natural values are mainly linked to its deciduous woods, see Figure 10-47. The area is located in a so-called "value district" for hardwood forest, as designated by the Swedish Environmental Protection Agency, whose principal natural values consist of the woodland environment. There are plans for a nature reserve next to the area planned for the final repository. The surface facility and the access road would have appreciable negative consequences for the natural environment in the area.

Figure 10-47. Deciduous woods in Laxemar.

With regard to the impact of discharges of leachate and drainage water on fresh water and marine environments, it is assessed that a final repository in Laxemar could have small to appreciable negative consequences if no preventive measures are taken. Details of the impact assessment for land use are presented in /10-44/.

Groundwater lowering

The groundwater lowering that occurs during the the final repository's construction and operating phases can have effects on the surrounding natural areas.

Laxemar is characterized by dry conditions. This means that the natural values that distinguish the area are not dependent on the location of the groundwater table. More important for the area's natural values is former traditional land use in the form of and grazing and haymaking. The hardwood forest and the old deciduous trees are also less sensitive to groundwater lowering, since the natural values are mainly dependent on the age and management of the forest.

There are a number of natural attractions that may be sensitive to groundwater lowering. They are described in /10-45/, where inventoried natural attractions have been classified based on their sensitivity to groundwater lowering.

The overall assessment is that a drawdown area of about 20 square kilometres will have small negative consequences for the majority of the affected natural attractions. The study has shown that the natural attractions that are affected by a major impact on the groundwater level have relatively high natural values.

There is also agricultural land within the predicted drawdown area. Based on experience from other cases, crop yields may decrease by an average of 5–10 percent on fen and mud soils (which dominate agriculture in the area) and 20 percent of coarser soils.

More than 50 private wells are situated within the predicted drawdown area. At worst, the capacity and/or water quality in a number of these wells could be adversely affected as a consequence of the groundwater lowering.

Details of the studies that have been done are presented in /10-38/ and /10-46/.

10.2.4.2 Recreation and outdoor activities

The area around the planned final repository is relatively quiet, with little impact from noise, with the exception of the environs around county road 743. The Misterhult archipelago, an area of national interest for outdoor activities, is nearby. Three areas are of moderate value for outdoor activities: Kråkelund, Hamnefjärden and Ostkustleden (the East Coast Trail), which are utilized by tourists, nearby residents and associations. The main impact the final repository would have on outdoor activities in the area is noise and increased human presence.

The proposed new access roads to a final repository in Laxemar would cross Ostkustleden. Since the trail has been assessed as having a relatively high value for recreation and outdoor activities, the consequences have been assessed to be moderate.

The overall assessment is that in spite of the disturbances which the the final repository and associated activity would have entailed, many of the outdoor activities that are pursued in the area today could continue to be carried on just like before /10-47/.

10.2.4.3 Cultural environment and landscape

In Laxemar, the cultural heritage values are associated with the landscape, and no environments of national, regional or municipal interest for cultural heritage preservation are affected by a final repository. There are no known archaeological remains in the area, and no new ones have been encountered in the surveys that have been conducted /10-48/.

The cultural landscape cannot be said to have any unique values, but is representative of this region and of large parts of the rest of Central Sweden, see Figure 10-48.

An establishment in the Laxemar area would impact a relatively unaffected forest and cultural landscape, since the scale of the facilities would compete with the small-scale landscape. On the other hand, the power line corridors through the area have already introduced a large-scale industrial element in the landscape, so that the impact of an establishment here would be limited.

Figure 10-48. The agricultural landscape around Laxemar.

10.2.4.4 Residential environment and health

Noise

Just like in Forsmark, construction of a final repository would entail an increase in the noise levels in the environs, but in Laxemar there are permanent residents closer to the planned facility than in Forsmark.

Operation of the skip, use of heavy vehicles on the work site and rock handling on the rock heap are the noisiest tasks. Seven properties with 20 residents would have noise levels above 35 dBA (guideline value for industrial noise in the evening and at night in vacation home areas), which is higher than in Forsmark. In the daytime, no residents would be exposed to noise levels above 40 dBA (guideline value for industrial noise in the daytime in vacation home areas).

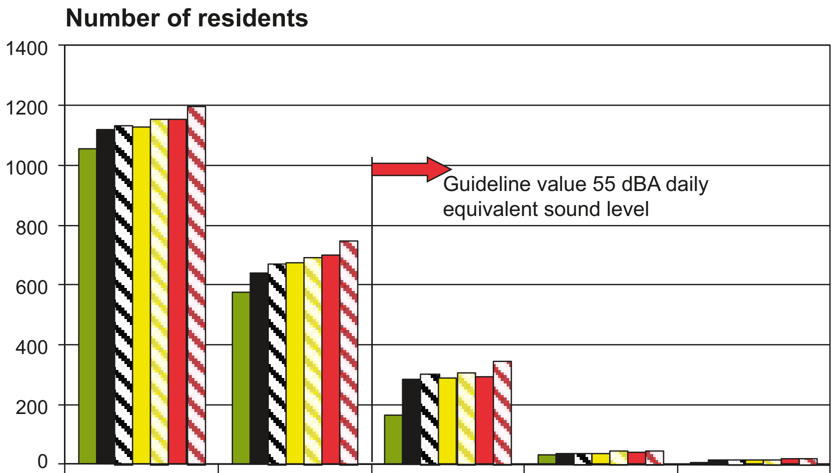
The assessment is that structure-borne sound from rock drilling would be audible, and noise from above-ground drilling would fall below the guideline values for construction noise.

When it comes to noise from transport on the public road network, sound propagation during transport in the operating phase is equivalent to that in the construction phase. The increase in the number of residents exposed to sound levels above 55 dBA as a result of transport to and from the final repository is about 50 (in Forsmark the number is about 15) during the operating phase compared with about 20 at most during the construction phase, see Figure 10-49.

The noise levels along portions of the transport route are experienced as disturbing today by nearby residents /10-39/.

Vibrations

The vibration levels from the blasting work would be so low that there would be no risk of comfort disturbances for residents, according to the National Board of Health and Welfare's guidelines. No buildings, installations or equipment in Laxemar and environs would have been impacted either.



Equivalent sound level	> 45 dBA	>50 dBA	>55 dBA	>60 dBA	>65 dBA
2006 current situation	1057	575	165	34	8
2015 zero alt.	1119	641	284	36	13
2015 build-out of final repository	1131	669	301	38	13
2018 zero alt.	1126	673	290	36	13
2018 build-out of final repository	1153	692	308	46	15
2030 zero alt.	1154	700	293	39	20
2030 operating phase	1196	749	345	45	20

Figure 10-49. Residents along the road section from Simpevarp to the Port of Oskarshamn exposed to equivalent sound level within different sound intervals.

Radiation and releases of radionuclides

Radiation and releases of radionuclides during the construction phase would derive from naturally occurring radioactive substances, such as radon, in the bedrock. Radon from a final repository in Laxemar would be dispersed in the same way as from a final repository in Forsmark. Adequate ventilation would keep the radon levels below the Swedish Work Environment Authority's limits with good margin.

Non-radiological atmospheric emissions

Transport during the construction of a final repository in Laxemar would make a very small contribution to air pollution levels in the environs and no environmental quality standards would be exceeded. As a result of less traffic along county road 743, the concentrations are slightly lower than along national road 76 in Forsmark.

Compared with Forsmark, more homes would have increased particulate matter concentrations in the residential environment. 57 permanent residences and 20 secondary residences would have increased particulate matter concentrations. The effect of the increased particulate matter concentration at the most polluted permanent residences would be the same as for Forsmark. The concentration contribution from the final repository does not change between the construction phase and the operating phase. SKB's concentration contribution from off-site transport is low and far below relevant environmental quality standards /10-41/.

10.2.5 Risk and safety issues during construction and operation

10.2.5.1 Environmental risk analysis

An environmental risk analysis has also been done for the considered alternative in Laxemar /10-29/.

An environmental risk associated with the construction of the final repository is an unexpectedly large water inflow. The natural environment in Laxemar is not as sensitive to groundwater lowering as in Forsmark. The assessment is that other environmental risks within the facility in Laxemar do not differ from the environmental risks in Forsmark.

Particular environmental risks are associated with transport. Both construction and operation of the final repository require transport of fuels, hydraulic oils and other chemicals. There are no water protection areas or other particularly critical areas near the operations area in Laxemar.

The consequences of accidents in the operating phase are assessed to be less than in Forsmark due to the less sensitive natural environment in Laxemar.

Unlike in Forsmark, flooding due to increased sea levels is not a risk in Laxemar, see Figure 9-19 in Chapter 9 about Clink.

10.2.5.2 Nuclear safety during operation

Nuclear safety during operation does not differ between Forsmark and Laxemar.

10.2.6 Post-closure safety

In the previous assessment of long-term safety, SR-Can /10-32/, a final repository in Laxemar was assessed in the same way as for Forsmark. A reference evolution, which can be said to comprise a typical example of the evolution of the repository over time, was studied first and served as a basis for a main scenario. In addition to the reference evolution/main scenario, a number of other scenarios were studied for the purpose of ensuring that all uncertainties are covered. A comparative analysis of safety-related site characteristics was then done, revealing differences in the prospects of satisfying SSM's risk criterion /10-49/.

In the case of Forsmark, SR-Site found that the biggest risk contribution comes from the corrosion scenario, i.e. the scenario where canister failure due to corrosion occurs due to erosion of the buffer, see 10.1.6.4. The risk of canister failure due to earthquake cannot be entirely ruled out, but the risk contribution is smaller than for the corrosion scenario and is assessed to be equivalent for the two sites. In order to compare the sites, it is therefore assessed to be sufficient to only compare the risk contributions from the main scenario, and only for the cases with loss of buffer and copper corrosion.

10.2.6.1 Conclusions

At 500 metres depth, the average distance between water-conducting fractures is about 10 metres in Laxemar, while the equivalent distance in Forsmark is more than 100 metres. This means that the groundwater flow through the repository is greater in Laxemar, and thereby also the advective transport of solutes in the groundwater to the buffer and canister. A much larger fraction of the deposition positions will suffer loss of buffer in Laxemar than in Forsmark. Buffer loss and advective conditions can lead to canister corrosion. With pessimistic assumptions, nearly all deposition positions that are in contact with water-conducting fractures will be exposed to advective conditions in the course of a million years, and half of these after only 100,000 years.

The risk contribution from canister corrosion in Forsmark is small and below the risk limit. In Laxemar, over a hundred canister failures are expected due to corrosion.

The first radionuclide releases take place after about 20,000 years, when the first canisters fail. After a very long time, the risk reaches a level approaching the risk from the natural background radiation. If deposition positions with high flows are not utilized, the number of canister failures, and thereby the doses, can be reduced, but this requires changes in the layout of the repository. The safety-related conditions are thus poorer than in Forsmark.

10.3 Summarizing conclusions

In order to clarify the differences between the applied-for activity and the considered alternative, a summary is made here of the conclusions that have been arrived at in the assessment of effects and consequences. The description of the considered alternative in Laxemar is of a comparative nature in relation to the applied-for siting in Forsmark.

The post-closure safety of the final repository as regards the possible dispersion of radioactive material in the very long term has been analyzed for both alternatives. The time perspective is a million years, and a number of different courses of events have been studied. The biggest difference between Forsmark and Laxemar is the greater water throughflow at repository depth in Laxemar. The water throughflow is important since it can transport solutes to the buffer and canister, which can affect the long-term function of the buffer and the canister. A larger water throughflow leads to greater solute transport via the groundwater to the buffer and canister and therefore poorer safety-related conditions. External processes, such as earthquakes or freezing of the buffer during future ice ages, do not differ between the sites. The probability of such impact is also assessed to be very small. The conclusion of the analyses is that Forsmark fulfils SSM's risk criterion with good margin, while this is not the case for Laxemar.

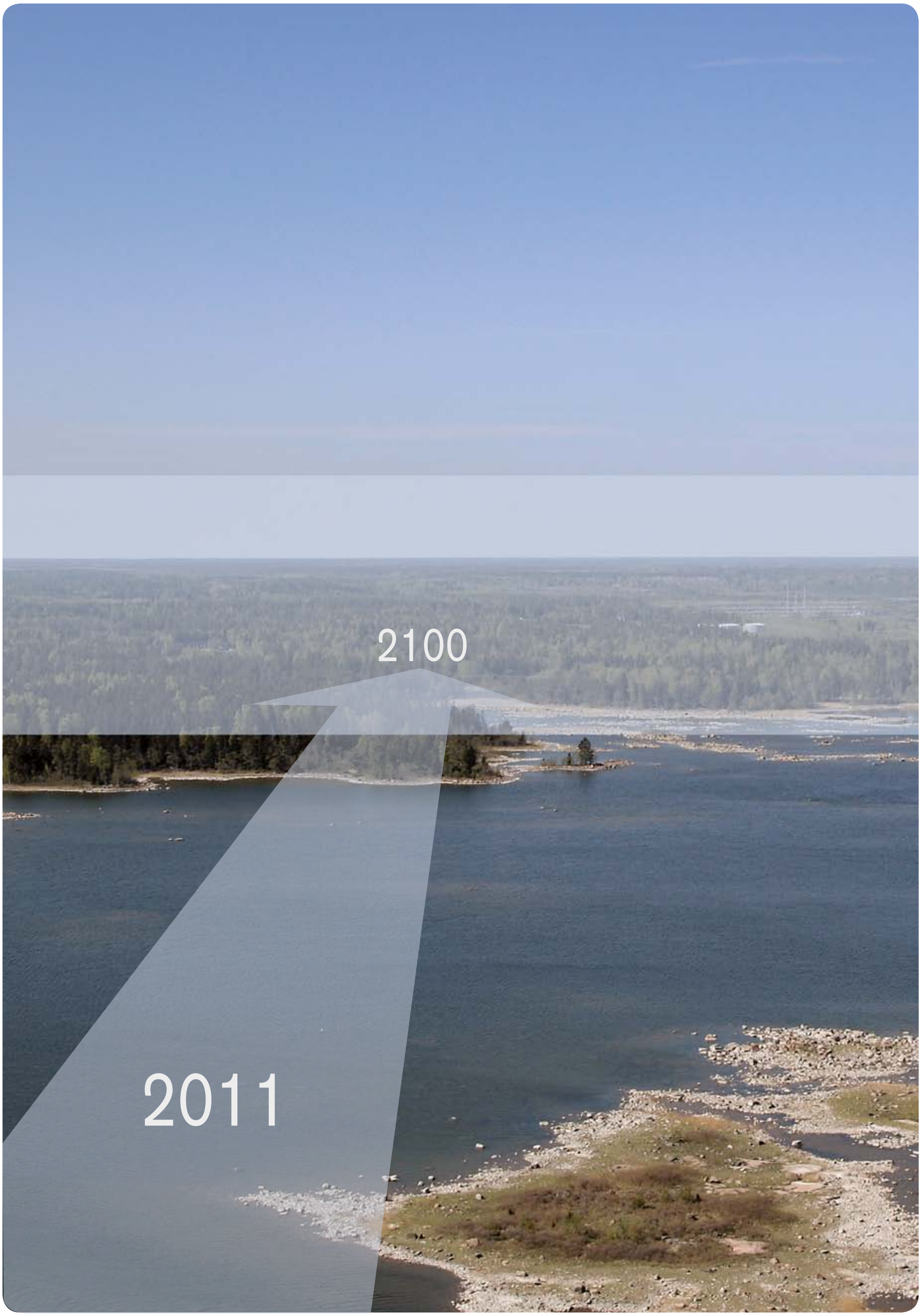
The natural environment in Forsmark harbours high natural values, mainly due to the occurrence of the pool frog. Three ponds, in two of which the pool frog has been observed, will be filled in. SKB intends to find suitable environments where ponds can be recreated in order to compensate for the ponds that are filled in. Furthermore, there are valuable natural attractions in Forsmark, mainly in the form of rich fens and ponds, which are very sensitive to groundwater lowering. These sites exhibit great biodiversity, with several red-listed and protected species. Groundwater lowering by as little as a decimetre can cause a change in vegetation in the natural attractions and thereby have an impact on species that are dependent on the vegetation. In order to prevent the natural attractions from being affected by groundwater lowering, local infiltration of water is planned in the most sensitive sites, where necessary. The natural values in Laxemar consist mainly of an area with hardwood forest of regional value. The natural values in the area are not primarily linked to the groundwater table, but to former traditional land use in the form of grazing and haymaking. The natural environment in Laxemar is thereby not as sensitive to groundwater lowering as the natural environment in Forsmark.

A final repository in Forsmark will occupy a smaller volume and surface area under ground than a facility in Laxemar. This means that resource consumption (waste production, water consumption, energy consumption, rock extraction) and material transport quantities will also be lower in Forsmark than in Laxemar. Transport to and from the final repository at both sites entails that slightly more residents than at present will be disturbed by noise, particularly in Laxemar where there are more residents near the repository and along the transport routes. Atmospheric emissions are assessed to be small at both sites in relation to the background concentrations, and there will be no radionuclide releases. Nor will radiation from the canisters affect the residential environment. All in all, this means that the risk of health consequences as a result of the final repository activity is very small in both Forsmark and Laxemar, but that the residential environment is affected to a slightly greater extent by a siting at Laxemar.

The above summary is also shown in Table 10-18.

Table 10-18. Consequences for the natural environment according to the environmental impact statement.

	Siting in Forsmark	Siting in Laxemar
Natural environment Land use	Three ponds, in two of which the pool frog has been observed, will be filled in. This gives rise to great negative consequences. In order to compensate for the consequences for the pool frog population, SKB is examining the possibility of creating new ponds suitable for pool frogs. Discharge of treated water is assessed to have limited consequences for a rich fen of regional interest. Increased primary production in Söderviken can be expected due to increased nitrogen concentrations where drainage water is discharged. The receiving water is relatively resilient, so no major consequences are expected.	Undeveloped land of regional interest due to the presence of hardwood forest will be occupied by the final repository. The consequences of this will be appreciable, since the area has development potential from a natural value viewpoint. However, the consequences will not be as great as in Forsmark. Discharge of treated water to fresh water and marine environments is assessed to have small consequences. The assessment is that the consequences will be smaller than in Forsmark.
Groundwater	The natural environment in Forsmark is characterized by natural attractions that are dependent on a high groundwater table, for example rich fens and calcareous ponds. The final repository will lead to groundwater lowering, which can have negative consequences. As a consequence-mitigating measure, preparedness for local infiltration of water is planned at the most sensitive natural attractions.	The natural values in Laxemar are mainly in an area with hardwood forest of regional value. The natural values in the area are not primarily linked to the groundwater table and are therefore not as sensitive to groundwater lowering as the natural values in Forsmark. More wells risk being affected than in Forsmark.
Cultural environment and landscape	The area does not harbour any particular cultural heritage values. The final repository has a visual impact on the landscape, mainly as viewed from the sea. The main development will be directly adjacent to the existing industrial area, however.	The area has some preservation value and does not harbour any historical remains. The landscape is a relatively unaffected forest and agricultural landscape, but power line corridors have already introduced a large-scale industrial element in the landscape. A development in Laxemar would change the landscape. The consequences are assessed to be greater than in Forsmark.
Recreation and outdoor activities	The area around the final repository is mainly utilized by people in the vicinity. The final repository can have an impact on outdoor activities in the area via noise and a greater human presence.	The consequences for recreation and outdoor activities will be slightly greater in Laxemar than in Forsmark, due to the fact that the area is utilized by both nearby residents and tourists. The final repository can have an impact on outdoor activities via noise and a greater human presence.
Residential environment and health Noise	Tasks such as blasting, skip operation and rock handling contribute to noise from the facility. The assessment is that guideline values for construction noise will not be exceeded at nearby residences. It is assessed that the number of residents along the transport routes to and from the final repository who will be exposed to noise levels above the guideline value for transport will increase by at most about 20. The distance from the road necessary to bring the road traffic noise level below the guideline value is assessed to increase by about 15 metres.	The noise sources are assessed to be the same as in Forsmark, but in Laxemar there are residents who live closer to the final repository. During the operating phase, seven properties with 20 residents will have noise levels above the guideline value in the evening and at night. The assessment is that the noise levels from the facility will be below the guideline values in other phases. It is assessed that the number of residents along the transport routes to and from the final repository who will be exposed to noise levels above the guideline value for transport will be more than in Forsmark, at most about 50 persons. The distance from the road necessary to bring the road traffic noise level below the guideline value is assessed to increase by about 20 metres, which is more than in Forsmark.
Non-radiological atmospheric emissions	Transportation and heavy equipment give rise to atmospheric emissions. Calculated background concentrations are considerably higher than calculated contributions from SKB's activity. The assessment is that environmental quality standards will not be exceeded.	Slightly more transport trips are required in Laxemar, and emissions are therefore assessed to be slightly higher than in Forsmark. However, calculated background concentrations are considerably higher than calculated contributions from SKB's activity, and the assessment is that environmental quality standards will not be exceeded.
Radiation and releases of radionuclides	The final repository will not release any radionuclides. The radiation that is not shielded off by the canister has a short range and will only reach personnel in the facility. Dose limits to personnel are met with good margin.	The facilities are assessed to be equivalent with respect to radioactive releases and radiation during construction, operation and decommissioning.
Risk and safety Non-radiological risks	In Forsmark, the greatest non-radiological risk is an unexpectedly large inflow of groundwater, which could have consequences for the valuable and sensitive natural environment. In the event of extreme rises in sea levels, there is a risk that parts of the Forsmark area will be flooded. As a preventive measure, the layout of the operations area has been modified to allow for flooding.	The consequences of an unexpectedly large inflow of water are assessed to be smaller in Laxemar than in Forsmark. On the other hand, the risk that undiscovered cultural heritage remains will be damaged may be greater in Laxemar. There is no risk that Laxemar will be flooded in the event of future extreme rises in sea levels.
Radiological risks	Various mishaps and disturbances during the operation of the final repository have been analyzed. No mishaps or disturbances are assessed to give rise to dispersion of radionuclides from the final repository.	The facilities are assessed to be equivalent with respect to radiological risks during operation.
Long-term nuclear safety	At repository depth, the average distance between water-conducting fractures is greater than 100 metres and the groundwater flow through the repository is limited. This entails great safety advantages for the long-term performance of the copper canister and the bentonite clay. Forsmark fulfils SSM's risk criterion for a final repository with good margin.	At repository depth, the average distance between water-conducting fractures is about 10 metres. The groundwater flow through the repository and around the deposition holes is greater in Laxemar, resulting in a higher risk that the bentonite clay will be eroded due to low salinities and that the copper canister will be damaged than in Forsmark. The safety-related conditions are thus poorer than in Forsmark.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The zero alternative

11 The zero alternative

The zero alternative describes the probable course of events if the encapsulation plant and the final repository are not realized. It will then be necessary to continue to store the spent nuclear fuel in Clab. The consequences of such a line of action are described in this chapter. The zero alternative also includes a description of the probable evolution of the landscape and society in Simpevarp and Forsmark if the encapsulation plant and the final repository are not realized.

11.1 Continued storage in Clab

11.1.1 Impact, effects and consequences

The description of effects and consequences of continued storage in Clab is based on the assumption that the reactors in Forsmark and Ringhals are operated for 50 years and that the reactors in Oskarshamn are operated for 60 years. In the reference scenario, SKB estimates the time from when the licence application is submitted until the final repository for spent fuel can be put into operation to be about 15 years. SKB thereby plans to be able to put the final repository into operation in around 2025. Possible delays during the licensing process or during the construction period can influence the planning.

An important factor affecting the start of operation of the final repository is the storage capacity in Clab. Clab currently has a licence for interim storage of 8,000 tonnes of uranium in the two rock caverns. A total of about 5,000 tonnes of uranium is stored in Clab today. At a receiving rate of about 200 tonnes per year, SKB estimates that Clab will reach 8,000 tonnes in around 2023. After 2026 the receiving rate will gradually decrease as shutdown of the reactors begins according to the reference scenario. The capacity of Clab can be increased to 10,000 tonnes by increased usage of compact storage canisters similar to those already present to some extent in the facility today. However, increasing the capacity of Clab would require a change in the operating licence and an extension of Clab's cooling chain. If these changes are implemented, Clab would be able to receive fuel for about another ten years.

Long-lived waste in the form of core components and control rods from the boiling water reactors are also stored in Clab. A solution for dealing with this waste could be to switch to dry interim storage instead. SKB plans to start a project aimed at exploring alternatives for interim storage of control rods, since this could permit greater interim storage capacity for spent nuclear fuel in Clab.

It is also possible to extend Clab with a third rock cavern with storage pools if this should prove necessary. However, such an extension will only be considered if the construction of the encapsulation plant or the final repository should be greatly delayed. An extension would probably be done in a similar manner as the Clab 2 extension, which was put into operation in 2008. With a third rock cavern, Clab could receive fuel for another 20 to 25 years. The lead times for projects of this nature are great, and an extension should therefore be initiated at least ten years before the rock cavern needs to be put into operation.

Experience from the Clab 2 extension can serve as a basis for an assessment of the environmental consequences of a Clab 3 /11-1/. Handling of rock spoil and drainage water during the construction phase will be done in roughly the same way as described during the construction phase for the encapsulation plant. Groundwater lowering will take place in the rock in the near-field around Clab during the construction period. Some impact on the groundwater level will persist during the operating period as well due to groundwater flow into the new rock cavern. An increase in the quantity of spent nuclear fuel that is interim-stored in Clab will also lead to an increase in the quantity of cooling water and thermal energy discharged to the sea, as well as the quantities of waste that arise in operation.

In addition to the fact that the zero alternative may require an increase in Clab's storage capacity, the storage period may also need to be prolonged. Such prolonged storage is expected, as long as it can take place under controlled forms, to have a similar impact as the operation of the existing Clab. There are, however, a couple of factors that are changed due to prolonged storage. In the first place, changes can take place in the environs, for example decommissioning of the Oskarshamn Nuclear Power Plant, and in the second place the radioactivity and heat output of the spent nuclear fuel will decline with time. The fact that the radioactivity of the nuclear fuel declines with time means that the quantity of radionuclides that goes to the treatment systems for air and water, and is to some extent emitted to the environment, declines with time due to prolonged operation of Clab.

When all spent nuclear fuel from the Swedish nuclear power plants has been placed in Clab, the transport requirement decreases. Atmospheric emissions and transport noise will then decline slightly in relation to the current situation. Decommissioning of the Oskarshamn Nuclear Power Plant will, however, have a much greater effect on the number of transport trips on the Simpevarp peninsula and the roads in the area.

Clab is supplied with water today from the Oskarshamn Nuclear Power Plant's water treatment plant, and waste water is treated in the Oskarshamn Nuclear Power Plant's sewage treatment plant. When the reactors are shut down, alternative solutions for water supply and sewage treatment may be required, since Clab accounts for a small portion of the water that comes from the water treatment plant and the waste water that goes to the sewage treatment plant today. After shutdown of the reactors, Clab will account for all discharge of cooling water into Hamnefjärden. The total temperature impact on Hamnefjärden will then decline slightly. The heat output via Clab's cooling water will also gradually decline as the fuel's decay heat declines with time.

11.1.2 Risk and safety issues

11.1.2.1 Risks in connection with prolonged controlled operation

In previous safety assessments for Clab, thorough mishap analyses have been carried out. Various scenarios that have been analyzed include fire, handling mishaps, long-term loss of cooling and makeup water supply to the pools, external processes, earthquake and boulder falling into the pool. What all of these scenarios have in common is that the consequences of prolonged storage are less than those calculated in the safety analysis report because the fuel's radioactivity, as well as its decay heat, decline with time.

Prolonged interim storage in Clab does not entail any serious risks for the environment, provided today's high quality of operation and maintenance can be maintained. From a technical point of view, Clab can, with reasonable maintenance, be safely operated for 100–200 years, and the fuel withstands long-term storage well.

11.1.2.2 Risks of unplanned abandonment

Since it is difficult to predict how society will evolve in a long-term perspective, the possibility that Clab will be abandoned at some time cannot be ruled out. In the event of unplanned abandonment, the risk increases mainly due to the fact that all systems are disabled and maintenance is not performed. Emissions of radionuclides to air and water as a result of an unplanned abandonment of Clab have been calculated for a scenario with 60 years' operation of all the reactors currently in operation. It entails that calculated levels are slightly overestimated in relation to the reference scenario that applies today for operation of the nuclear power plants.

Emissions of radionuclides to air

If the facility is abandoned, the water in the storage pools may boil off due to a lack of ventilation and cooling of the fuel, causing dryout. Certain radionuclides will then be vaporized and released from the fuel and subsequently be transported out of the facility by natural ventilation. Dryout would proceed fastest when decay heat is at a peak, which occurs in 2042. If the facility is abandoned at this point in time, it will take about one week before the water begins to boil and then another ten to twelve weeks before the pools are dry. Atmospheric dispersion calculations have been carried out for an unplanned abandonment of Clab. The calculations show that the dose to an individual decreases with distance from the facility and is dependent on when abandonment occurs. If abandonment occurs in 2042, when the fuel has reached its peak decay heat, an individual within a distance of one kilometre from Clab will receive a dose of around 0.1 millisievert per hour. This is equivalent to about 400 millisieverts per year for someone standing outdoors at this distance for eight hours a day for a year. The equivalent dose if Clab is abandoned in 2085 is 0.06 millisievert per hour, which is equivalent to an annual dose of 160 millisieverts /11-2/. According to the Swedish Radiation Safety Authority's regulations (SSMFS 2008:51), the sum of the dose contributions to the general public from all activities with ionizing radiation may not exceed 1 millisievert per year. In the event of a late abandonment of Clab, the fuel will not dry out, since the decay heat has declined to a level below that necessary to vaporize the water flowing into the facility when the water level is even with the top edge of the pools. The year 2800 is the calculated point in time after which dryout could possibly be avoided. Radionuclides will, however, be leached out to the pool water and emitted to the air with the water vapour. The expected dose in the event of a late abandonment of Clab will be much lower than in the case of an early abandonment /11-2/.

Discharges of radionuclides to water

If the facility is abandoned and eventually fills with inflowing groundwater, radionuclides may be leached out into the groundwater and carried to the receiving body of water. This dispersion can only occur when the decay heat in the stored fuel has declined to a level that is not sufficient to vaporize the groundwater at a rate to maintain the lowering of the groundwater table in and around the facility. This is expected to occur in around 3100. Dispersion calculations, according to a highly simplified dispersion model, for dispersion of radioactivity via the groundwater to the near-coastal parts of the Baltic Sea indicate that the radiation dose for individuals in the coastal area will then be 0.03 millisievert per year. These calculations only take into account mobile nuclides, however, and apply at the given point in time about 1,000 years in the future. In the long time perspective, poorly soluble radionuclides with a long half-life must also be taken into account, in particular americium-241, plutonium-239 and neptunium-237. A pessimistic estimate of radiation doses from these nuclides has also been done, with a result of about 15 millisieverts per year. This radiation dose is much higher than if only the more readily soluble radionuclides are taken into account. In a long time perspective, it is also necessary to take land uplift into account, since it means that radionuclides will reach land instead of the Baltic Sea, in which case the radiation doses will be even higher /11-2/.

Non-radiological risks

If the facility is abandoned and eventually fills with inflowing groundwater, rebar and concrete can affect the quality of the groundwater, mainly its pH and iron content.

11.2 Evolution of the site

11.2.1 Forsmark

In Forsmark, the zero alternative entails that the land is not utilized for surface facilities and roads, and that affected ponds with the pool frog and forests will be managed according to today's guidelines.

The zero alternative entails a slow natural infilling and terrestrialization of the pool frogs' spawning water. This process of terrestrialization may increase, so that the wetlands become more dependent on maintenance to stay open. Considerable invasion by reeds has been observed in rich fens in Norrtälje, which is probably also occurring in the Forsmark area /11-3/. Dense reed growth is deleterious for many rich fens, and may be a threat to the rich fens in Forsmark so that they will have lost much of their natural values by 2100.

A land area including those parts of the final repository that extend beyond the industrial area was acquired from Sveaskog some time ago. If the facility is not built in Forsmark, SKB may sell this land. In this case it is likely that land use will remain the same as today. Silviculture and nature conservation will naturally be dependent on who acquires the land and for what purpose.

A future rise in the sea level will affect the evolution of land and water areas in Forsmark. In the report /11-4/, three predictions of sea level rise have been used to estimate the levels in a hundred years. The most extreme scenario, corrected for local land uplift, has been calculated to be a maximum sea level of +56 centimetres. Extreme sea levels, caused by climate change in combination with temporary weather systems, have been calculated and found in the most extreme case to be a maximum sea level of +316 centimetres. These levels are slightly lower than in Laxemar/Simpevarp, owing to the more rapid rate of land uplift in Forsmark.

The nuclear power plant will eventually be decommissioned, changing the character of the area. It is not possible to predict today whether the land on which the nuclear power plant lies will be remediated or a new industrial enterprise will be established.

SKB's final repository for short-lived radioactive waste (SFR) will be built to hold the decommissioning waste from the Swedish nuclear power plants. It will also hold an increased quantity of operational waste resulting from the extended operating time of the nuclear power plants. There are different scenarios for how long SFR will be in operation, but it will probably be in operation after the Forsmark Nuclear Power Plant has been dismantled, since other reactors are planned to be decommissioned later.

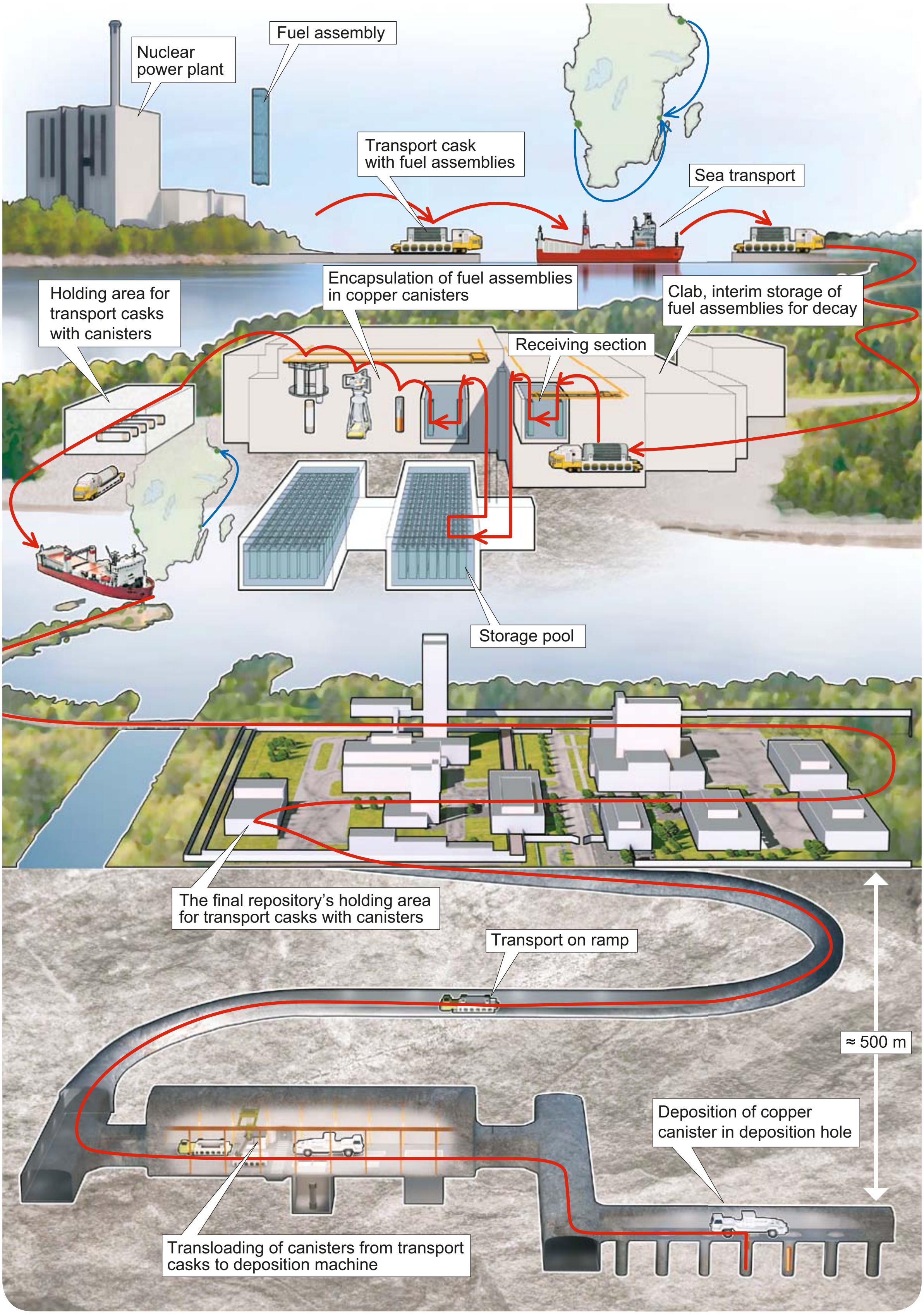
11.2.2 Simpevarp

If no encapsulation plant is built on the planned site at Clab, the evolution of the site will depend on silviculture practices. For a period of 60 years, the period the encapsulation plant would have stood on the site, it is most likely that forestry will continue to be conducted in the area. If silviculture continues in the form of thinning and logging on a smaller scale, the description of today's natural values will also apply to the zero alternative. Clearcutting within 60 years is also possible, resulting in diminished natural values. This outcome would have similar effects and consequences as the encapsulation plant with regard to land use, but recovery is assessed to be faster since the impact on the soil layer will be less.

Global warming in combination with other factors could cause a rise in the sea level up to 2100. Predictions of future sea level changes are associated with great uncertainty. In the report /11-4/, three predictions of sea level rise have been used for the hundred-year perspective. In the case of the most extreme scenario, corrected for local land uplift, the predicted maximum sea level in Laxemar/Simpevarp in 2100 is +115 centimetres (in the height system RH 70). Extreme sea levels, caused by climate change in combination with temporary weather systems, have also been calculated and found in the most extreme case to be a maximum sea level of +341 centimetres.

The nuclear power plant will eventually be decommissioned, changing the character of the area. It is not possible to predict whether the land on which the nuclear power plant lies will be remediated or a new industrial enterprise will be established.

The whole system for interim storage, encapsulation and final disposal of spent nuclear fuel


Nuclear power plant
Fuel assembly
Transport cask with fuel assemblies
Sea transport
Encapsulation of fuel assemblies in copper canisters
Holding area for transport casks with canisters
Clab, interim storage of fuel assemblies for decay
Receiving section
Storage pool
The final repository's holding area for transport casks with canisters
Transport on ramp
≈ 500 m
Deposition of copper canister in deposition hole
Transloading of canisters from transport casks to deposition machine

12 The whole system

This chapter provides a coherent picture of the impact and the consequences to which the whole system for interim storage, encapsulation and final disposal of spent nuclear gives rise. Cumulative effects and transboundary environmental impact are described, along with possible preventive and compensatory measures. An overall assessment is made of the different alternatives. Reconciliation with national and regional environmental objectives is done in a separate appendix /12-1/.

12.1 Overall consequences

The purpose of this section is to show the overall environmental consequences of construction, operation and decommissioning of an encapsulation plant integrated with Clab (Clink) on the Simpevarp peninsula in Oskarshamn and a final repository in Forsmark.

The purpose of the activity is to protect the environment and human health for a very long time from the harmful effects of ionizing radiation from the spent nuclear fuel. The facilities have been designed for this purpose so that no significant radiological consequences will occur. Long-term safety is therefore treated as one environmental aspect among others in the Environmental Impact Statement, but all the more thoroughly in the special safety analysis report and its assessment of post-closure safety.

Figure 12-1 shows an overview of the siting of the facilities and the transport of spent nuclear fuel between them, while Figures 12-2 and 12-3 show transport at each facility.

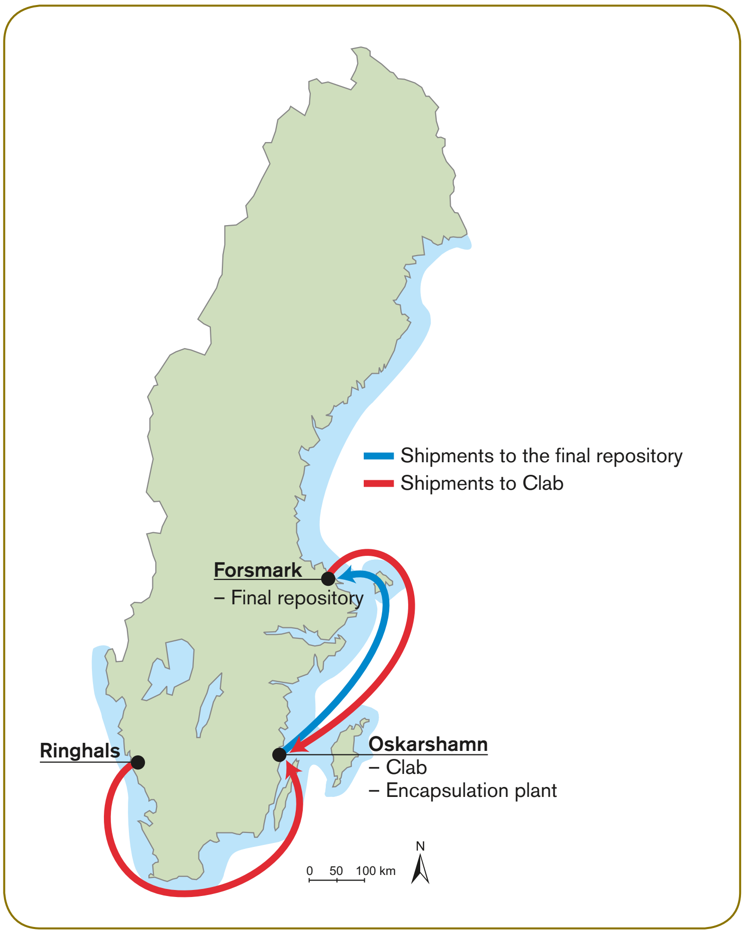


Figure 12-1. Siting of the facilities.

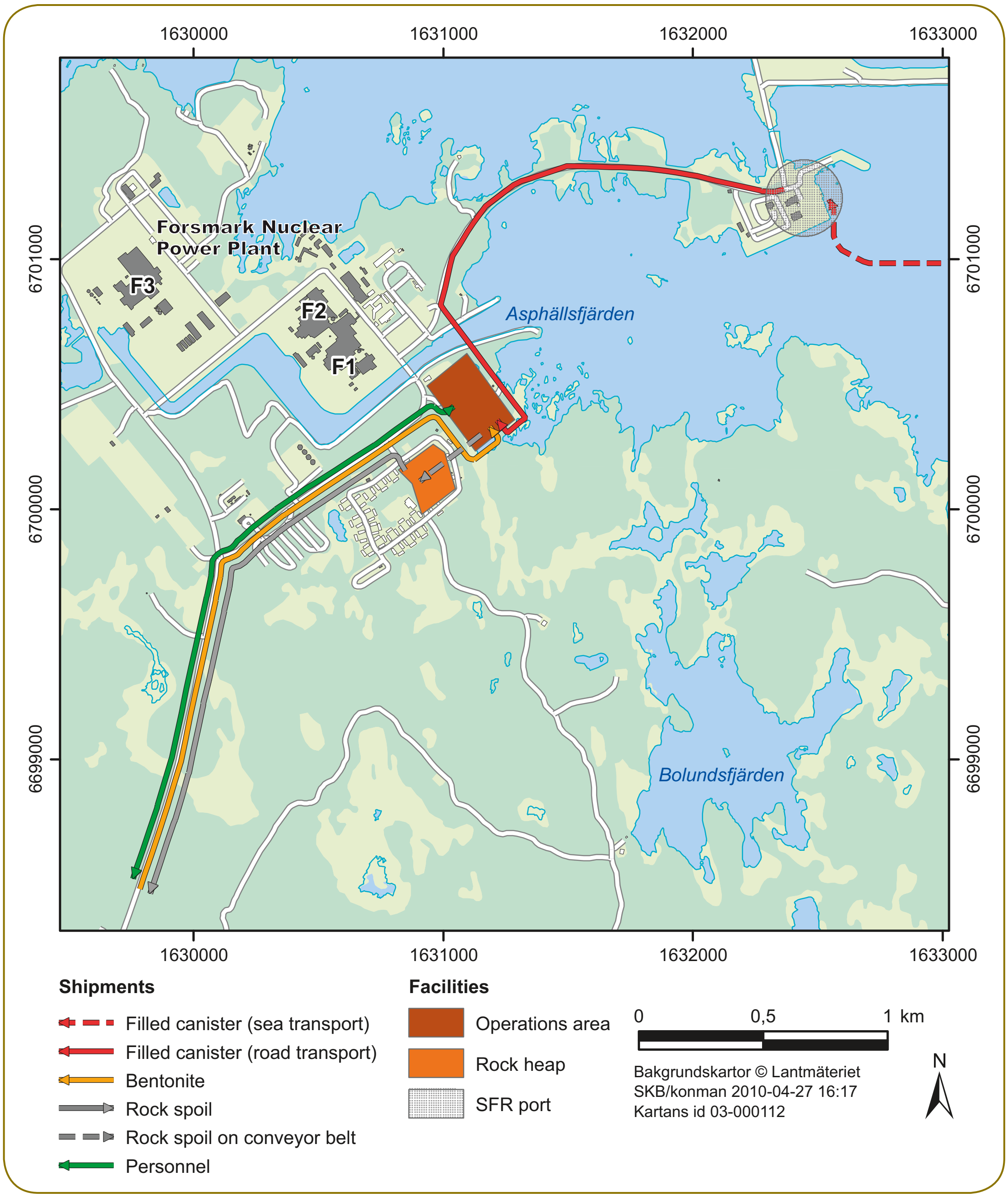


Figure 12-2. Shipments to and from the final repository in Forsmark.

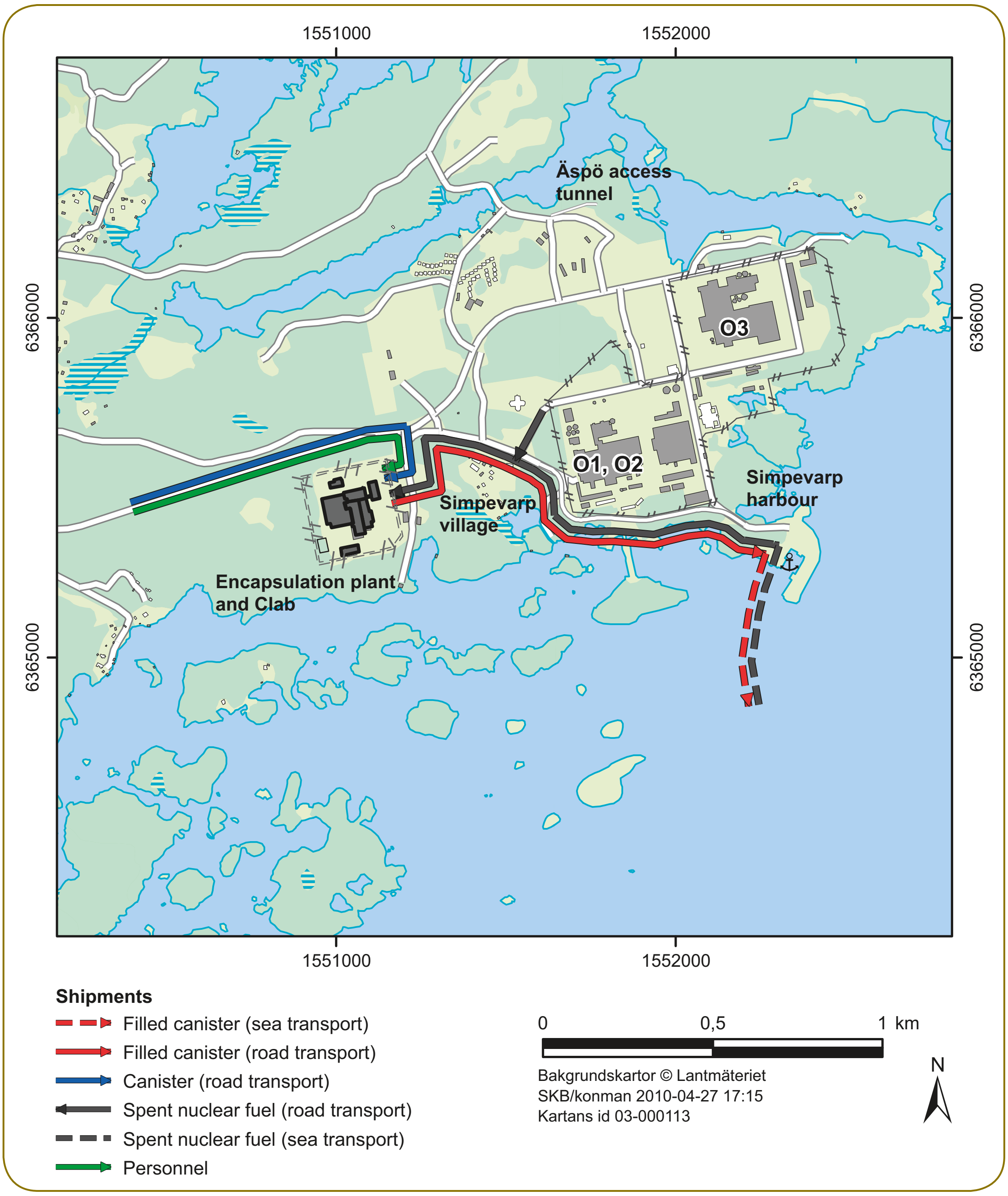


Figure 12-3. Shipments to and from Clab and the encapsulation plant in Simpevarp.

Since the facilities will be located about 450 kilometres apart, the only combined consequences will be those resulting from the shipments between the facilities, i.e. noise and atmospheric emissions. Other consequences will arise locally on each site and will not affect each other.

Table 12-1 shows an overview of the factors that have been studied. In the cases where it has been assessed that appreciable consequences do not arise, an explanation is given in the table, while appreciable consequences are described in greater detail in sections 12.1.1–12.1.3. Risk and safety issues are not included in the table but are dealt with separately in section 12.1.4, since these are events that are not supposed to occur in normal operation.

Table 12-1. Overview of impact and consequences for the whole system.

Factor	Impact	Appreciable consequences	Comment
Natural environment			
Land use	•	•	
Groundwater lowering	•	•	
Non-radiological effluents	•		Measures will be taken to mitigate the consequences.
Cultural environment			
Cultural environments	•		There are no archaeological remains or cultural heritage values of an indispensable character in Forsmark. Noise increases slightly on the outskirts of Forsmarks bruk (area of national interest), but the area is already exposed to road traffic noise today. Some few historical remains may be found in the forest areas occupied by the final repository or the encapsulation plant, in which case they will undergo a preliminary investigation. The consequences of the establishments are assessed to be minor.
Landscape	•	•	
Recreation and outdoor activities	•		Outdoor activities in Forsmark are mainly expected to be impacted by noise and increased human presence. No appreciable consequences are expected. Outdoor activities in Oskarshamn are not impacted by the construction of the encapsulation plant.
Residential environment and health			
Noise	•	•	
Radiation and releases of radionuclides	•		No radioactive releases will occur in the final repository, and SSM's requirements on radiation protection in the facility will be complied with. The ventilation will be designed to keep the radon levels in the facility below relevant limit values. Radioactivity will be released in Clab and emitted via air and water. Both the dose to personnel and the dose to the critical group lie below SSM's limits. Radiation doses due to radionuclide releases from the encapsulation plant to the environs will be virtually negligible in relation to the limit value.
Non-radiological atmospheric emissions	•		Emissions of air pollutants from transport, heavy equipment and handling of rock spoil will add so little to the background emissions that no residents in either the Forsmark or Oskarshamn area risk suffering any health consequences.
Psychosocial effects	•		Psychosocial effects have not been quantified; see discussion below.

12.1.1 Natural environment

Land is utilized for the new facilities in both Forsmark and Simpevarp. In Forsmark three ponds are affected, of which two where the protected pool frog has been observed within the future operations area. The consequences for the pool frogs are significant locally, but SKB's ambition is to compensate for this by creating new ponds. Yet another rich fen of national interest may be affected by the construction of the northern ventilation station. With planned protective measures for handling and treatment of leachate, plus measures in connection with the construction of the ventilation station with associated road, the consequences are assessed to be limited. In connection with the discharge of drainage water in Söderviken, limited effects in the form of increased primary production can be expected in the bay and in Asphällsfjärden due to increased nitrogen concentrations. Availability of phosphorus will limit vegetation growth, however. Since the receiving water is assessed to be relatively resilient, the impact is considered to be small and no major consequences are expected.

The final repository's underground part will give rise to groundwater lowering in the area. If no measures are taken, the groundwater lowering may entail very great consequences for two wetland sites (these sites are assessed to be of national interest), great consequences for 15 sites and appreciable consequences for eight sites. By means of measures such as infiltration of water around the most valuable sites, the consequences can be mitigated.

A part of a forest area adjacent to Clab will be occupied by the encapsulation plant. No high natural values have been found and the consequences will be small. Contaminated water will be purified before it is discharged and no consequences are expected for the marine environment. The groundwater in the area around Clab is already lowered and only a marginal further lowering of the groundwater level will occur in connection with the construction of the encapsulation plant.

12.1.2 Landscape

The tallest buildings in the final repository – the skip building and the production building – will be visible from the water, but since the facility will be built close to the nuclear power plant the visual consequences for the landscape are assessed to be small. If the nuclear power plant is dismantled, the final repository will stand out more in the landscape.

The encapsulation plant will probably not be visible from county road 743, since it is obscured by a wide forest screen. Clab is visible today from the water in the southeast, and the encapsulation plant will slightly alter the building's silhouette. The consequences of this are assessed to be small.

12.1.3 Residential environment and health

12.1.3.1 Noise

Noise from the activity at the final repository is not assessed to have any appreciable health effects for nearby residents, since no permanent residents are exposed to equivalent levels above 35 dBA in the evening, which is the guideline value for vacation areas. The new temporary housing at Igelgrundet will have maximum equivalent levels of 55 dBA in the daytime and 45 dBA in the evening, which is below the guideline values for construction noise.

The final repository's transport volumes will cause increased noise along the transport routes. The noise increase will be greatest nearest the facility, decreasing as the distance increases. The number of residents exposed to road traffic noise above the guideline value 55 dBA is at most about 20 more than at the same time without a final repository. No serious health effects are expected from this.

It will be possible to comply with the guideline values for construction noise in the daytime during the construction of the encapsulation plant, but noise barriers will be needed in the evenings and at night. The guideline values for industrial noise will not be exceeded during the operation of the encapsulation plant. The transport activity generated by the facility will lead to an increase of about 40 residents who are exposed to noise levels above 55 dBA.

12.1.3.2 Psychosocial effects

By "psychosocial effects" is meant the impact on people's anxiety, well-being, health and quality of life caused by a measure or an activity. The psychosocial effects of the final repository system are dealt with in report /12-2/. The report is based on studies carried out within the framework of SKB's social science research programme.

While technical experts tend to emphasize the probability that an accident will happen, the general public's risk perception is influenced more by the consequences, i.e. what could happen in the event of an accident, regardless of whether the probability of its occurring is high or low. The public's risk perception is also affected by values and attitudes that are not always the same as those of the experts and decision-makers.

By "stigmatization" is meant the negative perception of a person, group or place as being deviant, dangerous or repulsive. The question of whether an encapsulation plant or a final repository for spent nuclear could lead to the stigmatization of a place has been examined within the framework of SKB's social science research. This research shows that the inhabitants of Östhammar and Oskarshamn are of a completely different opinion than the population in the rest of the country. While the population in general believes that there is a great risk that an encapsulation plant or a final repository for spent nuclear fuel would lead to stigmatization, this opinion is very unusual among the population in Östhammar and Oskarshamn. Assessing a theoretical risk is, however, not at all the same thing as living in an area where an actual accident occurs. But as long as no major accidents occur it is likely that the attitude of the population towards a final repository will become increasingly positive.

As is evident from a number of studies presented in /12-2/, there is much to indicate that a final repository in Oskarshamn or Östhammar would have smaller or much smaller psychosocial effects than in any other municipality in the country. Important reasons for this conclusion are:

- Several studies clearly show that people in both Östhammar and Oskarshamn municipalities are much more positive to both nuclear power and a final repository than people in other municipalities in Sweden.
- Residents of Oskarshamn and Östhammar judge the risks of nuclear power and a final repository for spent nuclear fuel to be much lower than residents in other parts of the nation.
- Residents of Oskarshamn and Östhammar know a lot more about nuclear power and waste disposal than residents in the rest of the nation.

12.1.4 Risk and safety issues

Sweden has been using electricity generated by nuclear power for more than 30 years. A safe system exists today for management and disposal of the nuclear waste where SFR and Clab, two facilities that have been in operation since the mid-1980s, are important constituents. Two facilities are needed for final disposal of the spent nuclear fuel: an encapsulation plant and a final repository. These two facilities will be built and operated with a focus on safety, radiation protection and environmental considerations. Both facilities will be designed so that illicit trafficking in nuclear fuel is prevented. The results of analyses of disturbances and mishaps during the operation of Clab/Clink and the final repository show that there is little risk that something will occur that can have consequences for the barriers in the final repository or increased releases to the environs. In the case of Clab/Clink the acceptance criteria for environmental dose are met, and in the case of the final repository no radioactive material is released from the facility. In connection with shipments of both encapsulated and unencapsulated fuel, safety is mainly guaranteed by the transport casks. The casks can withstand severe accidents without any consequences for the environment. The calculated doses to an individual in the event of a hypothetical accident are far below dangerous levels and relevant limit values.

The post-closure safety of the final repository will be based on a system of passive barriers and be designed so that the repository remains safe without future maintenance or monitoring. No disturbances or mishaps will give rise to any consequences for long-term safety. The results of the assessment of long-term safety show that the regulatory requirements are met even after closure of a final repository in Forsmark.

The overall conclusion is thereby that the planned activity and the facilities in the final repository system, with the reported design, will achieve safe final disposal with respect to nuclear safety and radiation protection in both the short and long term.

Other environmental risks associated with the construction of the two facilities are the same as for any large construction project. The greatest risks are spills of oil, diesel or other substances on the building site or along the transport routes. The risks are prevented and reduced by regular inspections and high preparedness. Shipments of encapsulated nuclear fuel between the encapsulation plant and the final repository go by sea on m/s Sigyn or another equivalent ship. The probability of an accident occurring at sea is low. Certain environmental risks will arise in connection with the dismantling of the facilities, such as leakage/release of hazardous substances, fire or spillage of acids used for decontamination. The planned measures will mitigate the consequences. An expectedly large inflow of groundwater (causing an unexpectedly large groundwater lowering) is a serious environmental risk, even though the probability of its occurring is low. This is due to the potential consequences of a large groundwater lowering for the valuable natural environments and species in Forsmark. The risk is reduced by sealing of the rock and preparedness to adopt compensatory measures, such as infiltration.

A rising sea level due to global warming has been studied from a 100-year perspective and constitutes a risk that could cause flooding in the operations area and the rock heap. Flooding will not give rise to radioactive releases, since the canisters of spent nuclear fuel are not affected; however, the bentonite buffer may need to be replaced if open deposition tunnels are flooded. Flooding could also lead to dispersion of contaminants, such as nitrogen residues from the rock heap and oil spills from the operations area, so that they pollute the surrounding land and sea. Requirements are made on the different parts of the final repository in order to prevent this happening, and in particular the height of the facility is adapted to predicted future extreme water levels. Future climate change that could lead to sea level rise is included in the assessment of long-term safety. In the case of Clink, predicted future extreme water levels entail that the intake building for cooling water would be under water. Other parts of the facility are situated higher and are not affected.

12.1.5 National interests

There are a number of areas of national interest according to chapters 3 and 4 of the Environmental Code in both Forsmark and Laxemar, see section 7.1.2 and Figure 7-5 as well as section 7.2.2 and Figure 7-33. The different national interests may conflict and interact with each other to varying degrees.

At both sites there is an area of national interest for final disposal of spent nuclear fuel and nuclear waste that can accommodate the planned encapsulation and final disposal activities.

12.1.5.1 Forsmark

The national interests for energy production, highly developed coast, wind power and cultural environment are not assessed to be adversely affected by the planned activity. This assessment is based on the fact that the areas in question are either not affected by the planned activity or that the activity is compatible with and does not harm these national interests.

The national interest for outdoor activities may be affected by noise and land use. With the exception of a ventilation station, land use is in principle limited to areas within or adjacent to the existing zoned industrial area (see section 7.1.1.2). The planned final repository entails that a slightly larger area than today will be affected by noise levels above 35 dBA (see section 10.1.4.2 and Figure 10-34). Most of the additional area that is affected by noise above 35 dBA is located east of the nuclear power plant, is poorly accessible and has low value for recreation and outdoor activities. The additional noise occurs during a limited time, and the assessment is that the planned activity will only have a marginal impact that does not compromise the national interest for outdoor activities in Forsmark.

The sea and the coast outside Forsmark are of national interest for commercial fishing. Both discharges to water and lowering of the groundwater may be of importance for fish stocks and fishing in the area. Leachate from the rock heap will be treated to remove nitrogen. The drainage water that is pumped from the underground facility also contains nitrogen residues, but in low concentrations, and is discharged in the deeper part of Söderviken. The assessment is therefore that the effluents from the final repository will not be of any importance for fish stocks and fishing. The diversion of groundwater from the underground part of the final repository is not assessed to give rise to any significant effects on the water levels in Bolundsfjärden and Norra Bassängen. Nor is the importance of the lakes as nursery grounds for fish and for fish migration to and from the sea assessed to be affected (see section 10.1.4.1). All in all, the planned activity is not assessed to cause any harm to the national interest for commercial fishing.

The national interest for nature conservation at Forsmark-Kallrigafjärden is based on such characteristics of the area as its wilderness character, its calcareous till and its rich flora and fauna. There is a risk that the national interest would be impacted by groundwater lowering, with consequences for wetlands such as rich fens and shallow ponds. The risk cannot be ruled out that the impact could be considerable if wetlands with a long continuous evolution and great diversity of species are affected /12-3/. In order to mitigate the consequences for the area's natural values and the most valuable natural attractions, a number of measures are planned, as described in section 12.4.1. Some risk of appreciable harm to the national interest for nature conservation remains even after the adoption of measures, however. This risk must be weighed against the benefit of the final repository for spent nuclear fuel.

12.1.5.2 Oskarshamn

The assessment is that planned activities in the form of construction of the encapsulation plant, operation of Clink and sea transport of the encapsulated spent nuclear fuel will not cause appreciable harm to any national interest. The assessment is based on the fact that the national interests in question are not affected by the planned activity, which is concentrated in the existing industrial area, or that the activity is compatible with the national interests.

12.2 Cumulative effects

By "cumulative effects" is meant how an activity or a measure, in combination with other activities, impacts the environment in an area. This section describes the activities that already exist in connection with Clab and the planned facilities, plus additional ones that can be expected to occur on the two sites during the period the encapsulation plant and the final repository will be built and operated. Activities that give rise to possibly considerable impact and that affect the same area as Clink or the final repository, or that utilize the same transport routes, are described. Many of the activities lie far off in the future, and certain projects are still in an early planning stage. This means that information on the time, scope and impact of the projects is preliminary and subject to change.

Figures 12-4 and 12-7 show when the projects are planned to be implemented. Figures 12-5 and 12-8 show the geographic location of the activities.

12.2.1 Forsmark

12.2.1.1 Forsmark Nuclear Power Plant and planned activities

As described in Chapter 7 on site-specific conditions, the Forsmark Nuclear Power Plant is already located within the industrial area at Forsmark today. A number of peripheral activities are associated with the nuclear power plant, such as power lines, a sewage treatment plant, a near-surface repository for low-level waste (Svalören) and an area with temporary housing. The existing detailed development plan permits extension of the near-surface repository, which is planned to take place in 2018–2019, see Figure 12-4.

The nuclear power plant with peripheral activities affects the character of the area and the landscape. Releases of radionuclides during normal operation amount to less than one percent of the relevant limit value. The discharge of cooling water causes an increase in the water temperature in Öregrundsgrepen, but conventional atmospheric emissions from the activity to air, soil and water are small /12-4/. FKA conducts environmental monitoring to keep track of the radiological and conventional environmental impact caused by the activity.

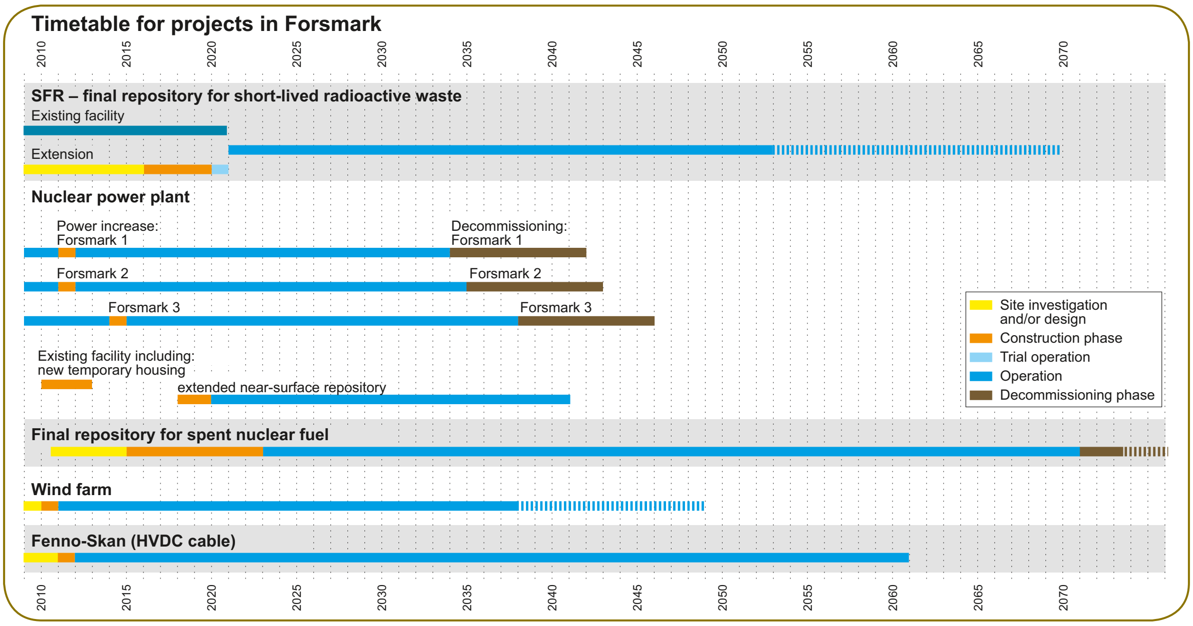


Figure 12-4. General timetable for projects in Forsmark. The timetable for decommissioning of the nuclear power plants is based on operation of the reactors in Forsmark for 50 years.

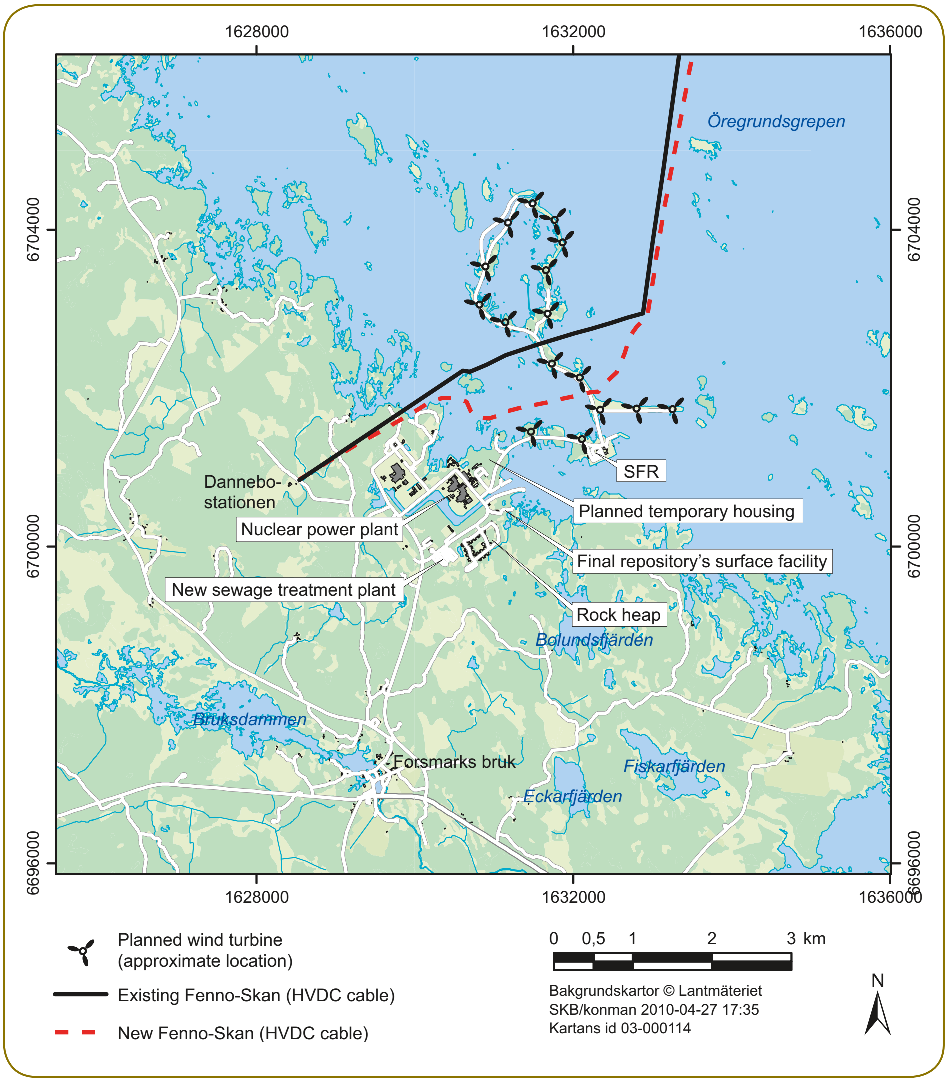


Figure 12-5. Geographic location of activities in Forsmark.

Goods and people are transported to and from FKA, giving rise to environmental impact. FKA is a large workplace with around 900 employees plus several hundred consultants and contractors. Refuelling and maintenance outages are carried out a few times a year at the nuclear power plant, usually during the summer. The number of people working at the power plant increases from a few hundred up to a couple of thousand during the audits, depending on their extent. The scope of transport activities to and from the nuclear power plant increases during audits and rebuilds.

Certain changes will take place in the activity at FKA during the time the final repository for spent nuclear fuel is being built and operated. Before construction of the final repository begins, a new sewage treatment plant will be built and new temporary housing will be erected (see further below). FKA has also received permission to increase the power level in the reactors, which according to current planning will take place in 2011 for reactor units 1 and 2 and in 2014 for reactor unit 3. While the work with the power increase is being carried out, noise and waste will be generated by certain rebuilding work.

Finally, decommissioning of the reactors is intended to take place during the period the final repository is in operation, presumably around 2040, see Figure 12-4 /12-5/. The dismantling work will entail environmental impact in the form of noise, among other things.

The decommissioning waste from the reactor units will consist of both conventional decommissioning waste and radioactive waste. Most of the conventional decommissioning waste will be used to restore the topography in the area. The radioactive waste, which is divided into short-lived and long-lived, will be disposed of in final repositories (SFR and SFL). Any shipments of radioactive waste will probably go by ship (the equivalent of m/s Sigyn).

12.2.1.2 Temporary housing

The detailed development plan for Forsmark permits new short-term housing to be constructed in a 0.1 square kilometre area at Igelgrundet, east of the nuclear power plant. See Figures 12-5 and 12-6. New temporary housing is planned to be erected before construction of the final repository begins, and the number of temporary housing units will be similar to the number today.

Figure 12-6. Photomontage of planned temporary housing at Igelgrundet.

12.2.1.3 Final repository for short-lived radioactive waste

Since 1988, the industrial area at Forsmark also contains the final repository for short-lived radioactive waste, SFR, a hard rock facility located about 50 metres beneath the seafloor northeast of the nuclear power plant. The facility is operated by SKB and contains short-lived low- and intermediate-level operational waste from the Swedish nuclear power plants. All radioactive waste is transported by m/s Sigyn to SFR's harbour. The environmental impact of the existing facility is relatively small and derives primarily from electricity use, use of fossil fuels (diesel) and chemicals for cleaning and maintenance. The surface part of the facility has some visual impact on the landscape. The ventilation plant gives rise to noise, but the sound level is well below the current limit (45 dBA at a distance of one kilometre from the tunnel mouth). Water and air released from the facility undergo regular testing, and environmental monitoring is performed to ensure that there is no significant impact on the surrounding environment.

SKB plans to extend the facility between 2016 and 2019 so that it can also accommodate decommissioning waste from the nuclear power plants. The extension will have a volume of 500,000 cubic metres and will involve rock works, including drilling and blasting, and give rise to heavy transport of e.g. rock spoil. The blasting and transport activities will cause environmental impact in the form of noise. Establishment areas on the ground surface will be needed during the construction phase. The extension work will also entail some impact on groundwater flows, but since the facility is located beneath the sea, this is not expected to give rise to any significant environmental consequences. Modelling performed by SKB indicates that the final repository for spent nuclear fuel and SFR will have partially overlapping impact areas with regard to groundwater. This is described in greater detail in /12-6/.

The expected environmental impact of the extension of SFR will be further studied prior to application for a licence for the extension.

12.2.1.4 Planned wind farm

Vattenfall has applied for a licence for a wind farm at the Biotest Basin in Forsmark /12-7/. Up to 15 wind turbines are planned, with a combined output of 30 to 40 MW. If the wind farm is realized, the greatest environmental impact will occur during the operating phase of the wind turbines. The turbines will have a visual impact on the landscape, cause shadows and noise, and affect the bird life. There are no residential environments within the area where disturbing noise and shadows may occur. The wind farm also has a positive environmental impact, since it generates renewable energy that does not give rise to emissions of greenhouse gases.

12.2.1.5 HVDC cable between Sweden and Finland

In operation since 1989, the Fenno-Skan cable is a high voltage direct current (HVDC) cable between Rauma in Finland and Dannebo in Sweden, near Forsmark. Svenska Kraftnät (Swedish Power Grid) and its Finnish counterpart, Fingrid, have received a licence to add a second land-based and submarine cable to the link, called Fenno-Skan 2. The planned cable will follow roughly the same route as the existing cable and will also be laid on the seafloor. Near land the cable will be buried about one metre deep to reduce the risk of damage due to external forces. From the shore to the transition to an overhead line, the cable will be buried for about two kilometres. According to the current timetable, the new cable will be in operation when construction of the final repository begins /12-8/.

Today, when there is only one power cable (a monopolar system), a return current arises in the water and the ground. In order to transmit and receive the return current, electrode stations have been built on both sides of the Baltic Sea. The electrode station on the Swedish side is located in Björn's archipelago near the island of Källen, some tens of kilometres northwest of Forsmark. Due to the return current, there is an increased risk of corrosion of large metal objects in contact with the ground or the water at the electrode stations. When the new cable is brought on stream, current will not normally be conducted through the ground and water via the electrodes. The current in the new cable will flow in the opposite direction compared with now, so that return currents will not arise to the same extent any longer. The corrosion problem will thereby be virtually eliminated. Current will only be conducted via the electrodes at high power and in the event of disturbances in one of the two cables /12-8/.

12.2.1.6 Overall assessment

Locating several nuclear activities in the same area is not expected to lead to any health consequences as a result of radiation. The nuclear power plant, which accounts for most of the radioactive releases at Forsmark, contributes less than a hundredth of the relevant limit value, which is 0.1 millisievert (mSv) per year. The dose limit of 0.1 mSv can be compared with the mean individual dose in Sweden from all sources, which is 4 mSv per year. If several facilities are located in the same geographic area, the 0.1 mSv limit applies to their combined contributions. When it comes to long-term safety as well, the requirements permit several repositories to be located within the same area.

Cumulative effects with other activities in Forsmark can be expected with regard to:

- Natural environment (land use, noise from transport and activities, and possible cumulative effects due to impact on groundwater flows).
- Landscape.
- Residential environment and health (noise and atmospheric emissions from transport).

Transport to and from the different projects, above all during the construction phase, is assessed to give rise to the greatest impact. The nuclear power plant and the final repository for spent nuclear fuel account for most of the transport volume. Other projects give rise to so little transport that it is not assessed to contribute to any appreciable increase in noise levels or atmospheric emissions.

As regards visual impact on the landscape, the coastline is already interrupted by the nuclear power plant, which can be seen from far away, for example from Gräsö and Öregrund. The final repository for spent nuclear fuel, SFR, the temporary housing and the wind farm will all be visible from the water and perhaps from Gräsö as well. The wind turbines will also be visible from Öregrund. The final repository and the residential area will be illuminated, and the wind turbines will have aircraft warning lights. All of this will create a visual impact that can be perceived as disturbing.

Noise arises from many different activities within the industrial area, from both mobile and stationary sources. Since the noise from the different activities differs in character and can therefore be perceived differently, even in cases where the decibel levels are equivalent, it has not been considered meaningful to describe the overall noise impact in the form of combined equivalent levels. Furthermore, the assessment is that no permanent residents will be disturbed by the noise.

Together with noise, motor vehicle traffic and human presence, the risk that birds will collide with the wind turbines could have a cumulative effect on certain bird species, such as raptors.

12.2.2 Oskarshamn

12.2.2.1 Oskarshamn Nuclear Power Plant

The Oskarshamn Nuclear Power Plant, which is run by OKG, is located on the Simpevarp peninsula. Just as in Forsmark, a number of peripheral activities are associated with the nuclear power plant, such as power lines, a sewage treatment plant, a near-surface repository for low-level waste (MLA) and a rock cavern for low- and intermediate-level waste (BFA). The nuclear power plant impacts the environment in a similar manner as the Forsmark Nuclear Power Plant does in Forsmark.

Around 1,600 persons work at OKG. About a hundred of them take the bus to work, but the majority commute by car. Just as in Forsmark, a few hundred to over a thousand additional persons are on hand during the annual audits, depending on the extent of the audit. Some of them live out at the power plant, but many live in a nearby holiday village and commute to and from work every day.

As in Forsmark, the activity at the nuclear power plant and peripheral activities will undergo changes, and eventually be discontinued altogether, during the time SKB's planned facilities are expected to be in operation. A power increase was implemented in the summer of 2009 in reactor unit 3 at the Oskarshamn Nuclear Power Plant, and a power increase is planned later in reactor unit 2.

Transport to and from the plant increases during such work. The nuclear power plant in Oskarshamn is planned to be decommissioned and dismantled in around 2040 (units 1 and 2) and 2050 (unit 3), see Figures 12-7 and 12-8. The dismantling work will entail environmental impact in the form of noise, among other things.

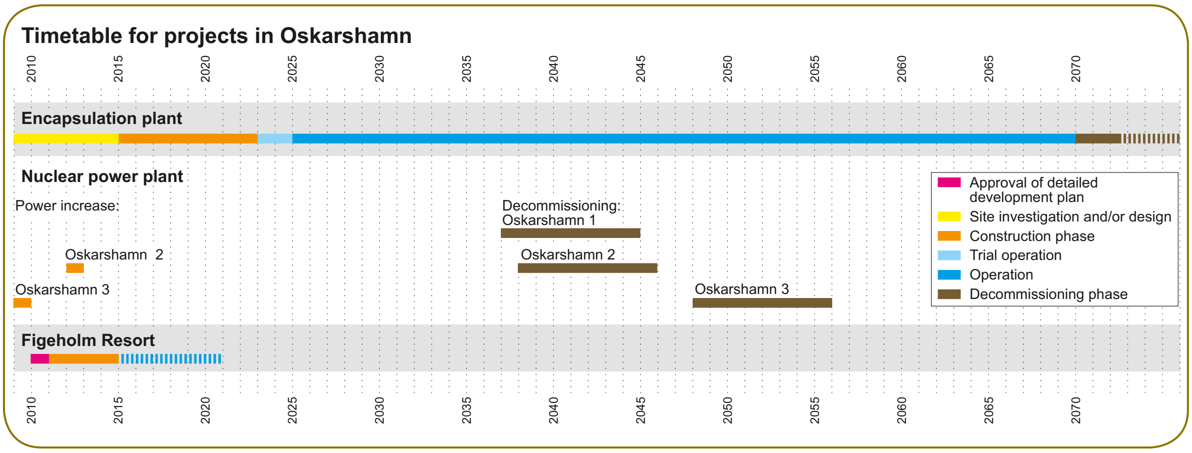


Figure 12-7. General timetable for adjacent projects in Oskarshamn. The timetable for decommissioning of the nuclear power plants is based on operation of the reactors in Oskarshamn for 60 years.

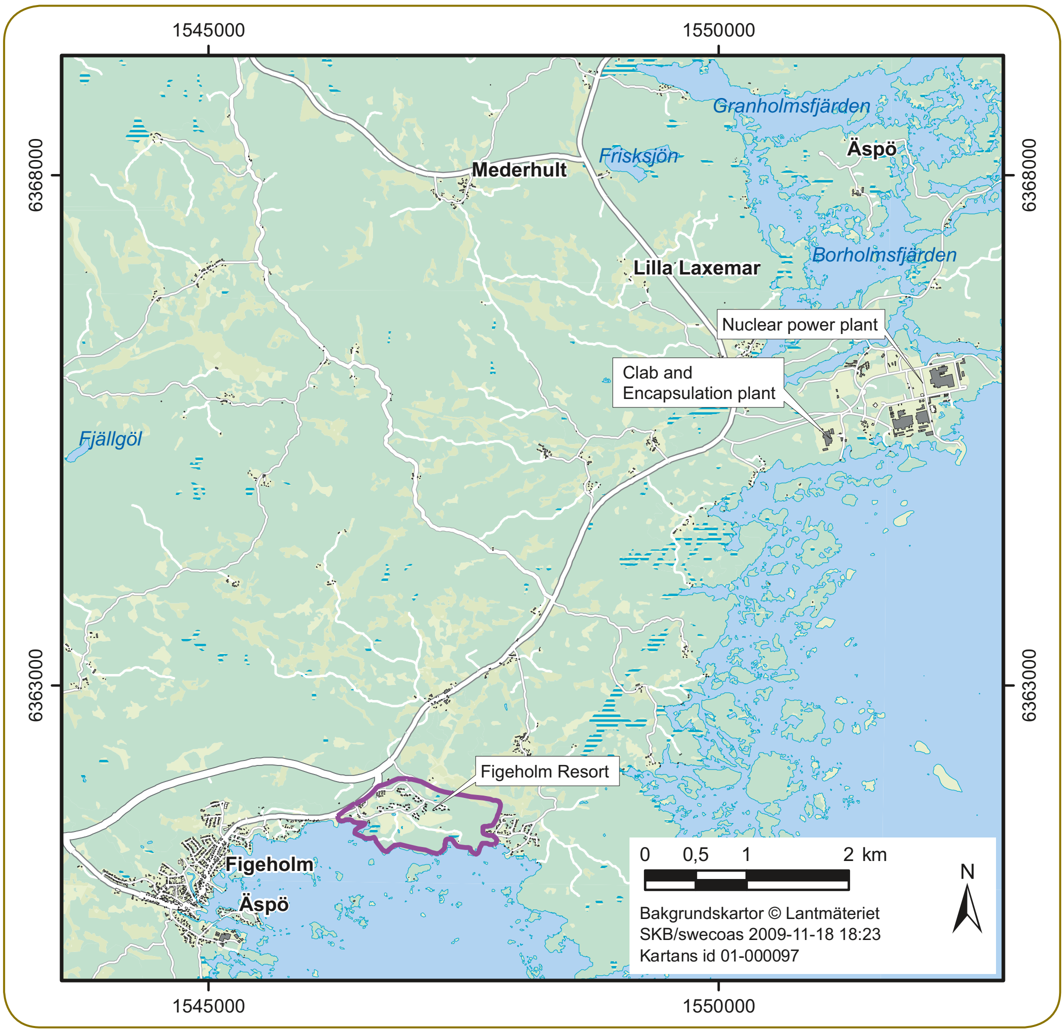


Figure 12-8. Geographic location of adjacent activities in Oskarshamn.

12.2.2.2 Figeholm Resort

Plans have been discussed for a major holiday resort at Figeholm, a few kilometres southwest of the Simpevarp peninsula, see Figures 12-7 and 12-8. The companies behind the proposal are Wendelboe West Properties and Nordlandia Hotels & Resorts. According to the proposal, as it was presented at Oskarshamn Municipality's consultation on the detailed development plan for the area in November 2008, the planned holiday resort will include around 1,200 cottages, a large centre facility, a hotel, a golf course, an aquapark, a marine and other facilities. The area could accommodate about 5,000 persons per day. Viewpoints were offered at the consultation that could affect the scope of the project and the timetable for its implementation.

If the holiday resort is realized, it will give rise to environmental impact in the form of land use, a change in the character of the area and visual impact on the landscape. Oskarshamn Municipality has decided that an environmental impact statement should be produced in connection with the preparation of a detailed development plan for the area. The main link with SKB's facilities on the Simpevarp peninsula is that the same road that SKB will use to and from the nuclear facilities, county road 743, will also be used for transport to and from the holiday resort. The cumulative effects that can arise due to the transport activities are noise and atmospheric emissions. At present there are no figures on transport volumes to and from the holiday resort, so the cumulative effects cannot be described in any greater detail.

12.2.2.3 Overall assessment

As in Forsmark, no health consequences are expected as a result of radiation due to the fact that several nuclear activities are located in the same area. This conclusion is explained in greater detail in section 12.2.1 on cumulative effects in Forsmark.

Cumulative effects with other activities in Oskarshamn can be expected with regard to:

- Natural environment (land use and noise from transport and activities).
- Landscape.
- Cultural environment.
- Residential environment and health (noise and atmospheric emissions from transport).

Transport to and from the different activities is assessed to give rise to the greatest cumulative impact.

The landscape on the Simpevarp peninsula is, as described in section 7.2.6, heavily affected by the existing industrial area. The fact that the encapsulation plant will be built adjacent to Clab will not cause any great change in the landscape or the character of the area compared with today. Nor is any great change in the cumulative effects in the area expected in terms of impact on the natural environment.

There are historic remains on the Simpevarp peninsula, including archaeological remains from the Bronze Age. Previous industrial establishments in the area have impacted the peninsula's historic remains, and the construction of the encapsulation plant may impact additional archaeological remains. The establishment of the encapsulation plant will therefore probably be preceded by some kind of archaeological survey. The consequence of a possible excavation depends on the nature of the remains.

12.3 Transboundary environmental impact

The UN Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention) states that the parties are obliged to assess the environmental impact of projects of the kind exemplified by the final repository. The parties are also obliged to inform each other and consult with each other concerning a project on their territory that is likely to cause significant adverse transboundary impact. See further Chapter 4 on how this is done.

Possible transboundary environmental impact would be if radionuclides were dispersed from Clab, the encapsulation plant or the final repository or in connection with transport of the encapsulated nuclear fuel. How much radioactivity could be released from different types of mishaps during the operating time of the facility is described in the various safety analysis reports that have been produced for the transportation system, Clink and the final repository. Analyses show that the doses calculated to an individual in the vicinity of the facility are far below relevant limit values. There is thereby no risk of any adverse transboundary impact.

SSM has a regulation with a risk criterion that SKB must show that the final repository will satisfy in the long term. The risk criterion states that "the annual risk of harmful effects after closure may not exceed 10^{-6} for a representative individual in the group exposed to the greatest risk". By "harmful effects" is meant cancer and hereditary defects. According to SSM, the risk limit is equivalent to a dose limit of about $1.4 \cdot 10^{-2}$ mSv/year, which is about one percent of the natural background radiation in Sweden. The assessment of the long-term safety of a final repository sited in Forsmark shows that SSM's risk criterion will be satisfied, see section 10.1.6. SSM's risk criterion applies to a representative individual in the group exposed to the greatest risk. Individuals living at greater distances from the final repository, for example in other countries, will be exposed to even lower risk.

12.4 Preventive measures and compensatory measures

According to relevant legislation, planned measures to prevent, mitigate and if possible remedy significant harmful effects of a project shall be described in the environmental impact statement. There are different ways to work with these measures, depending on whether the purpose is to prevent, mitigate or remedy the expected impact. In addition to these approaches, it is also possible to adopt compensatory measures.

Proposed measures are based on previous experience (mainly from the site investigations), design studies, results of the environmental studies that have been done and general practice. They are also based on viewpoints offered by various actors (interest groups, municipalities, county administrative board) at consultations. The term "measures" is used here in a broad sense. During different phases of the design work for the encapsulation plant and the final repository, certain protective and preventive measures have been integrated in the design of the facilities. These measures are described here as a part of the work to mitigate effects on and consequences for the environment.

12.4.1 Natural environment

During the site investigations, a special training was held on the specific characteristics of each area and how best to mitigate any impact by adopting precautionary measures /12-9/. Similar compulsory training is planned for everyone who will work outside the final repository's operations area in Forsmark or around Clab and the encapsulation plant in Oskarshamn. A specific environmental programme for the construction phase will also be produced.

12.4.1.1 Land use

Three ponds will have to be filled in as a part of the establishment of the final repository at Söderviken. Since the pool frog occurs in two of these ponds, SKB has to apply for an exemption from the Species Protection Ordinance and draft proposals on compensation for the loss of these environments. Special material is being gathered for the creation or restoration of four or more new ponds, located depending on local conditions (e.g. hydrology, sun exposure and land availability) and the population of pool frog (possible range within the area). The ambition is that conditions for the pool frog in Forsmark should be at least as good as they are today, even after the final repository has been established. The strategy is to compensate as close to the impacted area as possible so that the local pool frog population is not adversely affected. The timing of the infilling of the concerned ponds will be chosen with a view to the pool frog's ecology so as to mitigate the impact.

The access road to the northern ventilation station will be routed to avoid impact on sensitive ecosystems. Furthermore, technical measures may be necessary to mitigate the impact of the road on water flows to surrounding wetlands. If the detailed design of the road shows that local hydrological conditions may be impacted, the road can be built with a permeable road bank in order to limit this impact.

Previous experience from the site investigations has shown that it is mainly the physical intrusion and movements of people and equipment that can disturb the bird life in the area /12-10/. Wherever possible, work and movements of personnel and equipment outside the operations area will be limited during the breeding season when the impact is expected to be greatest.

12.4.1.2 Groundwater lowering

The most important measure for restricting inflow of water into the tunnel system in the final repository, leading to groundwater lowering, is injection of grout in order to seal the rock where water-conducting fractures occur. The ambition is to seal the rock as far as is technically feasible and economically reasonable so that the hydraulic conductivity in the grouted tunnel system is around 10^{-8} metres per second. A specific sealing strategy has been defined for different parts of the underground facility /12-11/. SKB is following the development of grouting methods and grouts in order to choose a method that entails as little risk as possible to the surrounding environment /12-12/.

Within the possible impact area for groundwater lowering there are several ponds and rich fens that harbour very high natural values and are sensitive to changes in the local hydrological and hydrogeological conditions. In order to remedy any impact on sensitive natural attractions, SKB has studied various technical methods for sustaining the water level on these sites. The application of measures is based on an extensive monitoring and/or self-monitoring programme. Changes in groundwater level caused by the final repository can then be quickly identified. It is proposed that preparedness be maintained for infiltration of water in and around the sites with the highest values that may be impacted by groundwater lowering. Details of the technical solution are described in /12-6/.

12.4.1.3 Management of SKB's land in Forsmark

SKB has acquired several properties in the area that will contain the final repository and the necessary roads and storage areas. The properties are heavily forested and otherwise consist of industrial land, coastal land, lakes and wetlands. SKB intends to draft a conservation-oriented management plan for these properties. Measures will be proposed in the plan that can to some extent counteract the negative effects of the planned activity on natural values.

Parts of the land SKB has acquired were included in an ecopark planned by Sveaskog. SKB's ambition is to realize this plan and thereby have conservation-oriented forest management. However, SKB's land also includes areas where forestry is practiced, and an important task is therefore to strike a balance between production areas and natural forest areas. Possible conservation-oriented management practices include thinning of coniferous trees in order to increase the proportion of deciduous trees, prescribed burning, and filling-in of old ditches to restore moist and wet woodland areas.

Important features in the area's natural environment are rich fens and ponds with very high natural values. A number of species worthy of protection occur in these environments. Some of the environments risk being impacted by groundwater lowering. At the same time they are undergoing more or less natural terrestrialization. SKB's ambition is to take measures to conserve these environments and the species associated with them, with a focus on wetlands that risk being impacted by groundwater lowering. Possible measures for wetlands are clearing of brush and trees or, if necessary, mowing in the case of wetlands with very high natural values.

12.4.1.4 Water management

The activities at the different facilities give rise to different types of water that needs to be collected and treated in a suitable way to limit the impact on receiving waters. A detailed description of the different technical solutions proposed is provided in /12-13/.

Drainage water from the final repository will undergo sedimentation and oil separation when it is pumped from the underground part.

The leachate will be filtered through a broad irrigation area before it is further purified in Lake Tjärnpussen. SKB and FKA have also discussed the possibility of mixing the water leaving the planned new sewage treatment plant with SKB's treated leachate, and in this way obtaining synergy effects in the form of higher water purity.

The stormwater from the encapsulation plant (and in part Clab) in Oskarshamn and from the final repository's operations area in Forsmark is planned to be managed in accordance with the principles of stormwater best management practice. This limits the need of infrastructure for transporting and treating the stormwater (pipes, collection pond etc.). In order for it to work, the following principles should be observed in the construction of the operations area:

- Minimize paved surfaces.
- Collected stormwater should be dispersed diffusely as far as possible, for example collected runoff from roofs can be spread on vegetation-covered surfaces where it can infiltrate.
- Utilize gently-sloping ditches, vegetated green areas and underlying fill volumes for retardation and purification.
- Have oil-separating devices where oil-contaminated stormwater can be expected, such as parking lots, holding areas and transloading areas.
- Perforated pipes can be used for infiltration into underlying fill in cases where stormwater must be drained off via wells and pipes.
- Prevent inflows of water or other liquids that should not enter the stormwater system.
- Trees have a good capability to capture, retain and evaporate a large portion of the precipitation. By planting trees in and around parking areas, runoff from these surfaces is reduced during heavy rains and pollutants are removed from the water.

An attempt will be made to use materials with a low tendency to leach out pollutants in off-site construction areas. Special emphasis will be placed on avoiding unpainted galvanized surfaces.

Management of stormwater at Clab will be improved by local infiltration and by diverting a fraction of the stormwater towards the side of the encapsulation plant where the water can be infiltrated more readily into the surrounding land. Remaining stormwater is planned to be piped to a sedimentation/equalization pond before it runs out into Herrgloet Bay /12-14/.

When the ponds in Forsmark are filled in, water will be displaced into the surrounding land, which consists to a great extent of permeable till. If the water percolates too slowly into the surrounding land, it can be pumped to a reed bed south of the operations area. Depending on the turbidity of the water, it may also undergo rough sedimentation in freight containers before being pumped to the reed bed. The reed bed will act as a natural filter, retaining small particles. The water will follow the natural flow and then run out in Söderviken.

12.4.2 Cultural environment

No measures are planned. Any archaeological remains that are encountered will be documented and excavated as required by law.

12.4.3 Landscape

In order to mitigate the visual impact on the landscape, the aesthetic design of the final repository will be adapted to local conditions, for example the surrounding countryside and existing activity. The architecture and colours and materials for the buildings will be chosen to fit in with the surrounding industrial landscape. The size of the area intended for the rock heap will be adapted so that the top of the rock heap is below the surrounding treetops and therefore does not have a visual impact on the landscape. The tallest building in the final repository is the skip building. The design of the skip has been repeatedly modified to minimize the height of the skip building.

The encapsulation plant will be integrated with Clab and designed to fit in with the architecture of Clab.

12.4.4 Residential environment and health

12.4.4.1 Noise

Noisy activities will be avoided in the evenings and at night wherever possible.

In the final repository, fan motors for external fans at repository depth are located under ground to reduce the noise.

At Clink, noise-suppression measures are planned for fans, along with noise barriers for drilling rigs and crushers, so that guideline values for noise are met.

12.4.4.2 Releases of radionuclides to air and water

Proposals for measures to reduce radioactive releases to water from the existing Clab and the planned encapsulation plant are described in a special study /12-15/. These measures need to be considered more carefully and can only be adopted in cases where the safety of the facility is not affected. The study resulted in the following proposals:

- reduction of the chemical load (from cleaning agents etc.) on the treatment system for floor drainage water,
- procedural change in connection with solidification of filter resins,
- testing of different selective ion exchange resins,
- pilot plant with membrane filter equipment for supplementary treatment of floor drainage water.

Preliminary studies indicate that some of the proposed measures are difficult to implement. If all measures prove to be possible to implement without affecting safety, they could result in a reduction of releases by 95–99 percent compared with previous predictions.

Furthermore, filters are proposed to reduce atmospheric releases of radionuclides from the planned encapsulation plant.

12.4.4.3 Non-radiological atmospheric emissions

In order to reduce atmospheric emissions, SKB will, in accordance with its management system, impose environmental requirements on the vehicles that will be used during the construction and operating phases.

Since dust from the rock heap accounts for a large portion of the particulate emissions, watering (with a sprinkler) can be used at and around the rock heap in order to keep dust from being suspended and dispersed. A dust-binding agent will be used as needed on gravel surfaces within the construction sites. The same methods are planned to be used in Simpevarp in conjunction with rock blasting when the encapsulation plant is built.

M/s Sigyn is the largest single source of atmospheric emissions in the system. A catalytic converter is used today to reduce emissions of nitrogen oxides (NO_x). The catalytic converter reduces NO_x emissions significantly and is operative around 50 percent of the time. All harbours where Sigyn docks during normal operation (Ringhals, Simpevarp and Forsmark) already offer land-based power supply for ships in order to reduce their fuel consumption while docked. The new ship that is planned to replace m/s Sigyn will have better performance and be equipped with better emissions control.

12.4.5 Energy consumption

SKB has worked systematically during the design phase with energy-saving measures for the different facilities. Heat recovery from the storage pools is planned in Clink, and heat recovery from exhaust air and drainage water is planned in the final repository. Ventilation accounts for a large portion of the energy consumption in the final repository, which is why ventilation will be demand-controlled. This means that ventilation can be minimized if there is no activity in an area.

12.5 Comparison of alternative system solutions

As described in Chapter 5, SKB is applying for a licence to site the encapsulation plant adjacent to Clab on the Simpevarp peninsula in Oskarshamn and operate both of them as a single integrated facility (Clink), as well as to site the final repository in Forsmark. As alternatives to the applied-for sitings, location of the encapsulation plant adjacent to the nuclear power plant in Forsmark and location of the final repository in Laxemar in Oskarshamn have also been studied. The possible alternative system solutions are thereby as follows:

- Applied-for alternative: Encapsulation plant adjacent to Clab in Simpevarp (Clink) – Final repository in Forsmark.
- Considered alternative 1: Encapsulation plant adjacent to Clab Simpevarp (Clink) – Final repository in Laxemar.
- Considered alternative 2: Encapsulation plant in Forsmark – Final repository in Forsmark – Clab in Simpevarp.

The requirements on the siting of the final repository that follow from the Nuclear Activities Act, the Radiation Protection Act and the Environmental Code entail in summary that the site shall be suitable in order to achieve the purpose of the activity, i.e. to achieve long-term safe final disposal, that the consequences shall be reasonable, and that on comparison of the sites, the site that entails the least intrusion and disturbance and offers the highest safety shall be selected.

SKB's assessments show that the groundwater flow at repository level in Forsmark is much less than in Laxemar. The rock conditions in Forsmark also permit a more efficient and robust execution than in Laxemar. The overall conclusion is that the prospects of achieving safe final disposal are more favourable in Forsmark.

During construction and operation of the facilities, there will be environmental impact and consequences regardless of the siting, but different factors will be impacted to different degrees. In the case of Forsmark, the surroundings are characterized by a sensitive natural environment with high conservation values. Adaptation to these circumstances in establishing the final repository is necessary and possible, but some measure of intrusion in the natural environment is nevertheless unavoidable. On the other hand, people's residential environment is affected to a small extent, since there are few permanent residents in the area. Nor are there any valuable cultural environments in the area.

An establishment of the final repository in Laxemar would entail much less impact on the natural environment than in Forsmark, despite the fact that it is a green field establishment. On the other hand, there are more people living and working in the area who would be affected by an establishment. The impact on the cultural environment and landscape is also somewhat greater in Laxemar.

Establishment of the encapsulation plant adjacent to Clab causes slightly greater impact on the natural and cultural environments than a facility in Forsmark, but the consequences are small. One advantage of the alternative where the final repository is located in Laxemar would be that the entire handling chain for the spent nuclear fuel would be gathered at one place in the country. There are no synergies to be gained by locating the encapsulation plant near the final repository in Forsmark. Sea transport of spent nuclear fuel from Clab is necessary anyway, the only difference being that the fuel is not encapsulated.

Table 12-2 shows a comparison between the applied-for alternative and the two alternative system solutions, as well as the zero alternative. The table presents a compilation and summary of the environmental consequences and the risk and safety issues that can be expected for the different alternatives.

Table 12-2. Summary of expected environmental consequences and risks for the studied alternative system solutions and the zero alternative.

	Applied-for activity: Final repository in Forsmark, Clab and encapsulation plant in Simpevarp	**Considered alternative 1:** Final repository in Laxemar, Clab and encapsulation plant in Simpevarp	**Considered alternative 2:** Final repository and and encapsulation plant in Forsmark, Clab in Simpevarp	**Zero alternative:** Clab in continued operation, neither the final repository nor the encapsulation plant is built
Natural environment Land use	Three ponds are affected within the future operations area in Forsmark, two of which harbour the pool frog. A rich fen of national interest risks being affected by the construction of the northern ventilation station. The consequences for the ponds are great locally but can be partially compensated for. SKB is investigating the possibility of creating new ponds suitable for pool frogs. With planned protective measures in the construction of the ventilation station with associated road, the consequences are assessed to be limited. A part of a forest area adjacent to Clab will be occupied in Oskarshamn. No high natural values have been found and the consequences will thereby be small.	Undeveloped land of regional interest due to the occurrence of hardwood forest will be occupied by a final repository in Laxemar. The negative consequences of this will be appreciable, since the area has development potential from a natural value viewpoint. However, the area does not have as high natural values as the area in Forsmark and the consequences will thereby be less. The situation for the encapsulation plant/Clab is the same as for the applied-for activity.	In Forsmark the situation is the same as for the applied-for activity. No further consequences are expected from siting the encapsulation plant adjacent to the nuclear power plant.	In Forsmark, the zero alternative entails that no land is occupied. If the facility is not built in Forsmark, SKB may sell this land. In this case it is likely that land use will remain the same as today. Silviculture and nature conservation will naturally be dependent on who acquires the land and for what purposes. The evolution of the site adjacent to Clab in Simpevarp will also be dependent on what silviculture measures are adopted in the forest area. Viewed over a timespan of 60 years, which is roughly the length of time the encapsulation plant would have existed on the site, it is most likely that forestry will continue to be practiced in the area.
Groundwater lowering	The final repository will give rise to a groundwater lowering in the area. Roughly 35 valuable and sensitive wetland sites risk being affected. For 17 of the sites, a drawdown would entail very great or great consequences. With measures such as infiltration of water, the consequences can be limited. The groundwater in the area around Clab is already lowered and only a marginal further lowering will occur in connection with the construction of the encapsulation plant.	The final repository will give rise to a groundwater lowering in the area. The majority of the natural values are, however, not linked to the groundwater table and are therefore not as sensitive to groundwater lowering as in Forsmark. The situation for the encapsulation plant/Clab is the same as for the applied-for activity.	In Forsmark the situation is the same as for the applied-for activity. No underground pools are planned in the encapsulation plant, which means there is no further impact on the groundwater.	An extension of Clab involves blasting to excavate an additional rock cavern with pools. Groundwater lowering then will take place in the rock in the near-field around Clab during the construction period. Some impact on the groundwater level will persist during the operating period as well due to groundwater flow into the new rock cavern. The situation in Forsmark is expected to be equivalent to today's situation.

	Applied-for activity: Final repository in Forsmark, Clab and encapsulation plant in Simpevarp	**Considered alternative 1:** Final repository in Laxemar, Clab and encapsulation plant in Simpevarp	**Considered alternative 2:** Final repository and and encapsulation plant in Forsmark, Clab in Simpevarp	**Zero alternative:** Clab in continued operation, neither the final repository nor the encapsulation plant is built
Discharges to water	A regional valuable rich fen next to Tjärnpussen is affected since leachate and treated sewage are discharged there. With planned protective measures for handling and treatment of leachate, the consequences are assessed to be limited. Limited effects in the form of increased primary production can be expected in Söderviken due to increased nitrogen concentrations caused by discharge of drainage water. The impact is assessed to be small and the receiving water is relatively resilient, so no great consequences are expected. Contaminated water from Clink will be treated before it is discharged and no consequences are expected for the marine environment.	The impact on and consequences for the marine environment are assessed to be equivalent to the situation in Forsmark.	In Forsmark the situation is the same as for the applied-for activity. No further consequences are expected from siting the encapsulation plant adjacent to the nuclear power plant.	An extension of Clab entails additional water that needs to be treated, mainly during the construction phase. After treatment via an oil separator and a sedimentation pool, the drainage water will be conducted to the existing stormwater system for Clab with outfall in Herrgloet. A larger quantity of spent nuclear fuel stored in Clab will also lead to an increased discharge of thermal energy to the sea. After shutdown of the reactors, Clab will account for all discharge of cooling water into Hamnefjärden. Since Clab accounts for a very small fraction of the cooling water discharges in relation to the Oskarshamn Nuclear Power Plant, the overall temperature impact on Hamnefjärden will decrease considerably. In the long term, the heat output via Clab's cooling water will also gradually decline as the fuel's decay heat declines with time. The situation in Forsmark is expected to be equivalent to today's situation up until when the nuclear power plant is shut down, at which point there will no longer be any discharge of cooling water to Öregrundsgrepen.
Cultural environment	There are no archaeological remains or cultural heritage values of an indispensable character in Forsmark. Noise increases slightly on the outskirts of Forsmarks bruk (area of national interest), but the area is already exposed to road traffic noise today. There may be some historical remains in the forest area occupied by the encapsulation plant, in which case they will undergo a preliminary investigation. The consequences are assessed to be insignificant.	Laxemar harbours areas with some conservation value and a few cultural remains. A development in Laxemar would impact a relatively unaffected forest and agricultural landscape. Since power line corridors have already introduced a large-scale industrial element in the area, the consequences are assessed to be moderate but slightly greater than in Forsmark. The situation for the encapsulation plant/Clab is the same as for the applied-for activity.	In Forsmark the situation is the same as for the applied-for activity. No further consequences are expected from siting the encapsulation plant adjacent to the nuclear power plant.	The situation on both sites is expected to be equivalent to today's situation.

	Applied-for activity: Final repository in Forsmark, Clab and encapsulation plant in Simpevarp	**Considered alternative 1:** Final repository in Laxemar, Clab and encapsulation plant in Simpevarp	**Considered alternative 2:** Final repository and and encapsulation plant in Forsmark, Clab in Simpevarp	**Zero alternative:** Clab in continued operation, neither the final repository nor the encapsulation plant is built
Landscape	The final repository will be visible from the water, but because the facility will be established near an area already impacted today, the consequences for the landscape are assessed to be small. If the nuclear power plant is dismantled, the final repository will stand out more in the landscape and the visual consequences for the landscape will thereby be greater. The encapsulation plant will probably not be visible from county road 743, due to the fact that it is obscured by a wide forest screen. Clab is visible today from the water in the southeast, and the encapsulation plant will slightly alter the building's silhouette. The consequences of this are assessed to be small, however.	A development in Laxemar would impact a relatively unaffected forest and agricultural landscape. Since power line corridors have already introduced a large-scale industrial element in the area, the consequences are assessed to be moderate but slightly greater than in Forsmark. The situation for the encapsulation plant/Clab is the same as for the applied-for activity.	In Forsmark the situation is the same as for the applied-for activity. No further consequences are expected from siting the encapsulation plant adjacent to the nuclear power plant.	The situation on both sites is expected to be equivalent to today's situation until the nuclear power plants are dismantled.
Residential environment and health Noise	The assessment is that noise from the activity at the final repository will not give rise to appreciable health effects for permanent residents, since no residents are exposed to noise levels above the guideline value in the evening. The number of residents exposed to road traffic noise above the guideline value is at most about 20 more than at the same time without a final repository. No health effects are expected from this. It will be possible to comply with the guideline values for construction noise in the daytime during the construction of the encapsulation plant, but noise barriers will be needed for evenings and nights. No guideline values will be exceeded due to noise during the operation of Clink. The transport activity generated by the facility will lead to an increase of about 40 residents who are exposed to noise levels above 55 dBA. The assessment is that only slight health effects can occur due to this.	There are residents closer to the final repository in Laxemar than in Forsmark, and 20 residents will be exposed to noise levels above the guideline value in the evening. The number of residents exposed to road traffic noise above the guideline value is at most twice as high as in Forsmark. Just like in Forsmark, no health effects are expected. The situation for the encapsulation plant/Clab is similar to that for the applied-for activity.	In Forsmark the situation is the same as for the applied-for activity. No further consequences are expected from siting the encapsulation plant adjacent to the nuclear power plant.	There are no additional noise sources. According to the Swedish Road Administration's forecasts, traffic on national road 76 in Forsmark and county road 743 and E22 in Oskarshamn will increase, which can be expected to lead to increased noise levels along the roads. However, fewer shipments will be required to Clab when all spent nuclear fuel from the Swedish nuclear power plants has been placed in Clab. Decommissioning of the nuclear power plants will also entail fewer transport trips on the Simpevarp peninsula and in Forsmark.

	Applied-for activity: Final repository in Forsmark, Clab and encapsulation plant in Simpevarp	**Considered alternative 1:** Final repository in Laxemar, Clab and encapsulation plant in Simpevarp	**Considered alternative 2:** Final repository and and encapsulation plant in Forsmark, Clab in Simpevarp	**Zero alternative:** Clab in continued operation, neither the final repository nor the encapsulation plant is built
Radiation and releases of radionuclides	No radioactive releases will occur in the final repository, and SSM's requirements on radiation protection in the facility will be complied with. Some radioactivity will be released in Clab and emitted via air and water. Both the dose to personnel and the dose to the critical group lie below SSM's limits. Radiation doses due to radionuclide releases from the encapsulation plant to the environs will be virtually negligible in relation to the limit value.	The situation will be the same as for the applied-for activity.	The situation will be the same as for the applied-for activity.	Extended storage under controlled forms does not differ significantly from the existing impact of the operation of Clab. The radioactivity of the nuclear fuel will decline with time, which means that the quantity of radionuclides that goes to the treatment systems for air and water, and is to some extent emitted to the environment, will decline with time in the event of a prolonged operation of Clab.
Risk and safety Non-radiological risks	In Forsmark, the greatest environmental risk is an unexpectedly large inflow of groundwater, which could have consequences for the valuable and sensitive natural environment. Measures are planned to mitigate this impact. In the event of extreme rises in sea levels, there is a risk that parts of the operations area, the rock heap and roads will be flooded. Flooding during operation does not give rise to radioactive releases. Rising sea levels are included in the assessment of long-term safety. Other environmental risks are spills of oil, diesel or other substances on the construction site or the operations area or along the transport routes, which can occur on both sites.	The consequences of an unexpectedly large inflow of water are assessed to be smaller in Laxemar than in Forsmark. On the other hand, the risk that undiscovered cultural heritage remains will be harmed may be greater in Laxemar. The assessment is that Laxemar will not be flooded in the event of future extreme sea levels. Other environmental risks are assessed to be equivalent.	The situation will be the same as for the applied-for activity.	The situation on both sites is expected to be equivalent to today's situation.

	Applied-for activity: Final repository in Forsmark, Clab and encapsulation plant in Simpevarp	**Considered alternative 1:** Final repository in Laxemar, Clab and encapsulation plant in Simpevarp	**Considered alternative 2:** Final repository and and encapsulation plant in Forsmark, Clab in Simpevarp	**Zero alternative:** Clab in continued operation, neither the final repository nor the encapsulation plant is built
Radiological risks	Situations can arise in the final repository that lead to consequences for the barriers as well as increased individual dose. No disturbances or mishaps will give rise to any radioactive releases or consequences for long-term safety. The canister transport casks can withstand very great accidents without any consequences for the environs. Mishaps in Clab and the encapsulation plant give rise to very small releases, and the assessment is that they will not cause any serious consequences for the environment.	The facilities are assessed to be equivalent with respect to radiological risks during operation.	The facilities are assessed to be equivalent with respect to radiological risks during operation.	The consequences of various mishaps have not been quantified but will be smaller than if an equivalent mishap were to occur with fresh fuel in the pools. Prolonged interim storage in Clab does not entail any serious risks for the environment, provided today's high quality of operation and maintenance can be maintained. Clab can, with reasonable maintenance, be safely operated for 100–200 years, and the fuel withstands long-term storage well. Since the radioactivity of the fuel declines, the consequences of mishaps will become milder with time. If, on the other hand, Clab should have to be abandoned in the future, this could have serious consequences.
Long-term nuclear safety	At repository depth, the average distance between water-conducting fractures is greater than 100 m and the groundwater flow is limited. Since water can transport solutes to buffer and canister, a limited groundwater flow offers great safety advantages for the long-term performance of the copper canister and the bentonite clay. A final repository in Forsmark satisfies SSM's risk criterion.	At repository depth, the average distance between water-conducting fractures is 10 m, which means that the groundwater flow through the repository, and thereby also the transport of solutes to buffer and canister, is greater than in Forsmark. This provides poorer safety-related conditions than in Forsmark.	The situation will be the same as for the applied-for activity.	Clab can, with reasonable maintenance, be safely operated for 100–200 years, and the fuel withstands long-term storage well. Since it is difficult to predict how society will evolve in a long-term perspective, the possibility that Clab will be abandoned at some time cannot be ruled out. In the event of unplanned abandonment, the risks increase mainly due to the fact that all systems are disabled and maintenance is not performed. If this happens, the facility eventually fills with inflowing groundwater and radionuclides may be leached out into the groundwater and carried to the receiving body of water.

12.6 Uncertainties

The planned activity is in a design stage. Assessments of impact, effects and consequences are based on calculations, modelling, predictions and estimates, which are in turn based on the design basis that is available at this time. This means that there is a measure of uncertainty in the assessments made in this EIS. This uncertainty is handled by means of a pessimistic approach whereby the assessments of impact, effects and consequences are to some extent overestimated. A sub-appendix to the EIS /12-16/ describes the methods and assessment criteria that have been used in the background studies to the EIS. The appendix indicates, where applicable, what uncertainties are associated with the respective study. The appendix that deals with diversion of groundwater from the final repository /12-6/ also reports uncertainties.

The description of the activity and its impact, effects and consequences extends about 60 years ahead in time. Due to the long time perspective, there are some uncertainties in the predictions. The uncertainty is greatest for the decommissioning phase, which lies furthest ahead in time. Decommissioning procedures are therefore presented in the form of alternatives and the consequences are described in general terms.

The years noted in the environmental impact statement are examples of typical years for the different phases of the project and are dependent on when licences are granted to build and operate the facility. It is also possible that it will take slightly longer to build the final repository in particular compared with the planning premises assumed in various studies. Taken together, this means that the estimated impact may occur at another point in time, depending on how the project progresses.

The time perspectives in the assessments of long-term safety are very long, which means that there are uncertainties in the assessments of repository evolution. According to the methodology used in SR-Site, first a reference evolution is studied that can be said to represent a typical example of the repository's evolution over time. The reference evolution serves as a basis for a main scenario. The evolution contains many uncertainties and it is difficult to cover all possibilities in the reference evolution/main scenario. For this reason a number of other scenarios are also studied for the purpose of ensuring that all uncertainties are covered.

Assessment of consequences is done based on the impact of the planned activity and the characteristics of the site. The applied-for sitings of both the encapsulation plant and the final repository are characterized to a high degree by the nuclear power plants present on the sites. What will happen on the sites after the nuclear power plants have been decommissioned represents an uncertainty when it comes to the cumulative effects caused by the nuclear power plants together with SKB's activities. Since parts of the utilities supply to Clab, the encapsulation plant and the final repository are associated with the nuclear power plants, decommissioning may require other utilities supply solutions.

SKB's planning assumption is that the reactors in Forsmark and Ringhals are operated for 50 years and that the reactors in Oskarshamn are operated for 60 years. Earlier decommissioning or prolonged operation lies beyond SKB's sphere of responsibility. The reactors' operating time affects the quantity of spent nuclear fuel that needs to be encapsulated, which in turn affects the planned operating time of the encapsulation plant and the final repository, as well as the size of the final repository. In the case of the zero alternative, prolonged operating time of the reactors entails that Clab may need to be extended or that alternative solutions for interim storage of the spent nuclear fuel may have to be considered.

13 Monitoring

The activity's environmental impact will be monitored via various types of monitoring programmes. The Uppsala County Administrative Board, the Kalmar County Administrative Board, Östhammar Municipality or Oskarshamn Municipality will be the supervisory authority for the environmentally hazardous activity, while SSM will be the supervisory authority for nuclear safety and radiation protection.

The permit application for environmentally hazardous activities and water operations under the Environmental Code includes a proposal for an environmental monitoring programme. The proposed monitoring programme describes how the activity's environmental impact, as well as the conditions issued by the environmental court, will be checked during the construction, operation and decommissioning phases. The monitoring programme will be developed and elaborated in consultation with the supervisory authority when conditions for the activity have been established. The activity's environmental impact will also be monitored within the framework of the self-monitoring that will be carried out by SKB in accordance with the Ordinance on the Activity Operator's Self-Monitoring. Furthermore, an environmental programme with detailed environmental requirements will be drafted for each facility in preparation for detailed design and construction.

Environmental monitoring programmes for radioactive releases prepared by former SSI (now SSM) exist for the areas around the Forsmark and Oskarshamn nuclear power plants. The encapsulation plant will be integrated with Clab to a single facility, Clink, for which the existing environmental monitoring on the Simpevarp peninsula is assessed to be sufficient. The encapsulation plant's radioactive releases will be common with Clab's, and the assessment is therefore that the system used for Clab's radiological release monitoring can also be used for the integrated facility.

The assessment is that radiological release monitoring is not needed for the final repository, since no radioactivity from the spent, encapsulated nuclear fuel will be released from the facility.

13.1 Construction and operating phase

13.1.1 Clab and the encapsulation plant, Clink

A monitoring programme will be prepared for Clink based on Clab's self-monitoring programme. It will include the following parameters for release and environmental monitoring:

- Cooling water – flow and temperature.
- Well measurements – groundwater level and conductivity.
- Diverted groundwater.
- Noise.
- Process water – alpha and gamma radiation plus corrosion chemistry parameters.
- Radioactivity measurement in ventilation chimney – alpha and gamma radioactivity and strontium-90.

During the encapsulation plant's construction phase, vibration levels and impact on groundwater and surface water quality may also be monitored.

13.1.2 The final repository

The following parameters will be monitored for the final repository:

- Diverted groundwater.
- The impact of groundwater lowering on groundwater and surface water levels.
- The impact of groundwater lowering on groundwater and surface water quality.
- Noise.
- Vibrations and air shock waves.
- Subsidence.

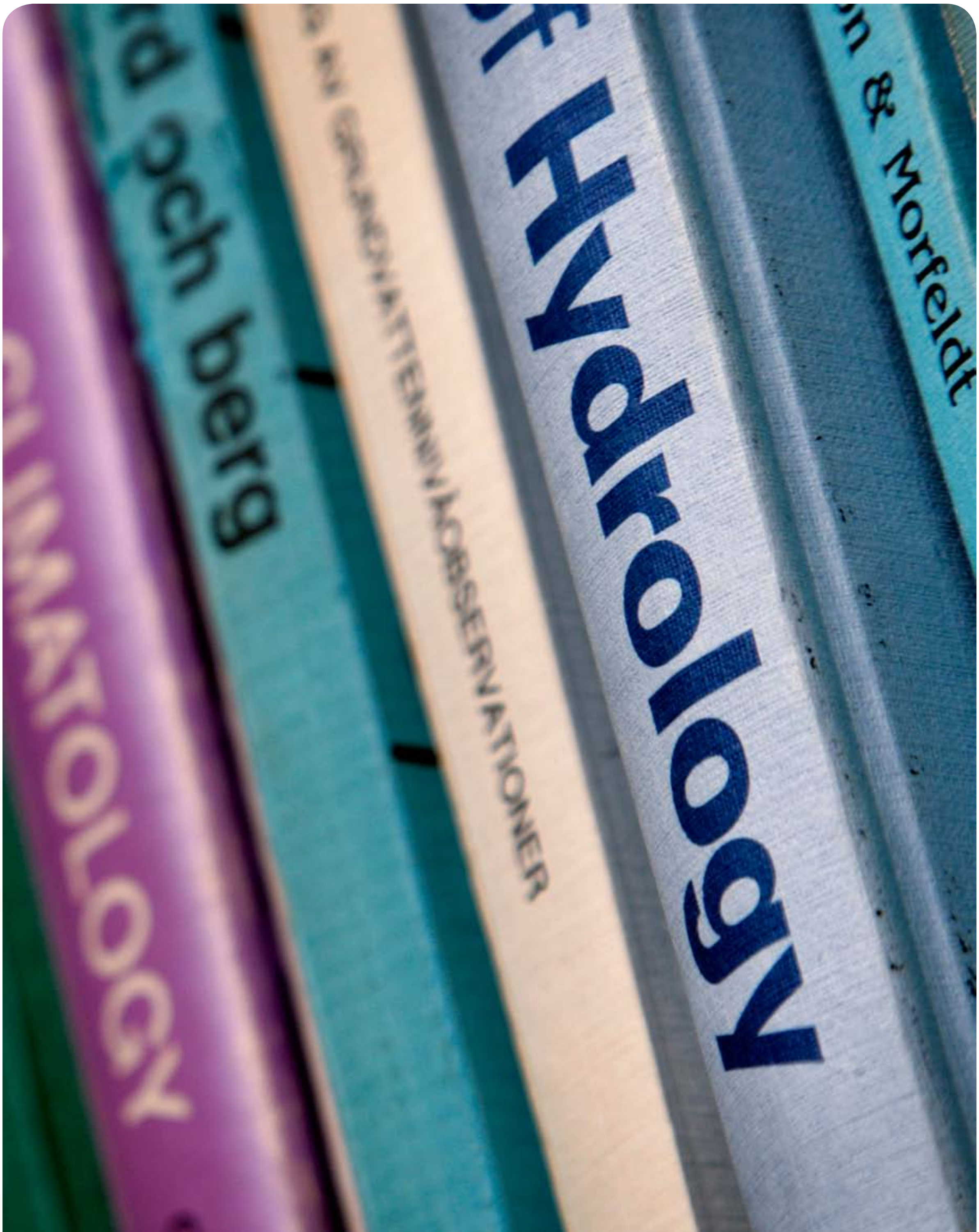
13.2 Decommissioning phase

Important parameters for monitoring in the decommissioning phase will be determined when it has been decided how the decommissioning of the particular facility is to proceed.

13.3 After decommissioning and closure

The final repository is designed so that monitoring of e.g. radioactive releases should not be necessary. For this reason, no post-closure monitoring is currently planned. Nor is monitoring assessed to be necessary in Simpevarp after Clink has been decommissioned.

Glossary and references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14 Glossary

The definition pertains to the meaning the word has in the EIS. In some cases this may be a narrower meaning than the general sense of the word.

Absorbed dose	The amount of energy deposited by ionizing radiation per kilogram of body tissue. The harmfulness of the dose depends on what kind of radiation is involved. The unit is the gray (Gy).
Actinides	Elements with atomic number 89–103, which have similar properties. (Actinium has atomic number 89.)
Advective transport	Transport of solutes with flowing water.
Air shock wave	A pressure change in the air that is generated and propagates in connection with rock blasting.
Barrier	In this EIS, barrier refers to an engineered or natural part of the final repository designed to contain, prevent or retard the dispersion of radioactive substances (radionuclides).
Becquerel (Bq)	Unit for measuring the radioactivity of an element. Number of atomic nuclei that decay (or disintegrate) per second while emitting ionizing radiation. 1 Bq =1 disintegration per second.
Bentonite	A strongly water-absorbing and swelling natural volcanic clay with low permeability to water. Transported and handled in powder form, can be compacted into blocks.
Biosphere	The parts of the earth and the atmosphere where living organisms are found. The biosphere can be divided into sea, fresh water, land and atmosphere.
Biotope	An ecosystem or part of a habitat characterized by a uniform set of environmental factors suitable for a certain assemblage of animals and plants. The area is naturally defined by e.g. local climate and type of soil. Examples are deciduous forest, coniferous forest, mire and coastal meadow. See also habitat and key habitat.
Brittle deformation	Deformation in which the bedrock responds by fracturing.
Buffer	A bentonite clay that surrounds the canister and fills the space between canister and rock. It has three functions in the final repository: • to prevent corrosive substances from reaching the canister, • to protect the canister from minor movements in the rock, • to retard the dispersion of radionuclides that may escape from a leaking canister. The buffer is one of the final repository's engineered barriers.
Catchment area	An area whose surface water is drained by a given watercourse.
Clearance	See "Release from regulatory control".
Clink	Clab and the encapsulation plant as an integrated unit.
Collective dose	Calculated to provide a picture of how much radiation an activity emits and is the product of the individuals' average radiation dose and the number of individuals in the group exposed to a given radiation source or activity. The unit is the man-sievert (manSv).
Controlled area	Radiation protection term meaning an area within which an individual may receive radiation doses that are not negligible, or from which radioactive contamination of importance from a radiation protection viewpoint may be spread to the environment.

Convention	An international agreement concluded between two or more states and subject to international law.
Core components	Components such as control rods that have been close to the fuel (the core) in a nuclear power reactor and have become radioactive.
Cored borehole	Made to obtain a continuous sample of the rock in the form of a drill core. A cored borehole is usually 76 millimetres in diameter. It is normally drilled to a depth of between 500 metres and 1,000 metres.
Critical group	A representative real or hypothetical group of persons from the population who can be expected to receive the highest radiation doses from a radiation source.
dBA	Unit of noise measurement. Decibel A, where A indicates use of a filter that suppresses low frequencies and accentuates medium frequencies.
dBC	Unit of noise measurement. Decibel C, where C indicates use of a filter that suppresses very low frequencies to only a small extent and is used to measure low-frequency noise.
Deformation zone	Collective term for different types of zones of weakness in the bedrock.
Dose rate	Indicates how large a radiation dose a person receives during a given time. The unit can vary. Examples are absorbed dose (gray) per second (Gy/s) and equivalent dose per year (Sv/year).
Drainage water	Inflowing groundwater (rock drainage water) and flushing water that is diverted to keep the rock caverns dry.
Drawdown	See "Groundwater lowering".
Drill cuttings	Residual product from drilling that is pumped to the ground surface. Consists of the same materials as the geological formations through which the borehole passes.
Ductile deformation	Deformation where the bedrock behaves like a viscous mass.
Ecopark	A large, contiguous forest landscape with high natural values and conservation ambitions. An ecopark has no protection under the law.
Ecosystem	The community of plant and animal species living in a particular area and their physical environment.
Effective dose	The sum of all equivalent doses to human organs or tissues, weighted for their differing sensitivity to radiation. The unit is the sievert (Sv), but the dose is normally given in thousands of a sievert, millisieverts (mSv). When people talk about radiation doses, they are usually referring to the effective dose.
Endemic species	An animal or plant species that only occurs within a specific area or biotope.
Engineered barriers	Man-made barriers in a final repository.
Environmental quality standard	Highest permissible concentration of air pollutants or other environmental states. The current ordinance on environmental quality standards stipulates the maximum permissible concentrations of nitrogen oxides, sulphide dioxide, lead and particulate matter in outdoor air.
Equivalent dose	The sum of absorbed dose for each type of radiation multiplied by a weighting factor (depending on the relative biological effects of the different types of radiation). The equivalent dose is considered to be proportional to the probability of damage within a wide dose range and for many types of damage. The unit is the sievert (Sv), but the dose is normally given in thousands of a sievert, millisieverts (mSv).

Equivalent level (noise)	Average sound level during a given period of time, in traffic contexts usually 24 hours.
Fauna	Animal life.
Final repository facility **Final repository**	The facility required to build the final repository and carry out the activities needed to deposit the encapsulated spent nuclear fuel. The facility consists of a surface part and an underground part. The actual final repository is the underground part that will remain after closure.
FKA	Forsmarks Kraftgrupp AB, which operates three nuclear power reactors.
Flora	Plant life.
Fracture domain	A grouping of fractures whose properties are similar.
Geology	The science dealing with the solid materials (rocks, soil and other deposits) that make up the Earth's crust.
Geophysical surveys	Measurements of the physical properties of the rock, for example magnetic field, electrical resistivity or other parameters in the soil layers and/or the bedrock for the purpose of surveying geological conditions.
Glacial	Refers to phenomena and formations related to a continental ice sheet. Glacial period: another more scientific word for an ice age.
Granite	Plutonic igneous rock (rock formed at great depth in the Earth's crust when molten rock (magma) is pushed up and solidifies) consisting primarily of the minerals quartz, feldspar, mica and/or hornblende. It is usually grey or red in colour.
Gray (Gy)	Unit of absorbed dose. A gray is equal to one joule per kilogram.
Groundwater	Water that fills voids in soil and rock.
Groundwater lowering (drawdown)	Lowering of the groundwater level due to withdrawal and/or inflow.
Grouting	Injection of cavities with a liquid substance, which then solidifies. Concrete is usually used for grouting of rock. It is forced into the fractures to seal them and prevent or reduce water inflow.
Guideline value	A value that should not be exceeded. If it is exceeded, the activity operator is obligated to adopt remedial measures. See also "Limit value".
Habitat	An area inhabited by a particular species or group of organisms. A habitat differs from a biotope in that conditions in a habitat are not necessarily uniform.
Half-life	The time it takes for half of the atomic nuclei in a radioactive substance to disintegrate.
High-level waste	Waste which, due to its high radioactivity and heat output, requires both cooling and radiation shielding, for example spent nuclear fuel.
Hydraulic boundary areas	The way the groundwater moves in the area of interest for the repository and in what quantities is determined in part by the hydraulic properties (permeability and groundwater pressure) in the surrounding area. When models of the groundwater flow and the chemical composition of the groundwater are constructed, these zones will comprise so-called "hydraulic boundary areas" and will be a kind of starting point (boundary condition) for calculations of the groundwater flow within the repository area. They are therefore important to characterize, despite the fact that they lie outside the area of interest for the repository.

Hydrogeochemistry	Chemical conditions in surface water and in groundwater in rock and soil.
Hydrogeology	Surface water and groundwater in rock and soil.
Hydrology	Study of the flow and distribution of water on the Earth, and in particular how water circulates between lakes, rivers and oceans, land areas and the atmosphere. The science also includes the physical and chemical properties of water and its interaction with living things: plants, animals and humans.
Impact area	The impact area is defined as the area where disturbances of various kinds (groundwater lowering, noise, vibration, light pollution, and air and water pollution) can cause significant impact on the environment. The area may differ in size for different types of disturbances. In the case of groundwater lowering, the impact area is defined as the area where the groundwater change is more than 0.3 metre (concerned party, water operations) or 0.1 metre (natural environment) in relation to the surrounding natural groundwater level.
Indicator species	A species used by the National Board of Forestry in key habitat inventories to find forests with high natural values.
Individual dose	Collective term for effective dose or committed effective dose. The unit is the sievert (Sv).
Inert	Substance that does not react chemically with other substances.
Infiltration	Process by which water on the ground surface enters the soil.
Intermediate-level waste	Radioactive waste that requires radiation shielding, but not cooling, for handling. For example ion exchange resins.
Ionizing radiation	Radiation that is emitted when radioactive atomic nuclei disintegrate. It can be of different types: alpha, beta, gamma or neutron radiation. These types differ in their penetration capacity and harmful effects. See also “Radioactivity”.
Isoline	A continuous contour line on a map along which the same level of e.g. pollutants or noise prevails.
Key habitat	A quality concept within nature conservation. A small land or water area that serves as a habitat for sensitive or rare animal or plant species. It may also harbour red-listed species. See also “Biotope” and “Habitat”.
Leachate	Precipitation and melted snow that has passed through the rock heap.
Limit value	Value that may not be exceeded according to the provisions of a regulation or the like. A limit value on pollutant emissions can be prescribed as a condition in the environmental licensing of an activity. See also “Guideline value”.
Load-bearing class	Roads of the highest load-bearing class (BK 1) can support heavy vehicles, up to 60 tonnes GVW (gross vehicle weight).
Long-lived waste	Radioactive waste for which it may take around 100,000 years before its radioactivity is on a level with that of naturally occurring uranium ore. For example spent nuclear fuel and core components.
Low-level waste	Radioactive waste that can be handled directly without cooling or radiation shielding. For example protective clothing, tools, filters and other items that may have been contaminated with radioactivity.
Meta-	Prefix used in front of the name of a rock to indicate that the rock has been metamorphosed.

Millisievert	See "Sievert".
National interest	Area harbouring such special values or having such special characteristics that it is deemed to be of importance for the nation as a whole. According to the Environmental Code, areas of national interest shall be protected as far as possible against measures that may be prejudicial to their utilization for this interest.
Natura 2000	An ecological network in the EU that works to ensure biodiversity by establishing special protection areas.
Nature reserve	Area set aside owing to its natural values. Activities within nature reserves are regulated by decisions taken by the local county administrative board or municipality.
Nuclear facility	Facility where nuclear material or nuclear waste is handled. The existing nuclear facilities in Sweden are the nuclear power plants in Ringhals, Oskarshamn (including Clab) and Forsmark (including SFR), Studsvik, Westinghouse Electric Sweden AB's fuel factory, Ranstad Mineral and the Ågesta plant.
OKG	Company that operates the three nuclear power reactors on the Simpevarp peninsula.
Percentile	Statistical value. The 98th percentile, for example, is a level that is only exceeded two percent of the time.
Percussion borehole	A borehole made by smashing the rock where no drill core is obtained. Usually drilled with a diameter of 115 millimetres and to a maximum depth of 200 metres.
PM10	(Particulate Matter 10). Designation of air pollutants in the form of respirable particles up to 10 µm (0.01 mm) in size that can affect the respiratory and cardiovascular systems.
Portal	Starting point for tunnelling.
Primary production	The quantity of energy used by plants to grow. The energy not used for growth is used for cell division.
Priority area	Area which is prioritized in a stepwise process for complete site investigation.
Radioactivity	Natural disintegration of unstable (high-energy) atomic nuclei, whereby ionizing radiation is emitted. See also "Ionizing radiation".
Ramp	Inclined tunnel on which canisters are transported to the underground part of the repository.
RD&D programme	The programme for Research, Development and Demonstration published every three years by SKB in accordance with the requirements of the Nuclear Activities Act.
Receiving water	Body of water into which waste water is discharged.
Red-listed	Included in a list of plant and animal species exposed to different degrees and types of threats.
Regulation	Compulsory requirements issued by a regulatory authority.
Release from regulatory control (clearance)	Exemption of materials, buildings (or parts thereof) or land from the provisions of the Radiation Protection Act so that they may be handled without restrictions from a radiation protection viewpoint.
Rich fen	Open or wooded fen with continuous inflow of mineral-rich water. The vegetation is dominated by different grasses and non-woody plants.

Rock domain	A grouping of rock types whose properties are similar.
SFR	Final repository for short-lived radioactive waste. SKB's facility in Forsmark.
Short-lived waste	Radioactive waste whose radioactivity declines to the level that occurs naturally within 500 years. For example protective clothing, tools, filters and other items that may have been contaminated with radioactivity.
Sievert	Unit of effective and equivalent radiation dose. Doses are normally given in thousandths of a sievert, millisieverts (mSv).
SKI	Swedish Nuclear Power Inspectorate. SKI and SSI were merged into the Swedish Radiation Safety Authority (SSM) 1 July 2008.
Skip	Hoist for transport of rock spoil, buffer and backfill.
Soil wells	Holes drilled through the overburden and a short way into the surface rock. Soil wells are used for environmental monitoring at drill sites, and for investigations of e.g. hydrological and hydrogeochemical conditions.
Spent nuclear fuel	Nuclear fuel that will be disposed of and not used again.
SR-Can	Assessment of the final repository's long-term safety that was produced in 2006. (Can stands for canister.)
SR-Site	Assessment of the final repository's long-term safety. Produced for the current applications under the Environmental Code and the Nuclear Activities Act. (Site refers to the site of the final repository.)
SSI	Swedish Radiation Protection Authority. SSI and SKI were merged into the Swedish Radiation Safety Authority (SSM) 1 July 2008.
SSM	Swedish Radiation Safety Authority. SSI and SKI were merged into the Swedish Radiation Safety Authority 1 July 2008.
Structure-borne sound	Sound that is propagated through buildings as vibrations caused by external sources such as passing vehicles. When the buildings vibrate, floors and walls begin to oscillate, generating a low-frequency sound.
Tectonic lens	Rock unit enclosed in a ductile deformation zone which is unaffected, or much less affected, by ductile deformation than the deformation zone as a whole.
Terminal vehicle	Vehicle for transport of transport casks containing fuel or waste.
The final repository system	The facilities planned by SKB to be able to carry out final disposal of spent nuclear fuel according to the KBS-3 method. The system consists of a central facility for interim storage (Clab), an encapsulation plant, a transportation system for transport of canisters of spent nuclear fuel and a final repository facility.
Topography	Description of the natural and artificial physical features of an area.
Zero alternative	A description of the consequences of not adopting a proposed measure or building a proposed facility.

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4-2	1208614 ver 1.0	Verksamheten och de allmänna hänsynsreglerna – slutförvarssystemet	SKB, 2010
5-9	1208614 ver 1.0	Verksamheten och de allmänna hänsynsreglerna – slutförvarssystemet	SKB, 2010
7-19	1091265 ver 1.0	Den geografiska avgränsningen av skyddsvärda kustområden vid Simpevarp	Mannheimer Swartling Advokatbyrå, 2005
8-3	1171993 ver 3.0	Transport av inkapslat bränsle till slutförvaring i Forsmark	SKB, 2010
8-12	1229823 ver 1.0	Clab – Reduktion av radioaktiva utsläpp från Clab	SKB, 2010
9-4	1171993 ver 3.0	Transport av inkapslat bränsle till slutförvaring i Forsmark	SKB, 2010
9-11	1229823 ver 1.0	Clab – Reduktion av radioaktiva utsläpp från Clab	SKB, 2010
10-7	1203765 ver 1.0	Material- och persontransporter till och från slutförvaringsanläggningen	SKB, 2009
10-15	1091132 ver 3.0	Säkerhet Slutförvarsanläggning för använt kärnbränsle – Allmän del (SR-drift) kapitel 7 – Strålskydd och strålskärmning	SKB, 2010
10-20	1224909 ver 1.0	Slutförvar för använt kärnbränsle, Forsmark – Sammanställning av resursförbrukning	SKB, 2010
10-31	1091141 ver 3.0	Säkerhetsredovisning för drift av slutförvarsanläggning för använt kärnbränsle (SR-drift) kapitel 8 – Säkerhetsanalys	SKB, 2010
10-36	1195211 ver 1.0	Slutförvarsanläggning, projekteringssteg layout D2. Sammanställning av materialflöden	SKB, 2009
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12-2	1091141 ver 3.0	Säkerhetsredovisning för drift av slutförvarsanläggning för använt kärnbränsle (SR-drift) kapitel 8 – Säkerhetsanalys	SKB, 2010
12-15	1229823 ver 1.0	Clab – Reduktion av radioaktiva utsläpp från Clab	SKB, 2010

Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Co) applies for a licence for interim storage and encapsulation of spent nuclear fuel on the Simpevarp peninsula in Oskarshamn Municipality and to dispose of the spent nuclear fuel in Forsmark in Östhammar Municipality.

This Environmental Impact Statement (EIS) is an appendix to the licence applications under the Nuclear Activities Act and the Environmental Code.

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