The final disposal facility for spent nuclear fuel

Environmental impact assessment report

POSIVA OY

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Radioactive waste generated by nuclear power plants should be managed so that it cannot harm organic nature. In practice, this means isolating it by final disposal deep in the bedrock. Finland has systematically managed nuclear waste and, in respect of low and medium level radioactive waste, steps have now progressed to the stage of final disposal. Preparations have also been underway for the past twenty years for the final disposal of spent nuclear fuel.

Thorough long-term studies have shown that the Finnish bedrock is suitable for the permanent isolation of spent nuclear fuel from organic nature. Legislation requires that besides safety, an assessment be made of any other environmental impacts of the final disposal facility.

Environmental impact assessment (EIA) in respect of the final disposal facility for spent nuclear fuel got under way in 1997 when Posiva Oy, which is responsible for the project, began work on an EIA programme. In practice, the programme is a plan for the EIA studies to be made to ascertain and assess the various environmental impacts involved.

In February 1998, this EIA programme was completed and handed over to the Ministry of Trade and Industry (KTM), which acts as the coordinating authority. Evaluation of the EIA programme also involved an extensive consultation procedure, after which KTM issued a statement on the programme in June 1998. Since then, work on the EIA procedure progressed by assessing the environmental impacts and culminated in the preparation of this EIA report. Under Section 24 of the Nuclear Energy Decree, an environmental impact assessment report must be appended to the application for a decision for the final disposal facility for spent nuclear fuel. The application is to be addressed to the Council of State.

Already when drafting the EIA programme and subsequent assessment of environmental impacts, prominence was given to an approach emphasising public involvement combined with studies carried out by experts. During the EIA procedure, we have held numerous events and discussions with residents and local groups in the candidate municipalities for the location of the final disposal facility, as well as with central and regional administrative authorities. We would like to thank them and all other organisations for the feedback received for our studies, as well as the research institutes and companies carrying out the studies for their contribution in making this EIA report.

Helsinki, May 1999

Posiva Oy

1 INTRODUCTION

1.1 Preparation for the management of spent nuclear fuel

Nuclear waste in this context means all the radioactive material generated in the production of nuclear power for which no further use has been planned. At Finland's two nuclear power plants, Olkiluoto in Eurajoki and Hästholmen in Loviisa, nuclear waste includes all low and medium level radioactive waste arising when cleaning the plants' process waters and in service and repair work, as well as low and medium level radioactive waste arising when the plants are decommissioned at the end of their useful life. Nowadays, spent nuclear fuel is also considered high level radioactive waste because as matters stand, it is no longer of use.

One of the general principles of nuclear waste management is to isolate the radioactive material contained in the waste from organic nature, so that at no time does it endanger our living environment. The aim is to isolate the waste so that it requires no supervision and that people are no longer actively responsible for its safety. Storage based on permanent isolation is known as final disposal, and includes both natural and man-made barriers to prevent radiation. Various types of waste call for different isolation in the final disposal system.

Teollisuuden Voima Oy (TVO) and Fortum Power and Heat Oy (Imatran Voima Oy until 1 March 1999) are responsible for managing, and the preparation and costs thereof, the nuclear waste they produce. From a very early stage, the companies have anticipated their responsibility for all measures relating to nuclear waste management and are accumulating funds in advance for this purpose.

Figure 1-1. Finland's two nuclear power plants are located at Olkiluoto in Eurajoki and at Hästholmen in Loviisa (r).

Each company is responsible for processing and the final disposal of its own low and medium level radioactive waste, as well as for temporary storage of spent nuclear fuel in the vicinity of its plants. The latest evidence of plans implemented is the final disposal facilities for low and medium level radioactive power plant waste built at Hästholmen and Olkiluoto. The environmental policies of both companies highlight environmental responsibility, which also includes the management of nuclear fuel cycle in accordance with environmental protection criteria.

The Loviisa and Olkiluoto nuclear power plants were built in the 1970s (Figure 1-1). When the nuclear power plant deal was made, it was agreed to return the spent nuclear fuel from the Loviisa reactors to the Soviet Union (later to Russia).

Studies on the management of high level nuclear waste from the Olkiluoto reactors began during the construction stage in the 1970s. In addition to work relating to the reprocessing of spent nuclear fuel, the studies also included planning and the readiness to build additional storage capacity for spent fuel. Preparations in respect of nuclear waste management gave rise to a joint nuclear waste report completed by TVO and IVO in 1978. This report showed that nuclear waste management could technically be safely dealt with in Finland. The same year, the power companies set up the Nuclear Waste Commission of Finnish Power Companies (YJT) to coordinate R&D. Cooperation also led to completion of the first nuclear waste management programme in September 1978. In practice, the above steps meant that power plants were preparing to be responsible for all measures relating to nuclear waste. Work began on drafting long-term action programmes for these measures.

In 1995, the power companies founded a joint company Posiva Oy, which was tasked with responsibility for the final disposal of spent nuclear fuel. Until then, TVO was preparing to finally dispose of the spent nuclear fuel from the Olkiluoto plant in Finland. IVO had already returned spent nuclear fuel from Loviisa to Russia in accordance with the original agreement.

1.2 Compliance with the law and decisions

Before existing legislation came into force, use of nuclear power was governed by the Atomic Energy Act dating from 1957. The law was amended in 1978 to take into account nuclear waste management. These amendments meant that power plants, as licence holders, assumed responsibility for all measures and costs relating to nuclear waste management. Under the Act, detailed regulations were incorporated into the licences issued to power plants.

The aims and schedules relating to implementation of nuclear waste management and associated research and planning were defined in the Council of State´s decision in principle dating from 1983. The Nuclear Energy Act and Decree, which came into force in 1988, provided clear guidelines on the implementation of nuclear waste management in Finland. Under an amendment made to the Act in 1994, measures relating to all types of nuclear waste should be carried out in Finland.

The authorities supervise all nuclear waste management measures and annually inspect research programmes aimed at implementing solutions that comply with safety criteria and that are technically suitable and feasible in accordance with the established objectives of the schedule. The authorities are also responsible for imposing nuclear waste management safety criteria and for ensuring that activities are in accordance with safety norms.

The overall schedule for the management of spent nuclear fuel is contained in the aforementioned government decision of 1983. The decision required that research and planning of the final disposal of spent nuclear fuel in Finland is to progress such that "by the end of the year 2000, a suitable disposal site has been chosen and studied so that the repository can be built if required". The decision also gave interim objectives for research and assessment to be carried out to choose the final disposal site, technical design of the repository and for safety analysis. Work has progressed in line with these interim objectives. The next objective is to select a final disposal site complying with environmental protection and safety criteria by the end of the year 2000. Once this has been done, under the government decision, research and planning work should progress so that work on building the final disposal facility can begin after 2010 and final disposal can commence in 2020.

The above criteria governing the schedule were also later presented in decisions concerning the principles of nuclear waste management made by the Ministry of Trade and Industry 7/815/91 KTM and 11/815/95 KTM and in the government's 1997 energy strategy. The power companies are bound by the research and planning objectives and the scheduling requirements of the valid Ministry of Trade and Industry decisions.

Under the 1994 amendment to the Nuclear Energy Act, nuclear waste produced in Finland must be handled, stored and finally disposed of in Finland. Fortum, too, has been preparing for final disposal in Finland of the spent nuclear fuel in its possession since then.

Companies responsible for nuclear waste management have provided for the cost of final disposal in accordance with the principles specified in the Nuclear Waste Act. Realised in accordance with the base alternative given in this report, the project is expected to cost FIM 4.6 billion, calculated on the disposal facility having an assumed operational lifespan of 40 years. The funds required for future nuclear waste management measures are being collected in advance by including them in the price of nuclear power and paying them into the State Nuclear Waste Management Fund.

In addition to the final disposal facility for spent nuclear fuel, the Fund is also collecting funds for other nuclear waste management liabilities such as decommissioning plant units. The Ministry of Trade and Industry confirms the amount of money to be paid into the Fund each year and also oversees the Fund. In 1999, TVO's share of the fund amounted to FIM 3,490.56 million and Fortum's share FIM 2,212.1 million. The assets accumulating in the Fund are returned to the companies as nuclear waste management measures are put into place.

1.3 Long-term R&D

Preparations to locate the final disposal site

Studies to evaluate the suitability of Finnish bedrock for the final disposal of nuclear waste began in the late 1970s (IVO & TVO 1978). Subsequent studies dealt with bedrock structures, groundwater flow, radionuclide retention and the impact of isostatic uplift and glaciation. The first stage of R&D into nuclear waste management sought to seek an answer to the final disposal of low and medium level waste from nuclear power plants. Site characterisation and safety studies were carried out at Hästholmen in Loviisa and Olkiluoto in Eurajoki in the 1980s and the final disposal facilities were brought into use in the 1990s.

The first fairly extensive study of the final disposal of spent nuclear fuel appeared in a series of reports published by the Nuclear Waste Commission of Finnish Power Companies (YJT) in 1982. The study examined the safety and technical feasibility of the final decision in Finnish conditions under the multi barrier principle. The study was a comprehensive account of the properties of Finnish bedrock compiled by Finnish experts and based on existing information in respect of the long-term safety of final disposal and the suitability of the rock for underground construction.

In 1983, Teollisuuden Voima Oy launched an R&D programme aimed at developing a solution to the final disposal of spent nuclear waste complying with safety and environmental protection criteria and selecting a disposal site by the end of the year 2000 in accordance with the government's decision.

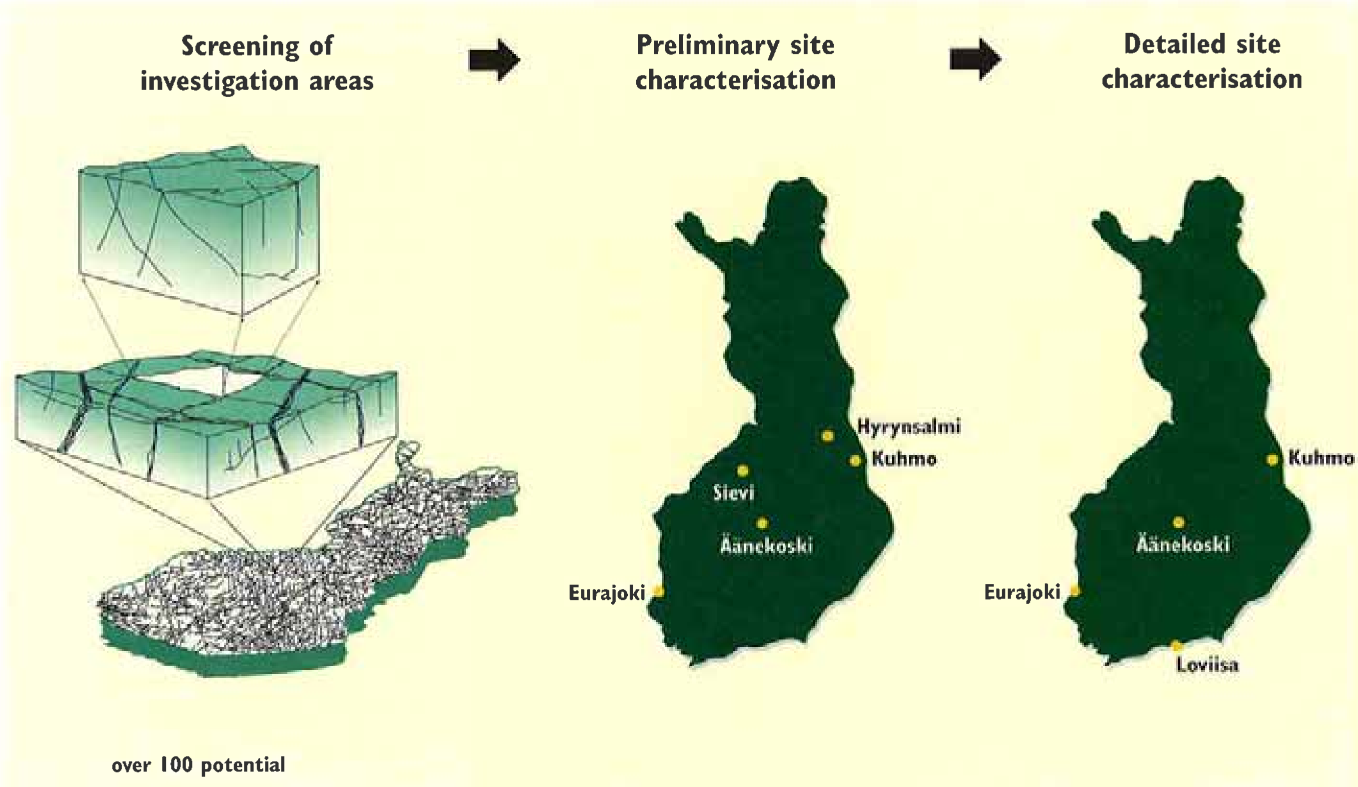


Figure 1-2. Work continues on studies begun in the early 1980s. After a complex selection process, the potential sites for the final disposal of spent nuclear fuel are Olkiluoto (Eurajoki), Romuvaara (Kuhmo), Hästholmen (Loviisa) and Kivetty (Äänekoski).

Investigation and choice of the final disposal site has progressed in stages (Figure 1-2). The idea was to first examine the bedrock conditions of several areas and to choose the most suitable of these for further detailed study. Working in this way has enabled us to obtain comparative material about deep bedrock conditions to ensure that the rock conditions of the site chosen provide possibilities for final disposal and that we can be certain they are typical for Finnish bedrock (Figure 1-2).

Initially, during 1983–1985, the aim was to use geological bases to screen areas suitable for study. The whole of Finland was examined. To this end, we first identified major crush zones in the Finnish bedrock. Then we examined the areas they were confined to and located the main crush zones they contained and the bedrock blocks they were confined to, which we used to determine the topography, rock types, fracturing and the amount of exposed rock.

Examination of the suitability for further studies of the areas emerging through screening evaluations were made on

- the homogeneity, size and depth of the formation
- groundwater flow on the basis of topography
- the impact of fracturing on the water conductivity of the bedrock and on the constructability
- the stability of the bedrock (major rock movements are presumably centred on major fracture zones)
- natural resources, which might be of importance for future use of the area.

Moreover, we also assessed demographic factors, conservation and groundwater areas, land use plans and feasibility for transports. We also ascertained land ownership, since permission of the landowner is required for field studies.

We also drafted a separate geological study of the suitability of Olkiluoto island and the immediate vicinity for further analysis because the area, as the location of the Olkiluoto nuclear power plant, has a special position in the site selection process.

Results of the screening research were forwarded to the authorities for examination in late 1985. The material presented 102 areas suitable for further study. A concept on the final disposal and the safety assessment thereof based on the Swedish final disposal solution KBS-3 was simultaneously forwarded to the authorities for evaluation.

Figure 1-3. Drill cores at a borehole site.

A statement made by the Ministry of the Environment resulted in the elimination of 17 areas from the shortlist of areas in the evaluations made of the screening material by the authorities and experts, and 12 areas were re-outlined because of pending protection plans.

Evaluation made by the Finnish Radiation and Nuclear Safety Authority (STUK) noted that the areas screened featured somewhat similar rock formations, but that this could be used as a basis when selecting areas for preliminary site characterisation. Nevertheless, special attention should be paid to geological variations between the areas.

Characterisation in several areas

Five areas were chosen for preliminary site characterisation in spring 1987. The areas were Veitsivaara in Hyrynsalmi, Kivetty in Konginkangas (now Äänekoski), Romuvaara in Kuhmo, Syyry in Sievi and Olkiluoto in Eurajoki. The areas chosen represent the main units in the Finnish bedrock, differing from each other in terms of rock type and age. The choice of areas was also affected by land ownership and discussions with municipalities during 1985–86.

A report was made of the preliminary site characterisation in 1992. Subsequent investigations were continued at four sites: Kivetty, Olkiluoto, Romuvaara and Hästholmen. Based on a feasibilty study carried out the year before, Hästholmen was chosen for site characterisation in 1997. The feasibilty study examined the provisional suitability of the bedrock in the area for the final disposal of spent nuclear fuel. Like Olkiluoto, Hästholmen, as the location of a nuclear power plant, also has a special position with regard to considering the final disposal site.

Bedrock studies sought to ascertain whether the areas to be investigated satisfy the safety criteria for the final disposal of spent nuclear fuel. Each area comprises a bedrock block on which field investigations have been centred. Extensive investigations, including geological mapping and geophysical measurements have been made over a much wider area. More detailed information has been obtained by deep drillings and borehole studies down to a depth exceeding 1 km at all sites (Figure 1-3). By the end of 1998, 8–13 deep boreholes had been drilled at each site. Numerous Finnish and international expert organisations have taken part in the investigations and in interpreting the material from them. Reports of the findings made during the work appeared in YJT and Posiva's report series. The reports were forwarded for use by the authorities, experts and the municipalities where the investigations took place.

In compliance with obligations imposed by the Ministry of Trade and Industry a further study supplementing the basis for choosing the area were conducted during 1991–96. These examined in closer detail the properties of the mafic volcanic and intrusive rock types in the Finnish bedrock and the suitability of these formations as a site for the final disposal of spent nuclear fuel. Even though these rock types are thought to have more suitable properties than felsic granites, investigations could not confirm this. On the other hand, rather rare mafic rock formations are often associated with ore potential, a disadvantage with respect to the final disposal of spent nuclear fuel.

In 1996, Posiva issued an interim report comprising the main findings of site characterisation and safety assessment and technology studies from

Figure 1-4. SKB's hard rock laboratory facilities at Äspö, Sweden.

1993–96. Besides characterisation of each candidate site, work also continued on generic studies of the properties of bedrock begun at the turn of the 1980s. These studies included an investigation of rock movements and an examination relating to the conditions prevailing at the onset of and during the ice age.

The latest summaries of the prevailing bedrock conditions at each alternative disposal site have been published as Posiva reports. These reports are essential background material in assessing the long-term safety of final disposal. Posiva has also published a report of this safety analysis, TILA-99.

International cooperation

Besides Finnish research, the power companies have, through the years, taken part in international cooperation projects. The most important of these were the investigations of the Stripa mine in Sweden, conducted in the 1980s, and R&D work at the Äspö deep rock laboratory, which is still going on (Figure 1-4), in Sweden. Finland, like Sweden, is located in the Fennoscandian bedrock area and the two countries have similar bedrock conditions. This is why the bedrock data acquired by the Swedish Nuclear Fuel and Waste Management Company (SKB) also largely applies to Finnish conditions.

Investigations conducted by Canadian AECL and Swiss Nagra also focus on a similar type of crystal bedrock as the one existing in Finland. This means that Finland has also been able to make use of the data and experience of investigation methods acquired by these countries.

During the past twenty years of investigation, the organisation responsible for the final disposal of spent nuclear fuel and Finnish research bodies have acquired a good insight into the overall properties of the Finnish bedrock and a detailed picture of the bedrock in the candidate areas investigated. The research findings were published regularly as YJT reports between 1978 and 1995, and thereafter as Posiva reports, a list of which is appended to this report. SKB, Nagra and AECL publications and collected reports of presentations held at international meetings also contain important research information for Finns.

1.4 Environmental impact assessment

The final disposal facility for spent nuclear fuel must apply for the Council of State's decision in principle that the government, when making, must consider whether building the facility in

Nuclear waste management programme assessment

When the Nuclear Energy Act came into force in 1988, the Ministry of Trade and Industry set up a working group to study nuclear waste management development needs. The group looked at alternative waste management and final disposal principles and alternative solutions for the final disposal of spent uranium fuel. In its report, the working group did not consider that the other final disposal options studied afforded benefits compared to the base alternative. The group considered the aims and overall schedule presented in the government's 1983 resolution as being justified, and that there was a need to further develop the base alternative for final disposal and to thoroughly characterise the chosen alternative sites.

In late 1992, a report was made of the findings of preliminary site investigations in accordance with the overall schedule. Updated technical plans concerning final disposal were also published together with the TVO-92 safety analysis in late 1992. During 1993, the Ministry of Trade and Industry held a Finnish nuclear waste management assessment implemented as IAEA's so called WATRP assessment.

General speaking, international specialists considered that Finnish nuclear waste management was well organised. The group of experts considered that Finland had adopted a good approach in respect of the disposal site. In its recommendation, the group proposed that choice of a site should not aim at finding the "best possible site", but a "suitable" site that complies with the safety criteria of a final disposal facility built in line with the multi barrier principle.

Finland is "in the overall good of society". This environmental impact assessment report is to be enclosed with the application for this decision.

Posiva began work on the environmental impact assessment (EIA) process in spring 1997, with the scoping of an assessment. Site characterisation had already been carried out since 1987, and the experiences obtained from interactive talks with local residents showed that above all, any impacts were social. The most important principle was to hold talks between the final disposal candidate municipalities and Posiva so that residents' points of view could be taken into account.

To identify impacts, local residents were informed of the reason for EIA and every effort was made to give them an opportunity to participate. Experts, including theme interviews, were also commissioned to provide information to issues preoccupying residents.

The EIA programme was handed over to the Ministry of Trade and Industry, the coordinating authority, in February 1998. Authorities also notified neighbouring states about the programme.

The Ministry's requests for further and supplementary information were taken into account when drafting this EIA report. Posiva's owners, TVO and Fortum Power and Heat, launched their own EIA projects concerning the possible construction of a new nuclear power unit in existing nuclear plant areas. In the event of one or more nuclear reactors being built in Finland in the future, it is also obvious that the spent nuclear fuel generated by these new plants would be managed and finally disposed of in the facility described in this report. This is why this report also deals with the final disposal of much greater volumes of spent nuclear fuel than current estimates.

This EIA document is supplemented by numerous expert reports published in Posiva's report series.

Chapters 2 and 3 in the report define and limit the final disposal project. Initially, the report looks at the options available for the management of spent nuclear fuel, and then the geological aspects and a comparison of the options available for the final disposal of spent nuclear fuel.

The final disposal project, the final disposal site options and the non-implementing alternative are described in chapters 4, 5 and 6. Chapter 7 examines EIA progress, organisation and assessment material.

The environmental impacts are dealt with in chapter 8 together with the methods used and the uncertainties associated, as well as the estimated risk of environmental accident. Chapter 9 assesses the environmental impacts of non-implementing the project.

Chapter 10 evaluates the various options and their feasibility. One of the aspects is the long life cycle of the project. Chapter 11 deals with actions warranted by the project after environmental assessment and gives a view of the environmental impact follow-up programme.

2 ALTERNATIVES AVAILABLE FOR THE MANAGEMENT OF SPENT NUCLEAR FUEL

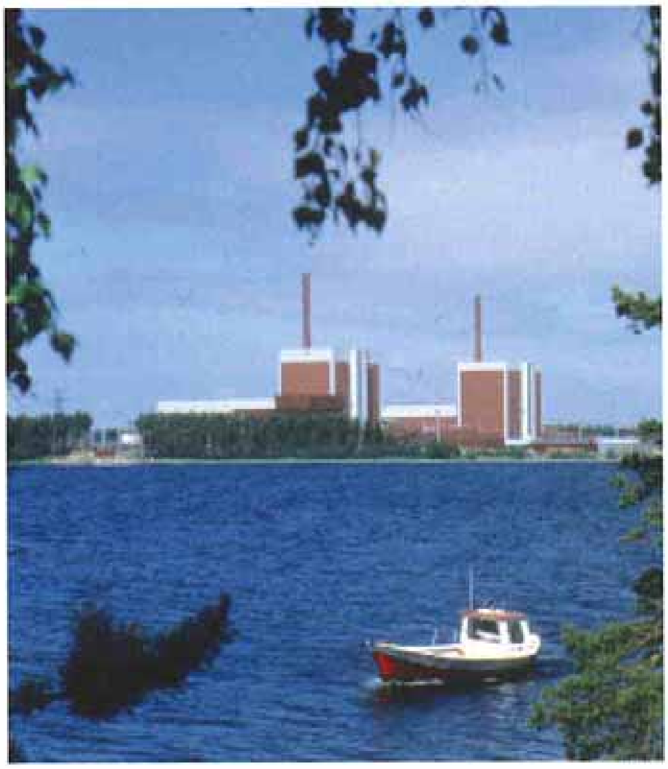


Figure 2-1. The Olkiluoto (left) and Loviisa nuclear power plants as seen from the sea.

2.1 Current situation

Finland's four nuclear power plant units at Olkiluoto and Loviisa (Figure 2-1) have been operating since the late 1970s. The plants generate about one quarter of Finland's electricity requirement. After completion of a project to increase reactor output at Olkiluoto in 1998, both plant units have a rating of 840 MW. Loviisa has a rating of 488 MW (net electricity power capacity). Thermal capacity is 2,500 MW and 1,500 MW respectively.

Each year part of the nuclear reactor fuel is replaced. Spent fuel is highly radioactive when removed from the reactor. At Olkiluoto, about one quarter and at Hästholmen about one third of the fuel in the reactor is replaced each year. Some 75–80 tonnes of spent nuclear fuel accumulate in Finland each year.

Nuclear fuel is loaded into the reactor core in fuel assemblies (Figure 2-2). Each fuel assembly used at Olkiluoto weighs some 300 kg and contains around 175 kg of uranium. Each fuel assembly used at Loviisa weighs just under 220 kg and contains around 120 kg of uranium.

Used and fresh fuel is similar in appearance except for the fact that part of the uranium decays into several other materials during use. Although the radioactive materials in spent nuclear fuel are highly radioactive and generate heat, actual nuclear fission ceases once the fuel is removed from the reactor.

Initially, spent nuclear fuel discharged from a reactor is highly radioactive although radioactivity rapidly decreases and most of the radioactive materials decay during the first one thousand years (Figure 2-3). Nevertheless, spent nuclear

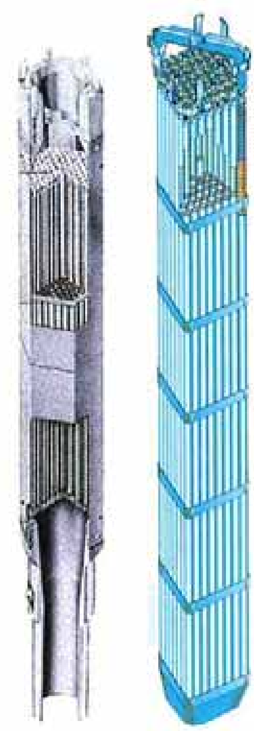


Figure 2-2. Illustration of the type of fuel assemblies used at Loviisa (left) and Olkiluoto.

fuel also contains some very long-lived radioactive elements. Although radiation from these elements is usually unable to penetrate even the outer layer of the skin, it can constitute a health risk when eaten or inhaled. For this reason, spent nuclear fuel has to be isolated for long periods from human contact. Some constituents of spent nuclear fuel are also chemically toxic.

A list of the radioactive materials, their active contents (1 year after removal from the reactor) and their radioactive half-life appears in the table on the next page.

Spent nuclear fuel assemblies from reactors are first transferred to cooling pools (Figure 2-4) in the reactor building. After a few years they are transferred to water pools for interim storage. The water in the pool cools the assemblies and protects the environment from radiation. The fuel assemblies in the reactor building and in interim storage facilities are dealt with at all times under water.

The interim storage facilities for spent nuclear fuel have been so designed to store fuel for tens of years. Radioactivity and heat generation fall significantly during interim storage. This makes it easier to handle and transport the fuel. After one year of being removed from the reactor, heat production per 1 tonne of spent nuclear fuel is appr. 10 kW. After 10 years this has fallen to about 1 kW, after 600 years to about 0.1 kW and after 10,000 years to around 0.01 kW (TVO 1992 a).

Figure 2-4. The water pool storage facility for spent nuclear fuel at Olkiluoto in Eurajoki. The insert photo shows the assemblies covered by water from above.

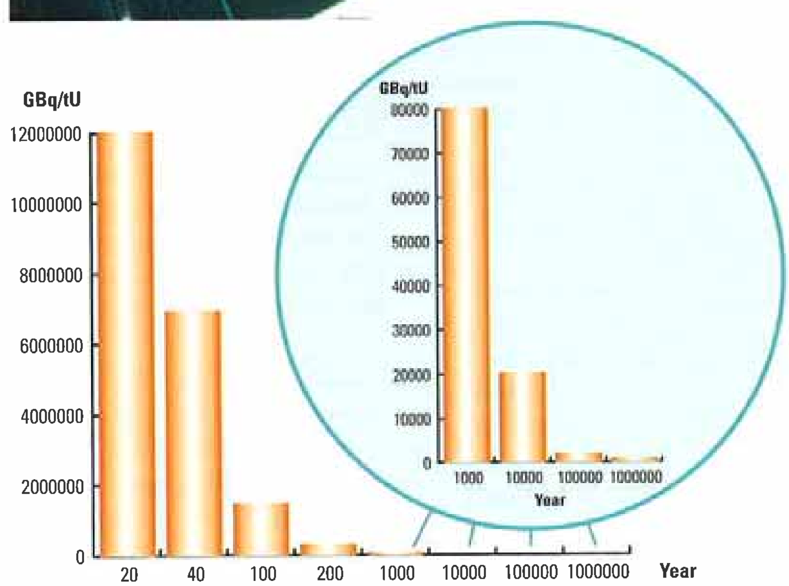


Figure 2-3. Decrease in radioactivity of spent nuclear fuel.

Composition of spent nuclear fuel

The radioactivity concentration of radionuclides (Bq/tU) in typical fuel at Olkiluoto (3.3% enrichment, 24.3 MW/tU intensity) and Loviisa (3.6% enrichment, 36.8 MW/tU intensity) by burning 36 GWd/tU after 20 years of being removed from the reactor. The table is based on reports (Vieno and Nordman 1999, Anttila 1992 and 1995). The contents of certain daughter nuclides are still small at this stage (indicated by a dash). This table excludes daughter nuclides with short half-life times and low-level insignificant nuclides. Bq/tU = becquerel/tonne of uranium.

Radionuclide	**Half-time** (years)	**Radioactivity concentration (Bq/tU)** Olkiluoto	Loviisa
Fuel (including activating products from impurities)			
H-3	$1.3 \cdot 10^1$	$7.1 \cdot 10^{12}$	$7.4 \cdot 10^{12}$
C-14	$5.7 \cdot 10^3$	$1.0 \cdot 10^{10}$	$1.3 \cdot 10^{10}$
Cl-36	$3.0 \cdot 10^5$	$7.3 \cdot 10^8$	$7.3 \cdot 10^8$
Se-79	$6.4 \cdot 10^4$	$1.6 \cdot 10^{10}$	$1.7 \cdot 10^{10}$
Kr-85	$1.1 \cdot 10^1$	$9.6 \cdot 10^{13}$	$1.1 \cdot 10^{14}$
Sr-90	$2.9 \cdot 10^1$	$1.8 \cdot 10^{15}$	$1.9 \cdot 10^{15}$
Zr-93	$1.5 \cdot 10^6$	$7.1 \cdot 10^{10}$	$7.3 \cdot 10^{10}$
Tc-99	$2.1 \cdot 10^5$	$5.2 \cdot 10^{11}$	$5.3 \cdot 10^{11}$
Pd-107	$6.5 \cdot 10^6$	$4.9 \cdot 10^9$	$4.5 \cdot 10^9$
Sn-126	$1.0 \cdot 10^5$	$3.2 \cdot 10^{10}$	$3.1 \cdot 10^{10}$
I-129	$1.6 \cdot 10^7$	$1.3 \cdot 10^9$	$1.3 \cdot 10^9$
Cs-134	$2.1 \cdot 10^0$	$8.5 \cdot 10^{12}$	$8.5 \cdot 10^{12}$
Cs-135	$2.3 \cdot 10^6$	$2.4 \cdot 10^{10}$	$1.7 \cdot 10^{10}$
Cs-137	$3.0 \cdot 10^1$	$2.6 \cdot 10^{15}$	$2.7 \cdot 10^{15}$
Sm-151	$9.0 \cdot 10^1$	$1.6 \cdot 10^{13}$	$1.5 \cdot 10^{13}$
Ra-226	$1.6 \cdot 10^3$	–	–
Th-229	$7.3 \cdot 10^3$	–	–
Th-230	$7.7 \cdot 10^4$	–	–
Pa-231	$3.2 \cdot 10^4$	–	–
U-233	$1.6 \cdot 10^5$	–	–
U-234	$2.4 \cdot 10^5$	$4.7 \cdot 10^{10}$	$4.9 \cdot 10^{10}$
U-235	$7.0 \cdot 10^8$	$6.7 \cdot 10^8$	$7.6 \cdot 10^8$
U-236	$2.3 \cdot 10^7$	$1.0 \cdot 10^{10}$	$1.1 \cdot 10^{10}$
U-238	$4.5 \cdot 10^9$	$1.2 \cdot 10^{10}$	$1.2 \cdot 10^{10}$
Np-237	$2.1 \cdot 10^6$	$1.7 \cdot 10^{10}$	$1.6 \cdot 10^{10}$
Pu-238	$8.8 \cdot 10^1$	$1.4 \cdot 10^{14}$	$1.1 \cdot 10^{14}$
Pu-239	$2.4 \cdot 10^4$	$1.3 \cdot 10^{13}$	$1.4 \cdot 10^{13}$
Pu-240	$6.5 \cdot 10^3$	$1.9 \cdot 10^{13}$	$1.9 \cdot 10^{13}$
Pu-241	$1.4 \cdot 10^1$	$2.3 \cdot 10^{15}$	$2.1 \cdot 10^{15}$
Pu-242	$3.8 \cdot 10^5$	$8.1 \cdot 10^{10}$	$6.9 \cdot 10^{10}$
Am-241	$4.3 \cdot 10^2$	$1.6 \cdot 10^{14}$	$1.6 \cdot 10^{14}$
Am-243	$7.4 \cdot 10^3$	$1.1 \cdot 10^{12}$	$7.9 \cdot 10^{11}$
Cm-244	$1.9 \cdot 10^1$	$8.4 \cdot 10^{13}$	$5.0 \cdot 10^{13}$
Cm-245	$8.5 \cdot 10^3$	$1.9 \cdot 10^{10}$	$9.5 \cdot 10^9$
Cm-246	$4.7 \cdot 10^3$	$3.6 \cdot 10^9$	$1.8 \cdot 10^9$
Protective encapsulation, flow channel and structural parts			
C-14	$5.7 \cdot 10^3$	$2.4 \cdot 10^{10}$	$3.0 \cdot 10^{10}$
Cl-36	$3.0 \cdot 10^5$	$7.2 \cdot 10^8$	$3.5 \cdot 10^8$
Ni-59	$8.0 \cdot 10^4$	$2.0 \cdot 10^{11}$	$1.4 \cdot 10^{11}$
Ni-63	$9.6 \cdot 10^1$	$2.9 \cdot 10^{13}$	$1.9 \cdot 10^{13}$
Zr-93	$1.5 \cdot 10^6$	$2.7 \cdot 10^{10}$	$2.3 \cdot 10^{10}$
Nb-94	$2.0 \cdot 10^4$	$1.0 \cdot 10^{10}$	$5.5 \cdot 10^{11}$

2.2 Alternative measures after interim storage

Reprocessing

Spent nuclear fuel must be kept isolated from organic nature to protect people and the environment. Existing interim storage facilities comply with this aim. These storage facilities can continue to be safely used for tens of years with relatively low service and maintenance. Nevertheless, interim storage facilities are not intended as a final solution, and the aim is to find a definitive solution for the disposal of spent nuclear fuel.

In many countries, as is also the case in Finland, large-scale plans were made to build nuclear power plants in the 1970s. In those days, it seemed evident that uranium would enjoy rapid growth and the price of uranium ore accordingly. It was clear that against this prevailing background, nuclear power companies wanted to get the maximum amount of energy out of uranium. This is why work began on plans to reprocess spent nuclear fuel.

Reprocessing separates the remaining unspent uranium and the plutonium created in the spent fuel for re-use. It was planned that re-use would take place either in the same or similar reactors or later in so-called breeder reactors, which produce more fissionable material than they consume. In those days it was assumed that breeder reactors would be in commercial service by the year 2000.

A Soviet initiative in connection with the power plant deal resulted in an agreement to return spent fuel from the Loviisa reactors to the former Soviet Union (Russia). The Soviet Union sought to re-use the useful elements contained in the spent nuclear fuel.

Figure 2-5. Great Britain intends to reprocess most of its spent nuclear fuel. Photo of the Sellafield reprocessing plant and surroundings.

Studies were also made of the options available to reprocess the spent fuel from the Olkiluoto reactors and negotiations on reprocessing agreements were held with foreign companies. Nevertheless, there was little reprocessing capacity available and the prices asked were high. Furthermore, agreements required the reprocessing waste to be returned to Finland. When the price of uranium plummeted in the early 1980s, and there was no guarantee that the uranium and plutonium separated in reprocessing could be used, no reprocessing agreements were signed.

Because the need is so small, building a reprocessing plant in Finland has not even been considered.

The grounds for abandoning reprocessing plans were essentially economical. Many other countries, including the United States, also abandoned such plans. Although the reasons given there were primarily the risk of nuclear weapons spreading as a result of growing reprocessing technology.

Returning spent nuclear fuel to Russia ended in 1996 in consequence of an amendment made to the Nuclear Energy Act in 1994. Parliament considered that each country, including Finland, should be responsible for dealing with its own nuclear waste.

The economic viability of reprocessing has subsequently been assessed. A comparison drawn up in 1990 noted that reprocessing was still not economically viable. (Lunabba & Vira 1990), nor have circumstances changed significantly since then.

In principle, reprocessing is still possible and, for example, Great Britain and France intend to reprocess most of their spent nuclear fuel (Figure 2-5). Even reprocessing does not entirely eliminate nuclear waste because all existing plants offering reprocessing facilities return the ensuing nuclear waste to its owners after reprocessing. Part of this waste is high level radioactive waste and thus requires similar further management.

Reprocessing spent fuel can reduce the need for uranium ore and thus any adverse environmental impacts arising from quarrying. On the other hand, reprocessing can also cause environmental impacts in the vicinity around the plant (Vuori 1996). So the difference between quarrying and reprocessing may only be in where the environmental impacts occur.

In Finland, reprocessing might further complicate nuclear fuel management because in addition to being responsible for high level radioactive waste, long-lived medium level radioactive waste could also arise. For example, in Great Britain it is planned to dispose of this waste deep in the bedrock in the same way as high level radioactive waste.

Whilst dependency on foreign waste management facilities also carries its own inherent risks, it would make little economic sense to build an expensive reprocessing plant just for the waste generated by Finnish nuclear power plants. Building reprocessing facilities could be an option worth considering if a decision is taken to base future energy management in Finland and elsewhere on nuclear power. In which case, the reprocessing and recycling of uranium and plutonium would considerably increase the energy potential of the world's uranium reserves.

Direct final disposal

At the same time as Teollisuuden Voima (TVO) abandoned reprocessing plans in the early 1980s, it started to make preparations for the final disposal of spent nuclear fuel direct into the Finnish bedrock. The final disposal solution was based on the KBS solution developed in Sweden. The existing solution is the so-called KBS-3 type, based on packing the spent nuclear fuel in tight, long-lasting copper containers and burying the containers deep into the bedrock. This solution requires no supervision or monitoring by future generations.

Plans for direct final disposal are also underway in many other countries in Europe besides Finland, as well as in the United States and Canada. The Swedish Nuclear Fuel and Waste Management Company (SKB) has continued work on final disposal preparations based on the KBS-3 solution. Many countries already have highly advanced direct final disposal technology. Alongside technological R&D, studies have also been made to assess the safety aspects and environmental impacts of this solution.

In principle, there are different ways in which direct geological final disposal into the bedrock can be carried out.

Besides the KBS-3 type solution planned by Posiva,
- the WP-Cave solution based on hydraulic cage or
- a deep hole solution

could also be suitable to Finnish conditions.

Additionally, studies have been made of several other options that differ from the KBS-3 solution only in terms of the way the containers are placed or positioned. Such variations include
- horizontal placement
- long hole
- medium-long hole and
- short hole, all of which are shown in chapter 3.2.

Its simplicity, relatively low capital outlay and infrastructure requirement make direct final disposal an ideal way to dispose of nuclear waste in small countries like Finland. The solutions above are based on freeing future generations from the responsibility for nuclear waste and other safety aspects. In the WP-Cave solution, there is a gradual shift to this type of passive safety.

Transmutation

When the nature of nuclear reactors became known at the time, it was noted that the mediaeval alchemists' dream of changing one material to another was at least, in principle, possible. Controlled nuclear reactors can change elementary isotopes into others. At the same time elements can be changed into other materials. This process is known as transmutation.

In nuclear reactors, uranium is continuously being transmuted into plutonium and some of the energy in the nuclear reactor is derived from plutonium fission. To avoid the expected shortage of uranium, much work was done, especially in the 1970s, to develop equipment that could produce new nuclear fuel artificially. One of these development ideas was based on strong neutron flux brought about by particle acceleration, which would, for example, transmute thorium into fissile uranium.

Interest in transmutation has revived in recent years, although now the principle is being considered in respect of nuclear waste management. In neutron flux, the life-time of radioactive nuclides can also become shorter or directly stable. In principle, this would eliminate radioactive nuclides or at least shorten the life of the radioactive elements they contain. In conventional light water reactors (LWR) of the type used in Finland, there is insufficient neutron flux, as is the case in fast breeder reactors or a combination of powerful particle accelerators and so-called spallation reactors.

In one principal solution (Rubbia et al. 1997), high energy charged particles (protons), produced by a particle accelerator, would be shot into the target material (lead), where so-called spallation, or a kind of fission reaction, would generate huge numbers of neutrons. Transformable nuclides would be loaded into the reactor core, which would form part of a lead-cooled subcritical fast breeder using metallic thorium as fuel.

In practice, using transmutation to destroy waste would require partitioning of different radionuclides and radionuclide groups. Conventional reprocessing technology separates uranium and plutonium from other elements. The use of transmutation to destroy long-lived radionuclides would additionally require at least the partitioning of so-called transuranium from fission products. Nevertheless, there are also other very long-lived radionuclides that must also be able to be separated from other elements if long-term isolation is really to be avoided. Existing reprocessing technology is incapable of this.

At the time of writing, it is difficult to assess the potential possibilities of transmutation to destroy nuclear waste.

Although global research on the subject is currently being done, there are greatly differing views as to technological potential (Anttila et al. 1999, IVA 1998, NAS 1995).

However, researchers are unanimous in their view that nuclide partitioning and transmutation technology will not eliminate all nuclear waste (Anttila et al. 1999, NAS 1995). Even if it were at all possible, it would in any case be extremely expensive to destroy all radionuclides. It should also be remembered that transmutation facilities, like existing reactors, produce new radioactive materials (activation products) and medium and low level nuclear waste inevitably accumulates from leakage during the partitioning process. Whilst it is perhaps possible to shorten the lifetimes of nuclides contained in nuclear waste, it will never be possible to fully eliminate radioactive material.

There might be potential for widespread use of nuclide partitioning and transmutation technology if there is a new upswing in nuclear power development and construction programmes in leading industrial countries. The technology could then improve the possibilities to use global nuclear fuel reserves and facilitate nuclear waste handling. In any case huge investment would be required to build such facilities. Compared to existing nuclear power plants and the proposed final disposal methods, the environmental and safety factors surrounding transmutation plants is nevertheless questionable.

Japan and France in particular are investing heavily in partitioning and transmutation technology. To date, transmutation is a future possibility that can be compared with fusion, the practical applications of which, if successful, would be implemented over several decades ahead. So far, there are insufficient grounds to make any reliable assessment of the potential of transmutation technology in spent nuclear fuel management (Anttila et al. 1999).

Other solutions presented

Other proposals for the disposal of spent nuclear fuel include the seabed, polar glaciers and launching the waste into outer space.

Nevertheless, none of these options has been taken very seriously in Finland. Not only is final disposal in glaciers is technically difficult, but constant glacial movement makes it hard to predict the outcome of this solution (Figure 2-6). This solution would also involve the waste being removed from Finland, something which current Finnish legislation prohibits.

Discussions about disposing of the waste in the seabed (Figure 2-7) or in the bedrock below it have been at a virtual standstill during the 1990s. Even though some researchers consider this option to be fairly safe, international agreements preclude it.

Sending radioactive waste into outer space using existing technology is not a realistic option owing to the enormous risks and costs involved.

To date, there is no technology available to completely eliminate nuclear waste definitively and safely.

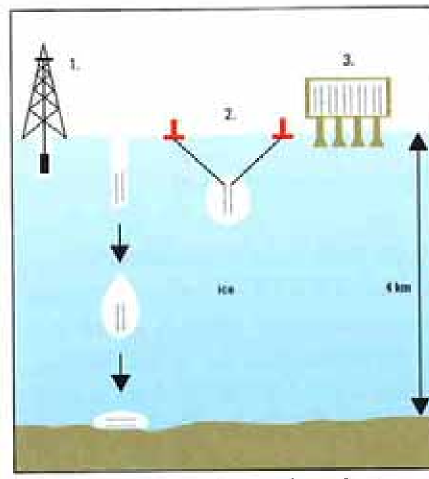


Figure 2-6. Final disposal in glaciers
1. Drilling platform and smelting
2. Anchoring
3. Facilities situated on the ice

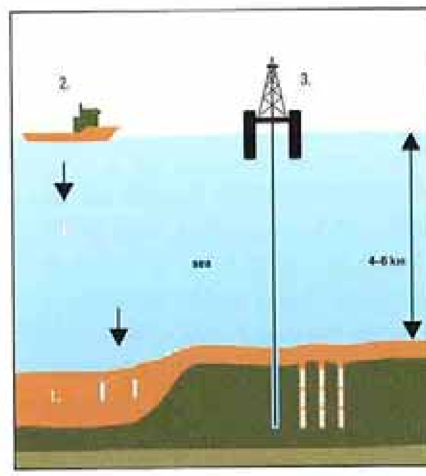


Figure 2-7. Final disposal in the seabed
1. Sediment layers
2. Free fall into the sea
3. Disposal in a bored hole

Reprocessing

Uranium and plutonium within the spent fuel can be reused if they can be separated from other actinides and fission products. There are reprocessing plants in France, Great Britain and Russia. These plants are huge, about the size of an oil refinery.

Existing reprocessing plants use a process based on splitting the rods mechanically and dissolving them in nitric acid and then the reaction of the solution created with tributyl phosphate dissolved in kerosene or dodecane. The fuel cladding is separated from other material in the nitric acid solution and, at the next stage, plutonium and uranium are separated together from the actinides and other fission products remaining in the solution.

The uranium and plutonium separated from the solution are further separated from each other in different solutions to be purified and transformed first into uranium and plutonium nitrates and then into uranium and plutonium dioxides. The remaining solution comprising actinides and fission products forms the high level liquid waste from the reprocessing plant. Evaporation can decrease the volume of this waste. Reprocessing also gives rise to low and medium level waste, some of which is long-lived.

Owing to storage safety risks, vitrification is used to turn highly radioactive concentrated liquid waste into radioactive glass. This glass must be finally disposed of in a similar way to spent fuel. In addition to U-235 and U-238, reprocessed uranium contains small amounts of other uranium isotopes that are gamma radiating or neutron absorbing.

Reprocessed plutonium also contains various plutonium isotopes. Gamma radiating isotopes result in the need for radiation protection in the manufacture of fresh fuel. The neutron absorbing isotopes weaken neutron economy when reprocessed fuel is used in the reactor.

A key factor in LWRs is the presence of enough neutrons to maintain a chain reaction, i.e. neutron economy. When uranium has been reprocessed several times, the activity of the isotopes mentioned above increases. This is why uranium is reprocessed just once.

Plutonium also "deteriorates" during reprocessing. This likewise makes it possible to reprocess it only a few times.

If fast breeders are brought into more widespread use in future, they can use reprocessed uranium and plutonium many times over.

2.3 Current alternatives available

Under the Nuclear Energy Act, nuclear waste generated in Finland *"shall be handled, stored and disposed of in Finland in a manner intended to be definitive"*. Fortum and TVO's nuclear waste management also operates on this principle. In principle, Finnish legislation does not ban reprocessing, which should take place entirely in Finland. The waste generated during reprocessing also needs a final resting place.

The Nuclear Energy Decree specifies Finnish ground or bedrock as the place of final disposal. Since it is likely that Finland will be entirely covered by a continental ice sheet in several tens of thousands of years, definitive disposal, safely isolated from life and organic nature, can only mean final disposal deep in the bedrock. This solution too must be one that requires no constant supervision or maintenance, since this would be impossible to ensure under glacial conditions.

As things stand, only geological final disposal solutions based on passive safety are to be considered in respect of any decision concerning the final disposal of spent fuel or reprocessing waste in compliance with the Nuclear Energy Act. Postponing the decision would mean the continued interim storage of spent fuel for an indefinite period (the so-called zero alternatives).

In its statement on Posiva's EIA Programme, the Ministry of Trade and Industry presents the following view for consideration, *"that the EIA report also examines generally such spent fuel management options in principle, the feasibility of which is uncertain or that do not comply with the criteria of existing legislation"*.

Ignoring the requirements of the law does not in reality increase the options available, because despite R&D into nuclide partitioning and transmutation, there are no realistic options to geological final disposal, in other words disposing of the waste deep in the Finnish bedrock.

In practice, too, an option based on nuclide separation and transmutation would return to the zero alternative because it is impossible to assess the actual feasibility of such a solution using existing knowledge. Nevertheless, the European Union, Japan and United States are investing significantly in R&D in the field. Should such research yield results, use of nuclide partitioning and transmutation might affect the volume and composition of the waste to be finally disposed of. Experts, however, do not consider that nuclide partitioning and transmutation eliminate the need for geological final disposal (Anttila et al. 1999).

Since there are no means available to dispose of nuclear waste, the only options open are geological final disposal or to postpone the decision and continue putting the nuclear waste into interim storage facilities. The need for final disposal either applies to spent nuclear fuel as it is or to the high, medium and low radioactive waste accumulating from reprocessing.

The technical options in geological final disposal are described in chapter 3. The options are then compared and this EIA report primarily specifies the options to be examined.

Only direct final disposal is described since the same technical principles can also be used for the final disposal of waste generated during reprocessing. The main difference would be in the container and packaging used.

3 OPTIONS IN GEOLOGICAL FINAL DISPOSAL

3.1 Base alternative

Posiva's base alternative is described in detail in Posiva's report "Technology Studies 1993-1996" (Posiva Oy 1996a). Based on the Swedish KBS-3 plan, this solution was developed during the 1970s and 1980s and is the result of more than 20 years' R&D. Work was conducted in cooperation with different research institutes and scientific bodies and in interaction with foreign nuclear waste management organisations.

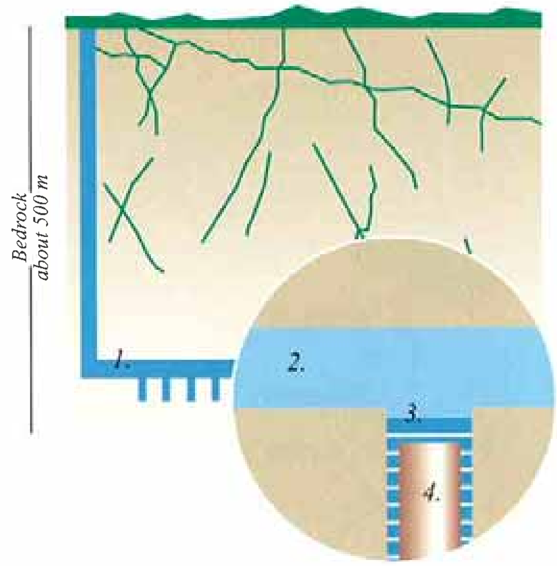


Figure 3-1. Final disposal in line with the multibarrier principle. Spent nuclear waste is isolated deep in the bedrock. Various barriers prevent release.
1. Final disposal tunnel
2. Backfill material of tunnel
3. Bentonite
4. Metal canister

Because the final disposal facility will not be operative until after about 20 years, it is obvious that further technological progress will be made before then. Work is currently under way on further plans for the final disposal facility. This report examines any impacts of changes in as much as these can be envisaged at the time of writing. Certain technological options in respect of the basic plan are dealt with in the technology studies report (Posiva 1996a).

Implementation of the base alternative
- *radioactive substances are packed into watertight, long-lasting containers and*
- *the containers are placed at a depth of 400–700 metres in the bedrock,* where they remain isolated from human life and are stored encapsulated without supervision for as long as their contents can be harmful to organic nature.

This option is based on the multibarrier principle (Figure 3-1), which means that the radioactive substances are isolated using a series of independent protective barriers. In this way, if one barrier fails it does not affect overall barrier function. Long-lasting, watertight containers are intended to prevent radioactive substances from entering the groundwater. The stable bedrock in turn protects the container. If, for any unforeseeable reason, it lost its isolating capacity, the rock would retard and hamper the release of dangerous substances into nature. Bentonite clay between the container and the rock acts as a further guard to reduce water movement and, in the event of leakage, would keep the radioactive substances from passing forward.

The final disposal facility consists of a facility area to be built above ground and the final disposal repository proper deep in the bedrock (Figure 3-2). The encapsulation plant, auxiliary premises - shaft buildings, office, laboratory facilities, storage, workshop and HEPAC premises - are to be located above ground. An area will also be earmarked to store blasted rock and crushed stone.

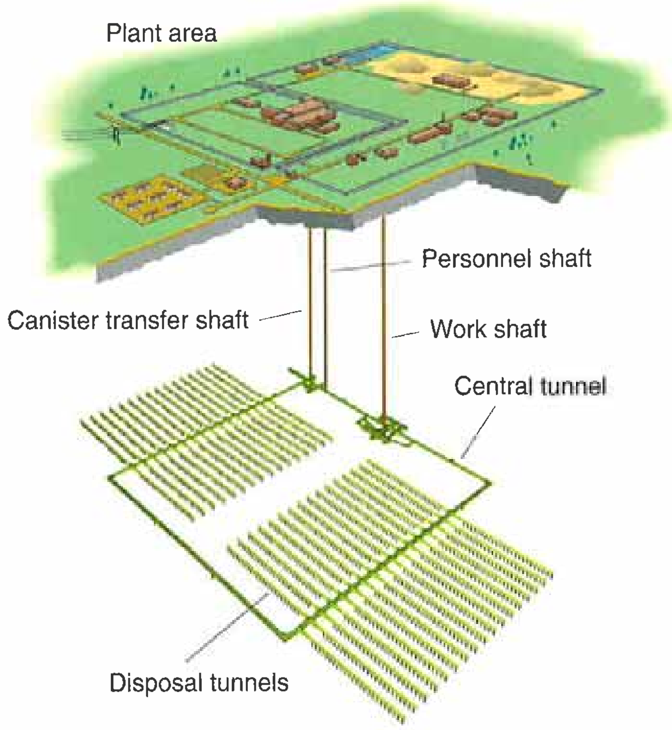
Three vertical shafts, work, personnel and canister transfer shafts, will lead down from the surface to the final disposal facility. The canister transfer shaft will be linked to the encapsulation plant above ground and the personnel shaft to the office building within the encapsulation plant complex. An access tunnel could also be used instead of a shaft. The plant complex (buildings, roads, storage facilities and land area) totals around 15 ha.

The actual final disposal facilities in the base alternative comprise disposal tunnels situated at roughly 25-m intervals, 100–300 metres in length and linked by a central tunnel. The position and lengths of the actual disposal tunnels will depend on local bedrock conditions. In the base alternative, the total length of the disposal tunnels is about 13 km.

Spent nuclear fuel is stored in interim storage facilities for at least 20 years before final disposal. The fuel is then taken to the final disposal facility by road, rail or sea. At the encapsulation plant, fuel waste will be packed into tight metal containers or canisters, which will then be lowered by lift to the repository at a depth of 400–700 metres. Each canister contains 12 fuel assemblies. The final disposal facility has a capacity of 250 tU a year and can handle 100–250 tU a year.

If there is no road to the chosen final disposal plant site, a strip of land some

Figure 3-2. The final disposal facilities consist of an encapsulation plant and auxiliary premises above ground and an underground repository connected to the earth's surface by shafts or tunnels.



20 metres wide will be earmarked for this purpose. In areas where there are existing nuclear power plants, it is unlikely a road will need to be built. Posiva reports (LT-Konsultit 1998) deal with the need to build a road at individual candidate sites in more detail.

At Olkiluoto in Eurajoki and Hästholmen in Loviisa, the sites of existing nuclear power plants, the encapsulation plant could also be built near the spent fuel interim storage facilities. This would mean the canisters would be filled and transported by transfer vehicle to the shaft building and then by lift to an underground repository.

The base alternative allows bedrock quality and structure factors to be flexibly taken into account: shaft location and tunnel design can be decided in accordance with the specific requirements of the bedrock at the final disposal site. If necessary, the tunnels could be located at several different levels.

This concept is based on being able to build final disposal tunnels also once the facility is in use. The plans also allow for the facility to be enlarged in the event of an increase in the amount of spent fuel to be disposed of because the operational lifetime of existing plants has been extended or new nuclear plant is built. New disposal tunnels could be built either at the same or at a different depth to existing ones, depending on bedrock conditions. The need for a new vertical shaft for ventilation and emergency exit will depend on the implementation of any enlargement and on local bedrock conditions. If the enlargement is at a different depth to existing facilities, it will be linked by an access tunnel or direct access via vertical shafts.

Even though the concept planned is intended to finally dispose of the spent fuel, the canisters could be retrieved if required. The base alternative would enable retrieval to be carried out at any stage in the project. The methods used to retrieve the canisters are described in Posiva's working report (Saanio & Raiko 1999).

When a canister is full, but not yet finally disposed of, it can be dismantled at the encapsulation plant. If a canister has already been placed in a disposal hole and the disposal tunnel has been sealed, the canister can be removed by breaking the tunnel seal, digging the backfill material out and treating the bentonite in the disposal hole so that it loses its strength. If the final disposal facility has already been closed, the plugs of the shaft and central tunnel and the backfill material must be removed before retrieving the canister.

The Swedish Nuclear Fuel and Waste Management Company (SKB) intends to demonstrate the technology involved at its Äspö hard rock laboratory in the foreseeable future (SKB 1998).

3.2 Variations on the base alternative

The position of the waste containers for final disposal does not significantly affect the safety or environmental impacts of the concept. The various positions are variations on the base alternative (Figure 3-3), presented and assessed in a study by Autio et al. (1996). SKB's PASS (Project Alternative Systems Study) project, in which Teollisuuden Voima (TVO) also took part, widely examined the technical application of the solutions in question. The findings of the PASS project were dealt with in reports (Birgersson et al. 1992 and SKB 1992).

A brief description of the variations examined is given below:

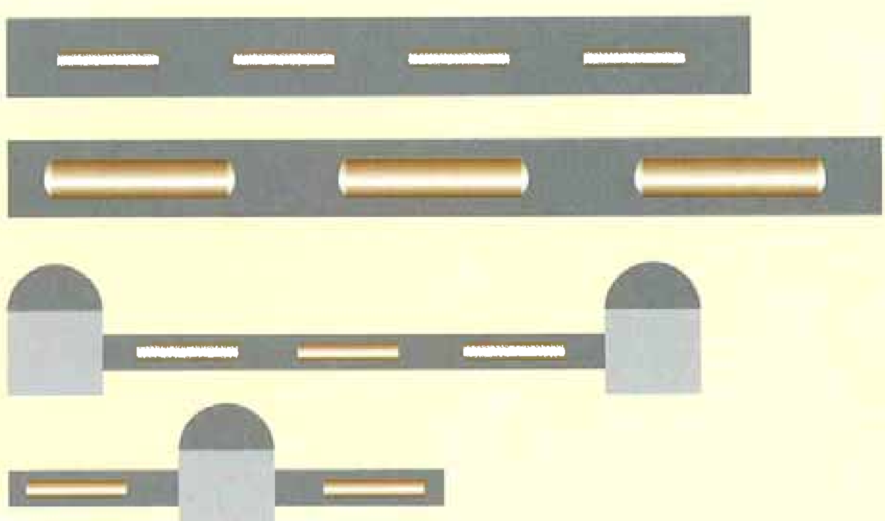
In the *horizontal solution* the canisters are placed horizontally in horizontal tunnels (long and medium hole solution) or in horizontal holes (short hole solution). In all horizontal solutions, links to the surface follow the same principles as in the base alternative.

In the *long hole solution* the spent fuel canisters would be placed one after the other in long round tunnels of about 2.4 metres in diameter. The tunnels are excavated in full profile. The spent fuel would be encapsulated in large canisters of 1.6 m Ø, each containing around 24 fuel assemblies. The canisters would be surrounded by compact bentonite clay. Positioning of the canisters and clay would be by remote control. Some 4 km of tunnels would be required for the basic amount of spent fuel envisaged.

In principle, this option is technically viable and cost competitive, compared with the base alternative. Long-term safety is also adequate provided that the canisters can be placed in the way planned. The largest problems are related to technical feasibility, because of the uncertainties involved with the handling and final disposal of heavy canisters in tunnels. Considerable R&D is certainly still required into dealing with fracture zones, water leaks, loose rocks, wrong canister positioning and solutions to the combined impact of these. If a canister is incorrectly positioned, it would be a risky, time consuming and technically difficult operation to remove swollen bentonite and a bulky, heavy (50 t) spent fuel canister from several hundred metres below ground. Removal of one canister would require the removal of all those in front of it.

The *medium hole solution* differs from the long hole solution in the sense that the tunnels are shorter (appr. 200 m). Canister size is the same as in the base alternative. Raise boring technology would be used to excavate horizontal tunnels at intervals of appr. 25 m. For the amount of fuel in the base alternative, 73 disposal tunnels would be required and a total of 3-km of side tunnels. The canisters would then be surrounded and placed in the same way as in the long hole solution. The medium hole solution requires highly automated positioning equipment. This solution is also more demanding in terms of bedrock properties than the base alternative. For example, rock fracture, water leaks and breakdown could result in malfunction. At its cheapest, this solution has been proven to be less expensive than the base alternative, although the uncertainties involved could make it far more expensive.

The *short hole solution* is similar to the base alternative as regards central tunnels and disposal tunnels. Nuclear fuel canisters are placed in short (appr. 10 m) horizontal holes drilled into the walls of the disposal tunnels. These holes are at an angle of 45° to the disposal tunnel. Positioning of the canister and bentonite is technically much more complex than in the base alternative, and there are also uncertainties that erode the reliability of this method. The most significant of these are the bentonite lining and the unfavourable movement of the canister in the hole either owing to groundwater pressure or to the fact that the bentonite has not been evenly saturated with water. On the other hand, the geometry of the rock stress surrounding the hole makes the durability of the rock surrounding the horizontal hole higher than in the base alternative. The solution is feasible if it turns out that the rock stress/rock strength ratio is higher than expected.



Horizontal solution

Long hole solution. *The canister is larger than in the base alternative.*

Medium hole solution. *The canisters would be located in holes drilled between two tunnels.*

The short hole solution *is virtually the same as the base alternative except that the disposal hole is horizontal.*

Figure 3-3. Variations on the base alternative.

The short and medium hole solutions are principally options to the base alternative and have the same environmental impacts. The amount of rock excavated in the short hole solution is slightly higher and in the medium hole solution slightly lower than in the base alternative.

In addition to the report by Autio et al. (1996), these variations on the base alternative have been examined in publications Öhberg 1992, Autio 1990, Autio 1992 and in summary reports by Posiva Oy 1996a, TVO 1992a and Autio et al. 1996.

3.3 Other ways of carrying out geological final disposal

In addition to the base alternative, feasibility studies were made of two other options for geological final disposal during R&D. The WP-Cave solution based on hydraulic cages and the deep hole solution. Teollisuuden Voima Oy's 1992 summary report (TVO 1992a) deals with these possibilities.

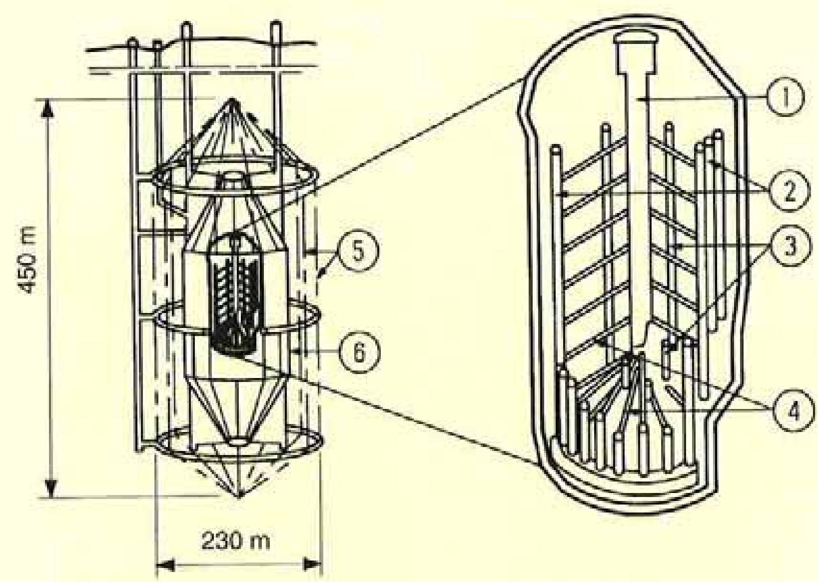
The hydraulic cage or WP-Cave solution (TVO 1992a, Öhberg 1992) works on the basic idea of isolating the repository silo, located at a depth of a few hundred metres, from groundwater circulation and from the surrounding bedrock by a hydraulic cage and by enclosing the silo in a sand-betonite casing of several metres thickness (Figure 3-4). The hydraulic cage comprises vertical holes and tunnels excavated around the silo at three different levels. The canister would be made of cast steel and contain nine fuel assemblies. A silo could take appr. 900 tU, which means that three such silos would be required for the nuclear fuel waste accumulating over a period of 40 years.

The scheme would involve excavating a total of some 1,700,000 m^3 of rock, almost five times the amount in the base alternative.

Since the canisters would be cooled by air for 100 years before the silo is finally closed, safety would require active management. Hydraulic cage function could not be easily ensured and, once the silo is closed, it would be extremely difficult to remove the steel canisters placed horizontally one after the other. There are still many uncertainties relating to final disposal in this way.

In the deep hole solution, disposal would be at a depth of 2–4 kilometres in holes larger than the appr. Ø 300 mm canisters (Figure 3-5). The deep hole solution considers that the bedrock itself is sufficient to prevent the escape of radioactive materials since groundwater flow is assumed to be minimal at these depths. The solution would use titanium or copper canisters each containing 4 fuel assemblies. Once the canisters are in place, the holes are capped with concrete, asphalt and bentonite. For the amount of fuel in the base alternative (appr. 2600 tU), 11–12 deep holes would be required.

To date, too little is known about the bedrock properties (structure, rock stress, rock strength around the hole, etc.). This means that we cannot be absolutely certain that the bedrock would prevent radionuclides from escaping. Considerable more R&D is required into the details and technology used to position the canisters. If for any reason, the canisters had to be retrieved after positioning, it would be extremely difficult to remove them from the narrow deep hole. It is impossible to be certain of the conditions prevailing at such depths, which means that there is a greater risk of nuclides being released



1. Central shaft
2. Outer cooling shaft
3. Inner cooling shaft
4. Canister duct
5. Hydraulic cage
6. Sand-betonite casing

Figure 3-4. The hydraulic cage or WP-Cave solution.

if the canisters are removed than in the base alternative and its variants. It would also be much more difficult to remove the material surrounding the canisters. The costs of deep hole solutions are considerably higher than those of the base alternative and horizontal disposal solutions.

3.4 Assessing and limiting the options

Different ethical, ecological and techno-economic grounds can be used to assess the options for the subsequent management of spent fuel. The general ethical and ecological requirements relating to nuclear waste management are covered by the Joint Convention of the Safety of Spent Nuclear Fuel Management and on the Safety of Radioactive Waste Management, to which also Finland is a signatory state. The criteria aimed at protecting nature and human life also constitute a core part of the government's proposed general safety regulations proposed for the final disposal of spent nuclear waste (Valtioneuvosto 1999).

The ethical and ecological criteria contained in the aforementioned recommendations and guidelines are:

– The protection of human health and the environment

Radioactive waste management is to be organised so as to ensure the protection of human health and the environment from the dangers of radioactive substances.

– The protection of future generations

Radioactive waste management is to be organised so that the predicted impacts on the health of future generations are no greater than those currently considered acceptable.

– Avoiding the burden of management on future generations

Radioactive waste management is to be so organised that it does not cause an unreasonable burden on future generations.

– The safety of nuclear waste facilities

The safety of facilities used in radioactive waste management is to be ensured throughout their entire life in the proper manner.

One important aspect with regard to planning and assessment is to prevent the misuse of nuclear substances. Although the international requirements in this respect are still unclear, the solutions can be examined from the aims of the Nuclear Non-Proliferation Treaty.

The *degree of technical development and the estimated overall costs of the solution* also naturally affected assessment of the options. Assessment of technical feasibility should also take into account the site criteria linked to the solution: Are the sites characterised to date still in the running or are new investigations and studies required? How much material transportation does the solution involve? Low cost based on reprocessing and nuclide separation is also linked to the opportunities to reuse the materials separated.

The choice between final disposal and continued interim storage (zero option) is examined in the table comparing the options at the end of chapter 10. In addition to the above criteria, the comparison assesses application of the solutions within the framework of *existing legislation*. Assessment of the solutions in respect of general safety criteria should take into account the fact that current safety criteria have been drawn up expressly with the KBS-3 type solution in mind.

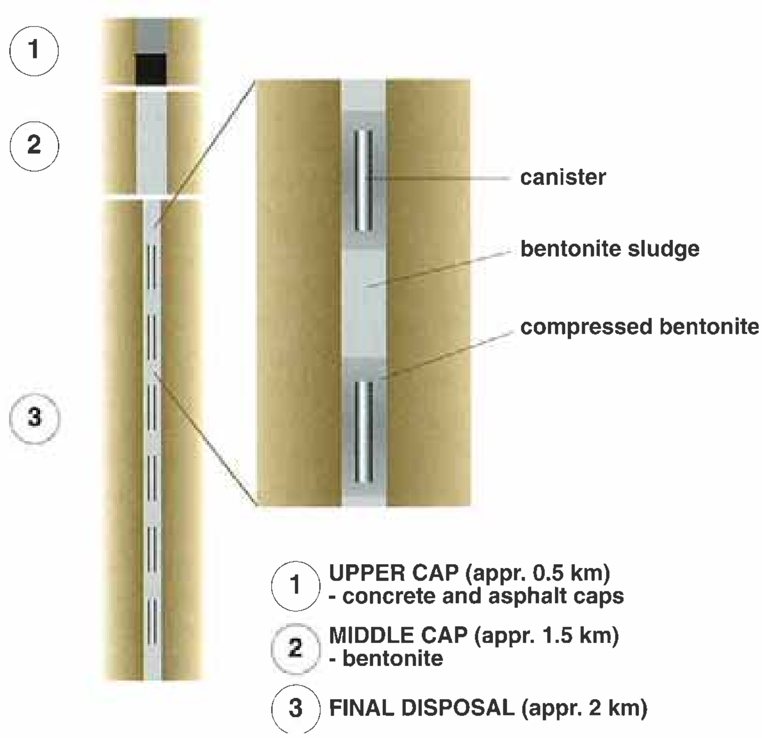


Figure 3-5. Deep hole solution.

The base alternative is technically advanced and its suitability for Finnish conditions is the best studied. Planning and research was based on many of the ecological and ethical principles. Careful investigations have shown safety and technical feasibility of the concept, neither does implementation involve major cost risks. The base alternative also complies with the reversibility and retrieval requirement even though from the very outset final disposal has not aimed at reversibility and retrieval.

The base alternative also complies with existing legislation and has been shown to meet the safety criteria.

Whilst variants of the base alternative are not as technically developed as the KBS-3 solution, their safety and environmental impacts can be assessed as being similar to the base alternative. Should the variants prove to be more interesting than the base alternative, the relevant technology could relatively quickly be brought up to the same level as that of the base alternative.

Final disposal based on the *hydraulic cage* method also strives towards the same ethical and ecological aims as the base alternative. The advantages of the method depend essentially how hydraulic isolation functions. Provided that it is technically feasible, the solution is safe as long as groundwater flow does not come into contact with the waste. Nevertheless, in the long-term it is somewhat impossible to ensure that "drainage" works. In the end, this makes the long-term safety of the method depend on the same factors as that of the base alternative.

In the short-term, the canister and the bentonite clay mix surrounding it in the base alternative provide at least as good protection as ditches. The environmental impacts of the WP-Cave method are likely to be similar to those of the base alternative. The solution is reversible as long as the packaging remains intact. Nevertheless, not only would the hydraulic cage be considerably more expensive than the base alternative, it would also require much greater investment in R&D.

The idea behind the *deep hole solution* is to protect organic nature and human life from the risks of nuclear waste without the need for active supervision. The views in favour of this solution are based on the assumption that at a depth of several kilometres in the rock, the groundwater would not be in contact with organic life and nor could any soluble radioactive substances in the waste thus harm nature or human life.

Very little is yet known about bedrock conditions many kilometres down and any reliable study of the conditions would require extensive new studies and research methods. At the time of writing, there is no data available to assess either the safety or the technical feasibility of the scheme. It is questionable whether the scheme is reversible and whether any handling errors could be rectified because it would be difficult to ensure that the packing remained intact at such depths. In respect of the Nuclear Non-Proliferation Treaty, the difficulties could also be an advantage, even though practical supervision of the solution is akin to that of the base alternative.

In the *reprocessing solution,* final disposal would involve solid high and medium radioactive waste instead of spent fuel assemblies. Because uranium and plutonium would be largely separated from the waste for reuse, there would be fewer long-lived radionuclides in the waste than in spent fuel. The main risk during the first few hundreds of years would be from fission products, which would need to be finally disposed of after reprocessing. In other words, reprocessing does not essentially reduce the criteria in respect of technical safety in final disposal.

The choice between reprocessing and direct final disposal also depends on aspects other than those directly linked to the management of spent fuel. Reprocessing would change the time and place of the environmental impacts caused by recycling nuclear fuel. The technology used in reprocessing plants in the United Kingdom and France currently gives rise to far greater operational emissions, at least today, than the storage of spent fuel and final disposal in keeping with the base alternative together. On the other hand, reuse of the uranium and plutonium separated during reprocessing would reduce the need to mine uranium, which would in turn cut emissions from mining operations. It is difficult to assess the difference in long-term risks between direct final disposal and reprocessing.

As far as controlling nuclear weapons is concerned, reprocessing plants and the plutonium separated in such plants require more attention than an encapsulation plant and spent nuclear fuel as such. Use of existing plutonium stocks has already proved to be problematical. In a reprocessing plant only a very small amount of material is suitable for nuclear weapons and presumably the need for supervision would be smaller than for spent fuel which is finally disposed of.

The most significant ethical advantage of the reprocessing option is that it saves energy resources. On the one hand it would also be very expensive if Finland had to buy reprocessing services from abroad. On the other hand, given the very small amounts involved, it would be cost prohibitive if a reprocessing plant were to be built in Finland. As a whole, the reprocessing option would be many times more expensive than the base alternative. Nevertheless, if the conditions affecting viability were to radically change, the final disposal method in line with the base alternative or its variants could fairly readily be transformed into a reprocessing plant for highly radioactive nuclear waste suitable for final disposal.

Although destroying radionuclides by *transmutation* is theoretically possible, much more research is required to develop the method on an industrial scale, neither would transmutation eliminate all nuclear waste. Transmutation would require more advanced nuclide partitioning than conventional reprocessing and reactors intended for transmutation reactions. Despite all this, we would still need some kind of final disposal facility, which perhaps could be implemented using less criteria than the base alternative. As we see it, the R&D required and the actual plants for nuclide partitioning and transmutation would call for such huge investments that they could hardly be sensibly justified unless the plant produced energy at the same time. This is why transmutation technology would require long-term commitment to nuclear power. Because based on present knowledge, transmutation is not a realistic option choosing it would, in practice, only mean postponing the decision, in other words the zero option.

To *sum up* these comparisons compared with the base alternative, the hydraulic cage and deep hole methods do not provide major advantages as far as safety and environmental protection are concerned. Indeed, it is likely they would be much more expensive and require further reseacrch and R&D. Whilst the environmental and social impacts do not differ significantly from the base alternative, the deep hole scheme would nevertheless require more advanced geological investigation methods and possibly a new site selection method with bedrock investigations.

Reprocessing would neither essentially alter the need for final disposal nor the risks involved. It would, however, result in considerably greater costs. To date, it is impossible to evaluate the feasibility of nuclide separation and transmutation technology. This means that no decisions could currently be made to adopt these technologies. The management of spent fuel based on transmutation would, at this stage, only mean postponing the decision, in other words the zero alternative. The current opinion is that transmutation would not entirely eliminate the need for geological final disposal.

The only viable options for geological final disposal currently available in Finland are the base alternative and its variants. Preliminary assessment shows that there is no significant difference in environmental impacts between the base alternative and its variants. Given this, environment impact assessment in this report concentrates on only the base alternative and the zero alternative.

Table 3-1: The final disposal options examined from the aspects of various ethical and ecological principles, technical feasibility and legislation.

	Base alternative and variations	**Hydraulic cage**
A. Ethical and ecological principles		
1. Protection of man and nature	Wastes are isolated from nature so that active maintenance is unnecessary.	Wastes are insulated against nature so that active maintenance is unnecessary.
2. Protection of future generations	The multiple barrier principle supports the isolation of wastes as long as they may present a danger.	Wastes remain separated from nature as long as hydraulic insulation is operationally effective.
3. Avoidance of burden on future generations	Does not require action on the part of future generations but does not prevent it either.	Does not require action as long as hydraulic insulation is operationally effective. Retrievability is dependent on packaging.
4. Operational safety of facilities	Can be implemented by means of strict release criteria.	Can be implemented by means of strict release criteria.
5. Prevention of misuse of nuclear materials	The illicit seizure of nuclear wastes would be arduous, costly and easily discernible.	The illicit seizure of nuclear wastes would be arduous, costly and easily discernible.
B. Technical implementation		
1. Technical maturity level	Based on technology available in Finland.	The technology required is already in existence.
2. Readiness for selection of disposal site	The required investigations have, for the most part, already been carried out.	Research already undertaken can be utilized to its advantage.
3. Costs	Costs have been anticipated.	Much costlier than the base alternative.
4. Need for transportation	Transportation shall be needed to a certain extent regardless of disposal site.	Transportation shall be needed to a certain extent regardless of disposal site.
5. Suitability for other energy system(s)	Appropriate for the nuclear energy system respective to a small nation.	Appropriate for the nuclear energy system respective to a small nation.
C. Applicability from the perspective of present legislation and regulations		
1. Compliance to the Nuclear Energy Act and its regulations	Fulfills the requirements.	Fulfills the requirements in the event that the hydraulic insulation is operationally effective without maintenance.
2. Compliance to the safety regulations of the Finnish Radiation and Nuclear Safety Authority.	Can be shown to comply.	Long-term indication of functionality in respect to hydraulic insulation is problematic.

'Deep hole'	Reprocessing and final disposal	Nuclide separation, transmutation and final disposal
Wastes are isolated from the environment in such a manner that active maintenance is not needed.	Useful materials are separated for further use; the rest are isolated from nature.	Useful materials are separated for further use; the rest are separated from nature.
Reliable assessment is not possible given the available data.	Final disposal can be implemented in the same manner as in the base alternative.	Final disposal as above; period of danger associated with wastes is shortened.
Does not require action, but retrieval of wastes is virtually impossible.	Final disposal can be implemented in the same manner as in the base alternative.	Requires future generations to develop the technology required.
Errors in handling may result in consequences difficult to control.	Reprocessing results in more releases than power stations.	Nuclide separation results in more releases than power stations.
Illicit seizure of nuclear wastes would be very difficult and dangerous.	The possibility of nuclear waste seizure is dependent on supervision.	Would also create potential for the production of nuclear weapons.
May rest in practice on available technology.	Based on technology employed abroad.	The technology needed is non-available.
Requires new sorts of site characterization and the development of investigation methods.	Depends on method of implementation. Siting of reprocessing plant as with power plant.	Depends on method of implementation. Siting of partitioning facility as with power plant.
Costs difficult to assess.	Much costlier than the base alternative.	Costs unknown as the technology is non-available.
Transportation would be needed to a certain extent regardless of disposal site.	Many kinds of transport required.	Many kinds of transport required.
Appropriate for the nuclear energy system respective to a small nation.	Poorly appropriate to a small nuclear energy system.	Mandates long-term commitment to the use of nuclear energy.
Fulfills requirements in the event that safety can be ensured.	Both reprocessing plant and final disposal facility should be built in Finland.	Separation, transmutation and final disposal facility should be built in Finland.
Hardly complies to requirement for complete isolation.	Regulations are lacking in respect to reprocessing.	Regulations are lacking in regard to separation and transmutation.

4 OVERVIEW OF THE BASE ALTERNATIVE

4.1 Accumulation of spent nuclear fuel

At the end of 1998, there were 5,472 spent fuel assemblies (approximately 840 tU) at Olkiluoto and 2,206 (approximately 270 tU) at Loviisa. There is less spent fuel at Loviisa because the reactors are smaller and most of the spent fuel accumulating was returned to Russia.

During their estimated operational lifespan of 40 years, the present power plant units at Olkiluoto and Loviisa are expected to generate around 2,600 tonnes of spent nuclear fuel before being shut down in 2020. If the estimated lifespan is 60 years, around 4,000 tonnes of spent nuclear fuel will have been accumulated by 2040 (Figure 4-1).

Generally speaking, the amount of spent fuel accumulating depends on the power plants'

– total power output,
– operational lifespan,
– capacity factor and
– fuel characteristics.

Detailed technical plans and safety assessments for final disposal are based on final disposal of the spent fuel from existing plant units. Uncertainty relating to operational lifespan and fuel characteristics was taken into account when planning the repository layout. The plans also took into account the possibility that new nuclear power units might be built in Finland and that the spent nuclear fuel from these could also be disposed of in the same facility as spent fuel from existing nuclear plant.

The amount of spent fuel accumulating from any new plant would depend on power output, capacity factor, operational lifespan and the type of uranium fuel of the plant. If a new 1,500 MW plant unit were in operation for 60 years, it would generate around 2,500 tonnes spent fuel.

This assessment examines the following cases:

1. Existing plants operate for 40 years and generate a total of 2,600 tU. This is termed the base case.

2. Existing plants operate for 60 years and generate a total of 4,000 tU.

3. How the environmental impacts change if the amount of spent nuclear fuel continues to grow (i.e. if Finland builds new nuclear plant).

Detailed estimates have been made for the amount of spent fuel generated by existing plant, i.e. cases 1 and 2. In case 3, with spent nuclear fuel from new plants, the report identifies the environmental impacts of final disposal that would change as a result of this additional plant.

4.2 Life cycle of the project

Preparations for the final disposal of spent nuclear fuel aim at commencing final disposal in 2020. Characterisation and detailed planning of the selected site are scheduled for completion by the end of 2010 and work on building the facility will begin after that.

Final disposal in line with the base alternative covers the following phases:
– selection of site and subsequent investigation phase (building underground research facilities and completion of site characterisation)
– construction of final disposal facility (building encapsulation plant and final disposal repository and other construction work)
– final disposal (transportation of spent fuel to encapsulation plant for encapsulation and deposition of canisters in the bedrock)
– sealing the final disposal facility (winding down the operations of the final disposal facility, sealing the repository and post-closure period)

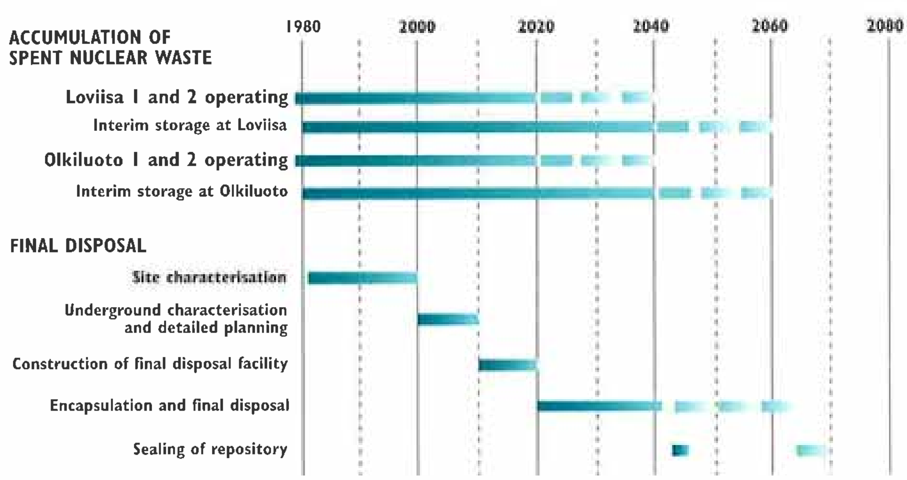


Figure 4-1. Phases and schedule of the final disposal of spent nuclear fuel from the Loviisa 1 and 2 and Olkiluoto 1 and 2 units given an operational lifespan of 40 and 60 years.

The time required for final disposal and sealing depends on the total amount of spent nuclear fuel accumulated. Although the final disposal facility would be able to handle a maximum of 250 tU of spent nuclear fuel a year, in practise this figure is likely to be in the range of 100 tU–250 tU a year.

The diagram 4-1 shows the project phases and the impact of the amount of spent nuclear fuel on the time taken to finally dispose of it given the waste generated by existing power plant units. The capacity planned would also be adequate to deal with spent fuel from any future nuclear power plant unit. The facility's operational time would then prolong from that shown.

In all the cases examined, the final disposal facility is scheduled to begin operation in 2020 and to close down when the existing nuclear power plants are permanently shut down by around 2040 at the earliest and 2100 at the latest.

4.3 Project phases and implementation

4.3.1 Investigation phase

Underground investigations will ensure the suitability of the bedrock properties at the chosen site. Information about the rock conditions will be obtained at the same time to enable a detailed planning of the final disposal for an application for a construction licence. The nature and significance of the major bedrock structures can be studied from underground shafts and tunnels with a view to positioning the final disposal repository. These will be used to search for the most favourable rock masses to build the shafts and final disposal tunnels. Deep underground facility can also be used for in situ tests on the properties of the rock mass and to test the proposed technology for final disposal.

The chemical conditions of the groundwater are in a key position in retaining the good isolation performances of the technical barriers and on the dissolution of the uranium fuel. Chemical conditions also reflect the stability of the bedrock. This is why the findings of groundwater chemical analysis are of major significance in making conclusions about the long-term evolution of the geological conditions. Groundwater samples are best taken from underground facility so as to eliminate as fully as possible, any perturbation from drilling.

A vertical shaft or access tunnel will be built at the final disposal site for underground investigations. The choice between the alternatives depends on the properties of the site. The research facilities to be built are intended to characterise and verify the properties of the site. In this respect, the nature of the investigations and the underground facilities needed for them may differ from those in existing underground laboratories, which focus on studying the final disposal system in general. Underground laboratories in Canada, Switzerland and in Stripa and Äspö in Sweden (Figure 4-2) have developed and tested characterisation methods, developed models on the behaviour of bedrock, conducted experiments with backfill and buffer materials and demonstrated the function of the proposed final disposal technology.

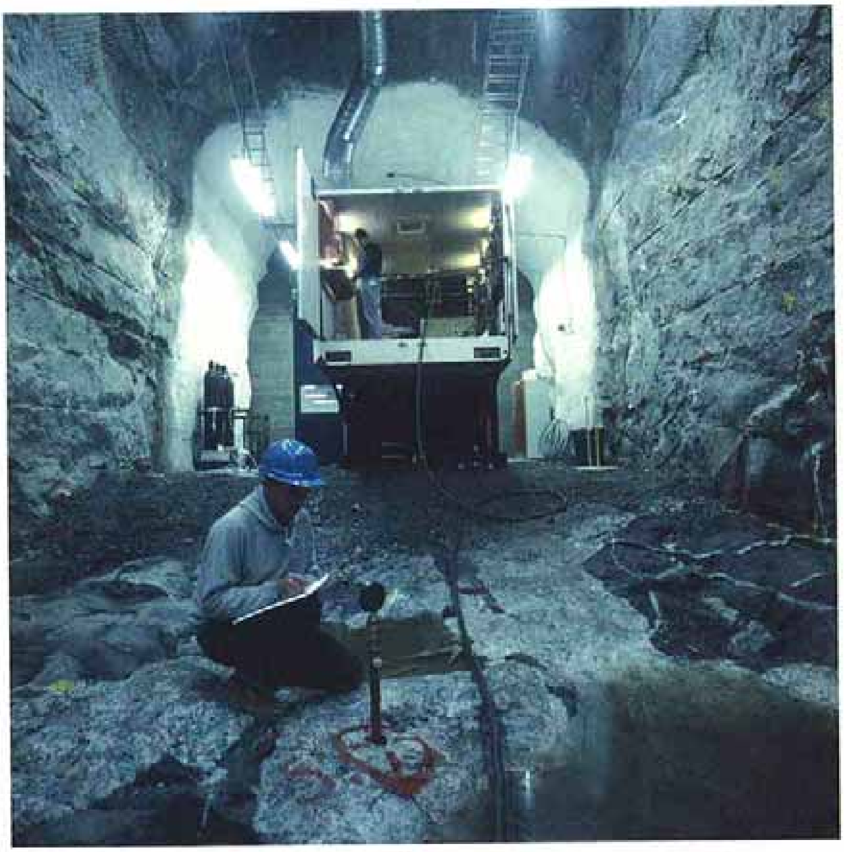


Figure 4-2. Underground studies at Olkiluoto.

Project life cycle

INVESTIGATION PHASE 2001–2010

Construction and maintenance of underground research facilities and characterisation

The project will begin after the decision in principle of the Council of State and selection of the site by planning the underground research facilities and investigations aimed at positioning them. Construction will commence a few years later. Working in three shifts, it is estimated construction will take around four years. Characterisation carried out in connection with construction could prolong building time.

CONSTRUCTION PHASE 2010–2020

Construction of the encapsulation plant and final disposal repository, other construction work

Construction of the final disposal repository will commence in the decade beginning 2010. Before then, a construction licence will be applied for under the Nuclear Energy Act. The central tunnel, personnel and canister shafts and underground auxiliary premises will be excavated during the construction phase. Around one tenth of the disposal tunnels will be excavated during the construction phase, and the rest in stages during the final disposal phase. Another option would be to excavate the entire tunnel system before final disposal. Working in two shifts, excavation work during the construction phase is expected to last about five years. The encapsulation plant and other surface buildings can be built at the same time as the repository.

Any increase in the amount of fuel to be disposed of would not significantly prolong construction time if the facilities are built in stages.

FINAL DISPOSAL PHASE 2020–

Transportation of spent fuel to the encapsulation plant, excavation of disposal tunnels, spent fuel encapsulation, deposition of the canisters in the bedrock and backfilling the disposal tunnels.

Encapsulation and final disposal is scheduled to begin in 2020 after final approval of the final safety assessment report and the granting of a operating licence. If the Loviisa and Olkiluoto power plants are permanently shut down in around 2020, final disposal would take about 20 years. If their operating time is extended, the final disposal phase would be extended accordingly, as would the construction of any new nuclear plant entering commercial service in about 2010. For example, two new nuclear power units could raise the total amount of spent nuclear fuel to 9,000 tonnes. The operational life would then be some 70 years. According to the basic plan, around 60 canisters are ready for final disposal each year. The disposal tunnels would then be sealed as they are filled with canisters.

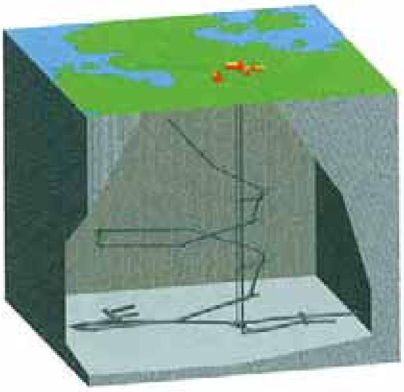
During the final disposal phase, tunnels are excavated every three years. Despite any rise in the amount of fuel owing to prolonging the life of existing plant or the construction of new nuclear plant, the repository can be extended and the number of shafts increased at the same time as final disposal takes place. If the amount of spent fuel finally disposed of each year is increased by raising the capacity of the encapsulation plant, excavation periods can be more frequent or more tunnels can be excavated at a time.

SEALING PHASE

Closing the final disposal facility operations, sealing the final disposal repository and the post-closure period

When all the fuel has been encapsulated and operations are wound up, the encapsulation plant will be decommissioned and all radioactive parts and materials will be taken to the final disposal repository. The central tunnel will be sealed and filled with crushed rock and bentonite. The shafts will also be plugged and filled with crushed rock, bentonite and concrete. This stage will last a couple of years. After sealing, the entire site will be landscaped. All buildings can be demolished if there is no further use for them.

Figure 4-3. The hard rock laboratory at Äspö, Sweden. The spiral access tunnel leads to a depth of 460 m. The vertical shaft has been built as a so called stoper bore.



In the tunnel option, the access tunnel can be straight or spiral depending on the site characteristics. As an example of a tunnel option built down to a depth of 460 m is the figure of the laboratory on the island of Äspö in Sweden (Figure 4-3).

The tunnel is excavated using traditional blasting and drilling methods. Lorries transport the blasted rock to the surface and to the sorting area. The cross-section of the tunnel is about 30 m^2. Tunnel excavation and investigations can be carried out at the same time. Drifts off the access tunnel are excavated for research purposes. Each of these drifts can vary in length from a few metres to several tens of metres. It is best to implement a research tunnel in stages so that the research findings can be evaluated before any decision to progress to the depth at which final disposal would take place. A vertical shaft will be built from the research tunnel to the surface for the purpose of ventilation and emergency exit.

Should the tunnel be built to a depth of around 500 m, it would be 4.5–5 km in length, depending on inclination. It is estimated that tunnel excavation will generate 250,000–300,000 cubic metres of loose rock. The volume of the research tunnel itself is around 150,000 m^3.

In the shaft option, a vertical shaft of Ø 5–8 m (cross section 20–50 m^2) would be excavated to the depth at which final disposal would take place. One or more sublevels would be excavated in the shaft to ascertain the properties of the bedrock before progressing to the depth of final disposal. Once the shaft has reached the planned depth, horizontal research tunnels are excavated. An additional shaft for ventilation and emergency exit purposes would be made by a raise boring from the research facilities.

The vertical shaft is excavated from the surface down using traditional methods. A hoist brings the blasted rock to the surface from where it is moved to a sorting area. Some of the blasted rock will be used to construct the facility area and roads. It is estimated excavation of the shaft and tunnels will generate 55,000 m^3 of loose rock.

The facilities to be built at the surface are similar in both the tunnel and shaft options. The buildings have a surface area of several hundred square metres. The land area required is about five hectares.

Once the excavation work is complete, the investigation phase will last for several years, and the underground facilities will be fitted out with water and sewage supply, ventilation, electricity, telecommunication, fire protection, alarm and lift systems. It is estimated that during construction of the research tunnel or shaft, some 50 vehicles a day will transport people and goods back and forth.

4.3.2 Construction phase

Construction of the final disposal facility

Construction of the final disposal facility will begin by excavating the auxiliary premises essential to underground activities and the connecting tunnel for additional future shafts (Figure 4-4).

Raising technique is used to excavate the personnel and canister transfer shafts. First a small-diameter rising is excavated from below upwards. After this the shaft is opened out to its final diameter from working downward from above. The blasted rock then falls to the final disposal level, from where it is brought to the surface via the work shaft or access tunnel. Shaft diameter is about 5 m. If a tunnel replaces any of the shafts, it too is excavated at this stage.

Excavation of the central tunnel and auxiliary premises continues at the same time as shaft excavation. In the base alternative, the central tunnel has a total length of more than 2 km. Boring and blasting technique is used to excavate the facilities at the final disposal level. The disposal tunnels are about 3.5 m wide and 4.4 m high. The idea is that the disposal tunnels are excavated gradually during the final disposal phase as final disposal progresses. Another option would be to excavate all the disposal tunnels required in advance during the construction phase.

Construction engineering works, and the installation of water and sewage, ventilation and electricity systems are carried out at the same time as the final disposal repository is built. Construction engineering works includes building the walls, floor and sublevels of various premises.

Figure 4-5 illustrates how the shafts, central tunnel and final disposal tunnels could be placed in relation to each other when the final disposal tunnels are located at the same level. Depending on bedrock properties, the tunnels could also be located at several levels. In the base case, total tunnel volume is approximately 360,000 m^3. This would generate a total of 720,000 m^3 of loose broken rock, of which some 290,000 m^3 would be generated during the construction phase. Excavation of the final disposal repository and construction engineering works will be carried out in two shifts.

The blasted rock will be brought to the surface via the work lift or an access tunnel and moved to the sorting area. The rock material will be used as blasted rock or crushed into suitable size as follows (Tolppanen 1998):
- blasted rock, crushed rock and macadam for the foundations of new road links to the facility area
- blasted rock, crushed rock and macadam for the foundations of new roads and buildings in the facility area
- macadam for the floor structures of tunnels in the repository and
- as crushed rock to backfill the final disposal repository

It is estimated that several hundreds of litres of water a minute will seep into the underground openings. The amount depends on the hydraulically conductive fracturing, the volume of underground space open at a time and the extent of grouting. After oil separation and settling, the water will be pumped up to the surface and returned to the ground. Once the water has been cleaned it can also be used in drilling and to wash the tunnels and machinery.

Figure 4-4. An example of buildings planned in conjunction with the work shaft. The office building and research facilities are in the foreground, the work shaft building is on the right and the heating plant and waterworks on the left. There is a sorting area for blasted rock and crushed rock in the background.

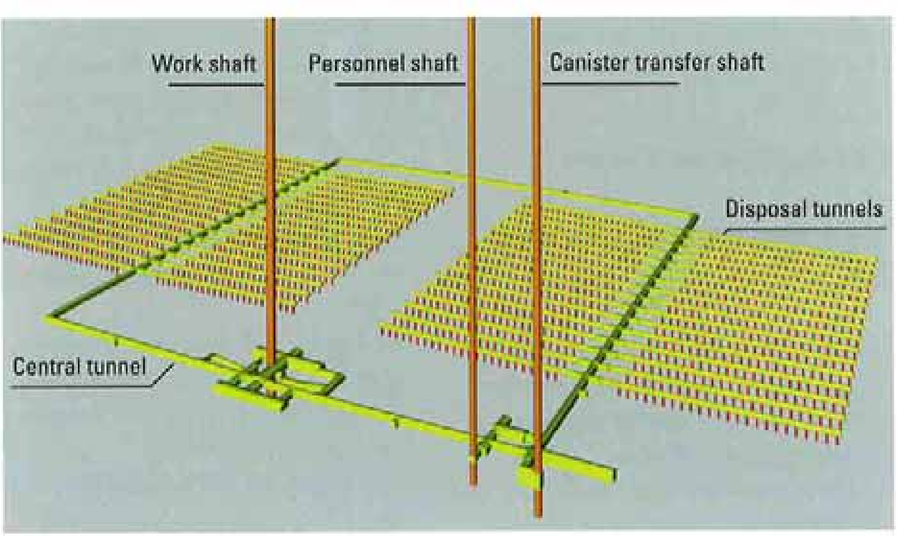


Figure 4-5. An example showing the layout of the shafts, central tunnel and repository tunnels.

Construction of the encapsulation plant and auxiliary premises

It is estimated that the encapsulation plant will take about four years to build. Should the canister transfer shaft be linked to the encapsulation building, it would make sense to excavate this shaft some tens of metres down before starting work on building the encapsulation plant. If the encapsulation plant is built near the interim storage facilities at a power plant site, but is separate from the shaft leading to the repository, a canister reception station is to be built at the head of the canister transfer shaft, to where the copper canisters are to be brought and from where a lift takes them down to the repository. An office building will also be built in the vicinity of the encapsulation plant. The building will house the control centre for the encapsulation plant and repository.

The core parts of the encapsulation plant are:
- reception facilities for transport casks of spent fuel
- encapsulation facilities
- control centre
- canister transfer lift
- bentonite processing facilities

The encapsulation plant will be planned in compliance with safety regulations (Valtioneuvosto 1999) so that in the event of disturbance or accident, the release of radioactive materials into the environment would remain insignificantly low. The framework of the plant is made of reinforced concrete, with structures ranging from 0.2 to 1.4 m in thickness. Maintenance levels, doors, hatches and some of the stairs are made of steel. The plant features several systems including electricity, water, sewage, ventilation, lifts, elevator and transfer systems, electron beam welding and testing equipment.

Figure 4-6. An example of buildings planned in conjunction with the encapsulation plant. The plant itself is right at the back on the left, to the right of it is the office building, the visitors centre is in the front right, with four buildings designed to accommodate visitors on the left.

In addition to the encapsulation plant and office buildings, other surface auxiliary premises are also required. These are:

- a work shaft building
- raw water and sewage treatment plants (Kuhmo only)
- a work shaft building office
- a power and heating centre
- a bentonite storage area
- a sorting and crushing area for excavated rock
- a building supplies depot
- a visitors centre
- visitor accommodation
- explosive and detonator storage facilities
- a building waste sorting area
- fuelling facilities
- roads and parking areas

Building volume in the plant area (Figure 4-6) totals around 65,000 m^3.

An average of 140 persons, of which 30 underground, will be required to work in the plant area during the construction phase. Traffic density is expected some 250 vehicles a day. The construction and raw materials are those typically used in rock and industrial construction; wood, steel and concrete, explosives and HEPAC components.

Some 150 m^3 of water a day will be needed during the construction phase. All the wastewater recovered will be cleaned before being returned to the ground. Ditches will collect the seepage water from the rock into a settlement pool from where, after oil separation, it will be pumped to the surface and returned to the ground. A wastewater treatment plant will clean the some 30 m^3 of grey water arising each day.

4.3.3 Final disposal phase

Transportation of spent nuclear fuel

Between 1981 and 1996, spent nuclear fuel from the Loviisa power plant was transported to the Tsheljabinsk reprocessing plant in Russia. A total of 2,823 fuel assemblies or 330 tU was transported in 15 journeys by rail (Figure 4-7). At the time, it was decided to transport the spent fuel by rail because the Russians had the fleet for it. The railway between Loviisa and Lahti was improved for the purpose. Similar transportation has long taken place in a host of countries, and so there is a track record of the transportation technology and supervision involved.

A study of the existing transportation technology and the viable routes and forms of transport between the interim storage facilities at nuclear power plants and the alternative final disposal sites was made to assess the technical feasibility of transporting spent nuclear fuel and the environmental impacts involved.

Since transportation would not begin until at least 2020, the transportation casks, forms and routes will be finally chosen from the options available at about that time.

Technology to be used in transportation

Spent nuclear fuel is in interim storage at Olkiluoto in Eurajoki and Hästholmen in Loviisa from where it will be transported to the final disposal site in special casks as a special load. The casks, cask handling, readiness for accidents and documentation will be governed by strict criteria. The principle being that the transport cask must retain its protective features even in the worst conceivable kind of accident. Transportation of spent nuclear fuel is currently governed by

- the Nuclear Energy Act and Decree
- the Conveyance of Dangerous Substances Act
- the Decree and decision by the Ministry of Transport and Communications on the Conveyance of Dangerous Substances by Road
- the Decree and decision by the Ministry of Transport and Communications on the Conveyance of Dangerous Substances by Rail

- the Decree and decision by the National Board of Navigation (now the Navigation Administration) on the Conveyance of Dangerous Substances aboard Vessels
- guidelines issued by the STUK Radiation and Nuclear Safety Authority.

The dimensions of the transport casks depend on the size and shape of the fuel assemblies. To some extent, various cask manufacturers each have slightly different technical solutions. Spent nuclear fuel can be transported in a cask either dry or immersed in water. Studies carried out to date have used two different types of CASTOR casks (Figures 4-8 and 4-9). Plans are based on dry transportation. Before being approved for use, the casks undergo many tests in the event of various accidents. The stress caused by accident tests is greater than any a cask is likely to encounter when actually being handled.

Figure 4-7. Between 1981 and 1996 spent nuclear fuel was transported 15 times from Loviisa to the Soviet Union (later Russia) by rail. The spent nuclear fuel was transferred by road from Hästholmen to Loviisa railway station where the transport casks were loaded onto goods wagons. Russian casks were used for transportation.

Figure 4-8. Castor-VVER cask used in studies of the transportation from the Loviisa plant. The cask weighs around 110 t, is 4.1 m long and 2.7 m in diameter. It can hold 84 fuel assemblies at a time.

Figure 4-9. Castor-TVO transfer cask used at Olkiluoto. The cask weighs around 80 t, is 5.2 m long and 2 m in diameter. It can hold 41 fuel assemblies at a time.

The casks must be able to withstand the following tests without sustaining any significant damage:
- a fall from a height of 9 metres onto a hard surface
- the effects of an ambient temperature of +800°C for 30 minutes
- immersion in water at a depth of 200 metres for an hour.

In road transport the cask is transferred by a special multi-axle chassis pulled by a lorry. During transport the axle weight remains within the limits allowed by roads and bridges. The transport cask (Figure 4-10) is loaded onto the lorry in the power plant premises where the spent fuel is in interim storage. The spent fuel is primarily transported along main and regional roads escorted by the police and a radiation controller from the STUK Radiation and Nuclear Safety Authority. The average speed is 35 km an hour and several similarly heavy loads are transported on Finnish roads each year.

Rail transport also includes road transport at the beginning and end of the route. Transfer from the power plant to the railway and from the railway to the final disposal facility require the same fleet, escort and safety measures as for road transport. A special train is needed to transport the casks by rail, with each cask on a special wagon as used nowadays.

Spent nuclear fuel can also be shipped between Loviisa and Olkiluoto. The same applies to Kuhmo, since nuclear fuel could first be shipped to Raahe and from there by road or rail to Kuhmo.

Shipping could be carried out by the M/S Sigyn owned by the Swedish Nuclear Fuel and Waste Management Company (SKB) or by another similar vessel (Figure 4-11). M/S Sigyn has been especially built to transport nuclear waste and is capable of shipping loads up to 1,200 tonnes. The transport system comprises a special vehicle which can be loaded with up to 120 tonnes.

Olkiluoto features a harbour at the plant site. The casks could be transported between the interim storage facilities and the ship by the special vehicle on board the vessel. At Loviisa, Valko harbour could be used. Valko is situated some 25 km from the facilities where the spent nuclear fuel is stored. The special vehicle aboard the vessel could transport the spent nuclear fuel from the ship to the final disposal facility.

Figure 4-11. The M/S Sigyn shipping spent nuclear fuel from Swedish nuclear power plants to interim storage facilities at Oskarshamn in Sweden.

Figure 4-10. Transport cask for spent nuclear fuel. The cask shown is being transferred from the Olkiluoto nuclear power plant to interim storage facilities at the plant site.

Practical transport arrangements

Transport could be by road, rail or sea. There is a wide variety of route options for these various forms of transport (Jakonen et al. 1998). To be able to assess environmental impacts, sample routes for each mode of transport were formed for the type of casks used at both Loviisa and Olkiluoto. The routes were used to examine differences between the forms of transport, transport route characteristics, transport volumes and the number of times. Basic data was also obtained for more detailed assessments and calculations.

To outline the sample routes a "techno-economic route option" and a "population avoidance route option" were chosen for each mode of transport. The techno-economic option is the shortest route. The population avoidance options sought to go round heavily populated areas. However, some stretches of the route are the same, in very sparsely populated areas, for example.

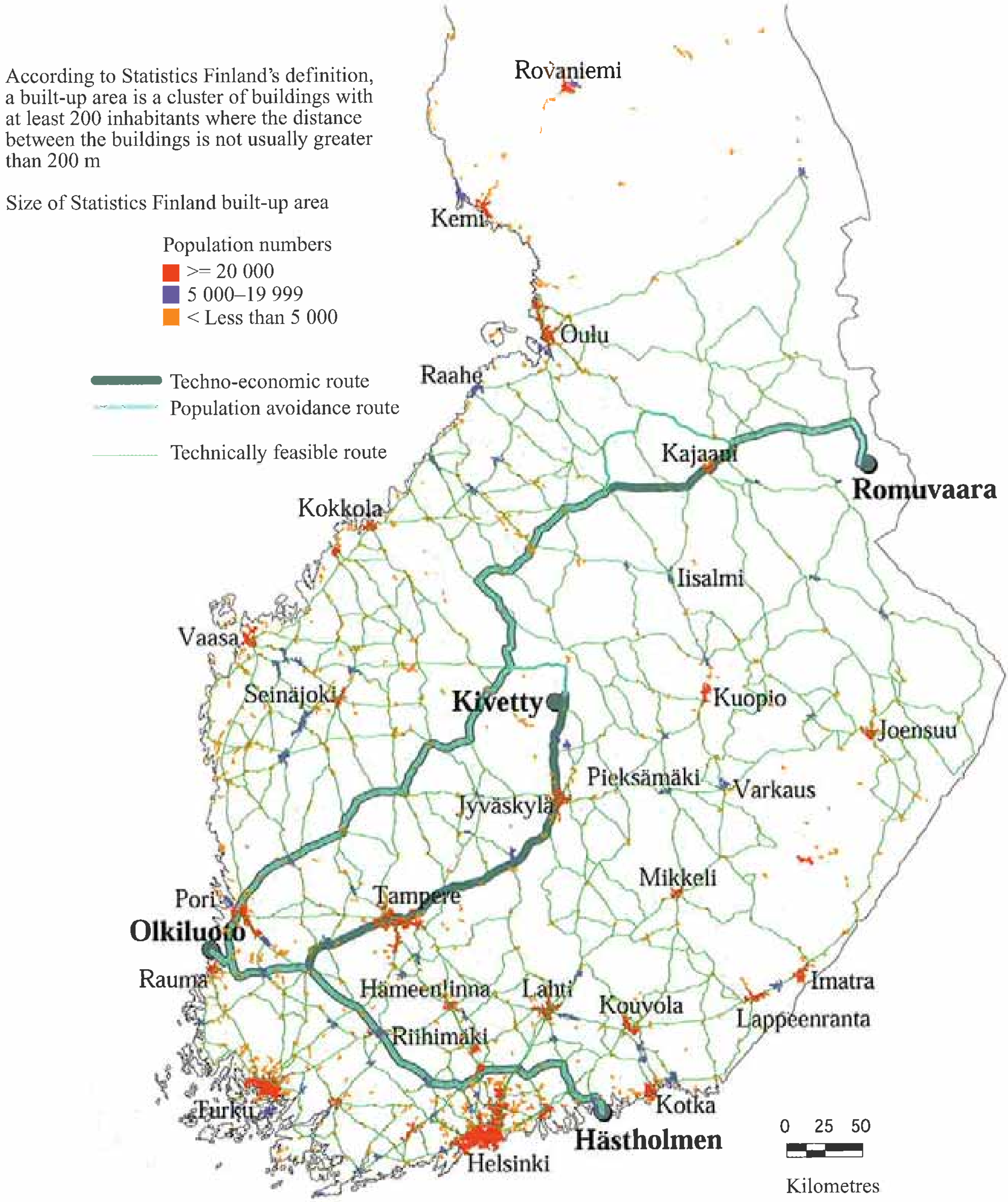


Figure 4-12. Possible road transport routes from Olkiluoto for a 100 tonne cask.

Karttakeskus L2633/99

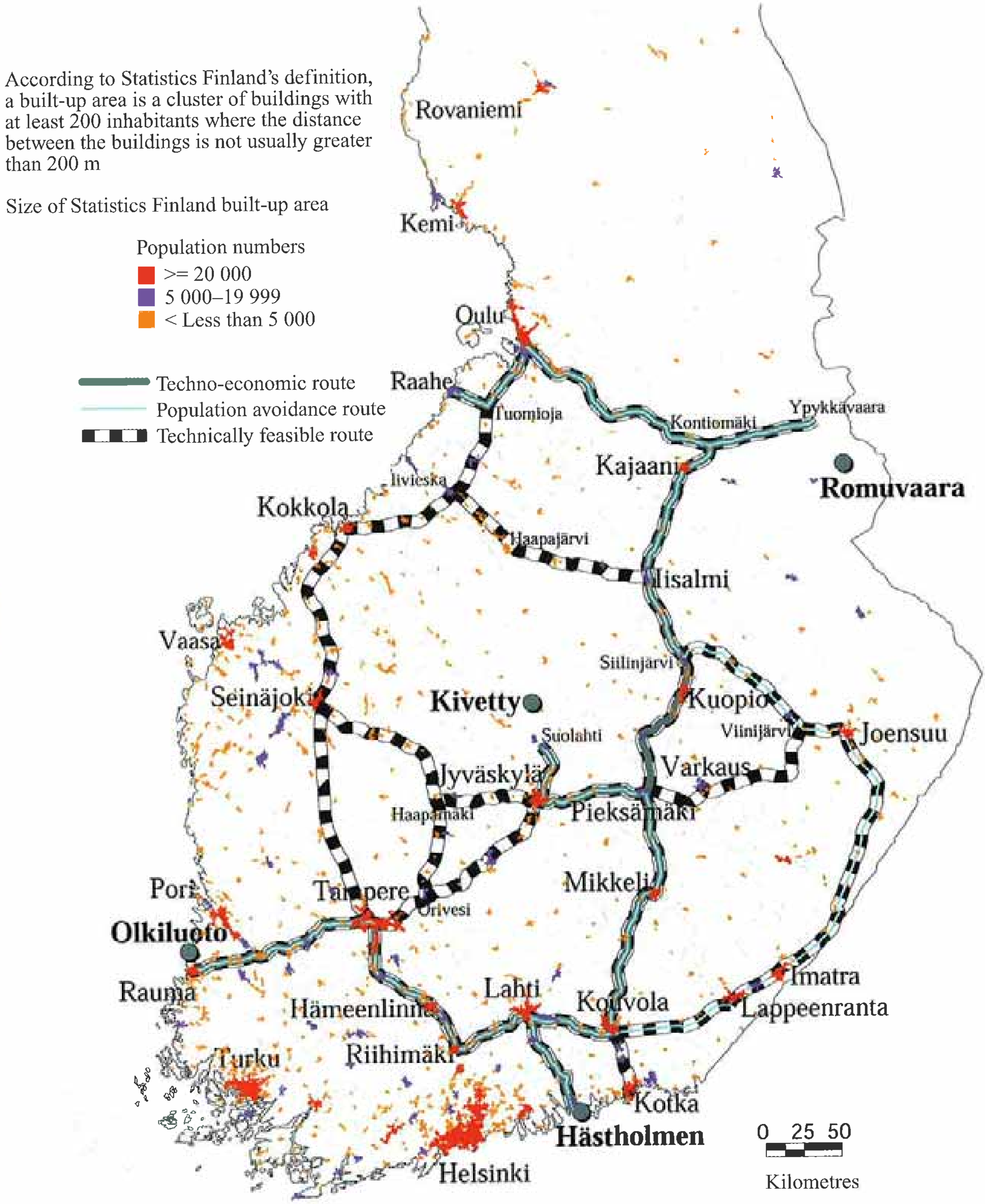


Figure 4-13. Possible rail transport routes from Loviisa and a shipping connection route from Raahe.

Karttakeskus L2633/99

Figure 4-14. Possible sea routes.

There were 20 optional routes (3 to Eurajoki, 10 to Kuhmo, 2 to Loviisa and 7 to Äänekoski) for transportation exclusively by road, There were seven optional rail routes (1 to Eurajoki, 4 to Kuhmo, 1 to Loviisa and 2 to Äänekoski). Additionally, there is also a sea route between Loviisa, Eurajoki and Raahe.

The transport routes are shown in greater detail on several maps in working report (Jakonen et al, 1998). Figures 4-12, 4-13 and 4-14 illustrate the sample routes formed and the various modes of transport for the purposes of assessing transport.

Transport mode and fleet have a major impact on the number of transportations. Road transport can convey 1-2 casks at a time and rail transport 2-4. The number of annual transportations for the base case is shown in Table 4-1.

Should the amount of spent fuel increase considerably than that envisaged in the base case, annual transportation volumes would remain unchanged but there would be an increase in overall volumes. Exceptionally, the average number of annual transportations can be doubled.

	CASTOR TVO cask From Olkiluoto or Loviisa	CASTOR VVER cask From Loviisa
1 cask	16	9
2 casks	8	5
3 casks	5	3
4 casks	4	3

Table 4-1. The annual number of spent fuel transportations assuming that the power plants have a life expectancy of 40 years. VVER casks can only transport fuel from Loviisa.

Encapsulation and final disposal

Handling of nuclear fuel in the encapsulation plant

The fuel assemblies taken from interim storage are sealed in copper canisters at the encapsulation plant (Figure 4-15). For this, the transport cask is docked to the handling chamber (Figure 4-16), where the cask lid is opened by remote control. If the transport cask has been filled with water to keep the fuel cool during transport, the fuel assemblies are lifted out of the cask one at a time and first placed in a drying facility. After drying they are transferred one at a time into a final disposal canister (Figure 4-17) in the handling chamber by remote control. One canister holds 12 fuel assemblies. Encapsulation and the technology used is described in more detail in the references (Kukkola 1999b). The final disposal canister comprises two parts: the outer copper container acts as a corrosion shield and the inner container of nodular cast iron gives the canister its mechanical strength. (Raiko & Salo 1999).

The canisters are ready delivered to the encapsulation plant. The canister is about 1 meter in diameter. The canister for spent nuclear fuel assemblies from Olkiluoto is 4.8 m long and weighs 25 tonnes. The canister for assemblies from Loviisa is 3.6 m long and weighs around 19 tonnes.

Once the fuel assemblies have been placed inside the canister, the lid of the iron insert is sealed and closed with bolts. After this the canister is removed from the handling chamber, the copper lid is fitted into place and the canister is transferred by remote control to the welding equipment. The copper lid is sealed by electron beam welding. After finishing and inspection the canister is taken by lift to the final disposal repository.

Figure 4-16. Isolated handling chamber. The transport cask is docked tightly to the station visible on the left. A remote controlled handling device positions the fuel assemblies individually into the copper canister linked to the station at the back on the right.

Figure 4-17. Diagram of final disposal canisters.

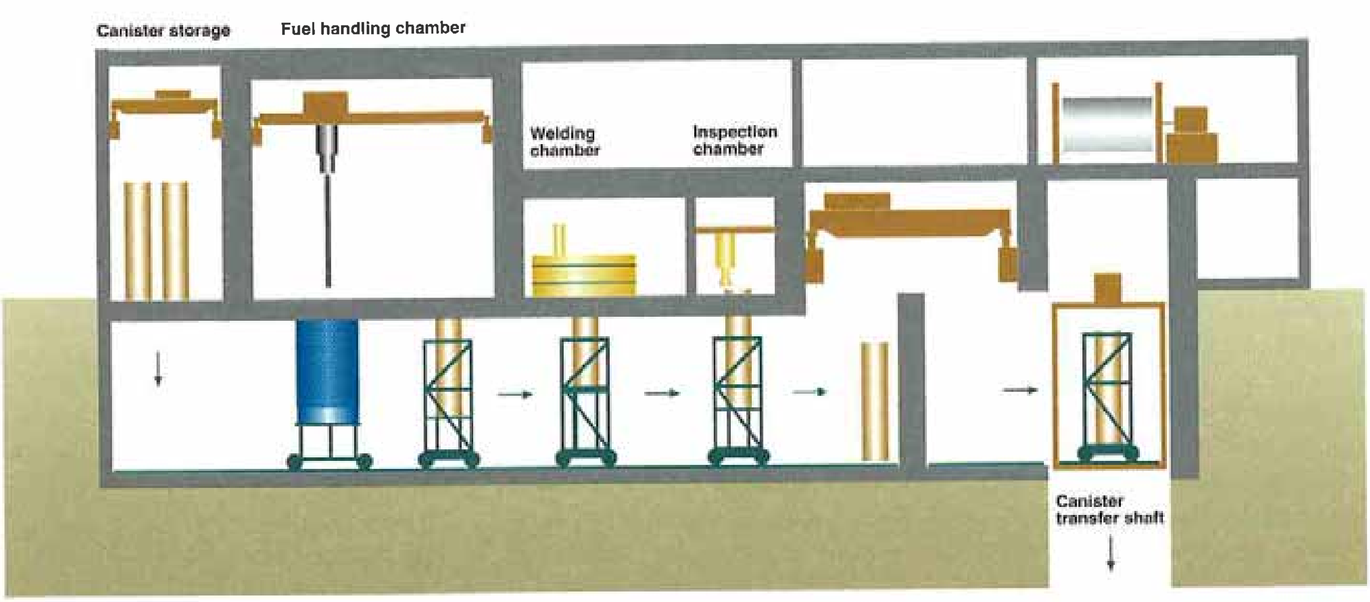


Figure 4-15. Diagram of the encapsulation plant.

If the encapsulation plant is located next to the interim storage facilities at the power plant site, a transport vehicle transfers the canisters to the reception building built at the top of the canister transport shaft and from there by lift to the final disposal repository.

The encapsulation process premises are fully shielded against radiation so that pressure prevails in the nuclear fuel processing facility. The extracted air is constantly monitored. The worst conceivable incident would be for a fuel assembly to break as a result of falling, for example. Gaseous and particulate substances could then be released inside the encapsulation plant. These would be recovered by the ventilation filter system. Safety regulations (Valtioneuvosto 1999) require that no significant amounts of radioactive substances should escape into the environment in such situations.

The radioactive dust occurring in the spent nuclear fuel handling chamber will be vacuumed and packed in the final disposal canisters. Solid contaminated objects such as air and water filters will be packed (for example, cemented in drums) and disposed of in a separate room earmarked for them in the final disposal repository.

Deposition of the canisters in the bedrock

In the base alternative, the copper canisters are placed in holes bored in the floor of tunnels. The holes can be bored using full-face boring technique (Figure 4-18). The final disposal holes will be cased with bentonite clay before the canisters are placed in them. The bentonite blocks needed for the casing will be manufactured in the handling plant above ground. Raw bentonite clay will be stored in steel containers. The bentonite blocks could also be produced elsewhere and brought to the plant.

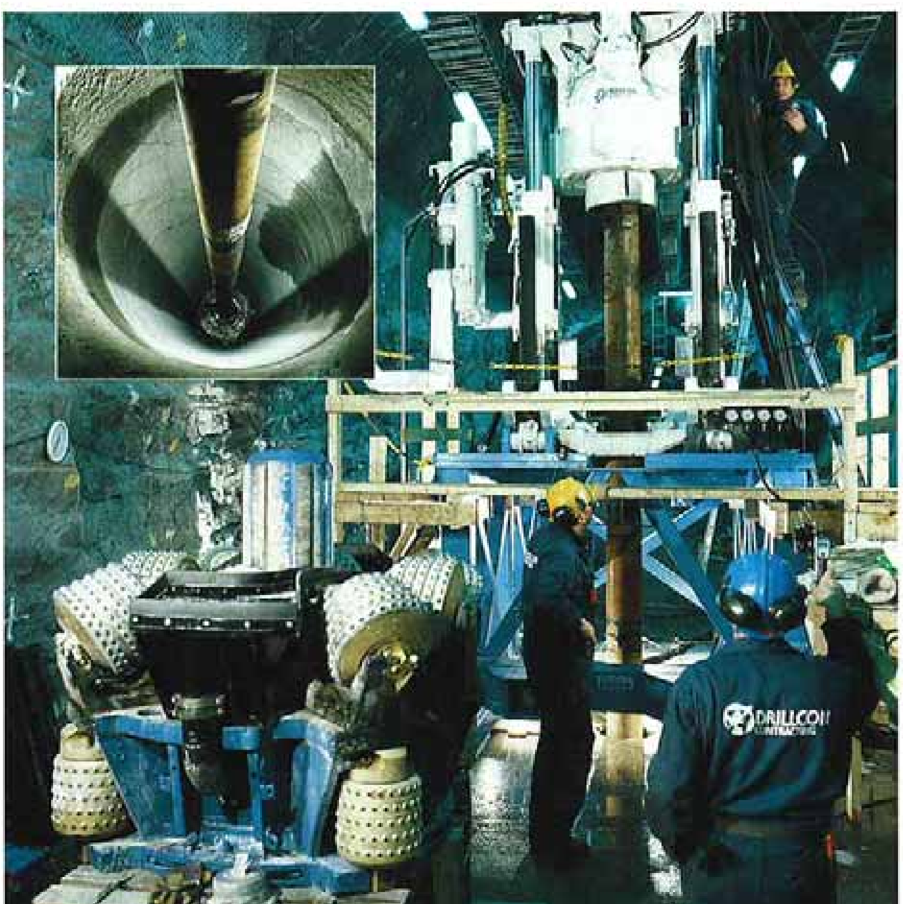


Figure 4-18. Canister holes can be bored using the full-face boring method. Photo of test boring being carried out in the research tunnel at Olkiluoto.

In the repository, a radioactive shielded vehicle takes the canister from the lift to the final disposal tunnel. The canister is placed in a hole, which is finally filled with bentonite.

The disposal tunnel is backfilled with suitable material such as a mixture of bentonite and crushed rock as the canisters are placed there (Figure 4-19). The tunnel backfill is made in the underground premises. Before being filled in the ventilation, electricity and water systems are removed and the tunnel is cleaned.

Final disposal tunnels are excavated about every three years during the final disposal phase. Working in two shifts, the excavation period lasts about one year. No excavation is carried out near

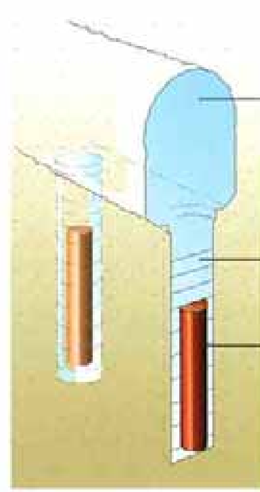


Figure 4-19. Canister that has been finally disposed of and disposal tunnel in accordance with the base alternative.

canisters that have been finally disposed of, neither is blasted rock transported in places where canisters are transferred.

The plans consider the possibility of the repository being enlarged during the final disposal phase.

If the operational lifespan of Olkiluoto and Loviisa is extended to 60 years, the final disposal stage will be extended for 20 years accordingly. The plans also take into account the possibility of accommodating the spent fuel from any new nuclear plant built in Finland.

Table 4-2 shows examples of the impact of amount of nuclear fuel on the underground facilities. Any increase in the number of canisters arising from greater amounts of spent nuclear fuel owing to prolonging the life of existing power plants would increase the final disposal repository volume by about 60 per cent. The area required in the bedrock would also grow in roughly the same ratio. Any increase in spent nuclear fuel would have no impact on the surface buildings.

Security arrangements and control

Security arrangements complying with the Council of State's decision (Valtioneuvosto 1991b) will be implemented at the facility. These arrangements are designed to prevent any unlawful activities in respect of the spent fuel or the facility itself. These demands require monitoring people and goods in the site area and constant monitoring of the equipment itself.

Finland's commitment to the Nuclear Non-Proliferation Treaty means international safeguards (monitoring of nuclear material for peaceful ends) wherever spent nuclear fuel is handled. Although the technical details of monitoring are still open, the facility plan takes them into account.

Personnel, raw materials and raw material transport at the final disposal facility

Some 110–130 people will be required at the site during the final disposal phase. Some 20 persons will work in the final disposal repository. These people will use a canister transfer vehicle, a bentonite transfer and handling vehicle, a crushed rock transfer vehicle and an backfill handling vehicle.

Some 60 canisters and 5,000 tonnes of bentonite a year will be required in final disposal operations. This will mean about 30 and 160 transportations respectively. The crushed rock infill will be produced on site.

The final disposal facility will require about 55 m³ of raw water a day.

4.3.4 Sealing phase

Sealing the final disposal facility

Once all the spent fuel has been finally disposed of and disposal tunnels sealed, work will start on dismantling the active parts of the encapsulation plant and transferring them to the repository. The waste will be packed in drums or concrete containers. The other buildings can be used for other purposes.

The structures and systems used during the operational phase of the repository will be dismantled. Whilst dismantling is taking place, work will begin on backfilling the repository and constructing the plugs. The backfill mixing station will be transferred from the repository to ground level. The premises at final disposal level and shafts will be filled with a mixture of crushed rock and bentonite in the same way as the disposal tunnels. Concrete structures will plug the upper parts of the shafts.

Post-closure period

Should there be no further use for the encapsulation plant and other surface buildings, they can be demolished and the area landscaped. Nature will then gradually return to its original state. A sign that the final disposal facility exists can be left for future generations.

Under the Nuclear Energy Act, the state assumes responsibility for nuclear waste once the STUK Radiation and Nuclear Safety Authority has stated that the nuclear waste has been disposed of definitively in the manner it approves. Final disposal operations are to be documented and the data perma-

Amount of fuel	2600 tU	4000 tU	9000 tU
Volume m³			
Shafts	39 000	39 000	70 000
Central tunnel	68 000	119 000	250 000
Disposal tunnels	199 000	350 000	713 000
Disposal holes	25 000	39 000	80 000
Other premises	30 000	35 000	45 000

Table 4-2. Impact of the amount of spent nuclear fuel on final disposal repository volume when the assumed disposal depth is 500 m.

nently archived. It is for the authorities to decide whether any subsequent monitoring is organised at the site.

4.3.5 Costs of final disposal

The cost of the base alternative, FIM 4.6 billion, mentioned in the preface comprises the cost of transporting the spent fuel, the cost of building and running the final disposal facility, and costs arising from decommissioning and sealing it.

Construction costs amount to roughly FIM 1.2 billion, half of which is accounted for by surface buildings. These costs do not depend on the amount of spent fuel. The cost of underground construction depends on the amount of spent fuel and the quality of the bedrock.

Operating costs are put at about FIM 2.9 billion. This includes the cost of the final disposal canisters which, for the 1,400 canisters envisaged in the base alternative, is FIM 1,250 million. Other operating costs depend on the amount of spent fuel, the schedule and, to a certain extent, bedrock quality.

Transport costs depend on the mode of transport, journey length and how many casks can be carried at a time. The costs are a maximum of FIM 200 million. Sealing costs depend on the amount of spent fuel and bedrock quality and are around 300 million.

The cost of final disposal is being collected in advance by including it in the price of nuclear power and paying it into the State Nuclear Waste Management Fund. The amount required for final disposal is examined annually to correspond to the actual situation.

5 FINAL DISPOSAL LOCATION ALTERNATIVES

Olkiluoto in Eurajoki, Romuvaara in Kuhmo, Hästholmen in Loviisa and Kivetty in Äänekoski are under consideration as the site of the final disposal facility. These sites have been shortlisted as a result of the multi-phase research and selection process described in Chapter 1. The present state of these areas and the planned location of the final disposal facility have been considered in association with the environmental impact assessment (EIA). This chapter provides general information about the alternative sites for disposal and the planned location of the facility.

Figure 5-1. Municipalities proposed as final disposal sites

Olkiluoto in Eurajoki

Located on the shore of the Gulf of Bothnia, Eurajoki is part of the Rauma Economic Zone. The centre of the municipality is located just over 10 km to the north of the centre of Rauma and less than 40 km to the south of Pori, on Highway 8. Commuter traffic between Eurajoki and Rauma is quite heavy.

The municipality has a population of more than 6,000. Agriculture, forestry, processing industry and service sector play an important role in the industrial structure of the municipality. Employing 500 people, Olkiluoto nuclear power plant is the biggest employer in the municipality. A further 200 people rely indirectly on the power plant for their living (Ollikainen & Rimpiläinen 1997a).

A potential final disposal site is situated in Olkiluoto in the vicinity of the power plant (circled on the map). The area is owned by Teollisuuden Voima Oy (TVO), Fortum and the Forest and Park Service. In the east, the area is bounded by agricultural and forestry lands, elsewhere by the archipelago. The closest residential buildings and summer cottages are situated in the eastern part of the island more than a kilometre away from the edge of the potential building area.

The encapsulation facility could be located either within the area of the present nuclear power plant, next to the interim storage for spent fuel or above the final disposal repository in the centre of the island.

In addition to the spent fuel generated by the Olkiluoto nuclear power plant, spent fuel intended for final disposal would be transported also from Loviisa by ship, rail or road.

Spent fuel arriving by sea would be unloaded in the Olkiluoto power plant harbour. The shipping route for sea transportation has yet to be determined.

Road transport would make use of existing road connections to the Olkiluoto power plant area. There are a number of alternatives as far as the connection between the Loviisa nuclear power plant and Rauma is concerned.

Spent fuel transported by rail would be loaded on road vehicles about 20 km from Olkiluoto, at the Vuojoki loading point located in the Eurajoki district. Construction of a new railway is unlikely. There are also some alternative routes for railway transport (Jakonen et al. 1998).

Map 5-1.
Geographical location of Olkiluoto

PORI
Ulvila
Friitala
Lattomeri
Niemenkylä
Luvia
Viasvedenlahti
Etelän Pirskeri
Järvikylä
Pyssykangas
Uskalinmaa
Pujonkulma
Kulvolahti
PORI – RAUMA 47
Eurajoensalmi
Olkiluoto
Irjanne
Aikonmaa
Reksaari
Nurmes
Eurajoki
Panelia
Isokylä
Sydänmaa
Lapijoki
Meriauma
RAUMA
Sampaanala
Unaja
Lappi
Vermuntila
Kodisjoki
Himmerjoki

Romuvaara in Kuhmo

The town of Kuhmo is situated in Kainuu. In terms of surface area, Kuhmo, which is about 5,500 km^2, is one of the largest municipalities in Finland. The town of Kajaani is approximately 100 km away. Kuhmo is home to more than 12,000 inhabitants.

Over 50% of the workforce earn a living from the service industry. The most significant employers are the town, the Frontier Guard Service and the Forest and Park Service. Tourism employs over a hundred people. Agriculture and forestry still remain quite important employers, although recent years have seen a decline in the number of agricultural jobs. The main agricultural production area is dairy cattle. Half of the industrial jobs are related to lumber and timber production (Ollikainen & Rimpiläinen 1997b).

The Romuvaara investigation area is situated 30 km from the centre of Kuhmo to the northeast (circled on the map). Romuvaara and surroundings are an uninhabited forest area owned by the Forest and Park Service. At Pitämävaara, which is located 2 km from Romuvaara to the west, there are 10 inhabitants. The two closest summer cottages are quite old and situated about 1 km away from the edge of the potential building area.

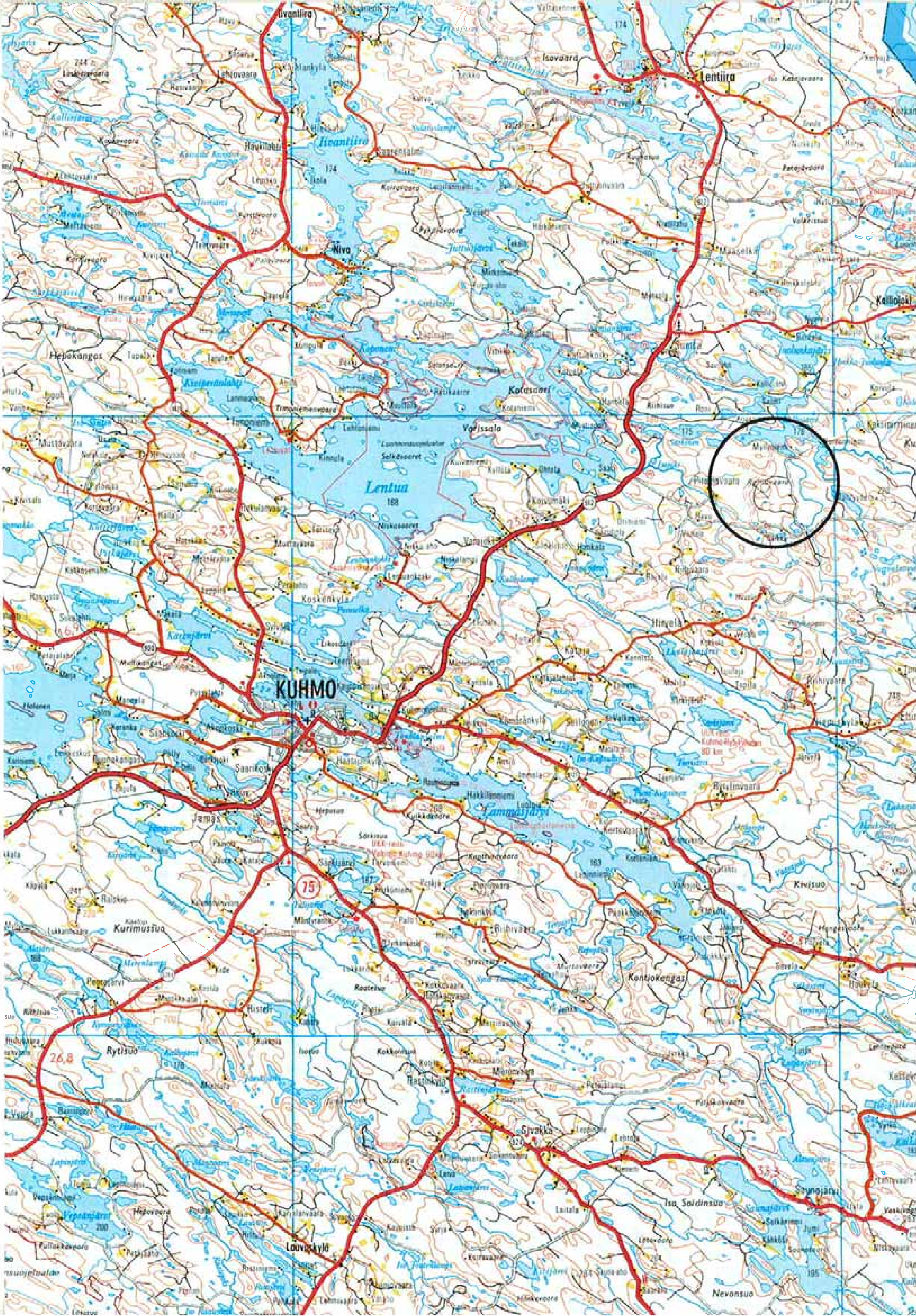
The encapsulation facility and the final disposal repository can be placed in the same 1-km^2 area in Romuvaara. A new approximately 3-km long road would need to be built to bypass the Särkkä ridge. It is unlikely a new railway would be built.

Spent fuel could be transported from the Olkiluoto and Loviisa nuclear power plants to Romuvaara by road or rail. Part of the journey could be made by ship.

Road transport is possible from Kajaani to Romuvaara via Sotkamo or Lentiira. Transportation via Nurmes is also possible if the condition of the one bridge along the route were improved. Also the route from Valtimo via Sotkamo can be considered (Jakonen et al. 1998).

Rail transport is possible along the Kostamus line to the Ypykkävaara loading point where the cargo would be loaded onto the road vehicles. The road section of the trip would be approximately 60 km. There are also a number of alternative rail routes.

Map 5-2.
Geographical location of Romuvaara



KUHMO
Lentua
Iivantiira
Lentiira
Lammasjärvi
Kontiomäki
Niva
Kolasaari
Varissalo
Hiivelä
Kurimussuo
Rytisuo
Louvinkylä
Sivakka
Saunajärvi
Nevansuo
Isovaara
Kellojoki
Maaselkä
Hepokangas
Koskenkylä
Rastinkylä
Kontiokangas
Kivisuo
Haukiaho
Jämäs
Halonen
Rumpu
Rekunjärvi
Saarikoski
Iso Saidinsuo
75
26,8

Hästholmen in Loviisa

The town of Loviisa is situated on the coast of East Uusimaa on Highway 7. Loviisa is home to just under 8,000 inhabitants, the most important built-up areas being the town centre and Valko. The city is bilingual, with a Swedish-speaking minority.

Service and processing industries are the most significant business sectors, whereas the importance of agriculture and forestry is small. More than half the population earns a living from the service industry (Ollikainen & Rimpiläinen 1997c).

The investigation area is situated on the Hästholmen nuclear power plant island and Fortum's area on the mainland (circled on the map). The nuclear power plant is located in the centre of the island, and the shore is virtually undeveloped. There are plenty of holiday homes in the proximity of the area. The closest dwelling and summer cottage are about a 100 m away from the edge of the potential building zone.

The encapsulation plant could be built on Hästholmen island. The road to the island is in good repair. The encapsulation plant would most likely be located next to the present spent fuel interim storage in the nuclear plant area. The final disposal repository could be built on Hästholmen island and possibly partly in the bedrock of the adjacent cape.

In addition to the spent fuel presently in interim storage in Loviisa, spent fuel from Olkiluoto would be transported there using sea, road or rail transport. The ships would be unloaded in Valko harbour and the cargo could be transported by the special vehicle on the ship or another form of the road transport for about 25 km to Hästholmen (Jakonen et al. 1998).

The terminus for rail transport would be in the centre of Loviisa, at the loading centre near the church. From there transport would be by road to Hästholmen.

Map 5-3.
Geographical location of Hästholmen

Elimäki
Pyhäjärvi
Kimonkylä
Villikkala
Pukaro
Pockar
Porlammi
Porlom
Lapinjärvi
Lappträsk
Ruotsinkylä
Svenskby
Kreivilä
Grevnäs
Mickelspiltom
Liljendal
Tammijärvi
Ruotsinpyhtää
Strömfors
Pyhtää kk
Pyttis kyrkby
Forsby
Koskenkylä
Loviisa
Lovisa
Tesjoki
Tessjö
Perna
Pernaja
Valko
Valkom
Abborfjärden
Pasalöfjärden
Hudöfjärden
Kejvsalö
Keipsalo
Sarvsalö
Sarvisalo
Härpe
Härkäpää
Kampuslandet
Orrengrundsfjärden
Orrengrunds skyddsområde
Orrengrundin suoja-alue
Orrengrund
Hamnholmen
Killinge
Luonnonsuojelualue
Naturskyddsområde
E18

Kivetty in Äänekoski

Äänekoski is a large population centre of 14,000 inhabitants situated in Central Finland, approximately 40 km away from the city of Jyväskylä on Highway 4. Äänekoski, Suolahti, Konnevesi and Sumiainen form a united employment area known as Ääneseutu.

The population of the area has risen slightly in recent years and is set to grow further early in the new millennium, until it starts decreasing again as the large age groups start to age. Throughout the 90s, the employment situation has been worse than the national average, although it has improved somewhat in recent years (Ollikainen & Rimpiläinen 1997d).

Alongside the traditional paper and chemical wood processing industry, the electronic industry is rising. The service industry, agriculture and forestry account for a much smaller share of business in the area than that of industry.

Kivetty and surroundings are an uninhabited forest and swamp area owned by the Forest and Park Service. The closest individual houses are approximately 3 km away from the potential building zone to the southeast. The closest holiday homes are about 2 km away. It is about 7 km to the village of Kongikangas and some 25 km to the centre of Äänekoski.

The encapsulation plant and the final disposal repository could be located in Kivetty where forest roads come from three different directions. Road connections can be improved by upgrading the condition of the existing roads.

The spent fuel arriving from Olkiluoto and Loviisa could be loaded onto road vehicles at the Suolahti loading point and transported further either via Äänekoski or along road 69 bypassing Äänekoski to Highway 4 turning west at the Lintulahti Esso service station towards Kivetty.

Another potential loading point could be Hietama, with further transport along less significant roads to Kivetty from the southwest.

A third option would be to load the spent fuel onto road vehicles at Kannonkoski and transport it along less significant roads to Kivetty. The primary road transport route would go along the national road network passing Äänekoski and Kongikangas to the Lintulahti Esso service station and further on to Kivetty (Jakonen et al. 1998).

Map 5-4.
Geographical location of Kivetty


Kannonkoski
Saarijärvi
Äänekoski
Suolahti
Uurainen
Lannevesi
Tarvaala
Pyhäjärvi
Summanen
Kolkanlahti
Koninkangas
Ala-Keitele
E75
Jyväskylä Viitasaari 99
Jyväskylä Kyyjärvi 116
Vuosjärvi
Hietama
Puratola
Upatonpohja

6 NON-IMPLEMENTATION

6.1 Zero alternative

Non-implementation of the final disposal project would mean that the spent nuclear fuel would remain in storage pools at the Olkiluoto and Loviisa nuclear power plants for an unlimited period of time. This report assumes that the spent fuel will continue to be stored in the present storage facilities or extensions thereto. The interim storage facilities are designed so that the fuel assemblies can be stored in them for decades. Experts consider there is no absolute technical time limit for continuing this type of storage indefinitely.

The goal of the licence holders with waste management obligation is to implement the management of nuclear waste safely as requiredby legislation, without passing unnecessary responsibility on to future generations. Continuation of storage in water pools cannot be a realistic alternative to final disposal, because the environmental protection objectives and ultimately the legislation call for permanent disposal of spent fuel in the ground or bedrock. If however the government and Parliament, while considering the decision in principle for the final disposal facility, end up with a negative outcome, this would in practice mean implementation of the zero alternative and postponing the decision about the final disposal until the future.

Although the zero alternative would include follow-up of other developments such as nuclide partitioning and transmutation in nuclear waste management, it would still necessitate coming back at some stage to the final disposal project. This is because the nuclear waste produced as a result of reprocessing or nuclide partitioning would almost certainly have to be stored and eventually finally disposed of in Finland.

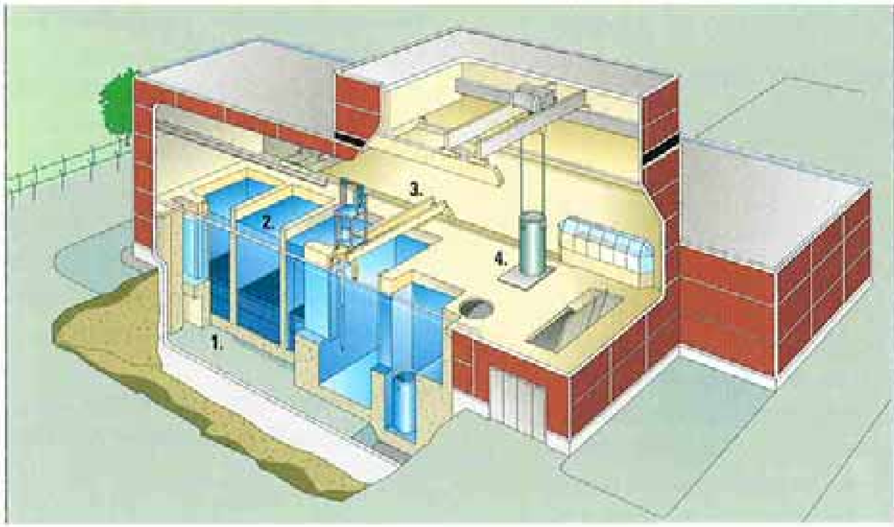


Figure 6-1. Interim spent fuel storage (KPA store) at Olkiluoto: 1. Fuel racks, 2. Storage pools, 3. Fuel handling machine, 4. Transfer cask

6.2 Interim storage of the spent nuclear fuel at Olkiluoto

The spent nuclear fuel of Olkiluoto nuclear power plant is temporarily stored in the reactor buildings of the plant blocks as well as in separate interim storage facilities for spent fuel located in the plant area (Figure 6-1). A few metres of water on top of the fuel assemblies attenuate the radiation coming from the fuel. Water also cools down the assemblies.

Olkiluoto 1 has the capacity to store a total of 1,520 fuel assemblies and Olkiluoto 2 1,560 assemblies. In practice, each unit can take about 1,000 fuel assemblies, which makes about 2,000 assemblies (350 tU) for the entire power plant.

In autumn 1987, an interim storage facility with three storage pools for spent fuel was built on the southwest side of the power plant units (see figure). Altogether, the storage facilities can accommodate approximately 6,800 fuel assemblies (1,200 tU). By the end of 1998 about 840 tU of nuclear fuel had accumulated at Olkiluoto, and the figure is increasing by almost 50 tU annually.

Design of the interim storage facilities for spent fuel (KPA store) was based on a technical lifetime of 60 years, which would be reached in 2047. Possible extension of the storage facilities was also taken into consideration at the design phase. The capacity of present storage facilities is adequate until the early part of the decade beginning 2010. Extension would mean building one or more new pools in connection with the existing storage facilities. If power plant production continues at its present rate, extension of the storage facilities will be relevant in the early 2010's.

The planned lifetime of the storage in the base case is assumed to expire in the year 2040, providing that all the spent fuel is delivered to the final disposal facility by then. It is intended to use the spent fuel storage for handling some of the components when the nuclear power plant units are eventually dismantled and for packing them for final disposal.

6.3 Storage of spent nuclear fuel at Hästholmen

Spent fuel generated by the Loviisa nuclear power plant is stored in storage pools at the power plant (Figure 6-2). Present storage facilities include discharge pools of the reactors situated inside the containment buildings of the units as well as storage 1 (two pools) and storage 2 (three pools) at the power plant. The capacity of the present storage facilities provides storage for approximately 3,000 fuel assemblies.

Return shipments of spent fuel from Loviisa to Russia ended in late 1996. At the end of 1998 there were a total of 2,206 spent fuel assemblies (approximately 270 tU). The amount of spent fuel being stored at the power plant is growing by some 30 tU annually. Present storage facilities can cover the need for spent fuel storage (approximately 280 to 290 tU) for the next ten years of power plant operation.

The expansion of the intermediate storage capacity of the Loviisa nuclear power plant has been studied extensively on the basis of different storage techniques. All in all nine different options have been considered and examined (Mayer & Palmu 1995, IVO 1996). The options are either to expand the present interim spent fuel storage 2 or to build a completely new storage facility.

The following options have been considered in respect of water pool storage technology:

- to expand present storage by building additional pools in two phases (4 + 4 pools)
- to replace the present spent fuel racks with so called dense racks and to build two new pools
- to build a completely new separate pool storage underground in connection with the final repository of the operating waste (VLJ-repository)

Once the fuel has cooled down in the pools, after an appropriate period of time it can be moved into the dry storage. The following options have been considered in respect of dry storage technology:

- storage in transport casks on the ground surface
- storage in transport casks in the connection of the VLJ repository
- dry silo storage, where fuel is stored in tubes filled with nitrogen
- dry silo storage, where fuel is stored in tanks filled with helium (three dif ferent applications)

The central objective of all these studies was to review all the realistic options that could be considered in connection with increasing the storage capacity at the Loviisa power plant site. Special attention was given to the options based on the dry storage idea that have been marketed as suitable for long term storage. All the options underwent CAD, adapted for the environment of the Loviisa power plant. In addition to technical feasibility, studies were also made of the design, investment, operating and decommissioning costs for each option. Correspondingly, the implementation schedule, connection to the power plant's existing storage system, etc. were also considered.

Based on these investigations, the technically and economically most suitable nuclear waste management solution was chosen for the Loviisa power plant. The solution was to extend the present interim storage 2 by building additional pools (Mayer & Palmu 1995, IVO 1996). During the first phase, four pools identical to the pools in the old part will be built. In 1997, The Finnish Radiation and Nuclear Safety Authority (STUK) approved the preliminary safety analysis report on the extension of the spent fuel storage 2 in Loviisa. Construction work began in autumn 1997. The storage facilities are sched-

Figure 6-2. Interim storage in storage pools above the ground at Loviisa

uled for completion in the year 2000 and after that there will be sufficient storage capacity until about 2010. The plans also allow another similar extension to be built at a later stage.

6.4 Other methods used in the interim storage of spent nuclear fuel

After removal from the reactor, spent fuel is first cooled in the storage pools, after which some other storage methods can be considered. Nuclear fuel can be transferred to dry storage, where necessary radiation protection and cooling due to the presence of residual heat can be provided without water.

In practice, fuel is transferred in to strong and heavy containers, which can also be used as transport casks. To store heavy watertight and airtight containers for a long period of time requires separate storage where cooling is provided by air conditioning that works by natural circulation. To fill the container, various materials can be used, e.g. helium due to its high heat conductivity. All these storage options have been considered in the above IVO's interim storage extension report at Hästholmen power plant. In principle they could be considered applicable in the present power plant areas (Figure 6-3). As regards underground storage facilities, there are some difficult problems such as the risk of fire or groundwater flooding into the storage facility if the pumping system fails.

Various superterranean silo solutions (e.g. MVDS, FUELSTOR, NUHOMS) have also been suggested for the dry storage of fuel. A common feature of these dry storage options is that the fuel assemblies are placed in tubes or canisters that in turn are placed inside concrete structures. Residual heat is removed by air through natural circulation.

Another proposal for long-term interim storage is the DRD (Dry Rock Deposit) storage. Several variants of this method have been presented, all with one common principle, namely that the rock surrounding the storage can be "dried" using either natural cruch zones of the rock or artificially made drains (Eggert et al 1987). Using this method, the waste packages placed in the caverns would never come into contact with the groundwater, neither would mechanical pumping be needed to keep the storage dry. This alternative could use a transport container similar to the one described above. Storage itself would be situated above the groundwater table and cooling would be by air circulation.

Since in Finland the groundwater table is quite near the surface and the described method would require draining of substantial rock volumes, only an area significantly higher than its vicinity would be suitable for building such a storage. Neither present power plant areas nor the sites characterised for the final disposal are suitable for this type of storage due to their low topography. In Finnish conditions, some parts of Northern Finland could be best suited for this type of storage because of their topographic conditions. Finding a suitable location would be a challenge in terms of adapting this method to interim nuclear fuel storage. Keeping the storage area dry would also require some active control to make sure that the draining system always remains open.

6.5 The costs of interim storage

The KPA store facility in Olkiluoto as built in the 1980s, so there are over ten years experience of operating this kind of storage. For this reason, in this connection the costs already incurred and the expected future costs of the KPA store can be used as an example.

By the time the spent fuel storage facility was ready in 1987, the construction expenses had amounted to approxi-

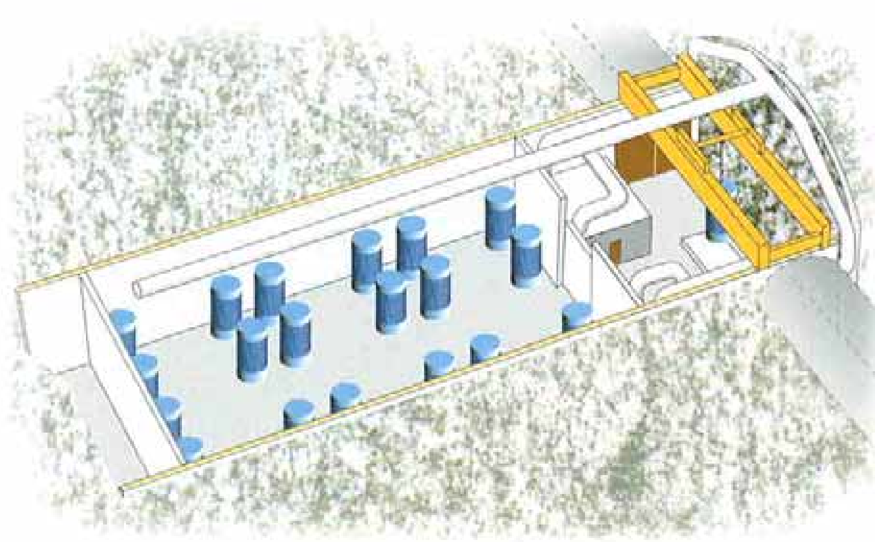


Figure 6-3. Example of an interim storage alternative based on dry storage facilities excavated in the rock.

mately FIM 200 million in the money of that time. The estimated expenses that might occur in the future relating to possible extension of the storage capacity amount to FIM 30 to 35 million. This estimate includes constructing a new pool and the costs of procuring the fuel racks to be placed in the pool.

At the present time, systems of the power plant are used at the storage. Nevertheless, the KPA store has been designed so that it could also function as an independent facility without support from the existing infrastructure. Detaching the KPA store from the power plant systems and transforming it into an independent facility would cost around FIM 10 million.

The estimated operating costs of storage amount to FIM 10 million a year, based on an input of 20 manpower years annually.

7 ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURE (EIA)

7.1 Purpose of the EIA

The facilities intended for the treatment, storage, and final disposal of the nuclear waste generated by the production of nuclear energy are governed by the Act on Environmental Impact Assessment Procedure; consequently, they require an environmental impact assessment. In compliance with the Nuclear Energy Act, an EIA report is related to the decision making.

Construction of a large-scale nuclear energy plant requires a decision in principle made by the Finnish Council of State that the construction of such a facility will be in the overall good of society (YEL 1987). Before such decision in principle is made, the developer has to prepare an EIA report to be appended to the application for the decision in principle. As the contact authority, the Ministry of Trade and Industry is responsible for organising the hearings of the EIA procedure and for compiling the statements and opinions.

The EIA procedure aims at increasing the availability of information to citizens and the possibility to be involved in the matter at a stage where no binding decisions have yet been made.

The EIA procedure gathers background information, statements, and individual views for the decision in principle. It does not replace other required reports or licences. To make the decision in principle, the Council of State also obtains many other reports. When considering an application for a decision in principle, the Council of State requests a preliminary assessment of the safety of such a facility from the Radiation and Nuclear Safety Authority (STUK) and asks for the opinions of the candidate municipalities' councils' on locating the facility in the municipality. The Council of State may only make a favourable decision in principle if the municipality approves of the facility being located in its area and if there are no other issues emerging which would mean it is unsafe to implement the project.

7.2 Public involvement

An important part of the environmental impact assessment of the project was the involvement of various parties in the EIA procedure. Public involvement aimed at generating interaction between the parties responsible for planning the final disposal facility and those participating in the EIA procedure. The candidate municipalities played the main role.

The cooperation and follow-up groups formed between the municipalities and Posiva considered it important to get as many municipal residents to participate as possible involved in the project discussion and to activate them in respect of current issues concerning the project. The target was during the drafting stage of the EIA programme to contribute specifically to scoping the impacts to be assessed and later in the assessing phase itself. The intention was to introduce expert information and peoples' views of the project and its assessed impacts into the public debate. Efforts were also made through interaction to reduce misunderstandings and conflicts arising from a lack of information between the parties. To ensure this, a third party expert also took part in creating interaction.

To stimulate participation
- people were informed of the opportunities to join in the debate,
- information was given on the planning of the project, the EIA procedure and progress and the completed reports,
- an ongoing dialogue was launched between the residents of each candidate municipality,
- open discussion on the project, its impacts, and environmental impact assessment took place and
- views on the adequacy of reports about the project and on the acceptability of the methods used were gathered.

The following methods were used to generate the above interaction
- EIA newsletters were distributed to each household in the final disposal municipalities,
- material was made available at Posiva's local offices,
- public events,
- small group meetings,
- information and discussion meetings arranged for the councils of the candidate municipalities and neighbouring municipalities,
- cooperation and follow-up groups established for municipal officials and elected officials,
- exhibitions presenting the project and the EIA, also providing an opportunity to give feedback
- surveys and theme interviews with citizens in connection with various studies,
- discussion meetings organised for the regional administration officials
- seminars for central administration officials and
- discussion in newspapers.

EIA newsletters and other material

Posiva made the project known in the candidate municipalities by publishing an EIA newsletter that presented the project and EIA procedure in an easily understandable manner. The text and layout of the newsletters were intended to appeal to ordinary people and to stimulate them to participate. Material distributed in the Loviisa region was also published in Swedish.

Four EIA newsletters were published in 1997 and two in 1998. The newsletters were distributed to each household in Eurajoki, Kuhmo, Loviisa, and Äänekoski. Approximately 20,000 newsletters were delivered in all.

In the Loviisa region, newsletters were also distributed to the neighbouring municipalities of Lapinjärvi, Liljendal, Pernaja and Ruotsinpyhtää because the region was considered to form a closer entity than the other municipalities studied and their neighbouring municipalities.

In 1998, an EIA newsletter was mailed to the permanent address of summer cottage owners in the municipalities studied (Figure 7-1).

EIA newsletters 1/97 and 2/97 included a feedback form. Posiva received feedback from a total of approximately 700 persons, including 400 opinions about either the actual project or the EIA procedure. The points of view and comments on the assessment were taken into account when making the decisions on the studies. The written feedback was collated in the form of a working report (Pasanen 1998).

Public meetings as well as meetings with discussion groups and small groups

To give residents a better chance to have a say in the matter, a series of meetings was held, consisting of public events and advanced discussion working groups in each locality.

The principal idea behind the public events was to incorporate issues of interest to the residents into the EIA programme and to stimulate the residents into taking an active part in the discussion working groups (Figure 7-2).

When the programme was being drafted, two public events were organised in each candidate municipality to give residents a chance to express their opinion about the project, to ask questions about the contents of the EIA programme, and to submit initiatives for study.

People were invited to the public events
- through newspaper ads, published twice in the newspaper with the largest local circulation (Länsi-Suomi, Sisä-Suomen Lehti, Kuhmolainen, Loviisa Sanomat, Östra Nyland),
- in Eurajoki and Loviisa, a letter of invitation was sent to each household,
- an open invitation in the EIA newsletters distributed to each household in the candidate municipalities
- a letter of invitation to the second event to the municipal council, government and environmental board, and to members of cooperation and follow-up groups.

Using various brainstorming and teamwork methods, the events addressed gathering the participants' views on the project and its impact. An outside party chaired the event and kept a record of it.

Figure 7-1. EIA newsletters

Figure 7-2. An exhibition presenting the final disposal project and EIA was held in connection with the public events.

The discussion working groups dealt in detail with the material gathered from the public events with special emphasis on the impacts of the project and their importance. Further measures to be undertaken regarding information dissemination and interaction during the assessment phase were also discussed. The discussion working group convened twice in each candidate municipality in the autumn of 1997.

When the EIA programme was being heard, the discussion working groups convened once. Representatives from associations and NGOs in the localities studied were invited to participate in the discussion working groups. Written invitations were sent on the basis of addresses received from the municipalities. In addition, all events were advertised twice in the local newspapers with a large circulation.

Also associations and other groups in neighbouring municipalities were afforded an opportunity to participate in the working groups through invitations in a newspaper ad or public events.

Invitations to discussion working groups were extended to, for example, the following parties:
- citizens' groups, such as village committees and residential associations in the candidate municipalities,
- local branch members of political parties and political organisations,
- local environmental associations and environmental groups,
- other local associations and
- contact persons appointed by the municipalities.

Detailed descriptions of, opinions of, and initiatives presented at public events during the programme phase were compiled in a separate working report (Leskinen et al. 1997).

Press representatives were also invited to the public events and to the discussion working group meetings. All public events were covered in the local newspapers. In addition, there was one article in a national newspaper. Also, the events received attention on local and regional radio channels.

Discussions for those small groups wanting them were organised in each locality studied. These discussions were announced through the EIA newsletter, which included both contact information and a feedback form for NGOs and associations to express their interest in such events. During the preparatory phase of the assessment programme in 1997, we organised such events for a total of 40 groups and during the assessing in 1998, for a total of 46 groups. The final disposal project and the EIA procedure were presented at such occasions. After this, environmental impacts resulting from the project were discussed by type. Efforts were made to scope the impacts of the project using the local knowledge and expertise of the participant group.

Exhibitions

Interest in public events was poor. This may have been due to the non-recurring nature or timing of the events, which were usually held during the evening.

To provide better access and to lower the threshold to participate, it was decided to hold a touring exhibition to serve the residents of those areas possibly having to deal with the impacts. The plan was implemented in autumn 1998, and municipal decision-makers and residents also in the neighbouring municipalities were informed with the help of a touring exhibition bus. The idea was to meet the residents living in built-up areas and villages in their own environment. The bus toured for a month, staying for about one week in each locality studied and neighbouring municipalities.

A total of 48 places in 30 municipalities were visited:
The municipalities visited were Kuhmo, Ristijärvi, Sotkamo, Valtimo, Lieksa, Hyrynsalmi, Suomussalmi, Nurmes, Äänekoski, Konnevesi, Laukaa, Uurainen, Saarijärvi, Kannonkoski, Viitasaari, Sumiainen, Suolahti, Vesanto, Eurajoki, Rauma, Nakkila, Luvia, Lappi, Eura, Kiukainen, Loviisa, Lapinjärvi, Liljendal, Pernaja and Ruotsinpyhtää.

The touring exhibition presented the survey sites and the technique to be used in final disposal. One of the exhibits was a prototype of the canister to be used for final disposal. Feedback from the municipal residents and how it had been taken it into consideration (e.g., a transport route report) were shown. The exhibition was open to the public daily from 9am to 7pm. Separate invitations were sent to the municipal decision-makers concerned. A total of approximately 1,500 persons visited the exhibition.

Municipal participation

In addition to the cooperation groups between Posiva and the municipality already in earlier operation in Eurajoki and Äänekoski, similar groups were also established in Loviisa and Kuhmo in 1997. The groups dealt with issues concerning final disposal, its planning and environmental impact assessment. Representatives from the municipalities and Posiva took part in the activities of cooperation and follow-up groups. Each group also includes a separately appointed EIA contact person. The groups met approximately once every other month.

Municipal councils were informed about the progress of the assessment. Regular information meetings were organised for the Eurajoki, Kuhmo, and Loviisa councils between 1997 and

1999. Neighbouring municipalities were also informed about the project during the EIA procedure. Due to the intended incorporation of the municipalities of Äänekoski and Suolahti, those councils were informed together.

Meetings with municipal officials and experts

The main officials in regional administrations were informed and negotiations were held with them during the drafting stage of the programme. Various representatives from regional environment centres, heads of provincial government social administration, employment and business development centres and provincial associations participated in these negotiations. Seminars were organised for central administration representatives during the assessment. The first of these, a general seminar on the EIA procedure was organised in October 1997. In August 1998, a nuclear waste transport seminar was organised for officials. A social impact assessment (SIA) seminar was organised for researchers in September and for authorities in November (Kivinen & Turunen 1999).

Other communications

Posiva also used other means of communication to raise awareness of the final disposal project, disseminating news material, and by organising events for the people to learn about the final disposal project. Local newspapers appearing in the localities studied published Posiva's 4-page supplements three times a year in 1997 and 1998. These supplements told about current issues and about the concerns in the locality.

In addition, a video film of the final disposal project was produced. It was available for those participated in small group and interactive meetings. Also it was possible to order the video free of charge using the form in the EIA newsletter. A total of some 3,500 video cassettes have been distributed.

Posiva participated in various fairs, exhibitions, and public events where it presented the final disposal project to the general public. For this purpose, Posiva built a portable exhibition container (Figure 7-3). One of the most prominent exhibition locations was Heureka, the Finnish Science Centre in Vantaa. A total of approximately 65,000 people have visited the container exhibition.

During the summers of 1996 to 1998, the nuclear waste transport vessel Sigyn, owned by the Swedish Nuclear Fuel and Waste Management Company (SKB), was used as a floating exhibition (Figure 7-4). The vessel visited Finland three times. In Rauma, this exhibition was visited by 5,000 persons, in Loviisa by 6,000 persons and in Helsinki by 4,000 persons. For the visits in Finland, the exhibition on Sigyn was adapted to correspond to Posiva's base alternative.

7.3 EIA programme

Posiva prepared its EIA programme in cooperation with several interested parties. Naturally, the programme included the views of those in charge of the programme as well as the subject areas suggested by the radiation and contact authority and other experts. Furthermore, various methods were used to collate the views of the citizens, candidate municipalities, neighbouring municipalities, provincial and national decision-makers and authorities within the sphere of assessment.

Figure 7-4. Sigyn, the Swedish vessel built for nuclear waste transport, during her visit to Rauma (above).

Figure 7-3. The container presenting Posiva's final disposal project in Kuhmo.

EIA programme to contact authority on 6 February 1998

Posiva submitted the environmental impact assessment programme of the project to the contact authority (Ministry of Trade and Industry) on 6 February 1998. The contact authority put Posiva's EIA programme on public display and announced the launching of the procedure. Posiva submitted 100 copies of the EIA programmes to each candidate municipality, 10 copies for use in the neighbouring municipalities and loan copies to the public libraries in both the candidate and the neighbouring municipalities. In the Loviisa region, the programme was also provided in Swedish. In addition, copies of the EIA programme could be borrowed from Posiva's local offices. The EIA programme was also published in English.

A summary of the EIA programme was distributed to each household in Eurajoki, Kuhmo, Loviisa and its neighbouring municipalities, Äänekoski and Suolahti. The summary could also be read in electronic format on Posiva's website on the Internet: *htpp://www.posiva.fi*.

The EIA newsletter 1/98 published during the public hearing contained an outline of the EIA programme. The EIA newsletter 2/98 featured the main points presented by the contact authority, municipalities and neighbouring countries.

Information meetings about the contents of the EIA programme were arranged for the cooperation and follow-up groups and the municipal councils. Depending on the interest expressed, information meetings were also arranged for the neighbouring municipal councils.

There was an exhibition of the EIA procedure for the duration of preparing the EIA programme at local offices of Posiva. In October 1997, the municipalities studied also had information points where written feedback and EIA initiatives could also be submitted to Posiva. These information points were located in municipal buildings except for Loviisa where, for practical reasons, it was located at Posiva's local office.

Notification of the assessment programme and public hearing

The Ministry of Trade and Industry announced the pending assessment programme on the bulletin boards of the following municipalities and cities: Eurajoki, Eura, Kiukainen, Lappi, Luvia, Nakkila, Rauma, Kuhmo, Hyrynsalmi, Lieksa, Nurmes, Ristijärvi, Sotkamo, Suomussalmi, Valtimo, Loviisa, Lapinjärvi, Liljendal, Pernaja, Pyhtää, Ruotsinpyhtää, Äänekoski, Kannonkoski, Konnevesi, Laukaa, Saarijärvi, Sumiainen, Suolahti, Uurainen, Vesanto, and Viitasaari.

Statements were requested from the aforementioned municipalities and also the Ministry of the Environment, Ministry of Social Affairs and Health, Ministry of Transport and Communications, Ministry of Defence, Finnish Centre for Radiation and Nuclear Safety, Finnish Environmental Institute, Technical Research Centre of Finland, Geological Survey of Finland, Finnish National Road Administration, provincial governments of South Finland, West Finland and Oulu, the Provincial Government of the Åland Islands, centres for environmental affairs in Uusimaa, Central Finland, Satakunta and Kainuu, East Uusimaa Regional Council, Central Finland Regional Council, Satakunta Regional Council, and Kainuu Regional Council. The water courts and the Provincial Government of the Åland Islands were afforded an opportunity to give a statement.

There was also a public announcement about the matter in the following newspapers:
Länsi-Suomi, Satakunnan Kansa, Uusi-Rauma, Kuhmolainen, Kainuun Sanomat, Karjalainen, Loviisa Sanomat, Uusimaa, Östra Nyland, Borgåbladet, Keskisuomalainen, Sisä-Suomen Lehti, Keski-Suomen Viikko, Hufvudstadsbladet, Helsingin Sanomat and Kansan Uutiset.

The EIA programme was available for public inspection between 23 February and 23 April 1998 during office hours in the municipal offices of the candidate and neighbouring municipalities. During the public hearing, residents had a chance to express their opinions on the EIA programme both in writing and orally. There were answer forms bearing the contact authority's address and pre-paid envelopes to enable people to presenting their opinions.

In March 1998, the Eurajoki municipality, the towns of Kuhmo, Loviisa and Äänekoski respectively organised information and discussion events about the EIA programme. Representatives of the persons in charge of the project, the contact authority and the Finnish Centre for Radiation and Nuclear Safety were also present at these events. The topics discussed were the project and the EIA procedure.

The Ministry of the Environment sent notification to the authorities in Sweden, Estonia, and Russia of the pending environmental impact assessment programme of the project. Notification is based on the United Nations' (UN) Economic Commission for Europe (ECE) treaty on the transboundary environmental impact assessment procedure between member states which entered into force in September 1997 and on the Act on the Environmental Impact Assessment Procedures. The Ministry of the Environment requested these states to announce that they would participate in the environmental assessment procedure of the project and to give a statement about the assessment programme being considered. Sweden, Russia, and Estonia will be notified also about the EIA Report.

Contact authority's statement of 24 June 1998

The Ministry of Trade and Industry received a total of 56 requested statements and 120 opinions. Based on the material received and on its own assessment, the Ministry issued its statement about the programme on 24 June 1998. The contact authority's entire statement is annexed to this report.

Supplementation of the EIA programme

In preparing this EIA report, Posiva took into account the contact authority's statement according to which the main areas needing studying were:

- non-implementation of the project, i.e., the 'zero option' and dealing with its environmental impacts,
- a more in-depth study of geological alternatives (deep hole, hydraulic cage) for final disposal other than the base alternative,
- a study of retrieving the fuel to the surface of the earth in various final disposal alternatives,
- general health impacts resulting from radiation and safety risks of transport to be dealt with in a relevant, easily comprehensible manner,
- social impact assessment methods and the contents of assessment discussed in a seminar for experts and authorities and
- more equal consideration of various residential groups (e.g., summer residents) in information dissemination and interaction

Furthermore, when preparing the EIA report, Posiva took into consideration the issues emerging during the interactive municipal events. These issues varied considerably from one municipality to another. Most of the questions presented are discussed under chapter Social Impacts.

During the EIA programme stage, Posiva's owners, TVO and Fortum, launched an environmental assessment project concerning an expansion of the present nuclear energy plants. During 1998, the companies prepared EIA programmes regarding the construction of a new plant unit, TVO in Olkiluoto, Eurajoki and Fortum in Hästholmen, Loviisa.

If one or more new nuclear energy plant units were to be built in Finland, it is evident that Finland would be home to final disposal of the nuclear waste generated by them and that the spent nuclear fuel would be treated and finally disposed of in the same final disposal facility as the waste from the present nuclear energy plant units. This would mean an expansion of the underground area of the final disposal facility now being planned.

In its statement, the contact authority stated that the scope of Posiva's project should be determined in relation to the amount of nuclear fuel to be disposed of permanently. The authority, however, does not see anything to prevent Posiva's EIA report from dealing with a larger amount of fuel than that produced by the present four nuclear power plants. This report assesses the possible effects a larger amount of fuel than that of today would have on the project's lifespan and environmental impact.

7.4 Assessors and assessment material

Posiva is liable for the environmental impact assessment. It has been responsible for having the necessary studies prepared for EIA, for the EIA programme and for preparing the report as well as the scheme for public involvement.

Both when the programme was being drafted and during the assessment stage, several experts (listed below) were involved in preparing the reports and carrying out the investigations. The background material has been published in the form of Posiva Reports and Posiva Working Reports distributed both to candidate municipalities and many other parties. The reports are listed below.

- ANSERI-Konsultit Oy
- Corporate Image Oy
- Diskurssi Oy
- Eurajoen Yrittäjät ry
- Fintact Oy
- Fortum Engineering Oy
- Galson Sciences Ltd
- Geological Survey of Finland
- Golder Associates Inc.
- University of Helsinki/Department of Chemistry, Laboratory of Radiochemistry
- University of Helsinki/Department of Social Psychology
- Imatran Voima Oy/Environmental Protection Division
- Saanio & Riekkola Consulting Engineers
- Urban Research Seppo Laakso
- Kuhmon Yrittäjät ry
- National Consumer Research Centre Finland
- Libenter Oy
- Loviisan käsityö- ja tehdasyhdistys ry
- Loviisan Yrittäjänaiset ry
- LT-Consultants Ltd
- Maakanta Oy
- PRG-Tec Oy
- Suunnittelukeskus Oy
- STUK Radiation and Nuclear Safety Authority/Natural Radiation Laboratory
- Taloustutkimus Oy
- Helsinki University of Technology/Centre for Urban and Regional Studies
- Tielaitos
- University of Turku/Department of Sociology
- Technical Research Centre of Finland (VTT)/Energy
- Technical Research Centre of Finland (VTT)/Communities and Infrastructure
- Technical Research Centre of Finland (VTT)/Chemical Technology
- Ympäristötutkimus Metsätähti Oy
- Yritystaito Oy
- Äänekosken Yrittäjät Oy

The list of the research institutes and consultants closely involved in the environmental impact assessment of a final disposal facility for spent nuclear fuel.

REPORTS PREPARED FOR THE EIA REPORT

POSIVA Reports

96-06 Geochemical modelling study on the age and evolution of the groundwater at the Romuvaara site

98-07 Geochemical modelling of groundwater evolution and solute residence time at the Kivetty site

98-10 Geochemical modelling of groundwater evolution and solute residence time at the Olkiluoto site

98-15 Normal evolution of a spent fuel repository at the candidate sites in Finland

98-16 The social impacts of the final disposal of spent nuclear fuel from the point of view of the inhabitants - Interview research (in Finnish)

98-17 Possible effects of a proposed high-level nuclear waste repository on consumer demand for goods and services produced in the host community (in Finnish)

99-07 Safety assessment of spent fuel disposal in Hästholmen, Kivetty, Olkiluoto and Romuvaara TILA-99

99-11 Final disposal of spent nuclear fuel in Finnish bedrock - Romuvaara site report

99-09 Final disposal of spent nuclear fuel in Finnish bedrock - Kivetty site report

99-10 Final disposal of spent nuclear fuel in Finnish bedrock - Olkiluoto site report

99-08 Final disposal of spent nuclear fuel in Finnish bedrock - Hästholmen site report

99-02 An overview of a possible approach to calculate rock movements due to earthquakes at Finnish nuclear waste repository sites

99-12 Site scale groundwater flow in Hästholmen

99-03 Site scale groundwater flow in Olkiluoto

99-13 Regional-to-site scale groundwater flow in Kivetty

99-14 Regional-to-site scale groundwater flow in Romuvaara

99-15 Site-to-canister scale flow and transport at the Hästholmen, Kivetty, Olkiluoto and Romuvaara sites

99-06 Radwaste management as a social issue (in Finnish)

99-05 The effects of the final disposal facility for spent nuclear fuel on regional economy (in Finnish)

99-04 The psychosocial consequences of spent fuel disposal (in Finnish)

99-17 Assessment of health risks brought about by transportation of spent fuel (in Finnish)

99-16 Assessment of radiation doses due to normal operation, incidents and accidents of the final disposal facility (in Finnish)

Working Reports

96-24 The nature inventory in Kivetty area in 1996 (in Finnish)

97-12 Kuhmo spatial description (in Finnish)

97-13 Äänekoski spatial description (in Finnish)

97-14 Eurajoki spatial description (in Finnish)

97-15 Loviisa spatial description (in Finnish; also published in Swedish)

97-44 Bird studies at Olkiluoto in Eurajoki, Romuvaara in Kuhmo, Hästholmen in Loviisa and Kivetty in Äänekoski in 1997 (in Finnish; also published in Swedish)

97-48 Study of the real estate price developments in Loviisa area (in Finnish; (also published in Swedish)

97-55 Notifications, plans, licences, permits and related decisions required for the final disposal of the spent nuclear fuel (in Finnish)

97-64 The nature inventory in Hästholmen area in 1997 (in Finnish; also published in Swedish)

97-65 The nature inventory in Romuvaara area in 1997 (in Finnish)

97-66 The nature inventory in Olkiluoto area in 1997 (in Finnish)

97-67 Public participation in the environmental impact assessment of the final disposal of spent nuclear fuel - Public meetings during the assessment program phase (in Finnish; also published in Swedish)

98-01 Tourists' attitudes toward the final disposal of spent nuclear fuel (in Finnish)

98-40 Use and crushing of excavated rock (in Finnish)

98-41 Transport, use and storage of explosives for the excavation of the repository of spent nuclear fuel (in Finnish)

98-44 Summary of recent observations from Hästholmen hydrogeochemical studies

98-47 Excavation, supporting and grouting at the construction phase (in Finnish)

98-48 Transport alternatives of spent nuclear fuel to possible locations for final disposal (in Finnish)

98-50 Survey of entrepreneurship in Kuhmo (in Finnish)

98-62 Radiation doses due to the natural radon gas releases from the final disposal facility of spent fuel (in Finnish)

98-63 Radioactive elements and ionizing radiation in the environment of the alternative sites for final disposal of nuclear waste (in Finnish)

98-64 Public feedback in the environmental impact assessment of the final disposal of spent nuclear fuel: written feedback, small groups, and newspaper articles (in Finnish)

98-73 Effect of underground facility on groundwater table and vegetation (in Finnish)

98-74 Some environmental impacts of the final disposal facility (in Finnish)

98-75 Water supply and sewerage of the final disposal plant (in Finnish)

98-78 Survey of entrepreneurship in Eurajoki (in Finnish)

98-79 Survey of property price developments and markets in and around Eurajoki, Kuhmo, Loviisa and Äänekoski (in Finnish)

98-80 Survey of property price developments in and around Eurajoki (in Finnish)

99-10 Survey of entrepreneurship in Äänekoski (in Finnish)

99-13 Expert seminars on environmental impact assessment of the final disposal facility of spent nuclear fuel (in Finnish)

99-14 Survey of entrepreneurship in and around Loviisa (in Finnish)

99-17 Final disposal plant, normal operation, disturbances and accident cases for release and dose calculations (in Finnish)

99-18 Chemical toxicity in final disposal of spent nuclear fuel (in Finnish)

99-23 The study on municipal images in 1998 (in Finnish)

99-24 Evaluation of the consequences for the municipal economy of the final disposal of spent nuclear fuel (in Finnish)

99-21 Retrievability of spent nuclear fuel canisters (in Finnish)

8 BASE ALTERNATIVE: ENVIRONMENTAL IMPACT

8.1 Assessment organisation

In this chapter assessment of the environmental impact of the base alternative has been organised by impact category as shown in the EIA programme. Impacts have been assessed at all four candidate sites. Assessments cover the entire life span of the project, from the investigation phase following the decision in principle to the post-sealing period. The impact areas for each candidate site have also been assessed in connection with each impact type.

Assessments examined the expected impacts as well as possible impacts resulting from environmental accidents. Anticipated environmental effects include for example the lowering of groundwater levels, and job creation, facility malfunctions and traffic accidents. Environmental accidents studied include oil spills and radiation and explosives accidents.

The main materials, methods and underlying assumptions used in assessments have been described in connection with each impact type. When assessments involve significant uncertainties, their importance was investigated separately. The potential effects of further planning on environmental impact have also been treated in connection with assessments, particularly regarding the alleviation and prevention of hazards.

The exact location of the facility at the final disposal site will be determined later on the basis of underground investigations. At all alternative sites however, a potential construction area, within which superterranean functions would be sited, has been already defined based on completed investigations. Evaluations have taken into account the possibility that operations can be situated anywhere within the potential construction area.

An example of siting final disposal facility was used to illustrate some impacts such as landscape modifications.

Detailed environmental impact assessments have assumed fuel quantities used by existing power plants over periods of 40 and 60 years. The effects of any growth in the volume of spent fuel were always brought up if it was thought that they would cause changes compared to cases already described. At the same time, the effects of certain implementation alternatives for the basic case, such as excavation of the repository at one time and the use of access tunnels, were noted.

8.2 Impact on nature and utilisation of natural resources

8.2.1 Current status of alternative sites

Olkiluoto

The main rock type of at Olkiluoto is migmatite, a mixture of mica gneiss and granite. Shorelines and islands are characterised by coastal meadows, rocky shores, extensive forests of common alder (Alnus glutinosa), as well as reeds. The inner parts of Olkiluoto primarily consist of grove-like forests and rock forests as well as small spots of lush swamps. An inventory carried out in the area (Siitonen & Ranta 1997a) found no nationally endangered plant species. Locally noticeably species were mainly found in the coastal meadows and spruce swamps of common alder. Three noticeable species of polypores, Ganoderma lucidum, Phellinus ferrugineofuscus and Phellinus chrysoloma, were found in the old forests of the area.

The area was found to contain 14 locally valuable natural objects and two more extensive ecosystems. Typically valuable areas included coastal meadows featuring an abundant variety of plant species, forests of common alder, islets inhabited by birds, spruce swamps of common alder and old forest areas. Of these, the old Liiklankari forest is a nature reserve and is part of the EU's Natura 2000 network (draft 20 August 1998). The island of Olkiluoto is bounded to the west by the Rauma islands that are similarly part of the Natura 2000 network. Locally valuable areas are concentrated along the shore.

There are an abundant number of terrestrial bird species. The area is rich in aquatic bird species, with greater numbers of water bird flocks there than at the other investigation areas. Among the species found in Eurajoki, the velvet scoter (Melanitta fusca) and scaup

Map 8-1. Olkiluoto, potential construction area for superterranean functions, an example of siting and natural features.

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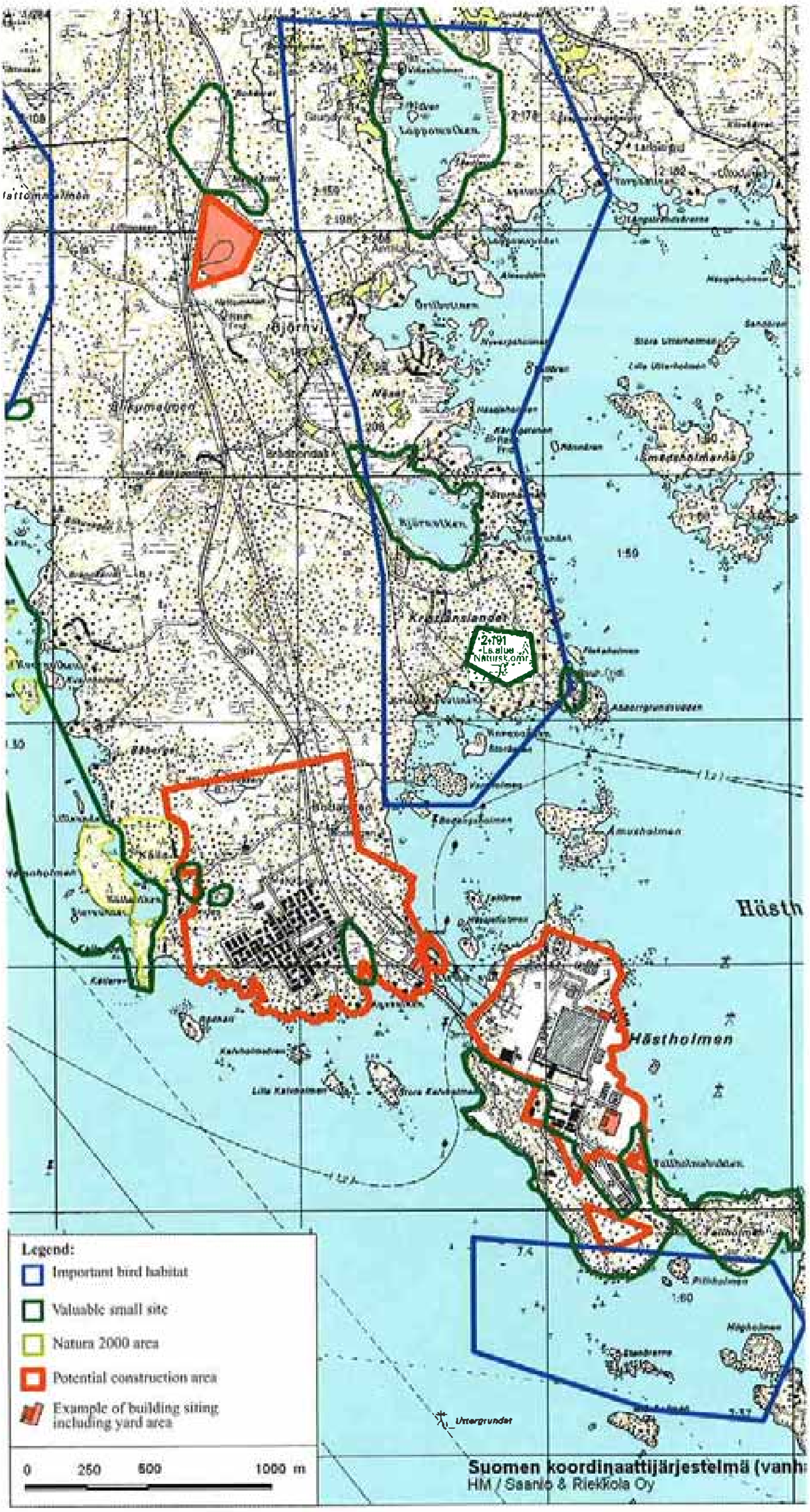


Map 8-2. Hästholmen, potential construction area for superterranean functions, an example of siting and natural features.

(Aythya marila) are rare in Finland and their populations are declining. The northern coast of Olkiluoto is the most valuable area for birds. Although there are few bird species within the immediate vicinity of the power plant, the influence of man on bird life can be felt throughout the entire area (Yrjölä 1997).

Hästholmen

Hästholmen island and its environs are part of the rapakivi granite massif of Southeast Finland. Stony pine forests featuring lush spruce swamps of common alder and small swamps dominate the mainland areas. The area also includes ridge islands featuring distinctive scenery and plant life, lush reed-lined bays and a historical cultural environment. Recent years have seen the cutting of extensive forest areas and summer cottages cover the shoreline. The largest island is the Hästholmen power plant island.

An inventory carried out in the area (Siitonen et al. 1997) found no nationally or provincially endangered plant species. In East Uusimaa, rare or particular species were, however, found in fairly abundant numbers. In certain locations, species related to coastal meadows, sandy beaches, grove-like spruce swamps and moist groves were significant. Grove-like spruce swamps and old forests rank among the most valuable natural features in the area. Previously, two small privately-owned nature reserves existed in the area and the area bounded by the Natura 2000 programme (draft 20 August 1998), relating to the Källaudden-Virstholmen ridge islands and capes.

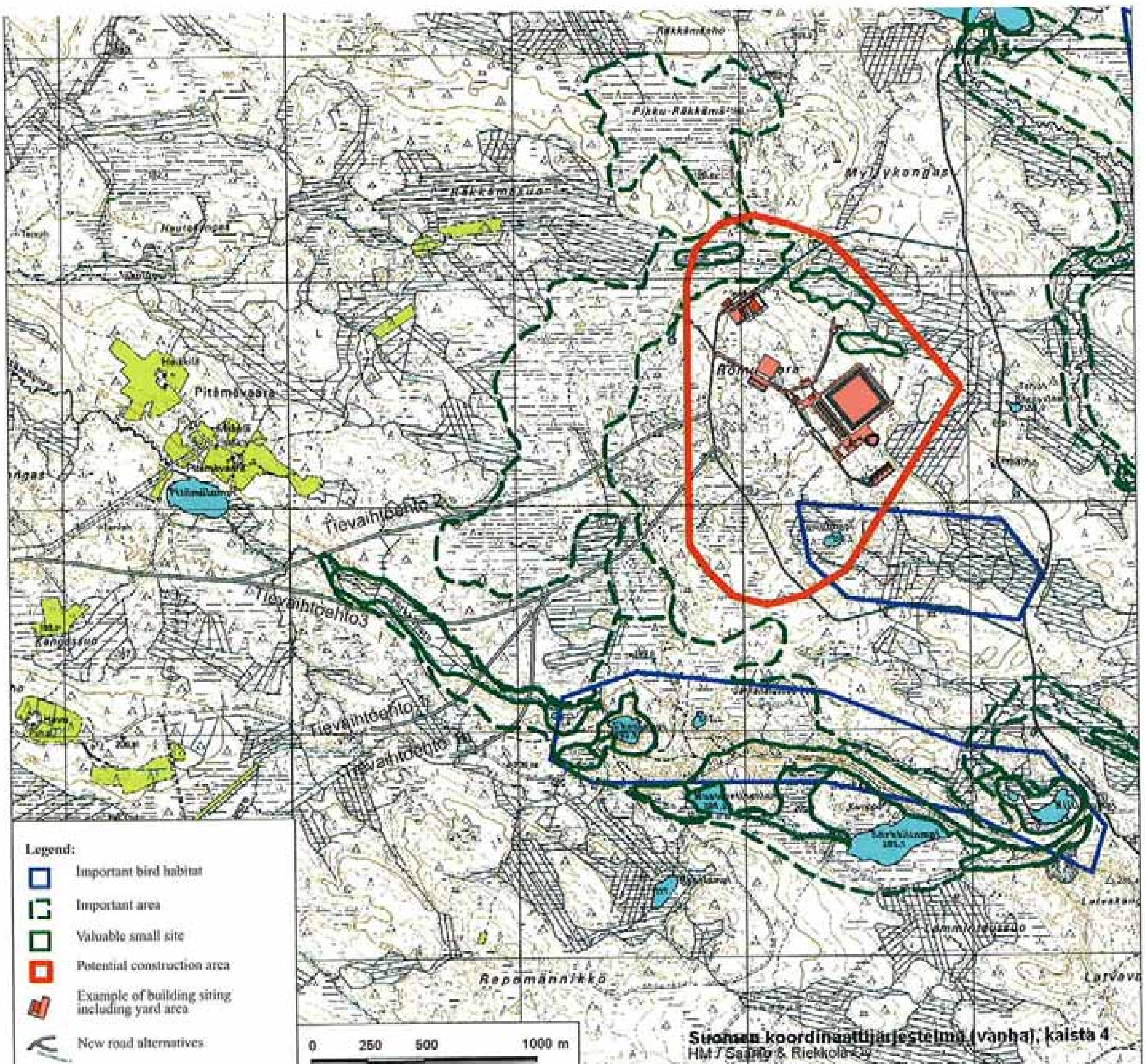
Terrestrial bird species are fairly abundant. The most locally valuable areas for waterbirds are at the eastern shoreline of the cape and the lake. Bird activities within the immediate vicinity of the power plant are modest due to the actions of man (Yrjölä 1997).

Romuvaara

The rock type of the Romuvaara bedrock is migmatite gneiss cut through by migmatite and granodiorite veins. The Romuvaara terrain at Kuhmo is typical of the forest and swamp environment at Kainuu. Except for a network of forest roads, there are few cultural features.

An inventory carried out in the area (Siitonen and Ranta 1997b) found no nationally endangered plant species. In Kainuu two endangered species were found: Early Marsh Orchid (Dactyllorhiza incarnata) and Epilobium davuricum. Additionally, other rare, particular or otherwise noticeable plant species and mushrooms were found. Species found in lush and damp places were particularly notable. Several locally significant natural objects, such as fen-like swamps and damp sections along brooks, were bounded within the area. The most noticeable natural object is the swamp and forest area connected to the Särkkä ridge formation.

The area is rich in fowl and species inhabiting old forests. There are few birds in the potential construction area (Yrjölä 1997).



Map 8-3. Romuvaara, potential construction area for superterranean functions, alternative road sites, an example of siting and natural features.

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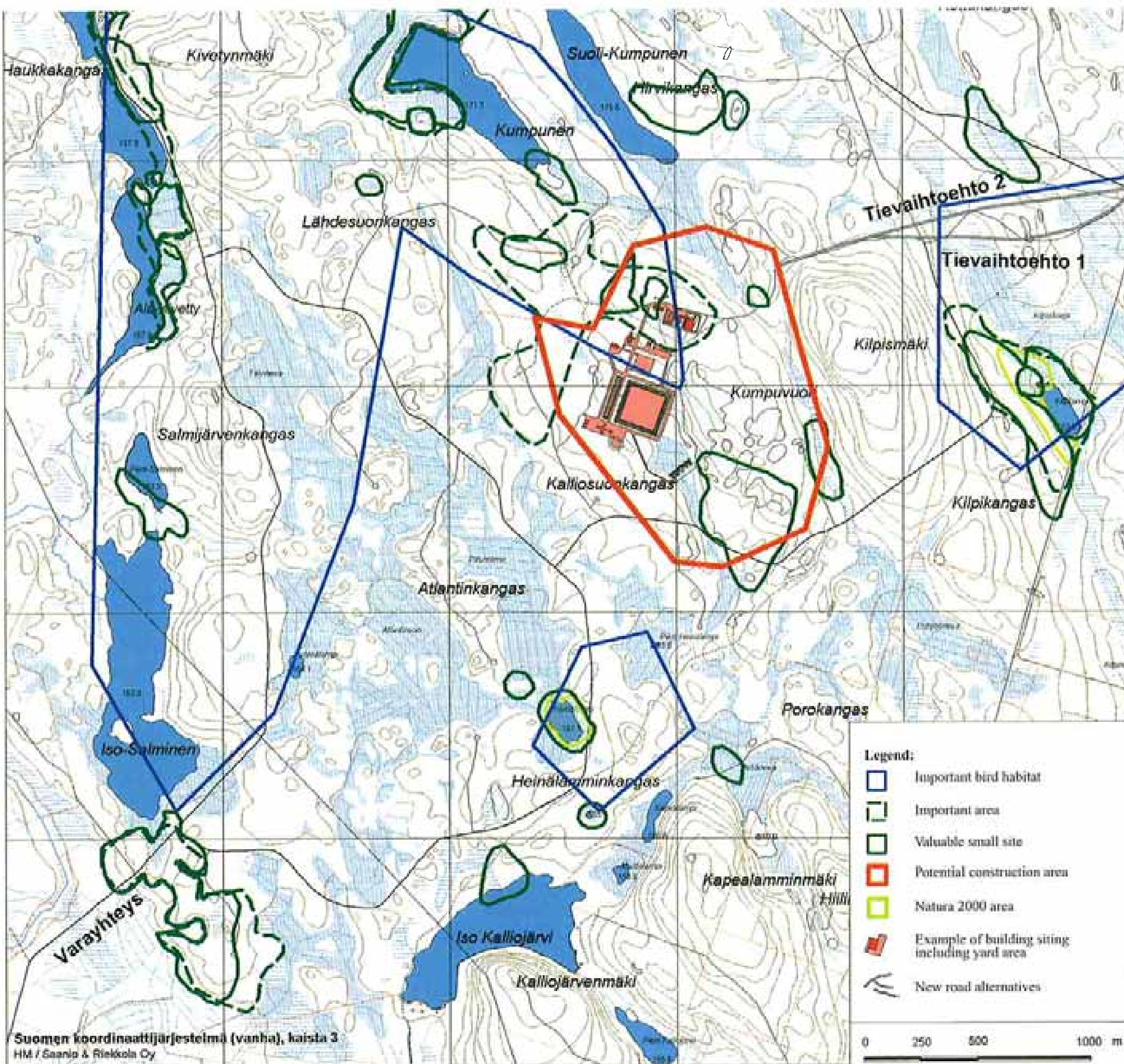
Kivetty

The dominate rock types of the Kivetty area are granite and porphyric granodiorite. The area is typical of the forest environments found in central Finland. Besides commercial forests, the area is characterised by numerous small lakes, ponds and swamps mainly ditched. An inventory carried out in the area (Siitonen 1996) found no nationally endangered plant species. In the former province of Central Finland, four species of vascular plants and one lichen were classified as requiring close observation. Several locally valuable biotopes and other natural objects were found within the area. Typical of the small local objects are spots of an old forest, lush stands, swamps that have remained in their natural state and minor waterways. Of these, Kilpilampi and Heinälampi are part of the EU's Natura 2000 network (draft 20 August 1998).

Kivetty has plenty of fowl and species inhabiting older forests. Rare and disappearing species such as the Black-throated Diver (Gavia arctica) and Red-throated Diver (Gavia stellata) are to be found among the species of waterbird at Kivetty (Yrjölä 1997).



Map 8-4. Kivetty, potential construction area for superterranean functions, alternative road sites, an example of siting and natural features.

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8.2.2 Impact on air

Excavation, crushing, stockpiling

During the investigation phase, bedrock will be excavated at ground level for approximately one month and during the construction phase for a period of 6–10 months. This surface excavation will be carried out for the construction of buildings, roads and yards. Crushing during the construction phase will be carried out for 2–4 months over 2–4 periods. During the operational and ecommissioning phases blasted rock will be crushed for approximately one month every other year. Excavation and crushing will not be carried out at night.

The sound of blasting in surface excavation can be heard at a distance of one kilometre, in coastal areas possibly 2 kilometres away, depending on wind conditions (LT-Konsultit Oy 1998). Dust released into the air by surface blasting can be observed at distances of a few hundred metres in the wind direction. Considering the duration and timing of excavation, as well as the size of the impact area, there are no significant environmental effects.

The audibility of underground explosion sounds has been assessed using comparisons from mines at equivalent depths. In mines, larger quantities of explosives are used in more open chambers, creating a more powerful sound source. The sounds created by excavations for the final disposal facility will be inaudible outside the site (Tolppanen & Kokko 1998). The dust released by underground blasting will have no effect at the ground surface.

Noise created by the crushing plant has been assessed according to the Finnish National Road Administration's guidelines. The Noise Abatement Act's design value (outdoors, daytime) for residential areas is 55 dB(A). A 5 dB(A) adjustment is made for impact noise measurements. The Finnish National Road Administration (Tielaitos 1993) specifies protection distances from crushing plants according to 50 dB(A). The noise level for normal conversation is 60 dB(A) and 40 dB(A) for a quiet residential area at night (Uudenmaan ympäristökeskus 1997).

The forest area begins at a distance of approximately 100 metres from the crushing plant. The noise level falls below 50 dB(A) at a distance of 500 metres and below 40 dB(A) at a distance of 1,200 metres. Distances have not taken the attenuating effects of structures or topography into account (Tielaitos 1993).

The rock pile is assumed to be 10 metres in height. If the blasted rock is situated at a distance of 50 metres from the crushing plant, the noise level will already fall below 50 dB(A) at a distance less than 200 metres and below 40 dB(A) at a distance a bit more than 500 metres (Tielaitos 1993). If, besides the blasted rock, the combined effects of forest and topography are taken into account, it is likely that the noise level will fall below 40 dB(A) at a distance of 500 metres from the crushing plant. In Loviisa and Eurajoki, the largest possible distance from the crushing plant to the shore or to cottages is approximately 500 metres. In Äänekoski, the crushing plant can be located so that the distance to the nearest summer cottage would be no less than 750 metres; in Kuhmo the equivalent figure is 1,400 metres (LT-Konsultit Oy 1998).

The dust effects of a portable crushing plant were assessed using design values specified by the government and the Finnish National Road Administration's guidelines. Crushing is carried out in warmer seasons, and dust release is reduced by sprinkling. In winter, tarpaulins or casings would shield dust sources. The protection distance is 300 metres. If the dust were limited only when necessary, the protection distance would be 500 metres. Protection distances have not taken into account the shielding effects of vegetation (LT-Konsultit Oy 1998, Tolppanen 1998).

Heaped backfill material must be protected with tarpaulins against falling leaves and needles. The covering would simultaneously present the release of dust from rock piles (Tolppanen 1998). Greater fuel quantities, excavation of all tunnels at one time and the construction of the vehicular access ramp would increase the size of the rock heap. For example, extending the operational life of existing power plants from 40 to 60 years would increase the size of the rock pile by approximately 50%.

The environmental impacts of crushing and stockpiling are not significant due to the short duration and the small size of the impact area.

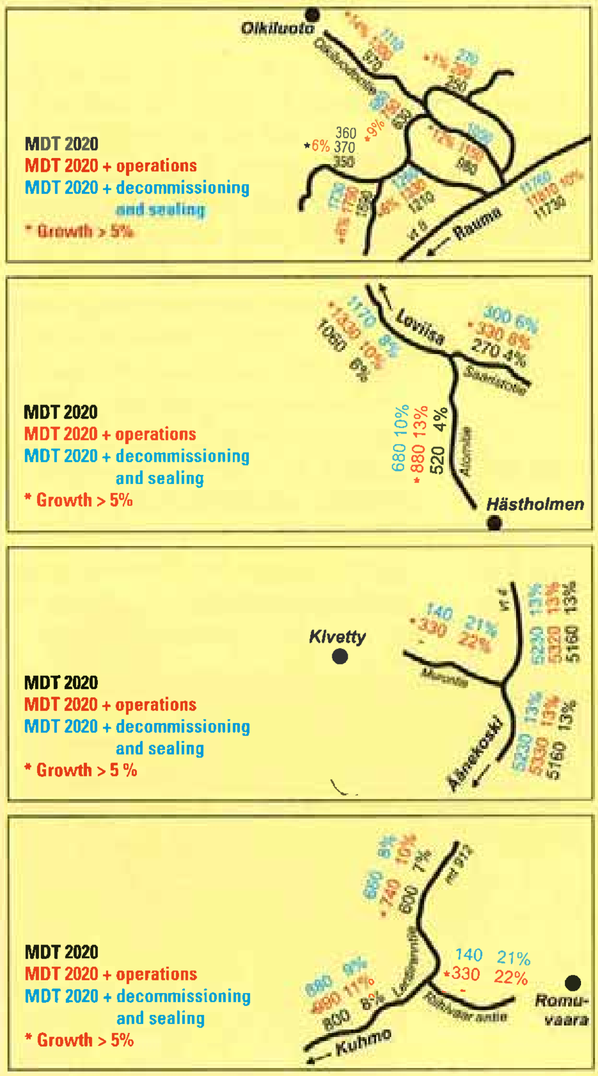
The increase of natural radon gas caused by the excavation of tunnels has been assessed in measurements by the Radiation and Nuclear Safety Authority and Posiva on the basis of test borings (Vesterbacka & Arvela 1998). It was estimated that distributions from spotlike sources would follow Gaussian distribution, achieving higher concentrations than would normally occur in reality. Within adjoining tunnels, these concentrations would, however, remain so low that their differentiation from radon concentrations in the outer air is practically impossible; for that reason significant environmental effects are not created.

Buildings

Facilities at Olkiluoto and Hästholmen would require their own heating plants at the latest during the decommissioning phase of the power plants. At Kuhmo and Äänekoski, the heating plant would be constructed simultaneously with other facility buildings. The impact of heating plant has been assessed by spread modelling for different distances and weather conditions. Additionally, concentrations and emissions have been calculated for several impurities. The results obtained were compared to limit and background concentrations (LT-Konsultit Oy 1998).

The heating plant's capacity is 9 megawatts and it consumes about two tanker trucks of light fuel oil per month. Source data was selected to ensure that calculated concentrations and emissions are overestimated. In relation to fuel consumption, emissions are equivalent to oil heating for small houses. Concentrations do not approach limit, even in poorer weather conditions (LT-Konsultit Oy 1998). For that reason the heating plant does not create a significant environmental impact.

The noise level at Olkiluoto was most recently measured in 1996 and at Hästholmen in 1998. Measurements show that noise levels in the power plant areas vary between 46–57 dB(A) and fall below guidance values outside it (for example, the average background noise level of Atomitie road at Loviisa was 43 dB(A)). Background noise at Kivetty and Romuvaara results from sporadic man-made and natural sounds. Measurements show that this kind of natural noise can vary between 20–40 dB(A). Noise from the final disposal facility has been assessed based on literature and empirical noise measurements. Noise is produced primarily from the heating plant's flue gas exhaust fan and tunnel ventilation. Higher fuel quantities, the excavation of all tunnels at a time and the construction of a vehicular access ramp would increase the required ventilation. Depending on the situation, the noise level in the facility area is 35–55 dB(A) (LT-Konsultit Oy 1998). This falls below the guidance value; consequently there are no environmental impacts, even in the plant area.



At Olkiluodontie road, the largest increase (34%) equals one-sixth of the present power station's additional traffic required by annual refuelling and maintenance outages. Traffic growth on other roads is insignificant.

From the Atomitie intersection to the centre of Loviisa, the greatest increase (25%) equals the traffic from Atomitie to the end of Saaristotie road. The additional traffic in the centre of Loviisa and at the end of Saaristotie road is insignificant.

At its busiest, a car would travel along Murontie road every third minute. In practise there would be no night-time traffic. The effect of additional traffic would disappear immediately when arriving at highway 4.

At its busiest, a car would travel along Riihivaarantie road every third minute. In practise there would be no night-time traffic. The increase would account for an approximately 25% growth in traffic along Lentiirantie road (912). The effect is insignificant in the centre of Kuhmo and after the Lentiira built-up area.

Figure 8-1. Growth of traffic volumes. Share of heavy traffic is shown as a percentage.

Traffic

Traffic volumes created during the various phases of the project were compared with the Finnish National Road Administration's traffic forecasts (LT-Konsultit Oy 1998). At Loviisa, blasted rock is transported a short distance along a public road (Atomitie) to the current stockpiling area, while elsewhere the transport of blasted rock remains within the plant area. The percentage increase in light automobile traffic primarily resulting from work trips would be approximately 70% in Loviisa and approximately 80% in other municipalities. Conservative traffic volume estimates assume that every employee travels in his or her own car. Heavy traffic includes service and guest traffic as well as the transport of construction materials, equipment, blasted rock, bentonite, fuel and canisters. It has been assumed that additional traffic will be divided at present rates in relation to the main road network.

At its maximum (operational phase) the mean daily traffic (MDT) in Loviisa will be approximately 360 vehicles per day on Atomitie road and approximately 330 vehicles per day on Saaristotie road. An equivalent effect (330 vehicles/day) is observable at Olkiluodontie road in Eurajoki, Murontie road in Äänekoski and Riihivaarantie road in Kuhmo (Figure 8-1). With the implementation of the project, the gravel roads Murontie road and Riihivaarantie road would have to be paved to prevent the spread of dust.

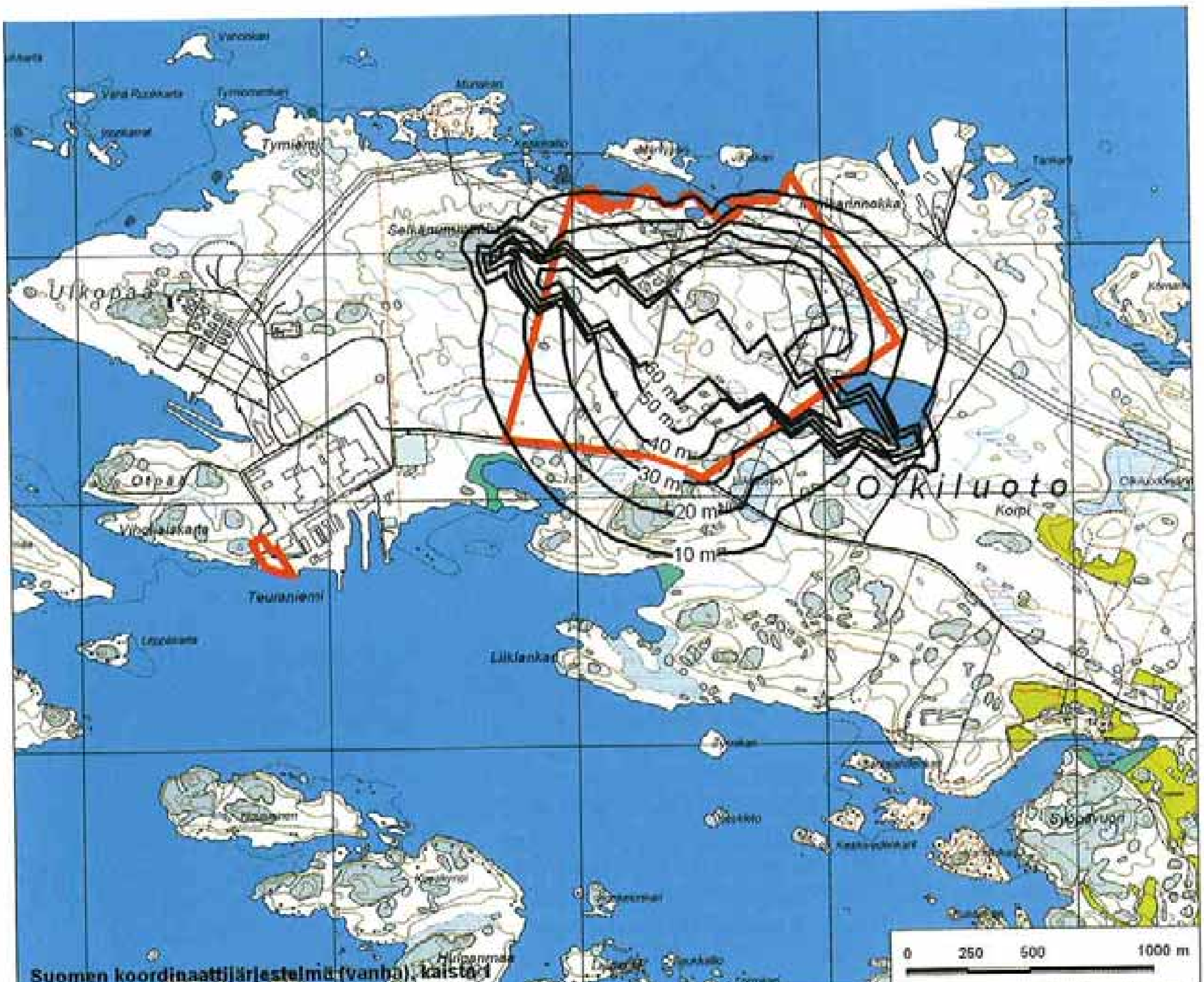
Eight different airborne emissions were calculated based on the Technical Research Centre of Finland's (VTT) emissions factors and the Finnish National Road Administration's vehicular distributions (LT-Konsultit Oy 1998). The emissions caused by traffic at various phases was compared to VTT forecasts. It has thus been ascertained that the project would, at the most lead, to an increase of a few percentage points in overall traffic emissions in the area. This has no significance from the aspect of local air quality.

Concentrations of oxides of nitrogen (NOx) were assessed for two extreme cases (LT-Konsultit Oy 1998). Concentrations were calculated according to models developed by the Finnish National Road Administration and the Ministry of the Environment. The results obtained were compared with the government's hourly guidance values. The impact of the project on road surroundings was ascertained as insignificantly minor. Concentrations clearly remained below guidance values.

Traffic-related noise calculations were performed with a software program developed by the Ministry of the Environment. Calculations assumed a driving speed of 80 km/h, ignoring the attenuating effects of topography and buildings (LT-Konsultit Oy 1998).

At its greatest, the noise zone along Olkiluodontie road at Olkiluoto and Atomitie road at Loviisa would grow by approximately 10 metres (from 40 metres to 50 metres). Equivalently, the noise zone along Murontie road in Äänekoski and Riihivaarantie road in Kuhmo would grow by approximately 20 metres (from 10 metres to 30 metres). Traffic would cause minor noise effects during the construction and operational phases at the aforementioned locations. On other roads (for example, highways 4 and 8, in the centre of Loviisa or Lentiirantie road), the effects, as during the project's investigation and decommissioning phases, will be insignificant. Due to the limited widening of the noise zone and the concentration of traffic during daytime hours, no significant environmental impact will be created.

In Kuhmo, the closest new alternative roads would pass within 600 metres of the houses at Pitämävaara. As far as Pitämävaara's residents are concerned, there are no appreciable differences between the alternatives because the noise level will fall below the guidance value at a distance of approximately 30 metres from the road, even for heavier traffic. Excavating all the tunnels at one time and excavating the vehicular access ramp would slightly increase traffic at the end of Atomitie road in Loviisa during the construction phase if blasted rock were transported to the



Map 8-5. Estimated drawdown of groundwater level at Olkiluoto in metres for an example of siting. There are no groundwater-influenced natural objects near the area. The potential construction area is shown in red.

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current stockpiling area. In this case as well, the additional traffic created will be insignificant from the aspect of local air quality (LT-Konsultit Oy 1998).

8.2.3 Impact on water

Open tunnels

When the tunnels are open, pumping of leaking groundwater lowers groundwater table in the vicinity of tunnels. The reduction was assessed by comparing the existing situation with analytical calculations and experiences in other tunnels (Ahokas & Sallasmaa 1998). Calculations were performed for various phases and different fracture zones. The raw data for calculations was selected to exaggerate values. Tests carried out since the 1980s have provided an accurate idea of groundwater levels and their fluctuations at the investigation sites.

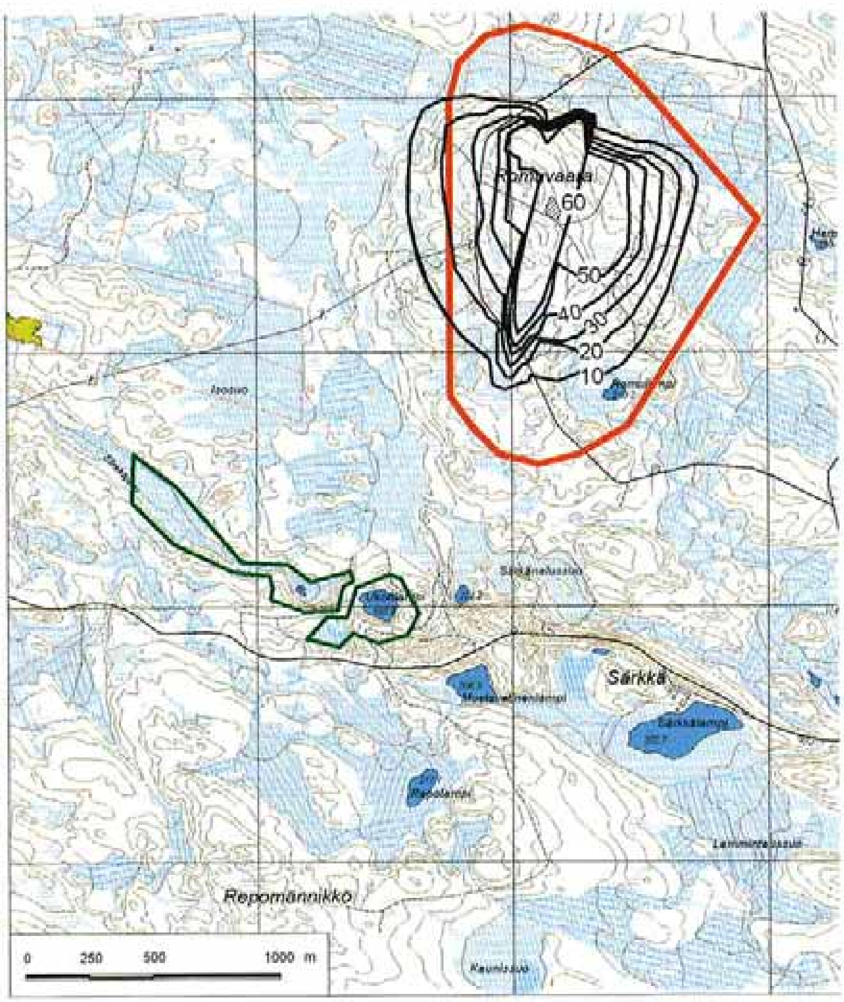
Excavations have caused individual wells to dry up at distances ranging between 0.5–2 kilometres. Desiccation has occurred in certain directions along fracture zones. The effect has been so localised that there have been cases of two adjoining wells in which one had dried out and the other was unaffected. In contrast to mines, final disposal facilities are grouted with cement to minimise the effects of the final disposal facility on groundwater levels and consequently wells. Posiva provides compensation for possible damage of dried well.

The enclosed maps (Maps 8-5, 8-6, 8-7, 8-8) illustrate how fracture zones could affect the shape of the groundwater drawdown. If all facilities are excavated at Hästholmen, the sea will limit the edge of the groundwater drawdown. If the facilities at Loviisa are excavated on the mainland side, the reduction pattern will extend, as in other municipalities, slightly less than one kilometre outside the shafts. Following the sealing of the tunnels, the groundwater will return to its former level within a few years. Excavation of all tunnels at one time, the excavation of a vehicular access ramp instead of a shaft, or the additional tunnels required by an increase in spent fuel quantities would increase the strongest drawdown.

Most plants take their water from surface water above the groundwater level. In this respect the groundwater level does not affect plants. For example, there have been no complaints concerning plants at Finnish mining sites.

At Eurajoki there are no groundwater-influenced natural objects within the potential construction area (Map 8-5). The drawdown could affect the vegetation distribution locally, but significant impacts at Olkiluoto are not expected.

At Kuhmo (Map 8-6), a groundwater-influenced area in the vicinity of Särkkäharju is located 600 metres from the edge of the potential construction area. Placing the shaft in extreme south-western corner of the potential construction area could extend drawdown to the edge of the spring area. In all probability, the facilities would, however, be situated so that drawdown could extend to the spring area only in the direction of a possible fracture zone. In which case the drawdown might affect local vegetation distribution in the spring area: the number of marsh plants would decrease while others would increase. Significant regional effects are also not expected at Romuvaara.



Map 8-6. Estimated drawdown of groundwater level at Romuvaara in metres for an example of siting. The groundwater-influenced Särkkä spring area is marked in green and the potential construction area is shown in red.

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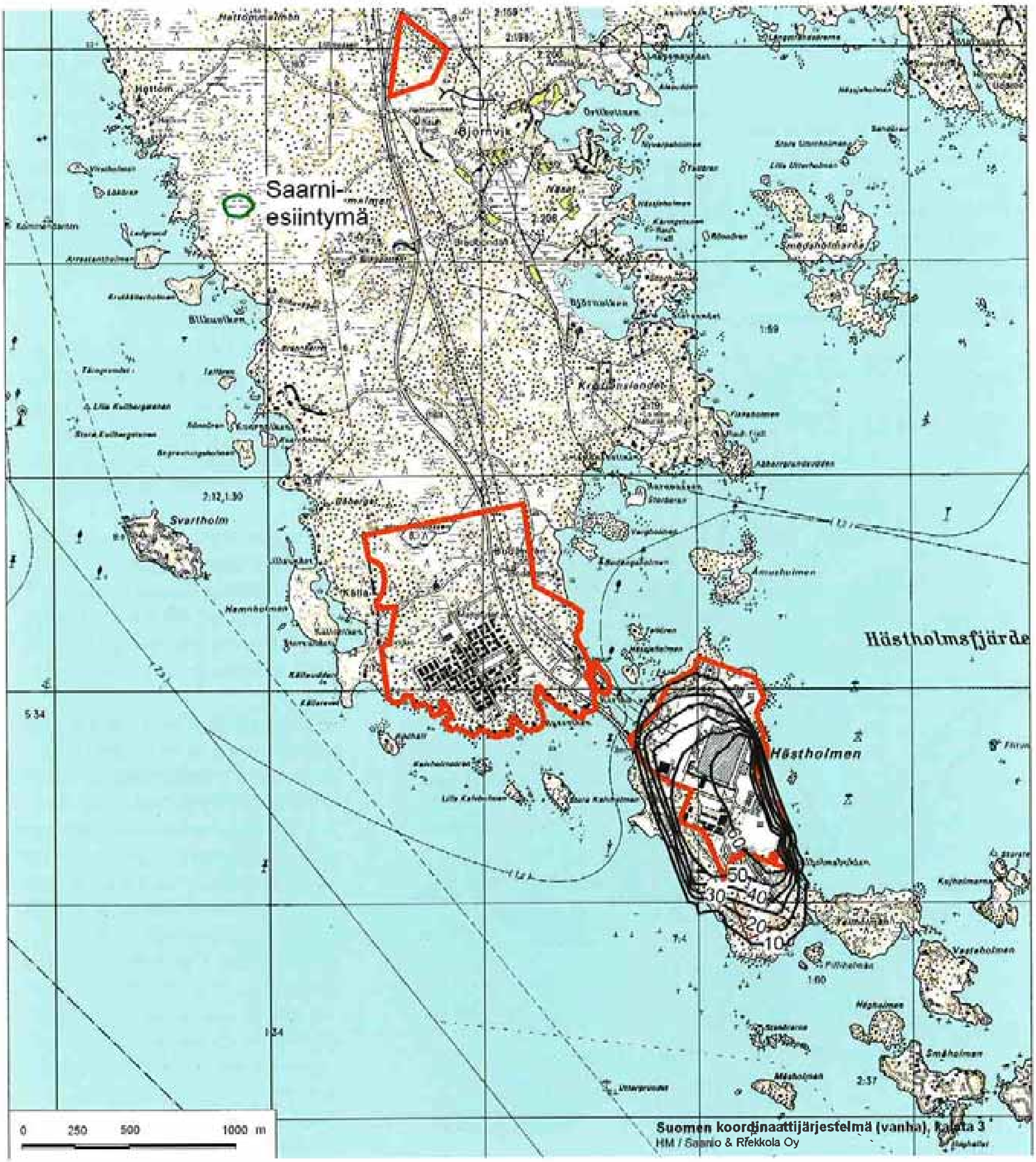
In Loviisa, (Map 8-7), the only possible groundwater-influenced natural object near the potential construction area is the ash grove at Blikumalmen, located 1,6 kilometres from the edge of the potential construction area. The drawdown could also extend to the ash grove if tunnels are excavated on the mainland side and the fracture zone connects the grove with the tunnels. In which case the drawdown might affect the local vegetation distribution in the grove: the number of marsh plants would decrease while others would increase. Significant regional effects are not expected at Hästholmen.

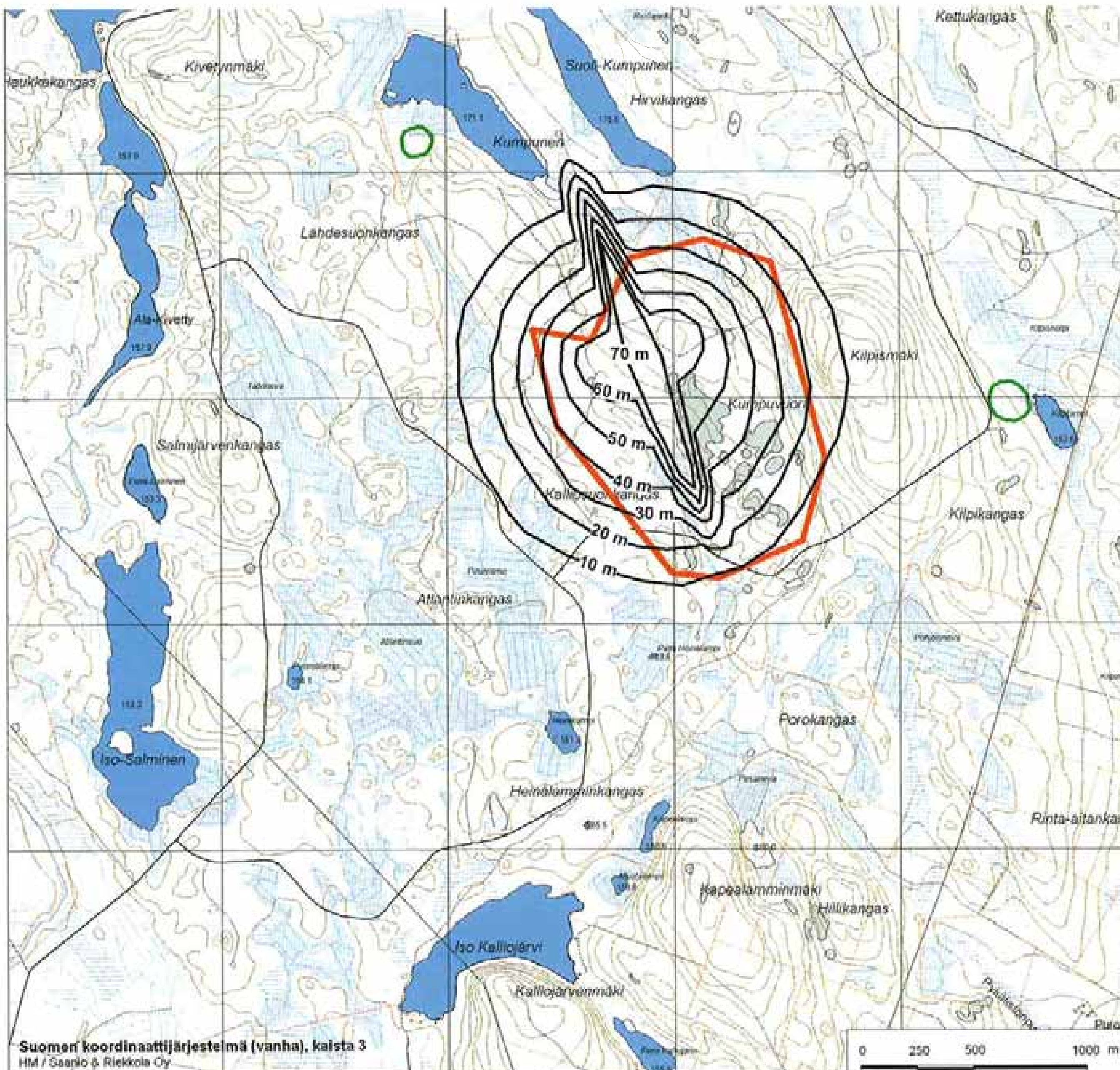
In Äänekoski, (Map 8-8), the groundwater-influenced Kilpilampi and Kumpunen spring surroundings are located one kilometre from the edge of



Map 8-7. Estimated drawdown of groundwater level at Hästholmen in metres for an example of siting. The groundwater-influenced ash grove is marked in green and the potential construction area is shown in red.

the potential construction area. The drawdown could also extend to them if tunnels are excavated on the mainland side and the fracture zone connects the springs with the tunnels. In which case the drawdown area might affect local vegetation distribution in the spring area: the number of marsh plants would decrease while others would increase. Significant regional effects are not expected at Kivetty.

At Olkiluoto and Hästholmen, final disposal facilities (VLJ repository) have been excavated for low and medium level waste at depths of approximately 100 metres. On the other hand, facilities for spent fuel will be constructed at depths of approximately 500 metres. At Olkiluoto, it is probable that groundwater in the vicinity of VLJ repository will maintain its present level. At Loviisa, there will also be no changes in groundwater levels in the vicinity of VLJ repository if the new tunnels are excavated on the mainland side. At Hästholmen, the groundwater level would, however, fall if the final disposal facility were also placed on the island. In which case the leaking water pumped from tunnels deep in the ground would reduce the amount of water leaking into VLJ repository. Because VLJ repository is open, the changes in flow direction caused by the final disposal facility for spent fuel would have no effect on the VLJ repository itself.



Map 8-8. Estimated drawdown of groundwater level at Kivetty in metres for an example of siting. The groundwater-influenced Kilpilampi and Kumpunen areas are marked in green and the potential construction area is shown in red.

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The VLJ repository may be sealed before the deeper repository. Unless the facilities are located close to each other, there will be no effects on VLJ repository. The groundwater flow at VLJ repository may, however, be different if the repositories are in closer proximity. Deep tunnels that must be kept open, and particularly nearby open shafts may direct groundwater flows from VLJ repository to open tunnels. If the final disposal repository for spent fuel is closed before the VLJ repository, the situation will return to its original state within a few years.

Water supply

The greatest quantities of water will be required during the construction phase (150 m³/day). During the operational phase the consumption will be 55 m³/day. At Kivetty, water is acquired from the Konginkangas municipal water network (Niini et al 1998), and at Olkiluoto and Hästholmen from power plant networks. At these locations, present capacities are sufficient to meet water needs.

At Romuvaara, preliminary site investigations for water supply carried out in 1996 and municipal records for groundwater areas (Niini et al 1998) were used as a basis to ascertain water supply. The Särkkäharju groundwater area is best suited to water supply. A fenced water intake plant, or drain pipe well would be constructed, reached by a narrow service road. "Groundwater area" signs would mark the water intake plant area. The theoretical yield of the ridge is more that ten times the required quantity; consequently the probable environmental impact will be minimal.

Oil spills

In crushing, the risk of oil contaminating the groundwater is very low because the crushing plant is powered by electricity (Tolppanen 1998). If the electricity were produced by aggregate, the fuel would be in double canisters.

The impact of possible oil spills on the groundwater was assessed with the assistance of areas' municipal records (LT-Konsultit Oy 1998). The need for protection was studied with the help of the Oulu region road authority.

Together, the light fuel oil used for heating and diesel fuel used for vehicles require about two tanker trucks of oil per month. The quantities of oil arriving at the plant are relatively small, and any possible leaks in yards would be immediately discernible.

There are no groundwater areas suitable for public use within the potential construction areas, at Olkiluodontie road, at the roads between Loviisa and Hästholmen, or at Murontie road at Kivetty. An oil spill would not cause a risk to public water use at Eurajoki, Loviisa or Äänekoski.

In Kuhmo, there are no groundwater areas suitable for public use within yard areas. The present Riihivaarantie road and its continuation Sarvijärventie road, however, cross over two groundwater areas suitable for public water supply. For the time being, there are no plans to bring them into use. The risk of groundwater contamination caused by the traffic volumes to and from the site are so low that, for example, the Oulu region road authority does not consider the construction of an equivalent road for groundwater protection necessary. An oil spill would not cause even a small risk at the Huosiuskangas and Särkkä groundwater areas if they were avoided or groundwater protection was built in roadside ditches.

Sanitary sewage

The final disposal facility would produce 30 m³ of sanitary sewage at day. At Kivetty this would be fed into the Konginkangas wastewater treatment plant (Niini et al 1998); at Hästholmen and Olkiluoto it would be fed into the power plants' own wastewater treatment plants. Consequently, sewage does not create a significant environmental impact. Current capacities at Konginkangas and Olkiluoto are sufficient to satisfy filtration needs. Treatment plant capacity at Hästholmen will be increased.

A biochemical treatment plant would be built at Romuvaara. The effects of treated sewage discharge can be compared to the current situation, information concerning which has been obtained from the Kainuu Environmental Centre, Kainuun Työvoima- ja elinkeinokeskus ("Kainuu Labour and Business Centre") and the city of Kuhmo (Niini et al 1998). Inland treatment plants do not have denitrification, even though nitrogen is reduced by 30% during filtration. Ninety-five per cent is removed from filtered substances. The residue is equivalent to the untreated sewage produced by a 4–5 member household living outside the municipal sewage system. Treated wastewater would be discharged at the nearby swamp, from where it ends in the River Myllyjoki that flows into Lake Kalliojärvi. In practice, treated wastewater would not affect the quality or use of the River Myllyjoki and Lake Kalliojärvi. For that reason, sewage does not create any significant environmental impact.

Encapsulation

All water used in the controlled area in encapsulation plant is treated internally within the plant using cleaning pulp. The used cleaning pulp is finally disposed and filtered water is discharged to waterways (Niini et al 1998). Cleaning water from the controlled area does not create significant environmental impact.

Construction waste and other waste management

During the construction and operational phases, small quantities of normal hazardous industrial waste are produced. These include waste oil, solvents, batteries, fluorescent tubes, waste paper and domestic waste whose properties do not appreciably differ from other equivalent waste. Hazardous waste is placed in interim storage within the plant in appropriate facilities, after which it is transported either to the municipality's collection point for hazardous waste or to a hazardous waste processing plant. Domestic waste is sorted for recycling: paper, wood, glass, as well as possibly waste food and reusable plastic and scrap metal. Waste is utilised for practical applications. Substances without effective value are transported to the municipal refuse tip.

Solid waste materials created in connection with construction at Olkiluoto, such as unnecessary quantities of earth and demolished concrete components, are sorted at the plant's current dumping area. Other municipalities would require their own dumping areas. Water from the dumping area is collected in sedimentation basins and inspection pools, from which it is led to discharge ditches by way of measuring and inspection wells. The water does not create significant environmental impact.

Excavation, crushing, stockpiling

Blasted rock may contain minor residues of explosives such as nitrogen compounds (nitrite and nitrate). Possible residues are diluted in the tunnel's bilge water that is fed to a sedimentation basin at the final disposal facility. The pool contains oil separation booms. The treated water is pumped to the surface and led to local waterways, and does not create significant environmental impacts. Explosive cartridges and the sprinkling of the rock heap prior to transport will reduce residue concentrations.

Blasted rock and crushed rock are mineral material that poses no threat to the environment. In Finland, there are no observations that rock heaps could cause damage to groundwater. Waters from rock heaps are fed to waterways through settling basins (Niini et al 1998).

Excavation, crushing and stockpiling have no effects on groundwater or surface water.

Earthmoving work and asphalting

The effects of earthmoving works on surface water were assessed using field inspections and maps (LT-Konsultit Oy 1998). At Kivetty and Romuvaara, the surface water network is almost in its natural state. At Olkiluoto the surface water network is dispersed and its natural state has been altered. There are no actual surface water channels in the potential construction area in Loviisa.

The construction of the facility will alter the absorption characteristics of the surface water when water flowing from roofs and paved yard areas (total 3 ha) is fed into waterways. Runoff directions from drainage areas can be maintained with drum pipes, even if runoff areas themselves change. Regardless of the scope of operations or their placement, the facility will not significantly influence surface water flows.

Canister materials

Radiation emitted from finally disposed radioactive substances is described in Chapter 8.4.3. Environmental risks caused by canister materials and the chemical properties of their contents have been studied in the same way as in safety analyses of radiation effects (Raiko & Nordman 1999). From the aspect of environmental impact, significant concentrations of elements in well water were assessed conservatively by assuming, among other factors, that the canister had completely lost its integrity after 10 000 years. Calculations demonstrate that concentrations would clearly fall below the limits established for domestic water. As a conclusion, it was ascertained that chemical toxicity is not a significant factor in the final disposal of spent fuel.

8.2.4 Impact on organic nature

Radioactive substances

According to the International Commission on Radiological Protection, radiation protection for humans shall ensure that other species and or their natural balance shall not be endangered (ICRP 1991). The International Atomic Energy Agency has reached the same conclusion, with the addition that certain ecological conditions could be marked as exceptions (IAEA 1992a). The effects of radiation on nature are treated in connection with health effects in Chapter 8.4.3. Ecological conditions in the potential construction area are described in the following section.

Utilised areas

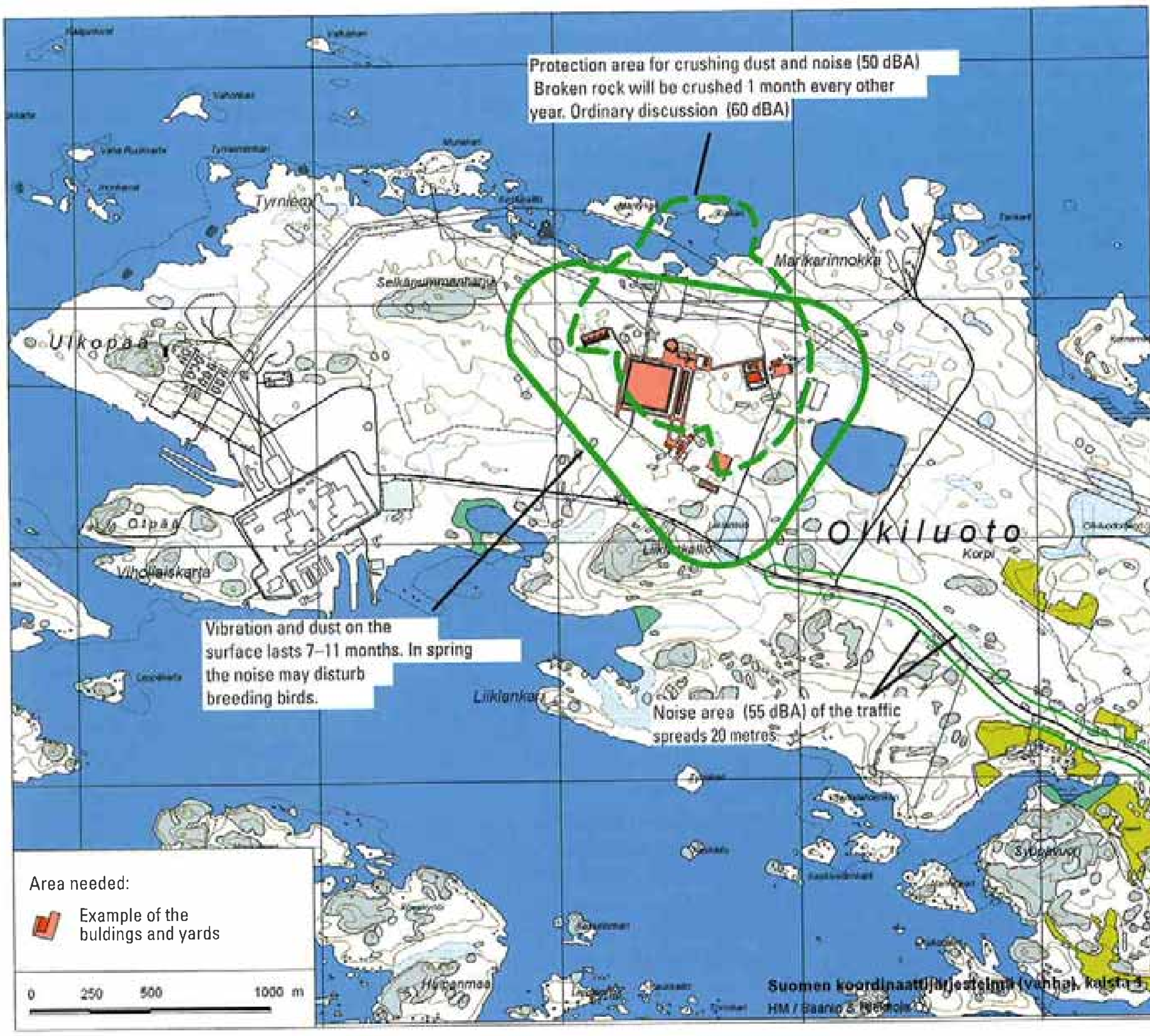
During 1996–1997, nature inventories and ornithological studies were carried out at all investigation areas (Siitonen 1996, Siitonen & Ranta 1997a, Siitonen & Ranta 1997b, Siitonen 1997, Yrjölä 1997). In Kuhmo, a separate study was carried out for road alignments. The investigated land areas were 8 km^2 at Eurajoki, 11 km^2 at Loviisa, 19 km^2 at Äänekoski and 17.75 km^2 at Kuhmo. The inventoried areas extended 1–2 kilometres outside the boundaries of potential construction areas and also included new stretches of road at Äänekoski and Kuhmo. The evaluations included systematic inventories of flora, biotopes and avifauna, as well as more generalised mapping of other populations. The results of the nature inventories were compared with the facility's preliminary area plan, and the placement of buildings and functions was assessed. Effects were estimated for the construction and operational phases in situations for which the utilised facility area was at its largest 15 ha and road areas in Äänekoski and Kuhmo approximately 10 ha (LT-Konsultit Oy 1998).

At Olkiluoto and Hästholmen no significant natural impacts are expected. There are no provincially or nationally significant objects, Natura 2000 areas or nationally endangered species in the potential construction areas. Area-ecological links remain unbroken. At Olkiluoto, there is one local object and at Hästholmen three local objects that should be taken into account when planning land use within the potential construction area.

During the investigation phase, it would be sufficient at Kivetty and Romuvaara to strengthen the existing gravel roads (Murontie and Riihivaarantie roads) and to build broadens for overtake. At Kivetty, improvements at the intersection with highway 4 could well be carried out at the beginning of the investigation phase.

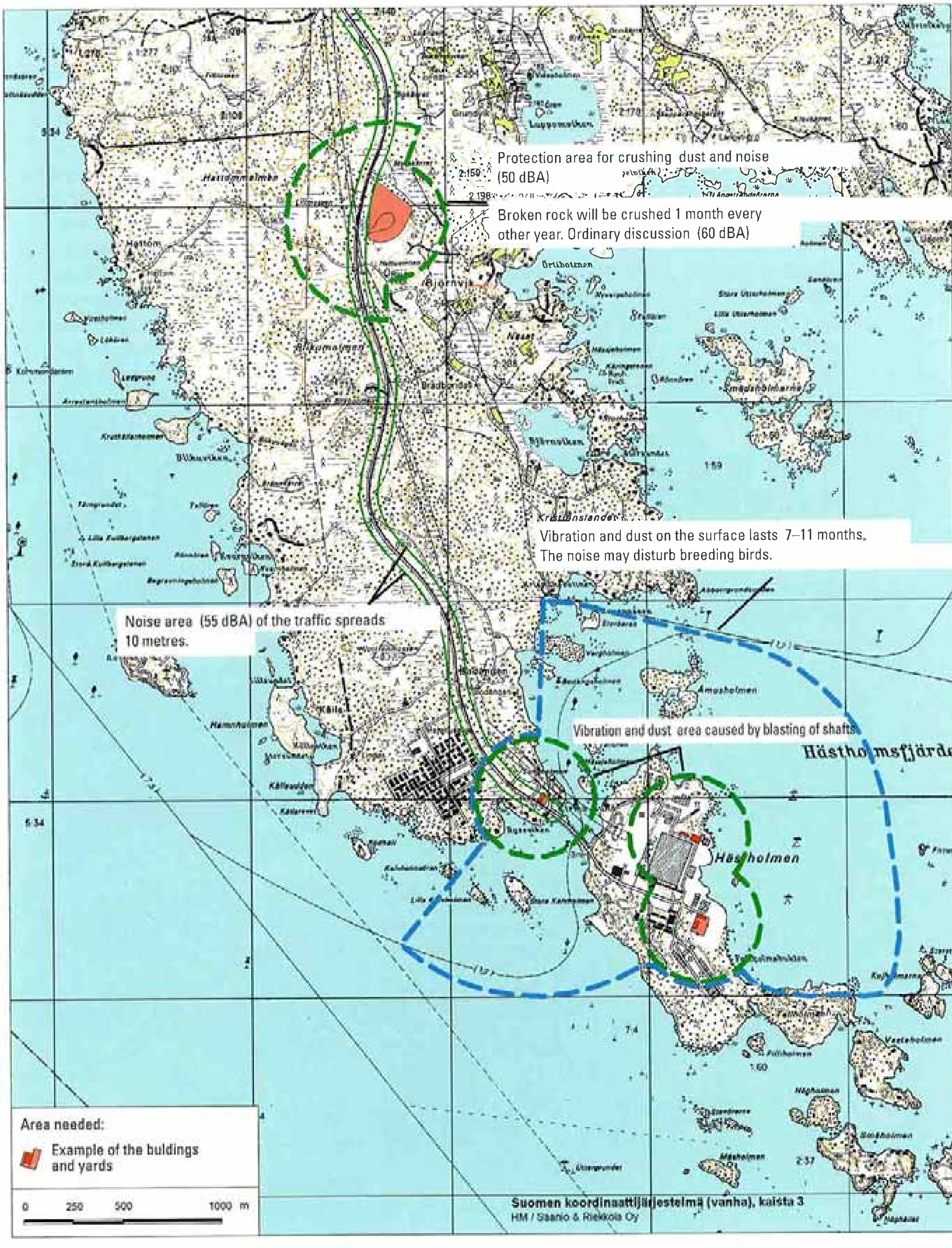
The new road connection at Kivetty and Romuvaara will be built at the beginning of the construction phase. On new stretches of road, the area to be cleared will be 22–40 metres wide and in repaired sections 15–25 metres, depending on topography. New sections of the paved road will be as wide as Äänekoskentie/Lentiirantie road, and the improved section as wide as Liimattalantie/Nurmeksentie road. LT-Konsultit Oy (1998) dealt with the number of landowners in the road area, as well as other road design factors.

At Kivetty, special transport can also use the existing road connection from the southwest. It can remain gravel-surfaced and 6 metres is sufficient for its width. The alternative road bypasses



Map 8-9. The incidence of noise dust and vibration as applicable to an example of siting together with the land area required at Olkiluoto.

Karttakeskus Oy L2633/99



Map 8-10. The incidence of noise dust and vibration as applicable to an example of siting together with the land area required at Hästholmen.

Karttakeskus Oy L2633/99

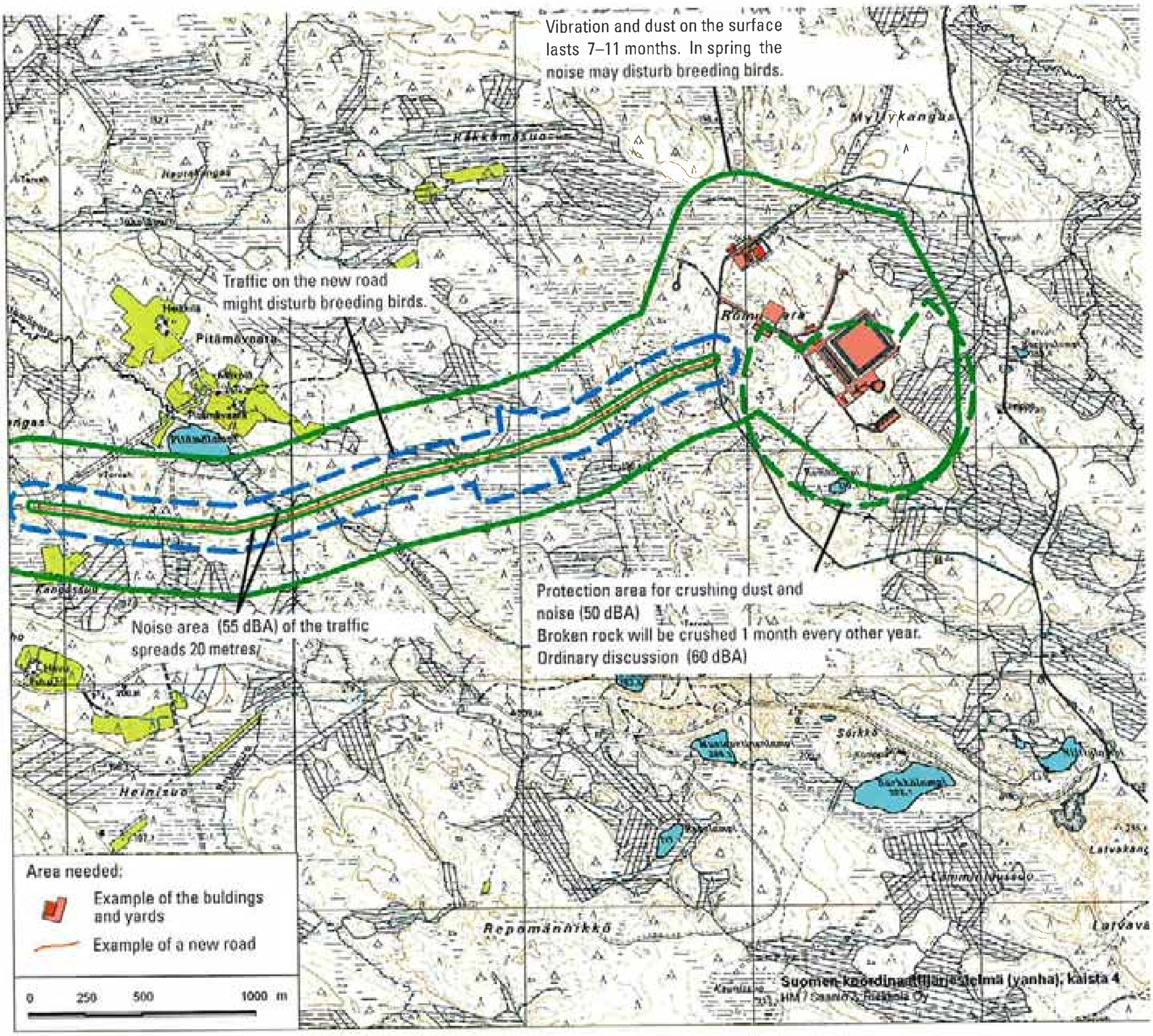
pond Heinälampi. With a small change in alignment, a sufficient distance from the shore would be achieved. This would maintain the pond's natural values.

In the Kivetty road alternative 1 requires slightly less area than alternative 2 because transmission lines and the road would run parallel (Map 8-4). On the other hand, the more northerly alternative 2 can be adjusted to the topography far more successfully.

The amount of cuttings and embankments in alternative 2 is only one-third of those required for alternative 1. The road's overall natural impacts are small at Kivetty.

At Kivetty, the nature in the northern part of the potential construction area is significant at the scale of the investigation area, but in other parts significant natural impacts are not expected. The natural objects in the northern part of the potential construction area should be taken into account.

There are no provincially or nationally significant objects, Natura 2000 areas or nationally endangered species in the potential construction area. Important area-ecological links are not broken. Regarding the alternative roads at Romuvaara, the worst is the improvement of the existing road at the provincially valuable Särkkä ridge, and the second worst is the alternative 3 (Map 8-3) that crosses a spring-influenced swamp. Of the more southern alternatives, alternative 1B is probably supe-



Map 8-11, The incidence of noise dust and vibration as applicable to an example of siting together with land area required at Romuvaara.

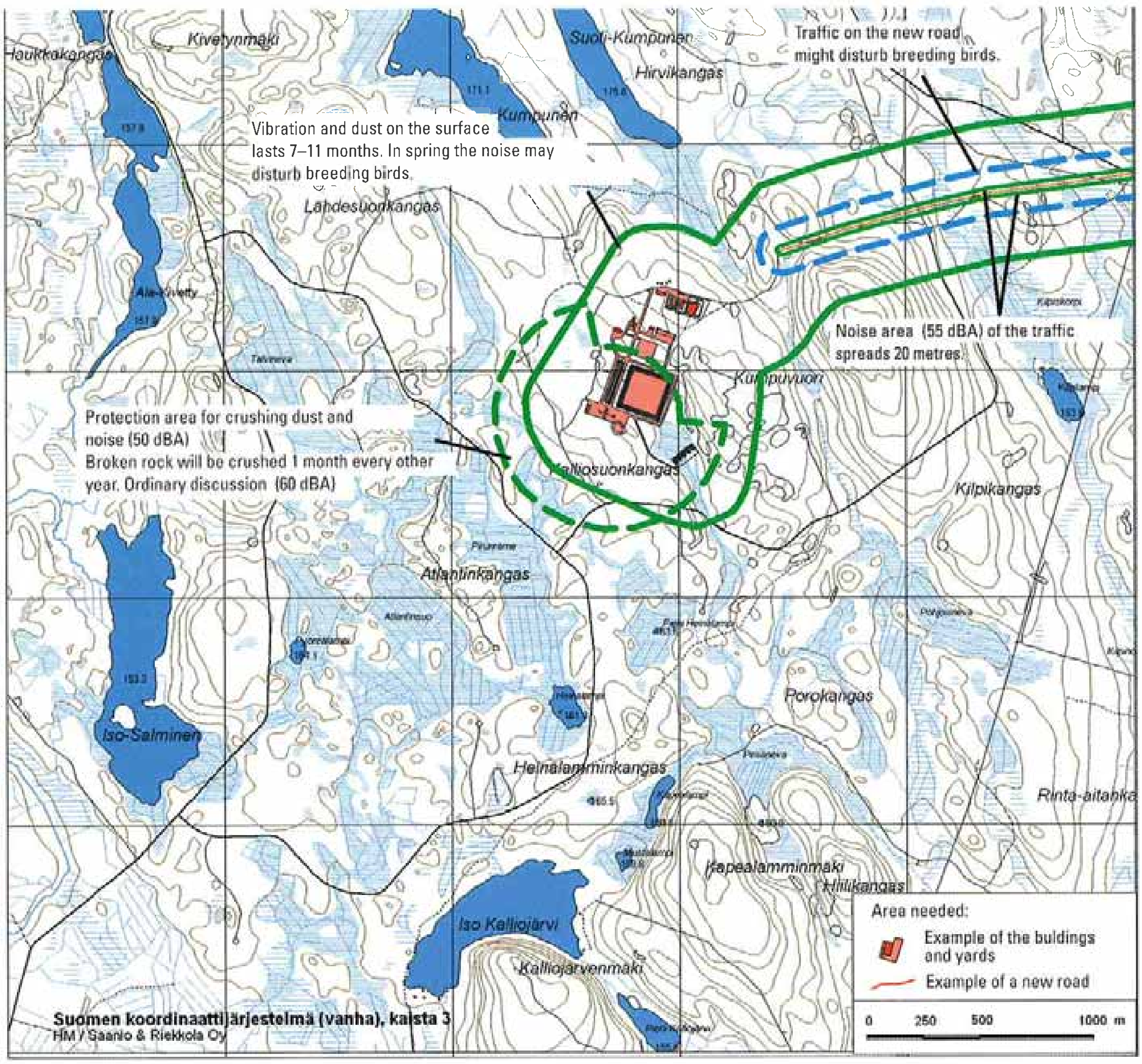
Karttakeskus Oy L2633/99

rior to alternative 1 concerning changes in living surroundings and species. Alternatives 1B and 2 both cross the brook and the swamp. From these alternatives, the solution with the small natural impacts can be found.

At Romuvaara, the potential construction area is average regarding flora and avifauna on the scale of the investigation area. The natural features of the northern part should be taken into account. The potential construction area has no provincially or nationally significant features, area-ecological links, Natura 2000 areas or nationally endangered species.

A growth in the quantity of spent fuel, the excavation of all tunnels at one time and the excavation of a vehicular access ramp would increase the size of the rock pile and consequently the size of the facility area. For example, continuing the operational life of existing power plants from 40 to 60 years would increase the 15 ha facility area by approximately 2 ha. If blasted rock could be sold as a construction material, the facility area would not have to expand.

Following the decommissioning and sealing phases, the area will be landscaped. The landscaped area will gradually revert to its original form. All buildings can also be demolished if they are no longer of any use.



Map 8-12. The incidence of noise dust and vibration as applicable to an example of siting together with land area required at Kivetty.

Karttakeskus Oy L2633/99

Traffic, excavation, crushing, stockpiling

The impacts of noise, dust and exhaust gases were assessed by comparing on-site research results with compiled data and estimated emissions (LT-Konsultit Oy 1998). The resulting dust and exhaust emissions are insignificant from the standpoint of natural impact.

Vibration caused by rock blasting was assessed according to calculation methods in general use (Tolppanen & Kokko 1998). A person is able to detect a vibration velocity of approximately 1 mm/sec. An explosion occurring in deep bedrock will cause a vibration velocity of < 1 mm/sec at the ground surface directly above the location of the blast. Underground blasting cannot be felt or heard outside the facility area and for that reason does not create adverse environmental impacts. During the investigation phase bedrock will be excavated at ground level for approximately one month and during the construction phase for a period of 6–10 months. The annoying vibrations caused by surface excavation would extend to a maximum distance of 200–300 metres, so that significant environmental impacts are also not created by surface excavation. Based on research carried out by Kala- ja Vesitutkimus Oy et al. (1996), the effects of blasting vibration on fish are insignificant due to the short duration and the size of the impact area. The impact of groundwater table on plants is explained in Chapter 8.2.3.

Noise from surface blasting may disturb birds during nesting at a distance of one kilometre in coastal areas and 100–300 metres in forests. Mammals are not generally disturbed by even loud noises. At Kivetty, the northwest corner of the potential construction area and road touches the border of local bird areas, as do the southeast corner and old road on a ridge at Romuvaara. The timing of construction outside the best nesting periods, or the placement of functions in other parts of the potential construction area will minimise impacts. At Romuvaara, instead of improving the existing road, a better alternative would be to avoid the ridge; the new road alternatives do not cross valuable bird areas. There are no local bird areas in the potential construction areas at Hästholmen and Olkiluoto. The sounds of the Olkiluoto and Hästholmen facilities (see Chapter 8.2.2) do not essentially alter the current sonic environment except during periods of surface blasting. From the aspect of avifauna, the best nesting areas do not extend into potential construction areas. The impact of noise on nature would most likely remain undetected at Olkiluoto and at Hästholmen it would be minimal.

Compared with power plant locations, Kivetty and Romuvaara show greater fluctuation in the sonic environment due to the character of these areas (see Chapter 8.2.2). During the operational and decommissioning phases of the facility, traffic on new road may disturb nesting birds at a distance of 100–200 metres. Local nesting areas in the potential construction area and near new road are easier to take into account at Romuvaara than at Kivetty. The impacts of noise on nature are minimal at Romuvaara. The noise produced at Kivetty during the construction phase may disturb nesting birds in the northern part of the potential construction area and along new road, even if traffic noise remains localised and minimal.

8.2.5 Impact on ground and climate

Soil conditions

The construction of facility areas (15 ha) and roads (10 ha) at Romuvaara and Kivetty requires earthmoving work (Maps 8-1, 8-2, 8-3, 8-4). At the Kivetty and Romuvaara facility areas, the area to be shaped accounts for approximately 20% of the total quantity, with 80% at road alignments. LT-Konsultit Oy studied the cutting and filling of road alignments, including longitudinal profiles, in 1998.

A growth in the quantity of spent fuel, the excavation of all tunnels at one time and the excavation of a vehicular access ramp would increase the size of the rock pile and consequently the size of the facility area. For example, continuing the operational life of existing power plants from 40 to 60 years would increase the 15 ha facility area by approximately 2 ha. If blasted rock could be sold as a construction material, the facility area would not have to expand.

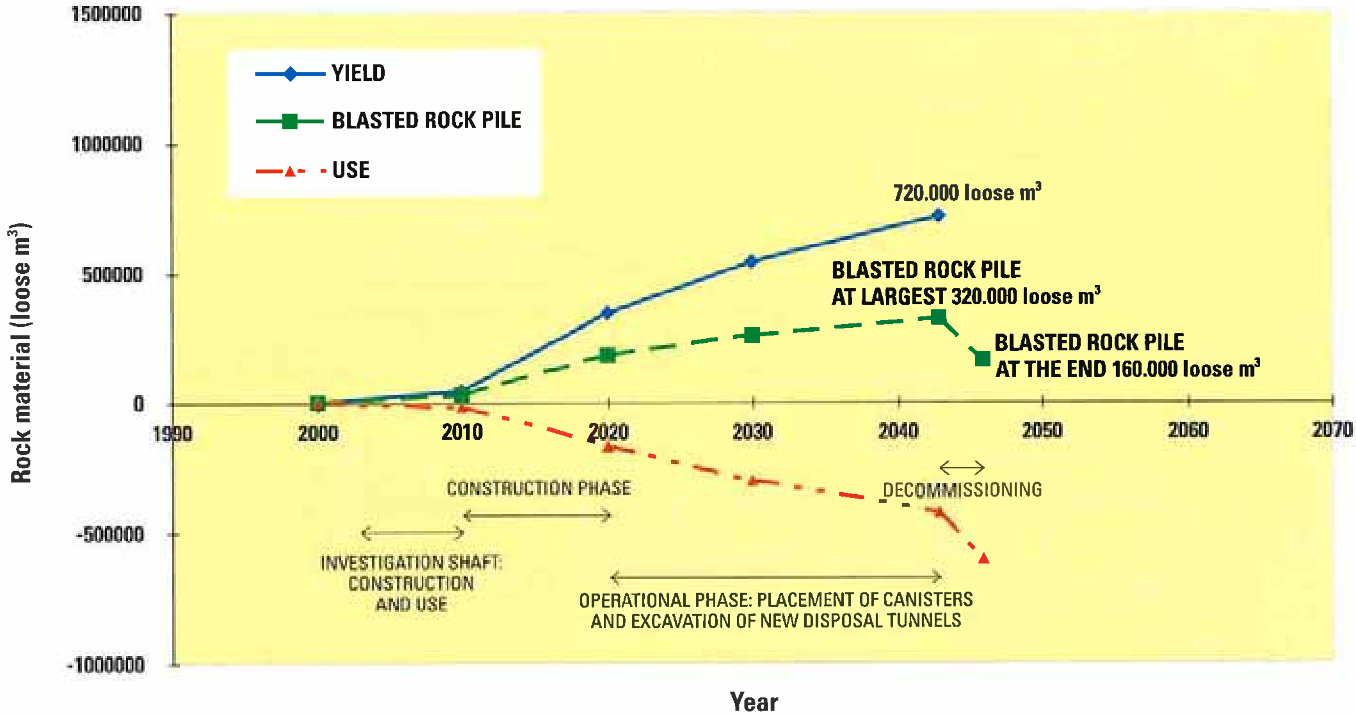
Bedrock

Bedrock will be excavated primarily underground. The rock material excavated for superterranean buildings and roads represents only a few percentage points of the total (Tolppanen 1998, LT-Konsultit Oy 1998).

In Loviisa and Eurajoki 75–80% of the blasted rock will be used to foundations of buildings, yards and roads, as well as to backfill the final disposal repository. The remaining 20–25% can be sold as construction material outside the facility (Tolppanen 1998).

At Kuhmo, blasted rock from the excavation of investigation shaft can be used to road alternative 1. Alternative 2 does not require rock materials from outside if 600 metres of central tunnel is excavated with investigation shaft. At Äänekoski, for example, road alternative 2 would require blasted rock excavated from investigation shaft and a central tunnel 200 metres in length.

At Äänekoski and Kuhmo 80–90% of the blasted rock will be used to foundations of buildings, yards and roads, as well as to backfill the final disposal re-



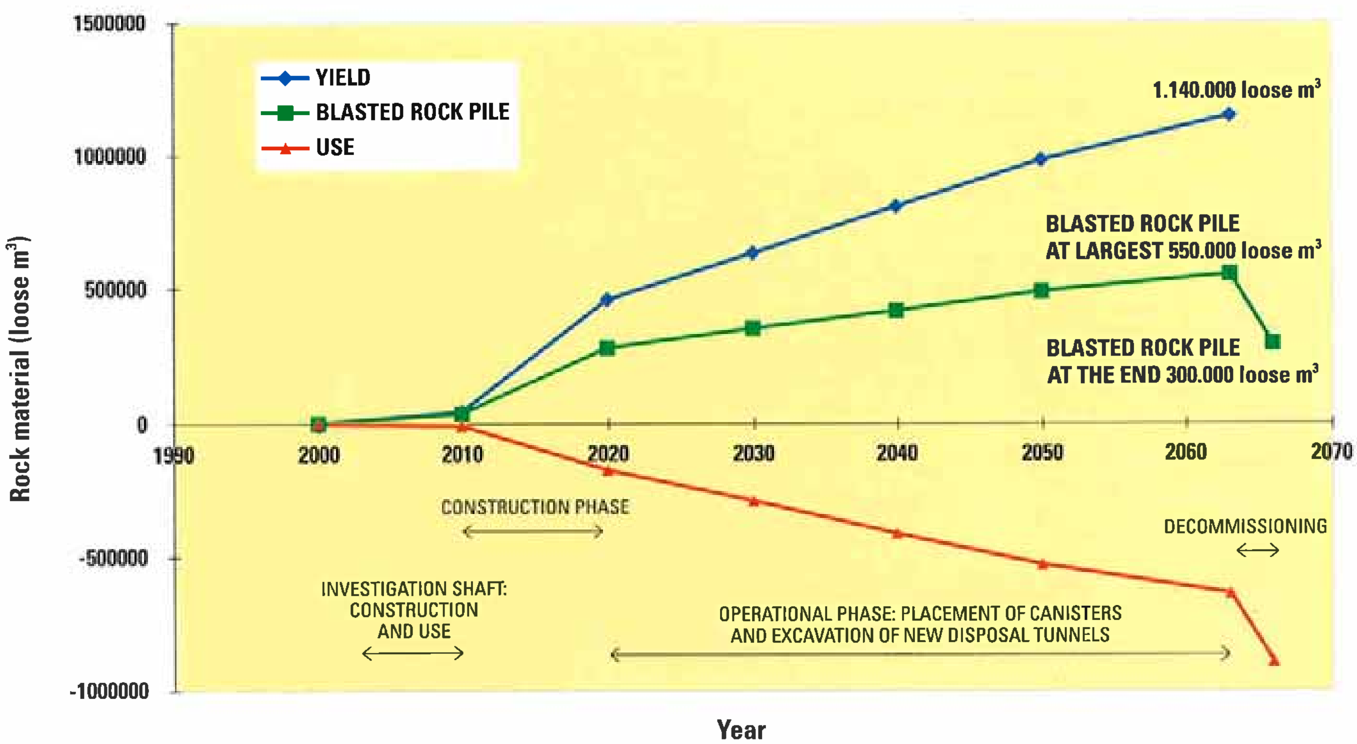
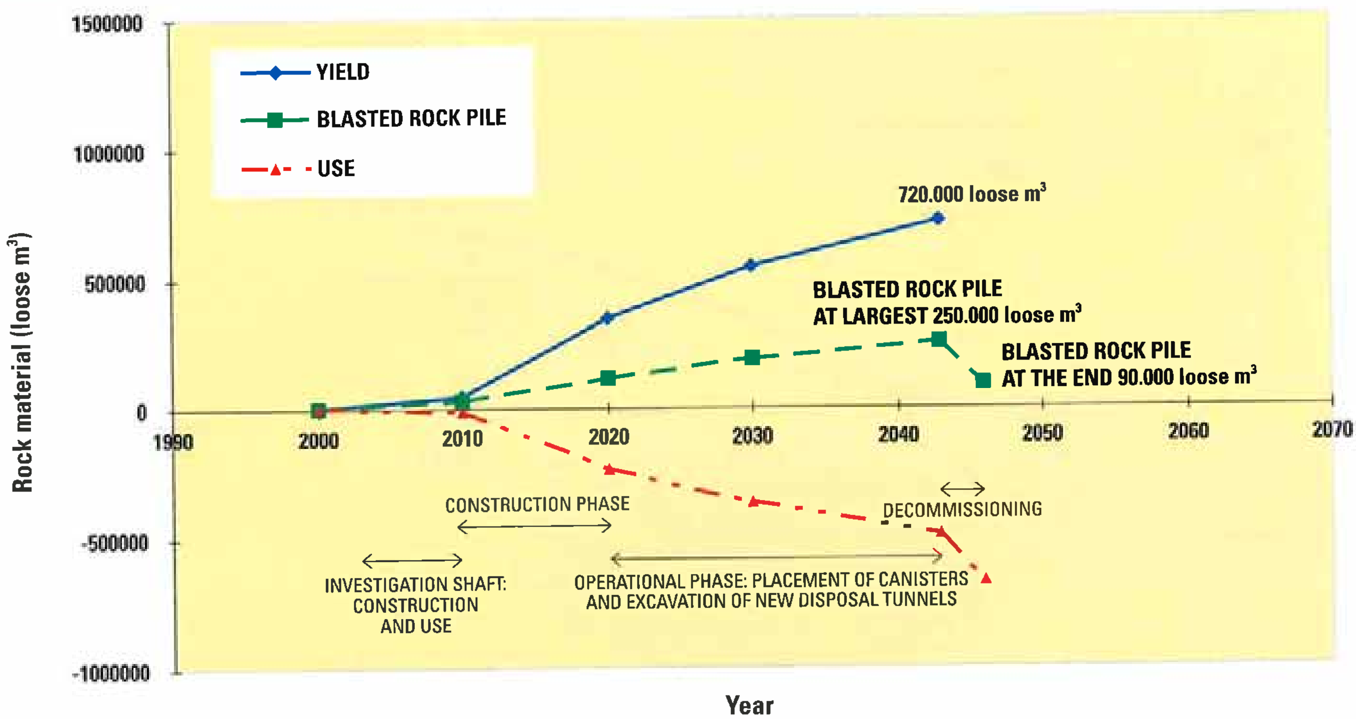


Table 8-1. Flow of blasted rock material expressed as loose cubic metres in ***Loviisa and Eurajoki****. A loose cubic metre describes the space occupied by detached rock material (Tolppanen 1998). The power plants' operating lives are 40 and 60 years. For the sake of comparison, approximately 1,000,000 loose m³ of bedrock was excavated over a period of 19 months for the new road between Koskenkylä and Loviisa that was completed in 1998.*



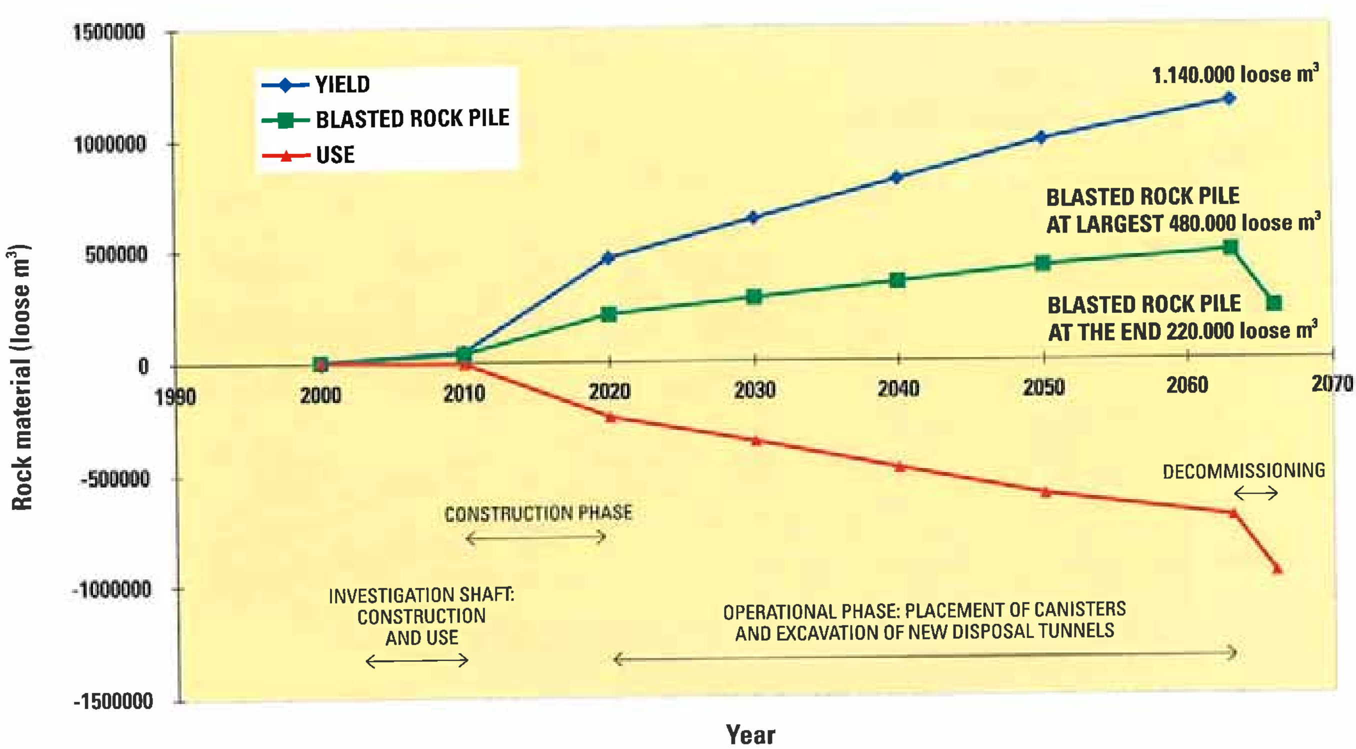
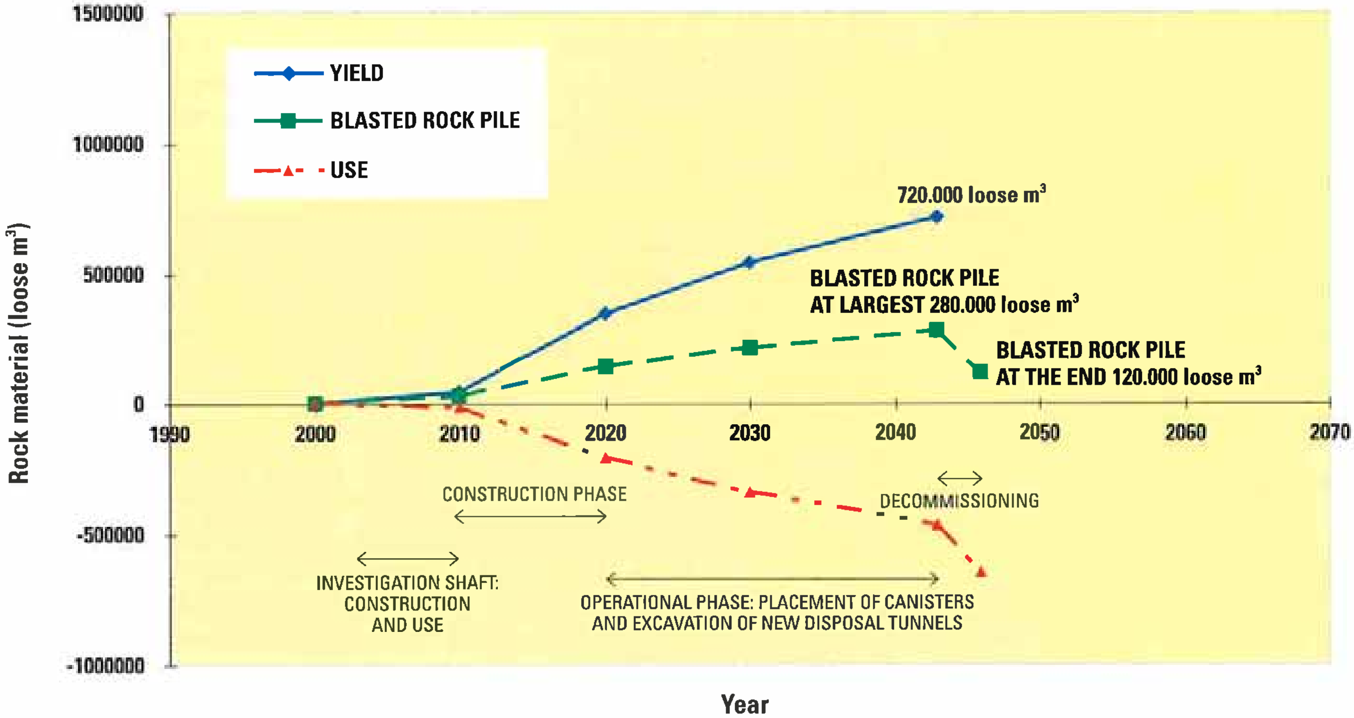


Table 8-2. Flow of blasted rock material expressed as loose cubic metres in ***Äänekoski****. A loose cubic metre describes the space occupied by detached rock material (calculated on the basis of references to Tolppanen 1998 and LT-Konsultit Oy 1998). The power plant's operating life is 40 and 60 years. For the sake of comparison, approximately 350,000 loose m³ of bedrock was excavated at a single construction site in the centre of Helsinki (Kluuvi parking garage and book storage) in 1998.*



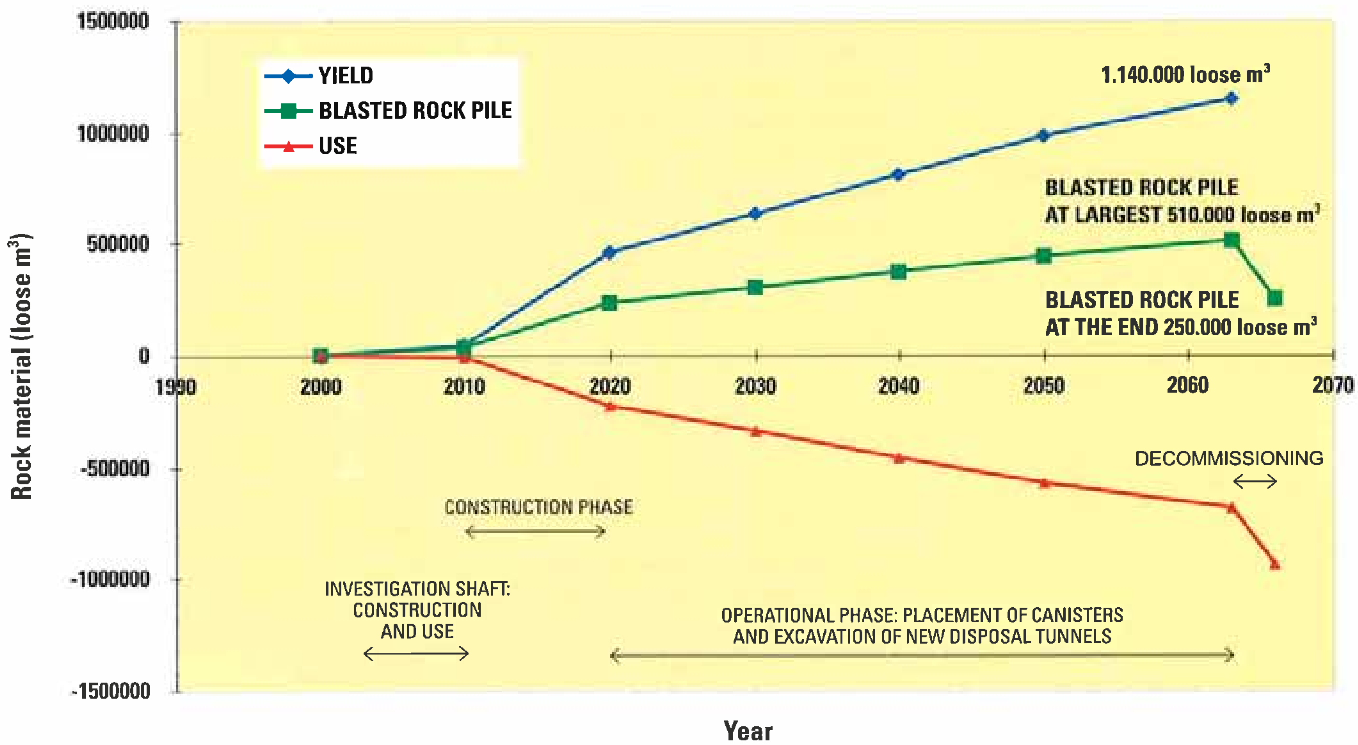


Table 8-3. Flow of blasted rock material expressed as loose cubic metres in ***Kuhmo****. A loose cubic metre describes the space occupied by detached rock material (calculated on the basis of references to Tolppanen 1998 and LT-Konsultit Oy 1998). The power plant's operating life is 40 and 60 years. For the sake of comparison, approximately 3,000,000 loose m³ of bedrock was excavated over a period of 1.5 years for the new traffic lane on the Järvenpää-Lahti highway.*

pository. The remaining 10–20% can be sold as construction material outside the facility (Tolppanen 1998).

A growth in the quantity of spent fuel, the excavation of all tunnels at one time and the excavation of a vehicular access ramp instead of a shaft would increase the amount of blasted rock. For example, the use of a vehicular tunnel would increase the quantity of blasted rock by 30–40%.

Canister heat generation

The effect of residual canister heat at the earth's surface is insignificant from the point of view of air temperatures. The heat flux rising to the surface from the centre of the final disposal facility would be at its maximum (0.1 W/m^2) approximately 1,100 years after final disposal (Raiko 1996). The average year-round heat flux from sunlight at the investigation municipalities is 9,000 times greater. There will never be perceptible differences in air temperatures. There are no climatic impacts.

Residual heat will cause the bedrock to expand. Element and analytical methods have been used to calculate that the ground surface located over the centre of the final disposal facility would rise approximately eight centimetres 1,000 years after final disposal (Reivinen et al 1996). Because the thermal expansion at the edges of repository is less than at the centre, surface fluctuations will not be discernible to the naked eye.

8.2.6 Impact on utilisation of natural resources

Use of copper

During the operational stage, the necessary quantity of copper is less than 1% of the production of Outokumpu's Pori unit, and under 0.01% of the entire world's annual copper production. Copper is widely available.

Use of bentonite

Bentonite is a clay consisting of powerfully expanding clay minerals not found in Finland. During the operational and decommissioning phases, the annual need for bentonite is less than 0.1% of the world's annual production. Bentonite is widely available.

Use of rock materials

At Loviisa and Eurajoki, 20–25% of the quantity of blasted rock would be for sale. At Äänekoski and Kuhmo the amount would be 10–20% because part of the blasted rock is used in road construction. The part for sale will preserve the region's glaciofluvial deposits commonly used as a source for gravel. A growth in the quantity of spent fuel and the excavation of a vehicular access ramp would increase the amount of blasted rock available for sale. The use of soil and rock materials is explained more specifically in Chapter 8.2.5.

Recreational use

During the nature inventories carried out in 1996–1997 (see Chapter 8.2.4), observations were also made concerning game birds as well as mushroom and berry harvests. At Äänekoski and Kuhmo, additional information was acquired from hikers, Ystävyyden Puisto and the Forest and Park Service (regarding hunting and fishing permits and catch limits). The impacts were assessed for situations during the construction and operational phases in which the utilised areas would be 15 ha at their largest and in Äänekoski and Kuhmo, with extra road areas of approximately 10 ha (LT-Konsultit Oy 1998).

Near facility areas, the utilisation of natural resources, such as mushroom and berry picking, hunting, fishing and forest management can continue as earlier.

As far as berry picking is concerned, the landscape at Olkiluoto is less desirable. Gathering berries and mushrooms is hampered by the area's difficult terrain and grass overgrowth. From the aspect of other outdoor activities, the area is practically insignificant because there are plenty of extensive forests that suits better for berry and mushroom picking and the hunting of small game birds. No water areas remain within the potential construction area, so there would be no effect on fishing. The project would not affect recreational opportunities at Eurojoki. From the aspect of Olkiluoto Hunting Society, the facility's placement in the centre of the island would, however, be significant.

At Hästholmen, a nature trail has been built for those visiting the power plant. Otherwise, possible recreational uses of the potential construction area at Hästholmen are currently minimal. The project does not affect the possibilities to use the surroundings of Loviisa or Hästholmen for recreational purposes. A protective park strip would be left between the Källa camping site and the potential construction area. The surrounding forest areas suits better for berry and mushroom picking and the hunting of small game birds. No water areas remain within the construction area, so there would be no effects on fishing.

At Kivetty, the potential construction area is well suited to hunting, berry picking and mushroom gathering. Similar landscapes are found nearby in abundance. The impact on recreation would be minor in relation to the total land area of the vast government-owned tracts nearby. A new road would improve accessibility to the area. No water areas remain within the potential construction area, so fishing would not be affected.

The Kivetty region is used as a local recreation area. The Forest and Park Service maintains recreational forests in the region for diverse other uses besides wood production (Heinonen et al 1997). Recreational forests would probably not be needed for construction: of the 100 ha potential construction area, 95 ha is taken up by commercial forests, easily accommodating the 15 ha required by construction. The facility area and roads would, however, diminish the wilderness character of the area.

At Romuvaara, although the potential construction area is suitable for recreation, it is not used extensively. Because similar landscapes are found nearby in abundance, the effects on recreational use would be minimal. The wilderness character of the area would, however, be altered. The new road would improve the accessibility of cloudberry and cranberry areas. Aside from a small muddy swamp area, there are no water areas remaining within the potential construction area, so fishing would not be affected.

Restrictions by authorities

The Finnish Radiation and Nuclear Safety Authority has the right to issue prohibitive actions regarding properties. These include prohibitions against entering repository deep in the bedrock (for example, mining operations or bored wells). Because of possible continued monitoring, construction in the area may be restricted. Following the decommissioning and sealing phases, the prohibitive action will be marked in the property register, land register or list of titles.

Bedrock investigations have established that there are no ore deposits within the potential construction areas.

8.2.7 Conclusions

The superterranean structures and yard areas of final disposal facility cover approximately 15 ha of land area. At Äänekoski and Kuhmo, a new road would require an additional 10 ha. At potential construction areas and new alternative road routes, there are no provincially or nationally significant natural objects, Natura 2000 areas or nationally endangered species. Area-ecological links remain unbroken. At Kivetty and Romuvaara, the areas are more forested compared to Hästholmen and Olkiluoto, where there is also industry. Natural objects of local interest have been identified and will be taken into consideration in further planning.

Most plants take their water from surface water above the ground water level. In this respect lower groundwater levels caused by underground facilities would not affect plants. Groundwater-influenced natural objects are so far away from potential construction areas that there would probably be no effects. In the post-sealing period, the groundwater level will revert to its original state within a few years. Groundwater levels and vegetation distributions at groundwater-influenced objects would, however, be monitored until the end of reversion of groundwater level. There are no groundwater-influenced objects at Olkiluoto.

Surface excavation causing vibration, dust and noise will be carried out during the construction for a total of 7–11 months. Vibration and dust can be observed at distances of 200–300 metres. Blasting can be heard over distances of approximately one kilometre, and two kilometres in coastal areas. Noise may disturb birds during the nesting season at a distance of one kilometre in coastal areas and 100–300 metres in forests. Excavation is not carried out at night. Underground excavation has no superterranean effects.

Blasted rock is crushed for a period of approximately one month every other year, with no crushing carried out at night. The noise level falls below the Noise Abatement Act's guidance value of 50 dB(A) at a distance of 500 metres from the crushing plant. If the rock pile is used to attenuate the noise, the noise level falls below 50 dB(A) at a distance of less than 200 metres. The noise level for normal conversation is 60 dB(A). The protection distance for dust is 300 metres. The noise and dust areas of the crushing plant will not extend to buildings and local bird areas if the crushing plant is correctly sited. At Kuhmo, buildings are situated so far away that crushing plant can be sited where ever in the potential construction area.

The traffic required by the facilities would widen the noise areas of Olkiluodontie road in Eurajoki and Saaristotie road in Loviisa by approximately 10 metres (from 40 metres to 50 metres), and at Murontie road in Äänekoski and Riihivaarantie road in Kuhmo by approximately 20 metres (from 10 metres to 30 metres). New road at Äänekoski and Kuhmo may disturb nesting birds within a distance of 100–200 metres. At Kuhmo, the old road crosses over local nesting areas, but new road alternatives do not.

8.3 Impact on land use, cultural heritage, the landscape, buildings and the urban image

8.3.1 Land use at Olkiluoto

The potential construction area is located in the central part of the island (Map 8-1). Additionally, a small area has been reserved near the current spent fuel storage facilities in case an encapsulation plant is built nearby. There is no need to construct new transmission lines. Posiva has a currently valid investigation licence from the area's landowners, TVO, Fortum and the Forest and Park Service. The closest privately owned dwellings and summer cottages are located in the eastern part of the Olkiluoto island at a distance of approximately one kilometre from the edge of the potential construction area.

Only limited agriculture is practised within the vicinity of the potential construction area. Commercial and recreational fishing are practised in surrounding water areas. Beside the power plant, Olkiluoto island has a harbour being used temporarily. TVO breeds crabs at the Ulkopää cape on the site of a former fish hatchery.

The Satakunta regional plans and the regional stage plan 5 (Map 8-13) are in effect at Eurajoki. The latter was ratified by the Ministry of the Environment in 1999.

In the 5th regional plan, the Olkiluoto area is designated as an area of communal engineering supply (ET). The harbour (LV) is situated in the northeast section of the island. The old Liiklankari forest is a nature reserve (SL). The exclusion zone of the power plant, with its restrictions on land use, is marked in the regional plan.

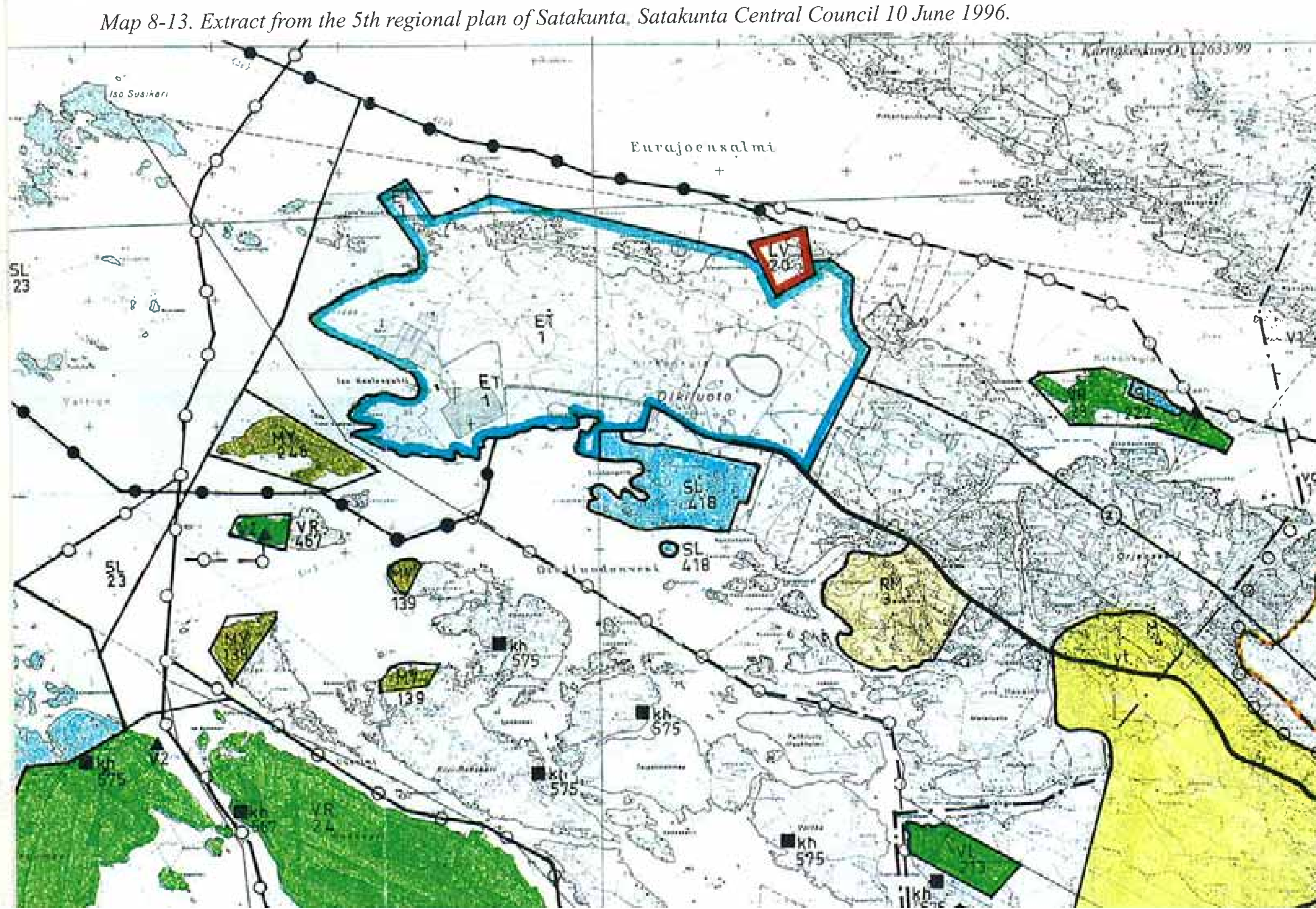
Olkiluoto does not have a ratified master plan, but an overall structural plan was ratified by the municipal council in 1988.

The building plan of the Olkiluoto site was ratified in 1974, and later amended in 1980 and 1997. The sector areas indicate sites zoned for industrial and warehouse use on which may be built nuclear power plants and other facilities, equipment and buildings related to power generation, distribution and transmission, unless otherwise restricted.

Three ratified shore plans relating to the eastern part of Olkiluoto are in effect. The master shore plan is currently being drafted and was on public display for the period 11 September–14 October 1998.

Olkiluoto's Natura 2000 proposal is shown in on the map 8-1. There are no other nationally significant protection or building plans near the construction area.

Map 8-13. Extract from the 5th regional plan of Satakunta, Satakunta Central Council 10 June 1996.



8.3.2 Land use at Hästholmen

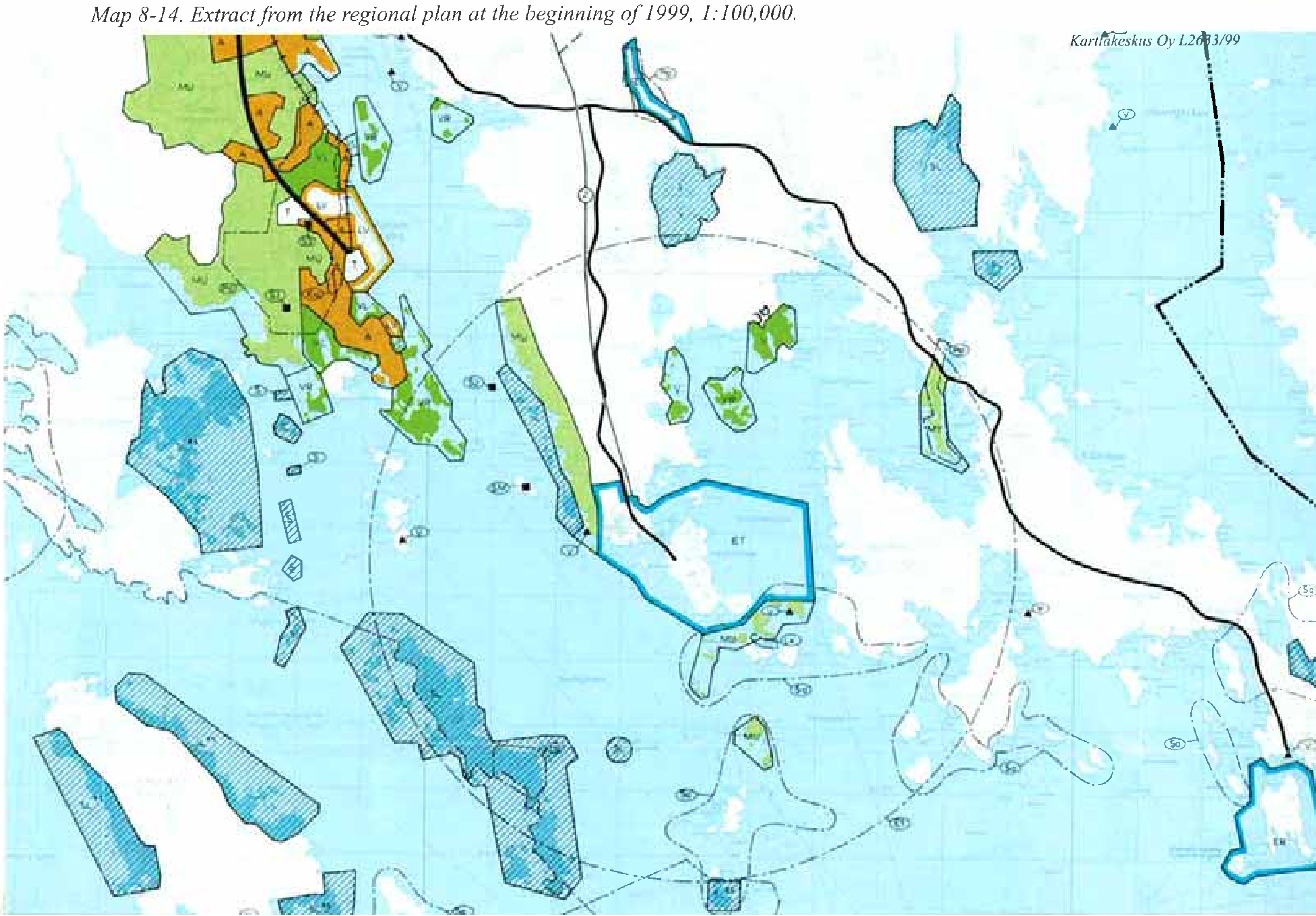
The potential construction area is located on the Hästholmen power plant island and the cape areas owned by Fortum (Map 8-2). The construction of new transmission lines is not necessary. Posiva has currently valid investigation licences from Fortum and the town of Loviisa. The Fortum site located in Björnvik will not be used for actual final disposal operations, but its current use for the crushing and stockpiling could continue. The power plant is located in the central part of Hästholmen and the shorelines are mainly free from construction structures. A considerable number of summer cottages are located in the immediate surroundings. The closest dwellings and summer cottages are located approximately 100 metres from the edge of the potential construction area.

Within the vicinity of the potential construction area, there is, except for the nuclear power plant, no other industry, and agriculture is practised only to a limited degree. Commercial and recreational fishing are practised in surrounding water areas. Hästholmen has a fish hatchery in which the power plant's warm cooling water is used to breed fry.

A regional plan related to recreation, protection and certain forestry lands was ratified on 8 October 1981. A regional stage plan relating to densely populated areas, traffic and technical servicing was ratified on 21 February 1986. A regional stage plan pertaining to town areas, ridges and amendments and supplements relating to previous regional stage plans was ratified on 17 April 1997. Currently, there is a regional plan being drafted that when ratified, will supplement and replace previous versions. The present situation is shown in Map 8-14. The 5th regional plan, available for viewing in 1999, is under preparation.

In the regional plan, Hästholmen has been designated as an area of communal engineering supply (ET). An exclusion zone, in which there are restrictions on land use, surrounds the power plant for a radius of 5 kilometres. The islands south of Hästholmen have been designated as agricultural and forestry areas necessary for outdoor recreational or environmental values (MU), the same applying to the eastern shore of the gulf of Loviisa on the mainland. The island area situated in front of it, to the northwest of Hästholmen, is a nature reserve (SL). The Svartholm fortification is a culturally historic area (SM). The islands of Smedsholmarna, situated a few kilometres to the north of Hästholmen, have been designated as areas for hiking and outdoor recreation (VR). Storholmen and the shore islands west of Smedsnäs on their northeastern side have been designated as recreation areas (V). At a distance less than five kilometres southwest of Hästholmen, the Hudö and Lilla-Hudö islands, along with the small surrounding islands, have been designated as a nature reserve (SL). The nearest dwelling area designated in the regional plan is Valko, situated on the opposite shore of the Gulf of Loviisa.

Map 8-14. Extract from the regional plan at the beginning of 1999, 1:100,000.



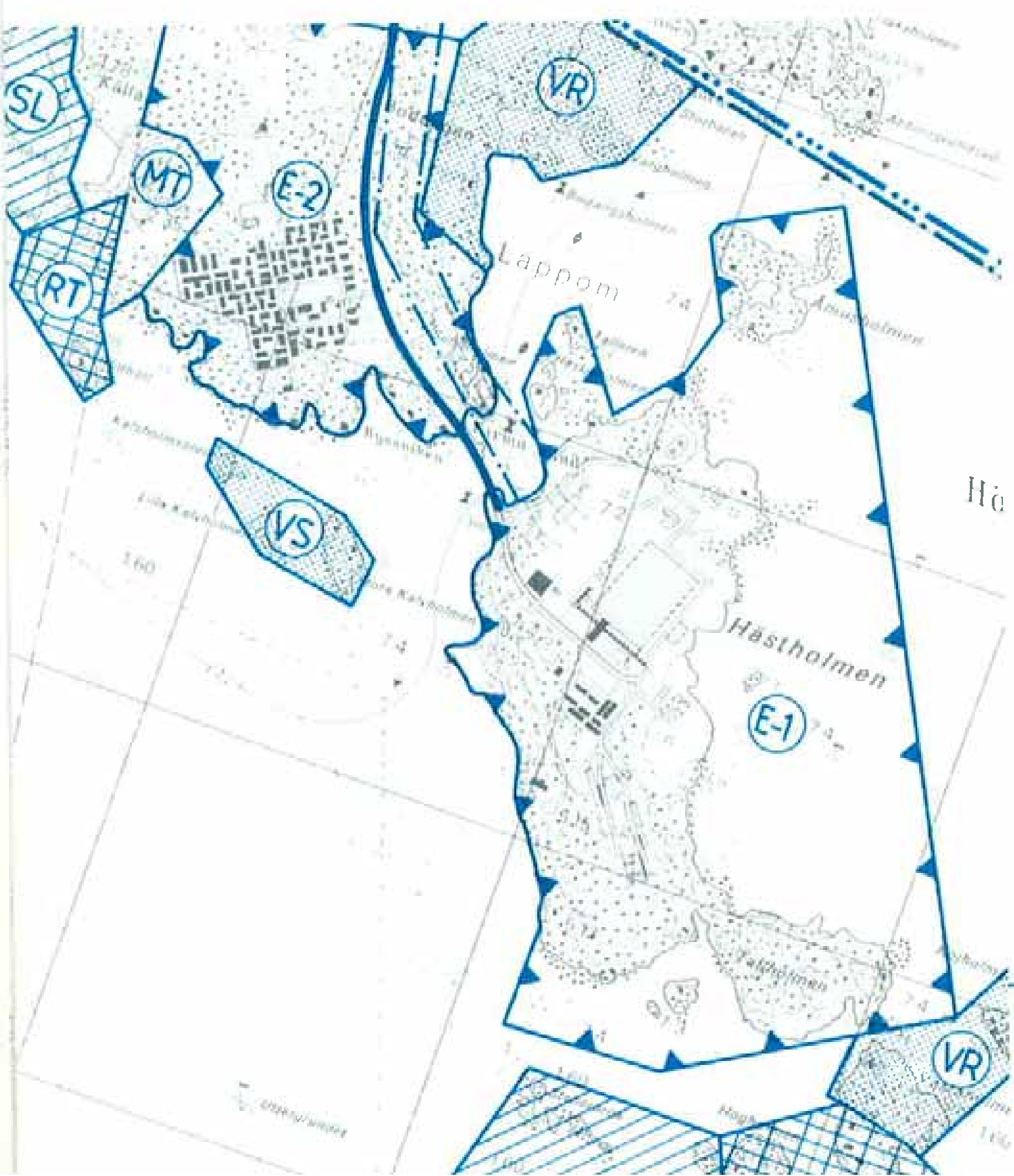
The master plan for Loviisa (Map 8-15) was approved on 9 December 1987. It indicates that Hästholmen is the area for the nuclear power plant (E-1) and that the accommodation area situated in Lappom is to be used as a support area (E-2) for functions essential to plant operations. Among the islands south of Hästholmen, Småholmen is a summer cottage area (RA), Måsholmen a nature reserve (SL) and Kojholmen, Storstenholmen and Björkholmen are areas for hiking and outdoor recreation (VR). Stora Täktarn is designated as an area for hiking and outdoor recreation (VR), and the other islands to the south are designated as a nature reserve (SL). The greatest part of the eastern shore of Loviisa is designated in the master plan as an area for hiking and outdoor recreation. Svartholm and the islands situated north of it are designated as areas containing ancient artefacts (SM). In the master plan these islands are earmarked for nature protection.

The town plan of the Hästholmen area was originally ratified in 1972, after which the plan was amended in 1974 and 1993. The central parts of the islands are zoned for industrial and storage use. Part of the shoreline utilised by the power plant is to be preserved in its natural state. Only structures deemed necessary to the security of the power plant will be constructed in this area. The buildings near the visitors' centre are intended for power plant-related joint training and short-term accommodation. The objective of the most recent amendment to the town plan was to enable underground construction to be carried out in the area. The plan ratified on 8 January 1993 allows the construction of 500,000 m³ of underground working and storage space as well as the construction of superterranean service structures. Underground facilities will be used to store low and medium level waste.

The village of Lappom, located on the continental side, had its town plan ratified in 1989. Boat coves and a parking area are situated near Atomitie road leading to Hästholmen. The southern shore area and the eastern part of the road are to be preserved as special areas in their natural state. The owner of the power plant may restrict freedom of movement within the area if necessary. Buildings and structures necessary for communal engineering and supervision are allowed in the area. Block 1204 is zoned for provisional accommodation, but commercial, shop, storage and administration buildings may also be constructed in the area. Permanent settlement is not planned for this area. The northern part of the accommodation is zoned for industrial and storage use. The town plan is bounded to the west so that the Källaudden camping area and the beach are excluded from the town planning area.

Loviisa's local shore master plan dates from 1985. Hästholmen lies outside this area. In the local master plan for the coast, the built-up parts of the islands south of Hästholmen have been zoned as areas for summer residence, with other parts of the island reserved for forestry and landscape management areas. Svartholm and Ruutikellarinsaari are protected landmarks with historical monuments, while other islands north of Svartholm are protected and hiking areas. The eastern side of the Gulf of Loviisa is a densely populated summer cottage area; for that reason it has been reserved almost entirely for summer residence.

In Ruotsinpyhtää, north of Hästholmen, a shore master plan approved on 7 April 1982, as well as separate shore plans, are in effect; those most closely related to Hästholmen being the Långstrand and Gäddbergsö shore plans. Besides the areas reserved for the regional plan, the Kristianlandet nature reserve has been designated separately. In Ruotsinpyhtää the intent is to prepare a shore master plan for the entire municipality's shores and islands. Work began in 1997. The Natura 2000 area (draft 20 August 1998) is shown on the map 8-2. There are no other nationally significant protection or building plans near the construction area.



Map 8-15. Extract from the general plan of Loviisa 1:20000.

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8.3.3 Land use at Kivetty

Kivetty's potential construction area and its immediate surroundings are uninhabited forest and swamp areas (Map 8-4). Because the existing line is sufficient, there is no need to construct new transmission lines. Posiva has a currently valid investigation licence from the area's owner, the Forest and Park Service. The closest dwellings are located a distance of approximately 3 kilometres to the southeast. The distances to the closest summer cottages are 0.2 km and 1.5 km. The distance from the site to the parish village of Konginkangas is approximately 7 kilometres away and to the centre of Äänekoski 25 km.

The 5th regional stage plan of Central Finland is in the process of being ratified by the Ministry of the Environment. The Regional Council approved the regional stage plan on 17 April 1996 (Map 8-16).

In the regional plan, land use areas have not been specified at the Kivetty investigation site, nor has the site location been designated as an area for planning. The investigation site is bounded on the west by the shore areas of Ylä- and Ala-Kivetty as well as those of Iso-Salminen and Pieni-Salminen, that have been designated as agricultural and forestry areas with recreational and environmental value (MU).

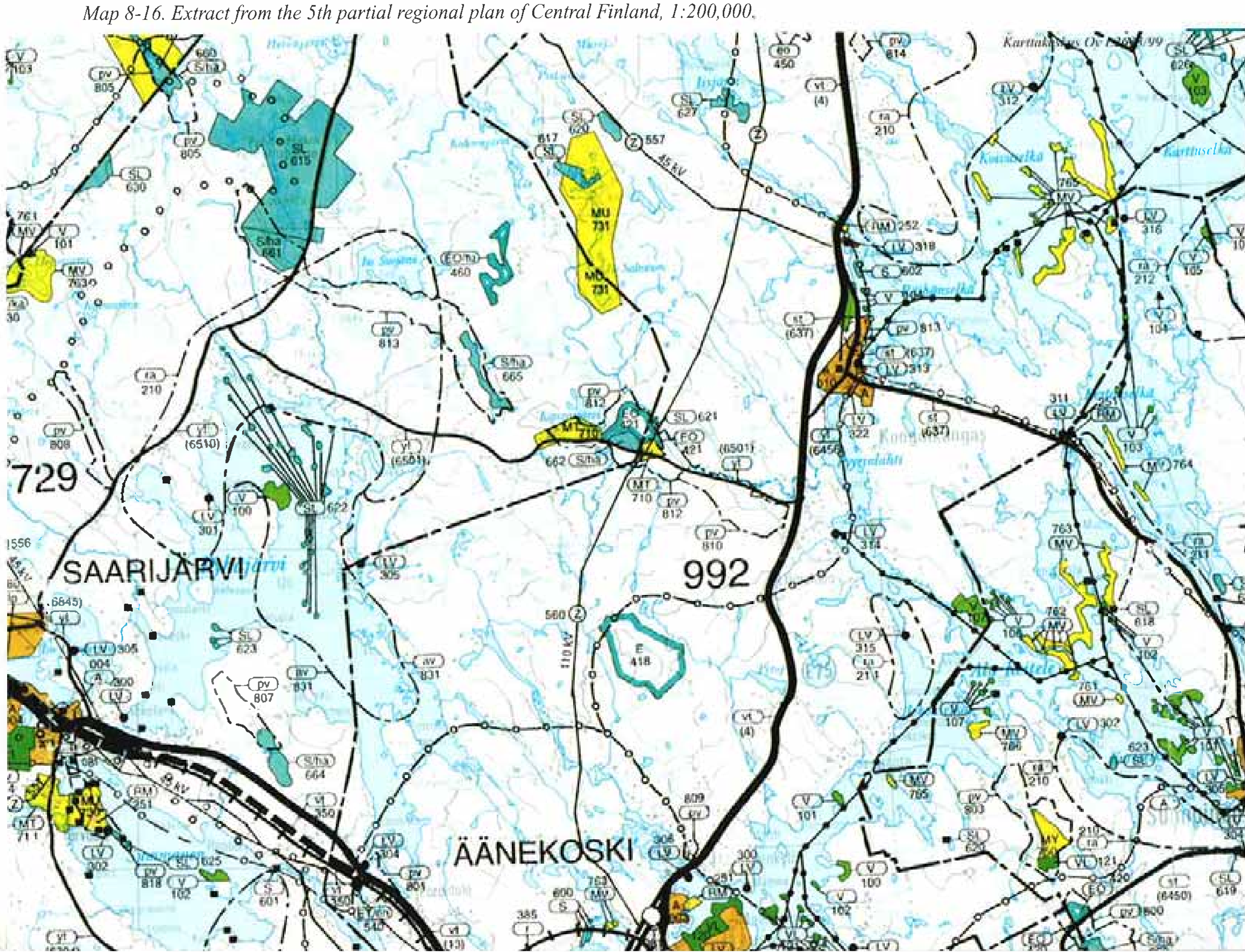
Situated northwest of Lake Ylä-Kivetty, the nature conservation forest owned by the Forest and Park Service is designated as a nature reserve (SL) in the regional plan. The Patvikonmäki and Räihänniemi virgin forests (SL) situated north of Kivetty will also be designated as nature reserves. The Hankasuo spruce swamp (SL) and Kangasjärvi ridge area (S/ha) lie to the south of Kivetty and the Syrjäharju ridge area (S/ha) are located southeast on the Saarijärvi side.

There are no local area development plans for the Kivetty area.

The Kivetty area is situated within the master shore plan for the southern and western parts of Konginkangas that the municipal council of Äänekoski approved on 20 January 1997, and that was ratified by the Central Finland Environment Centre on 23 January 1998. In this master shore plan, the shores of Ala- and Ylä-Kivetty have been designated as a recreational area, within which small sections will be reserved for summer residences as well as a nature reserve. A few more possible construction sites have been designated along the shorelines of ponds and lakes.

Kivetty's Natura 2000 area (draft 20 August 1998) is shown on the map 8-4. There are no other nationally significant protection or building plans near the construction area.

Map 8-16. Extract from the 5th partial regional plan of Central Finland, 1:200,000.



8.3.4 Land use at Romuvaara

Romuvaara is situated 30 kilometres northeast of the centre of Kuhmo. Posiva has a currently valid investigation licence from the area's owner, the Forest and Park Service. There are also uninhabited forest areas managed by the Forest and Park Service near the potential construction area (Map 8-3). Because the existing line is sufficient, there is no need to construct new transmission lines. At Pitämävaara, 2 kilometres west of Romuvaara, there are 10 inhabitants. The two closest summer cottages are situated at a distance of approximately one kilometre from the edge of the potential construction area.

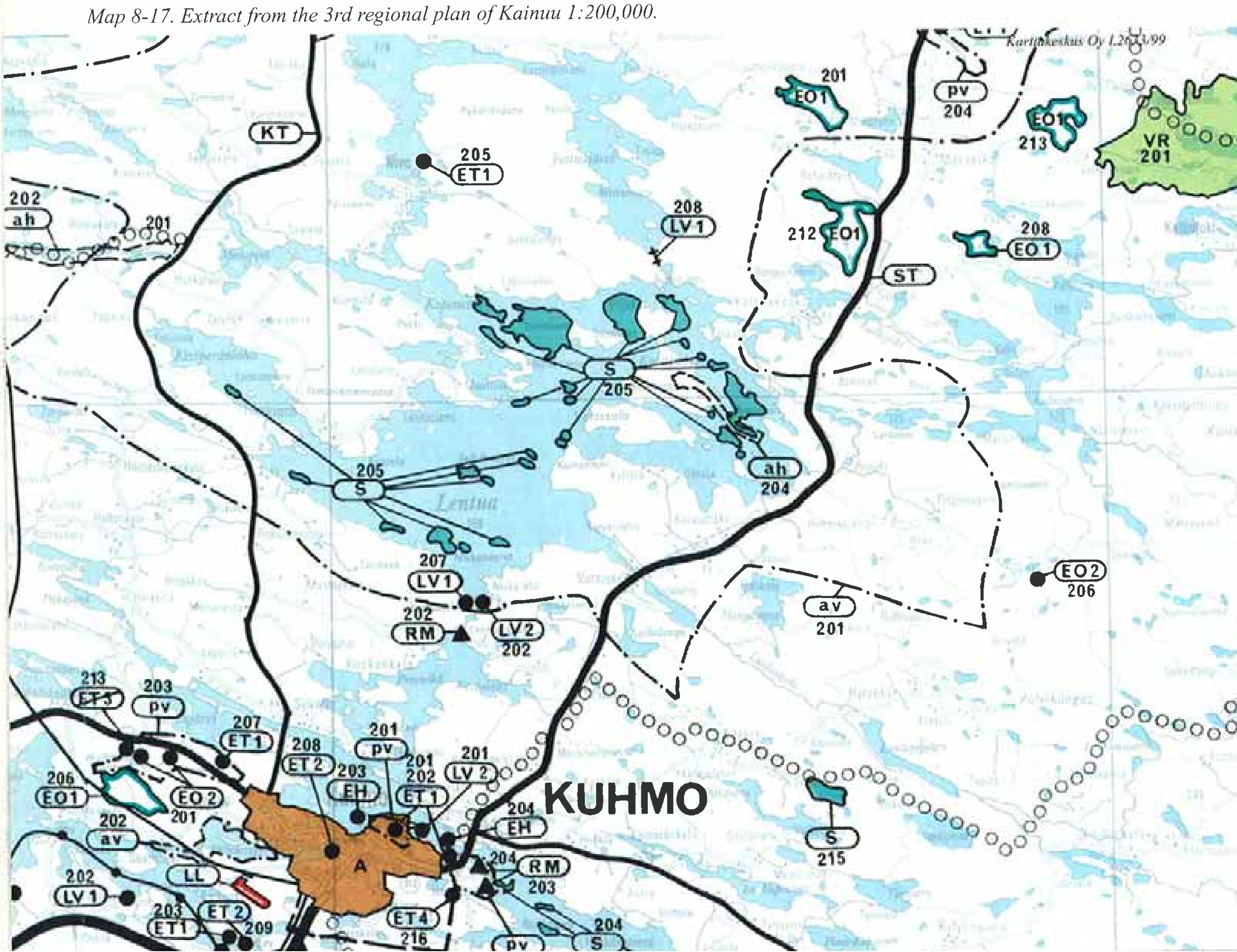
The third regional plan of Kainuu (below) is a combination of three regional stage plans. The first regional plan, comprising recreational, protection and certain agricultural and forestry areas, was ratified in 1980. The second partial regional plan of Kainuu, relating to densely populated areas, industry, summer dwellings, traffic and special functions was ratified by the Ministry of the Environment in 1983 and, regarding two summer residential areas, in 1987. The third regional plan of Kainuu was ratified by the Ministry of the Environment on 15 March 1991. The third phase of the regional plan includes amendments related to land use designations in the first and second regional plans as well as new reserved areas. The fourth regional plan of Kainuu is currently in preparation.

The regional plan contains no reserved areas within the vicinity of Romuvaara. The nearest reserved areas are the Latvavaara gravel pit (EO2 206) south of Romuvaara, the peat bogs of Koppelosuo and Rimminsuo (EO1 208 and 212) between Romuvaara and Lentiira, as well as the Lentua water area (av 201), whose border passes through Romuvaara acting as a watershed.

There are no master plans or local area development plans in the immediate surroundings of Romuvaara.

The nearest ratified shore plan area to Romuvaara is the Syväniemi shore plan area on the eastern shore of Lentua. The Syväniemi shore plan area is situated at the crossing of a private road leading to Romuvaara, a few kilometres to the north along road 912, and is situated on both sides of the road.

Map 8-17. Extract from the 3rd regional plan of Kainuu 1:200,000.



The proposed Luulajanjärvi shore plan, whose status is still pending, is located approximately 10 kilometres south of Romuvaara.

There are no Natura 2000 areas near Romuvaara, nor are there any other nationally significant protection or building plans near the construction area.

8.3.5 Impact on cultural heritage, buildings, the landscape and the urban image

Landscape experts have assessed impacts using maps, literature, site contours, photographs, longitudinal profiles and drawings (LT-Konsultit 1998). Additionally they have been in contact with the Satakunta, Porvoo, Central Finland and Kainuu Museums, as well as with the National Board of Antiquities. The essential source data used in impact assessments was assembled in Maps 8-18, 8-19, 8-20 and 8-21.

Confidential investigations obtained local viewpoints concerning environmental impacts (Viinikainen 1998, Pasanen 1998) were not considered significant. Regarding landscape impacts, more active interaction was sought in monitoring and cooperating teams as well as in public discussions.

The number of structures will be at its greatest during the construction and operational phases. This situation has been compared to present conditions (Figures 8-2, 8-3, 8-4, 8-5, 8-6 and 8-7 and 8-8). Illustrations have been traced over photographs, after which have been added an example of structures. The figures are drawn from the direction from which the impact on the landscape would be greatest.

Olkiluoto

Olkiluoto's landscape would change the least by preserving enough trees near the shore or by placing structures in the centre of the island (Figures 8-2, 8-3). The heating plant's 30-metre high chimney would be the only feature visible above the tops of fully grown trees. Buildings can be integrated into their surroundings by using the power plant's colours and materials.

Map 8-18. Olkiluoto: Cultural, building and landscape objects.

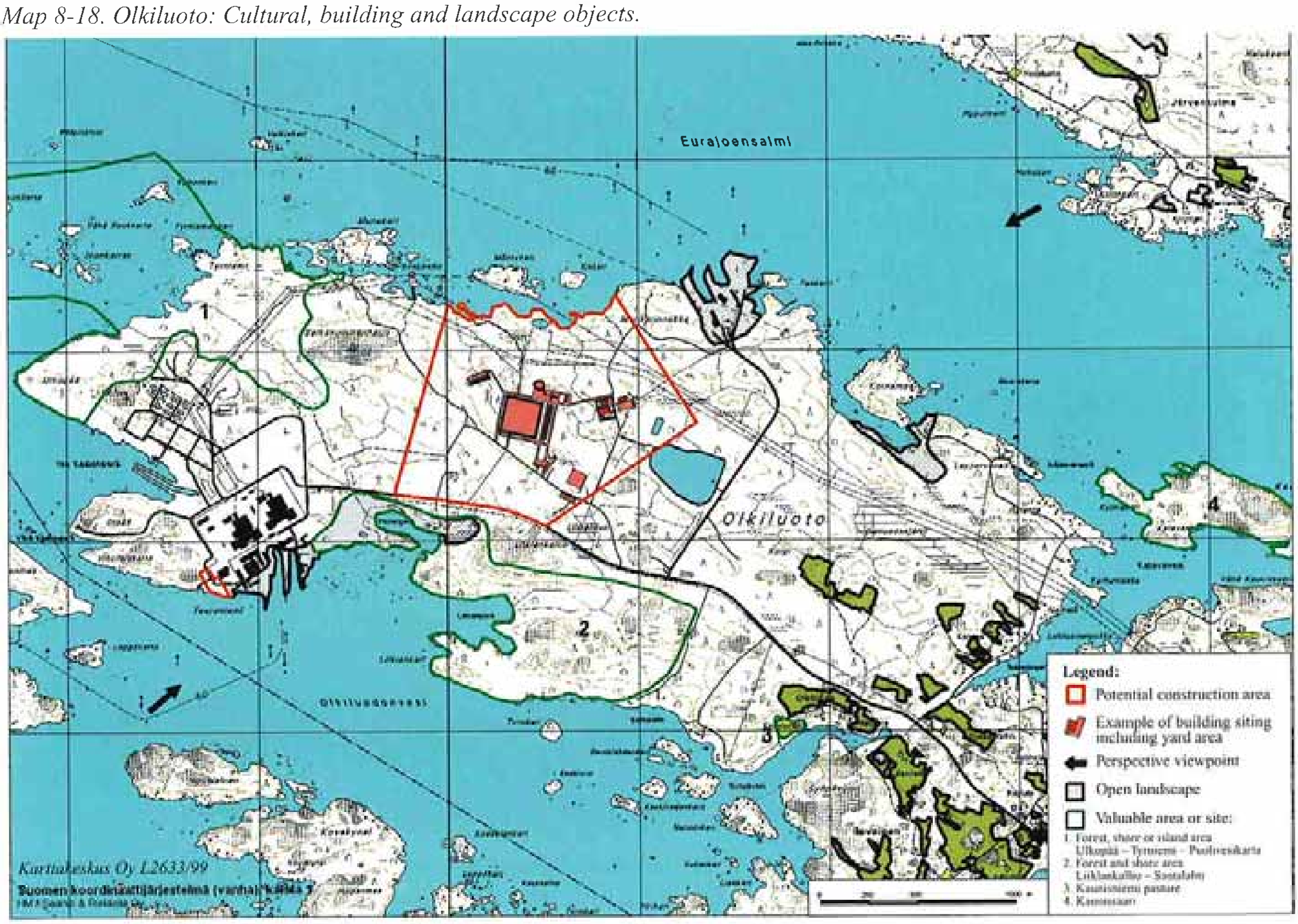


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Figure 8-2a. Aerial view of the Olkiluoto investigation area from the northeast (1995).

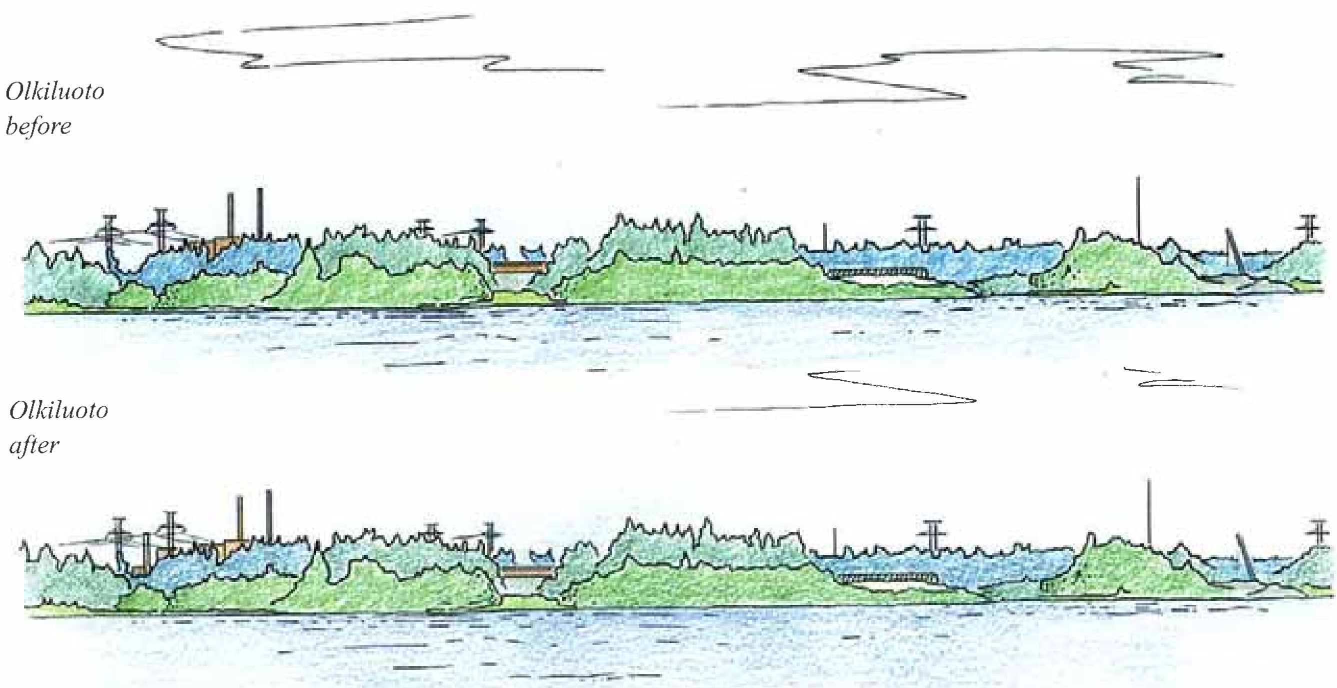
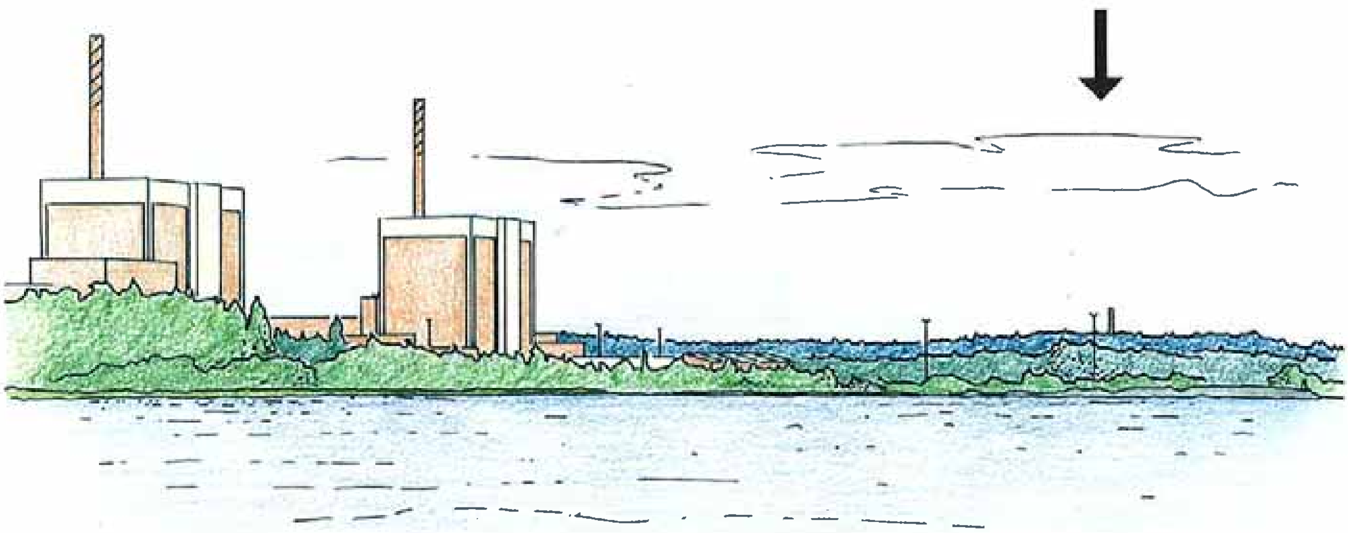


Figure 8-2b. View to Olkiluoto from the northeast as seen from the summer cottages on the Kiilinkari shore. Due to the existing low trees, the roofs of new buildings will be visible. The landscape is dominated by harbour buildings and transmission lines.



View of Olkiluoto southwest from the entrance channel. The chimney of the new heating plant rises above the trees. The landscape is dominated by the power plants.

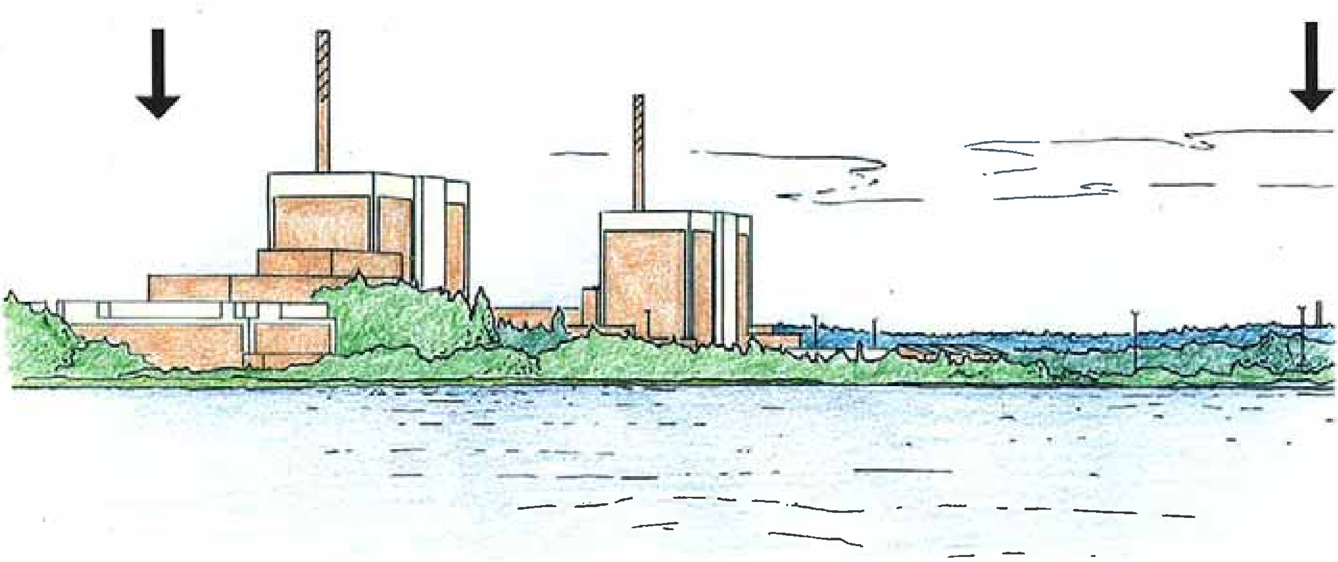
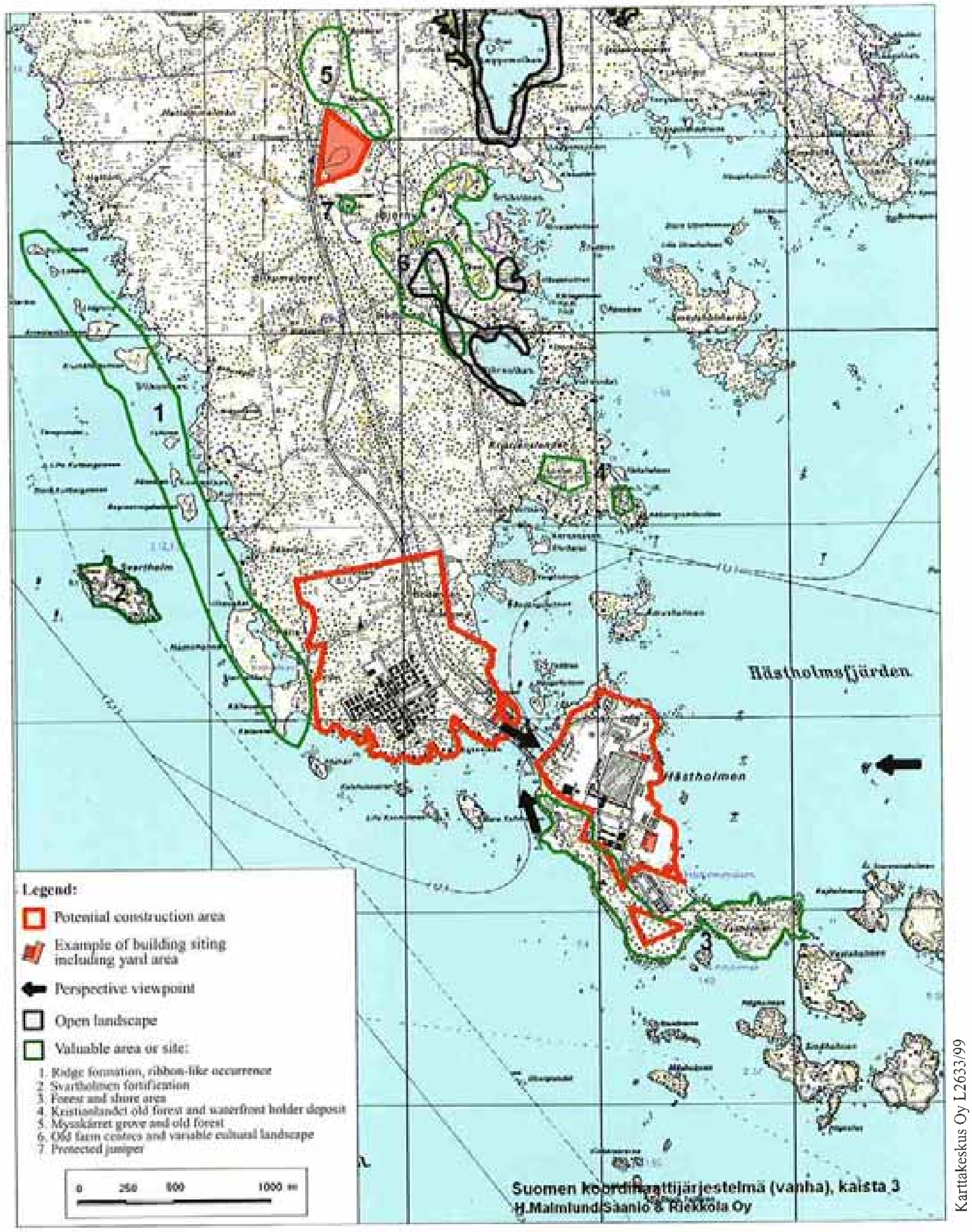


Figure 8-3. View of Olkiluoto from the southwest if the encapsulation plant is built next to the power plant. The landscape is dominated by the power plant.

Hästholmen

At *Hästholmen,* buildings placed near the shore will be visible in the landscape. Buildings placed in the inner sections of the mainland will be visible only at close distances, and are not visible above the tops of fully grown trees. From the southerly and westerly directions, the chimney would be the only feature visible above treetops. Changes to the landscape could be minimised with protective forest strips at shore areas. Buildings can be integrated into the landscape by matching same colours and materials to those used in the power plant (Map 8-19 and Figures 8-4, 8-5, 8-6a-b).



Map 8-19. Hästholmen: Cultural, building and landscape objects.

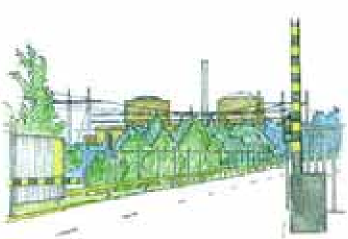


Figure 8-4. The gate to the Loviisa plant. The new building is behind the transmission line pylon.

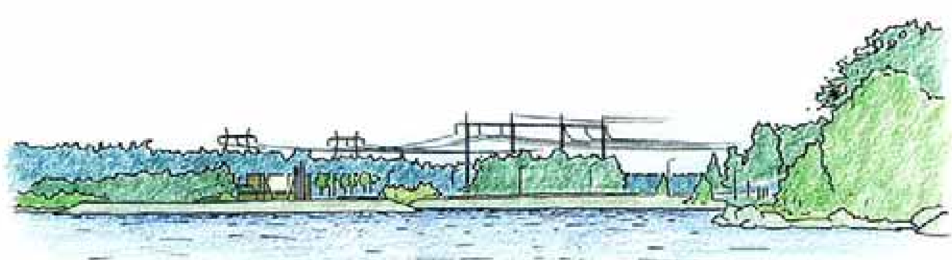


Figure 8-5. View from Hästholmen to the gate cafeteria and small boat harbour. The planned communications centre is outlined behind the cafeteria.

Figure 8-6a. Aerial view of the Hästholmen investigation area (1997).

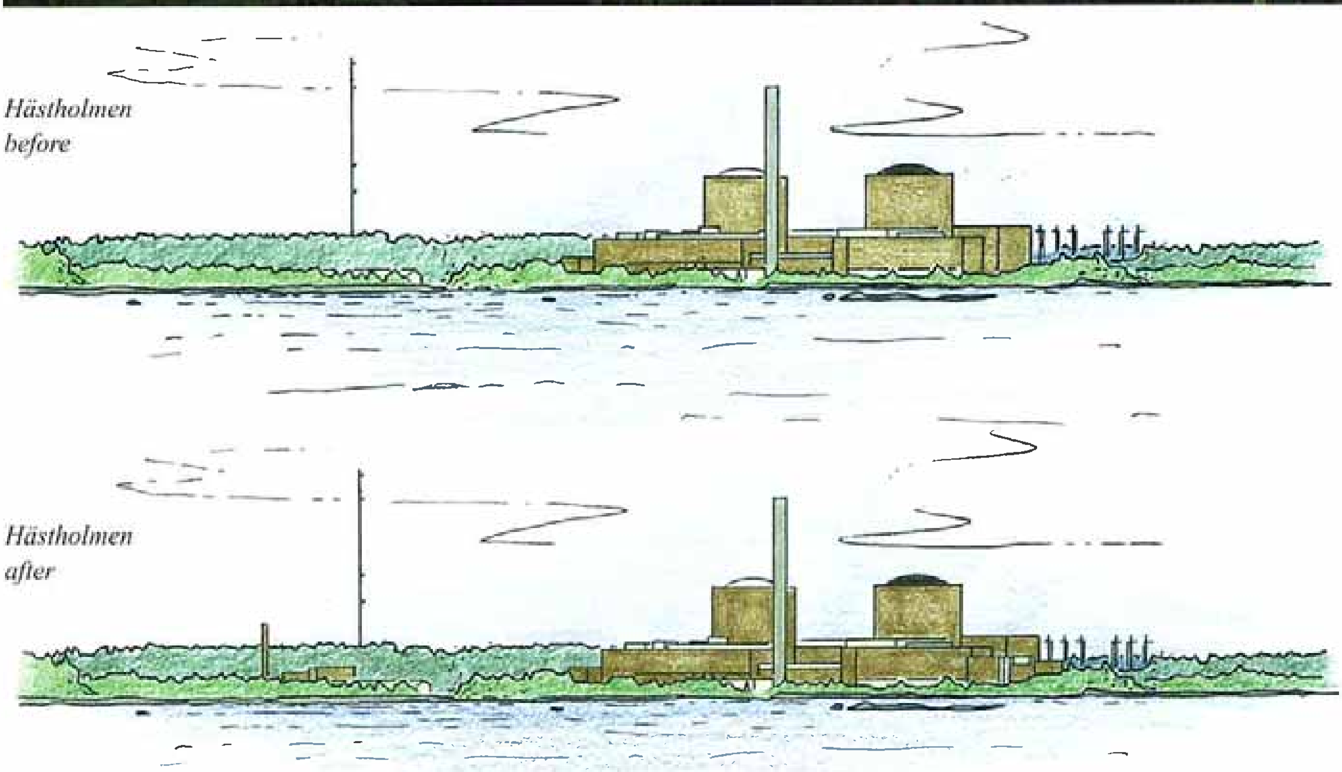
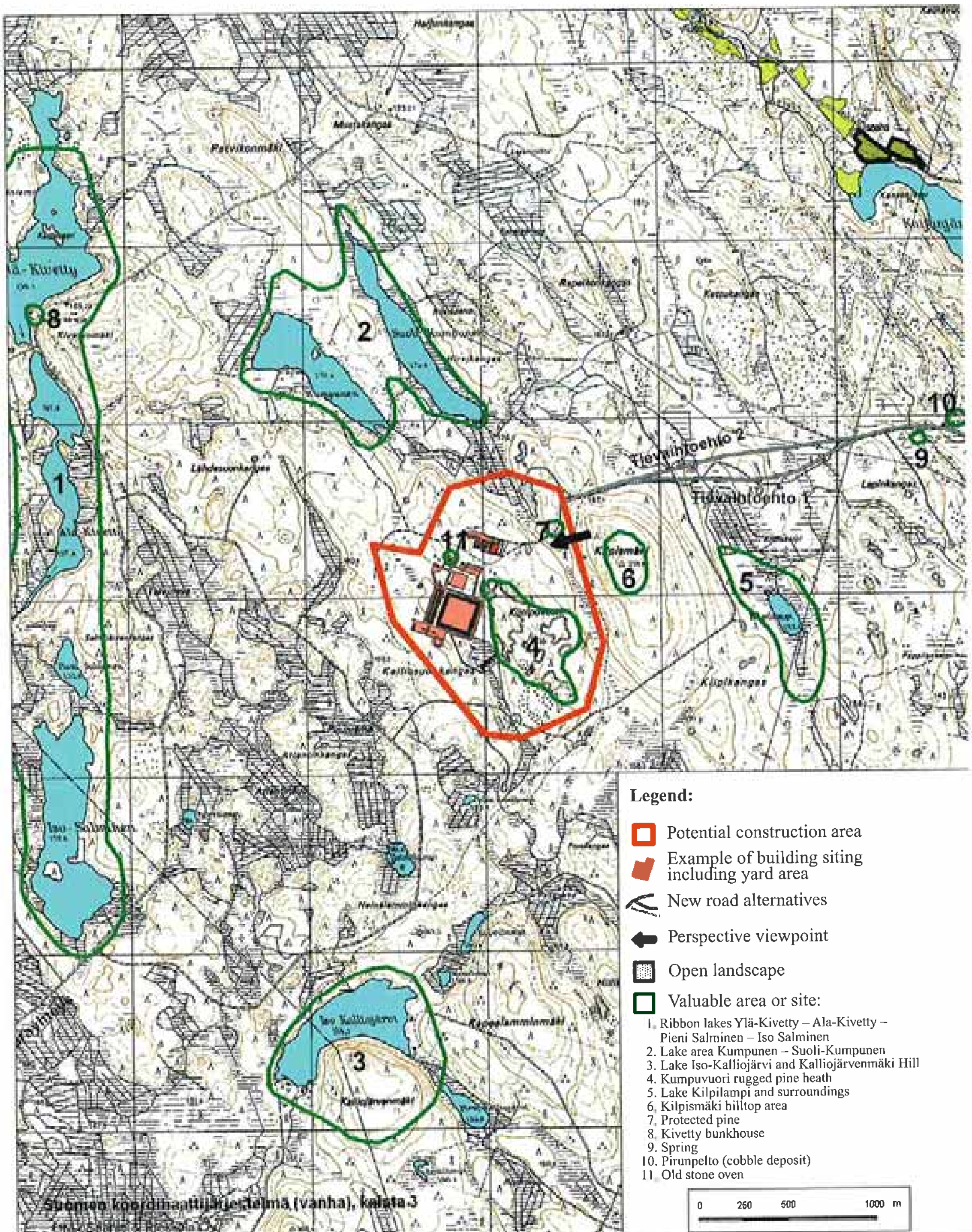


Figure 8-6b. View to Hästholmen as seen from cottages on the Gäddbergsö shore. The landscape is dominated by the power plants.

Kivetty

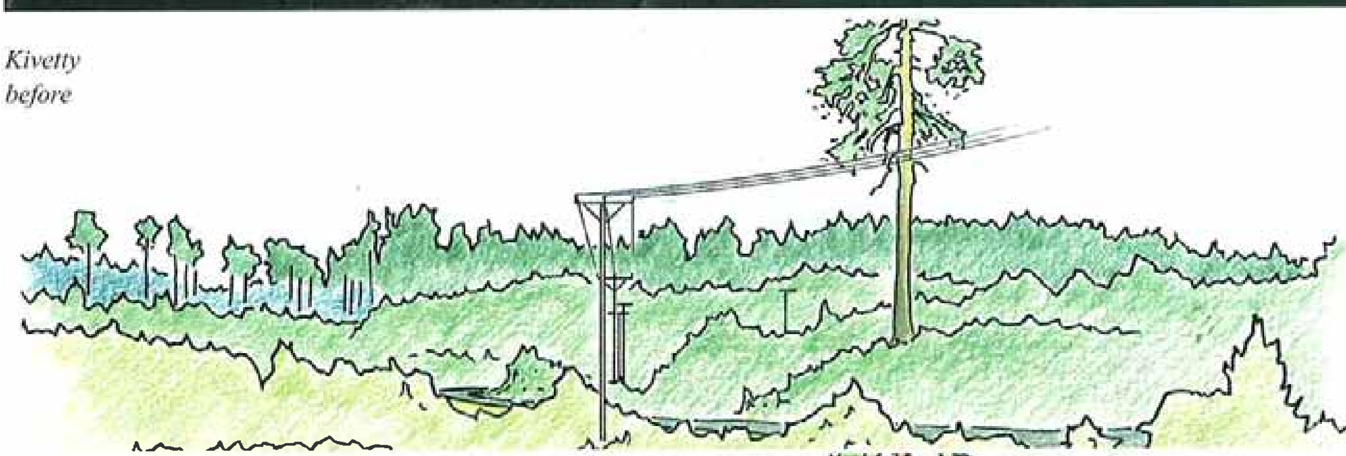
Kivetty is a forest area where buildings will not appreciably alter the landscape. For example, the view from the high hill at Kalliojärvenmäki will not change. The heating plant's 30-metre high chimney will only be visible at close distances, if an opening is left in the trees. Other buildings will remain completely hidden behind trees (Map 8-20 and Figure 8-7a-b). At Kivetty, a new road would naturally change the views from the sides. Even though road alternative 1 passes near the existing road, alternative 2 would cause more changes in the landscape because of more extensive earthmoving work.



Map 8-20. Kivetty: Cultural, building and landscape objects.

Figure 8-7a. Aerial view of the Kivetty investigation area from the southeast (1995).

Kivetty before



Kivetty after

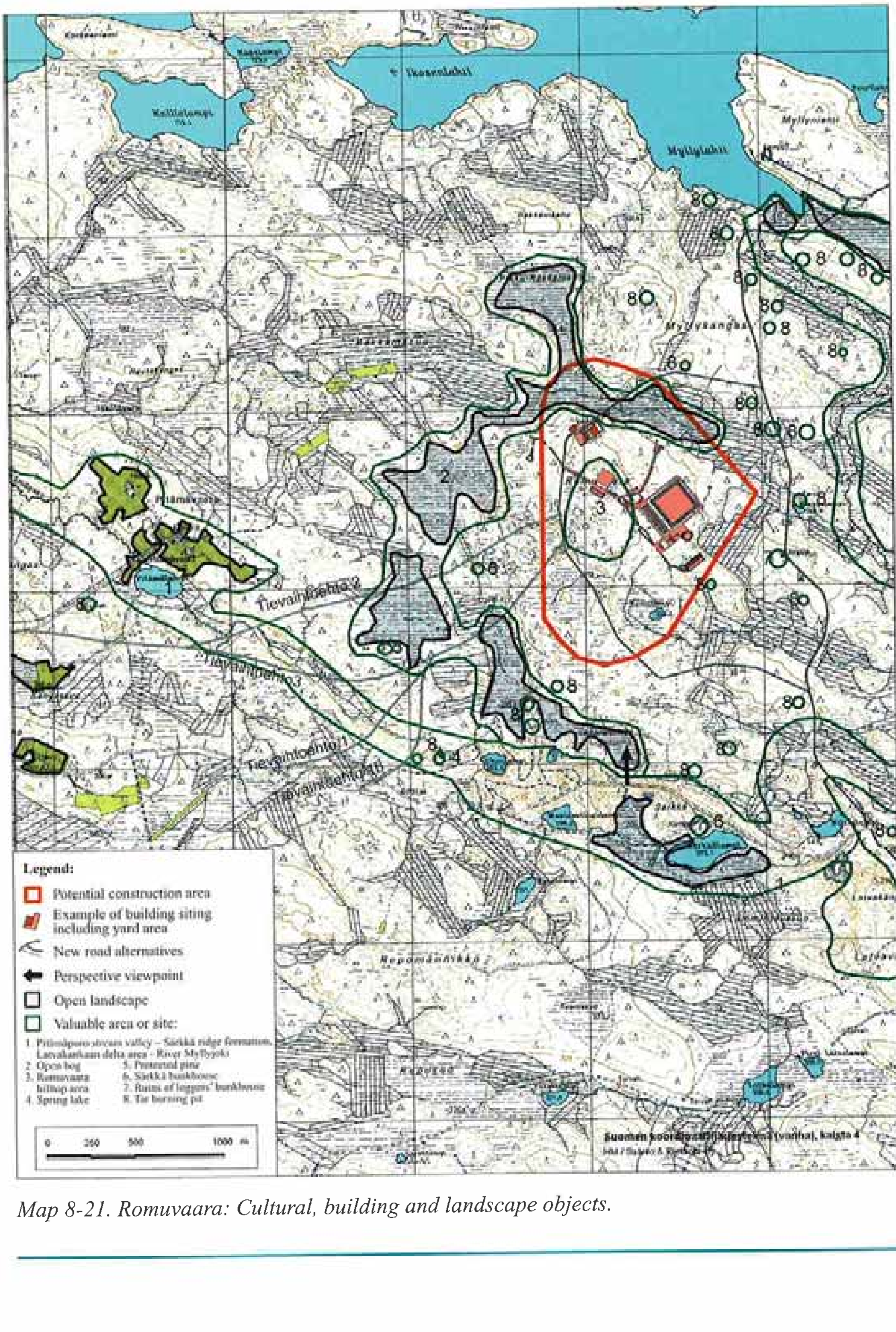
Figure 8-7b. View to Kivetty as seen from the northwest slope of Kilpismäki. The existing open cut makes the view possible. The picture also shows a protected pine tree.

Romuvaara

Romuvaara is a forest area and buildings would alter the landscape in only one place: the heating plant's 30-metre high chimney would be visible only from Särkkäharju.

Views from the farm at Pitämävaara or the summer cottages along Lake Kalliojärvi would not change. Buildings would remain completely hidden behind fully grown trees, and they will only be visible at close distances if an opening is left in the trees (Map 8-21 and Figure 8-8 a–b).

At Romuvaara, a new road would alter the views from the sides. Road alternatives do not differ appreciably from each other regarding their impact on the landscape. Improving the existing road would cause the least change to the landscape, but on the other hand, the existing road crosses the only provincially significant object, the Särkkä ridge.



Map 8-21. Romuvaara: Cultural, building and landscape objects.

Figure 8-8a. Aerial view of the Romuvaara investigation area (1995).

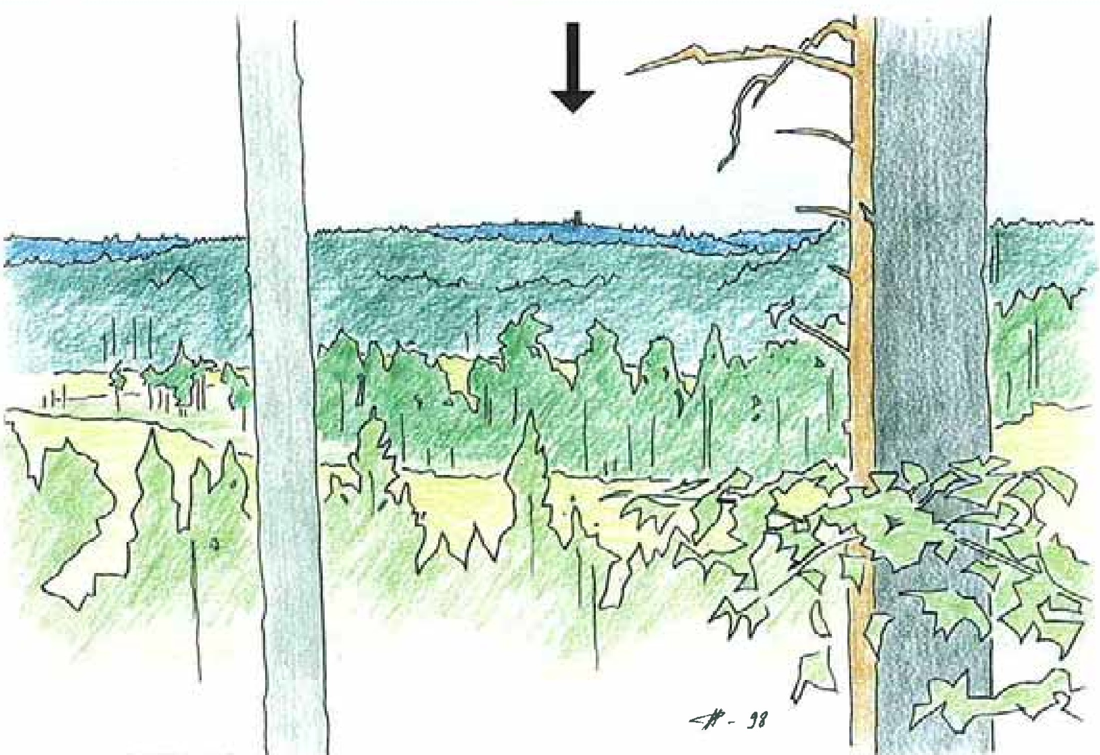


Figure 8-8b. View from Särkkä ridge.

An increase in the quantity of spent fuel, the excavation of all tunnels at one time and the excavation of a vehicular access ramp would increase the size of the rock pile. For example, continuing the operational life of existing power plants from 40 to 60 years would increase the size of the stockpile by approximately 50%. If blasted rock could be sold as a construction material, the stockpile would not grow. The blasted rock is not visible in the forest. If blasted rock was brought to the site occupied by the crushing plant in Loviisa, it is recommended that a protective strip of trees be left near Mysskärret and the road.

Impacts on the landscape are insignificant. Due to the siting of the facility, impacts on the urban image cannot be considered important. During the investigation and decommissioning phases, the impacts will be at their minimal. Following the sealing phase, all buildings can be demolished if they are no longer of any use. There are no culturally historic features or structures remaining under buildings.

The Department for Occupational Safety and Health at the Ministry of Health and Social Affairs has statistically studied accidents related to the use, storage and transport of explosives over an approximately 70-year period (Tolppanen & Kokko 1998). Considering these statistics, the number of explosives-related accidents has decreased due to the development of explosive materials, personnel training and increasingly stringent regulations.

Compliance with regulations and professional working procedures significantly reduces accident risks associated with the use of explosives. Environmental hazards are prevented by the proper placement of storage areas for explosives and intentional damage is ensured with sufficient guarding. When required, vibrations caused by surface excavation are monitored in adjoining buildings at Olkiluoto and Hästholmen. At Äänekoski and Kuhmo, existing buildings are situated so far away that vibration monitoring is not required. The enclosed maps (8-18, 8-19, 8-20 and 8-21) show the locations of the buildings in relation to the facility.

8.3.6 Summary

The superterranean structures and yard areas of the final disposal facility cover approximately 15 ha of land area. At Äänekoski and Kuhmo a new road would require an additional 10 ha of land area. At Kivetty, buildings would not be visible behind fully grown trees. At Romuvaara, the heating plant's 30-metre high chimney would be visible only from the Särkkä ridge. At Hästholmen and Olkiluoto, buildings would be visible from the sea if there are no stretches of protective trees. In both cases the landscape is dominated by the existing power plants. If buildings near shore locations are placed behind fully grown trees, only the top of the heating plant's chimney would be visible from the sea.

Surface excavation causing vibration will be carried out during construction for a total of 7–11 months. Vibration can be observed at distances of 200–300 metres. At Loviisa and Eurajoki, the proximity of existing structures may require vibration monitoring.

Underground excavation has no superterranean effects.

8.4 Effects on human health

Effects on human health, as discussed in this report, are defined according to the Ministry of Social Affairs and Health's draft guidelines (STM 1998) as changes in peoples' health or hygienic conditions, or the threat of changes (health risks) caused by a project. The changes specified in the draft guidelines can be direct or indirect, cumulative, short-term or long-term, favourable or detrimental, permanent or recurrent, serious or mild. This report will, however, emphasise the studying of the possibilities of health detriments.

A health detriment is:

- an illness diagnosed in a person, or
- other ailment, or
- a factor or condition that weakens the healthiness of the population's or individual's environment.

Reports concerning health effects have focused primarily on health detriments possibly caused by radioactive substances. This report will first generally examine how radiation from radioactive materials could affect people's health. Subsequently, an assessment will be made concerning possible exposure to radiation accompanying the transport of spent fuel, during the encapsulation and final disposal phases, and after the decommissioning and sealing phases. The assessment covers normal situations (operations functioning as planned) as well as various malfunction and accident scenarios. Evaluations of long-term safety relate primarily to assessing the importance of unexpected events and uncertainties. The valuation methods employed are explained with assessments.

Besides the effects of radioactivity, other health effects possibly caused by the project will be assessed. Risks caused by traffic, noise and dust will be among those examined. The review is based on the values presented in Chapter 8.2 regarding project-related emissions and other tangible changes in the environment. The possible health effects of spent fuel materials during the post-closure phase are treated separately.

In this connection, illnesses possibly induced by a project's psychosocial effects, such as fear and stress, are also examined. Possible discomfort and other social effects are examined in Chapter 8.5.

8.4.1 Health effects caused by impurities, noise and vibration

Non-radioactive emissions released into the air and water during the final disposal facility's investigation, construction and operational phases, as well as noise and vibration caused by operations, are examined in Chapter 8.2. From the overall perspective, emissions caused by operations, as well as other physical changes in the environment, are considered minor. The following is a summary of these assessments from the standpoint of human health and hygienic conditions.

Traffic

The project will increase the overall exhaust emissions in the area by a few percentage points at the most; for example NOx concentrations will remain well below the recommended values. The additional traffic has no significant effects on health or local air quality.

Because traffic is weighted towards the daytime and the 55 dB(A) noise area grows only slightly, the health effects of traffic noise are insignificant.

Crushing

Blasted stones are crushed for one month approximately every other year. Crushing is not carried out at night. At a distance of 500 metres from the crushing plant, the noise level of the plant falls below the Noise Abatement Act recommended value of 50 dB(A) for crushing plants. When the pile of blasted stones is used as a noise protector, the noise level falls below the 50 dB(A) value within 200 metres. The noise level of normal conversation is 60 dB(A). The protective distance of dust from the crushing plant is 300 metres. The crushing plant and the pile of blasted stones can be located so that there are no buildings within noise or dust areas. In that case, crushing causes no significant health effects.

Besides the crushing plant, noise is created by the heating plant's flue gas fan and air conditioning. The guidance level (55 dB(A)) for these kinds of noises are not even exceeded in the plant area, so there would be no significant health effects extending to the environment.

Excavation

Over a 20-year period, construction-related surface excavations producing vibration, dust and noise are carried out for a total of 7–11 months. Vibration and dust can be observed at a distance of 200–300 metres. Sounds from blasting can be heard over a distance of approximately one kilometre (2 kilometres in coastal areas), but the average noise level exceeds the guidance levels only near the excavation location. Excavation is not carried out at night. Underground excavations do not have an effect above ground. Considering these factors, excavation does not produce significant effects on health.

The concentration of radon released from bedrock is so small that it is virtually impossible to differentiate it from the concentration of radon in the outdoor air. Significant health effects are not created.

Wastewater treatment

Grey water is purified in a conventional wastewater treatment plant, and other waters are treated with various filtration processes to ensure that no significant health risks are created.

Heating plant emissions

In terms of fuel consumption, heating plant emissions are equivalent to that of oil heating in detached houses. Concentrations do not even approach guidance levels, even in poorer weather, and there are no significant health effects.

Encapsulated materials

Health risks posed by the chemical properties of canisters and their contents have been assessed in the same way as radiation effects (Raiko & Nordman 1999). Calculated concentrations clearly fall below concentration limits established for household water. Consequently chemical toxicity is not a significant factor in final disposal. Possible building areas do not contain groundwater areas applicable to public water use.

8.4.2 Traffic accidents

The number of traffic accidents is assumed to be directly comparable to traffic volume (Figure 8-1). Estimates of the risk caused by the project's additional traffic are based on average accident frequencies and traffic volumes for different types of roads (LT-Konsultit Oy 1998). The results have been compared to municipal accident statistics for the years 1992–1997. The traffic created by the facility would increase the number of personal injury accidents in the municipality by 1–3% during its entire life span (years 2001–2046). The estimate indicates the magnitude of the effect of the project.

8.4.3 Health effects of radiation

Radiation from radioactive materials

Basic definitions

Radioactivity means the ability of an atomic nucleus to transform or decay into another nucleus. A radioactive substance contains these kinds of unstable atomic nuclei that are capable of transforming themselves into other nuclei. Radioactive species of atoms and nuclei (nuclides) are termed radionuclides. Chemical elements can be either stable or unstable nuclides (isotopes).

Radioactive decay is a random phenomenon, but because there is normally a countless number of atomic nuclei within the quantity weighed for analysis, the rate of transformation can be accurately predicted. The rate of transformation is described by the so-called *half-life*: after the half-life characteristic of each radionuclide has transpired, half of the original unstable nuclei have decayed into other nuclei. When the next half-life period has transpired, half of the remaining nuclei have decayed, and so on. The nucleus resulting from the transformation can be radioactive, but the end result will be a stable (non-radioactive) nucleus. A substance's radioactivity thus decreases with time (Figure 2-3). The half-lives of radionuclides vary from a fraction of a second to billions of years.

The level of radioactivity is quantitatively defined as *activity*, the number of decaying nuclei occurring within a given time interval. The unit of activity is the *becquerel* (Bq), one decay per second. The becquerel is a small unit; for example the activity of the natural radionuclide potassium-40 found in the human body is typically thousands of becquerels.

Ionising radiation is generally created with radioactive decay. Ionising radiation is able to cause ionisation directly or indirectly by loosening electrons from atoms. In that case, the consequence may be chemical transformations. Examples of ionising radiation include alpha, beta, gamma, x-ray and neutron radiation. Alpha, beta and neutron radiation is particle radiation, while gamma and x-ray radiation is electromagnetic radiation.

Ionising radiation discharges energy and attenuates as it passes through materials, depending on the properties of the radiation and the substance: for example alpha radiation cannot pass through ordinary copying paper, but the significant attenuation of gamma radiation requires thick layers of materials. The radiation's interaction with the substance is quantifiably defined as the *absorbed dose*, whose unit is the *gray* (Gy). The absorbed dose expresses the quantity of energy transferred from the radiation to the material per unit mass (J/kg).

Ionising radiation found in nature originates in naturally radioactive materials and from outer space. In general, only minute quantities originate from artificially radioactive substances. People produce ionising radiation for example with artificially radioactive materials and x-ray equipment. The ionising radiation discharged from spent nuclear fuel originates from the artificially and naturally radioactive substances it contains. People are constantly subjected to radiation coming from outside their bodies (external radiation) as well as from radioactive substances entering their bodies through actions such as eating and breathing (internal radiation).

Health effects and risks of ionising radiation

When examining the health risks of radioactivity, most attention is devoted to the ionising radiation created in connection with radioactive decay, even though an atom's transformation to another chemical element may sometimes also cause harmful effects. The health effects and risks of ionising radiation depend on factors such as radiation characteristics, quantity, and the target organ or tissue.

Besides the absorbed dose, health risks are quantifiably defined as the *equivalent dose*, whose unit is the *sievert* (Sv). The equivalent dose is calculated from the absorbed dose by multiplying it with a factor depending of the species of radiation. The factor is 1 for beta, gamma, and x-ray radiation, 5–20 for neutron radiation, depending on the energy, and 20 for alpha radiation.

When, besides the species of radiation, the varying significance of organs or tissues on health and sensitivity to illness is taken into account using weighting coefficients, health risks are assessed using the *effective dose* (weighted equivalent dose), whose unit (Sv) is the same as for the equivalent dose.

When examining the entire population's or a part of the population's exposure to radiation, the quantitative measurement is the *collective dose* (generally the collective effective dose), whose unit is the *mansievert* (manSv). The collective dose represents the average radiation dose received by individuals multiplied by the number of persons. Because the gray and the sievert are large units, their thousandth parts (for example mSv) or millionth parts (for example μSv) are used.

Health effects and risks also depend on the *rate of dose accumulation*, the dose rate, whose unit is, for example, the millisievert per hour (mSv/h).

The health detriments of radiation can be classified as early and delayed effects. Early effects are caused when the radiation dose exceeds a sufficiently large value, the so-called threshold value. For example, if an individual is exposed to a large dose of radiation within a short period over his or her body, he or she may die of so-called radiation sickness within a few weeks. Early effects have appeared primarily as a result of the bombing of Hiroshima and Nagasaki, certain accidents and radiotherapy.

Delayed effects are random: the probability of effect appearance increases as the accumulated dose increases. Exposure to radiation increases, for example, the likelihood of contracting cancer. Cancer, however, appears only after many years of exposure. Delayed effects may also appear because of small radiation doses.

Tables 8-4 and 8-5 briefly illustrate estimates for the health effects and risks of radiation as a function of dose. Table 8-6 presents the permissible limit values for radiation exposure in Finland, and Table 8-7 depicts typical radiation doses and dose rates from various sources and activities. The doses from the aforementioned tables can be compared when it is pointed out that 1 mGy of gamma radiation equals 1 mSv.

Estimates of radiation-related health effects and risks are based on the observed effects of large doses (over 200 mSv) and dose rates, as well as radiobiological research. It has not been possible to observe the effects of small doses of radiation in statistical studies concerning large populations because the possible effect – concerning which it has been claimed that small doses can also be favourable – is minor and, for example, cancers appear many for other reasons.

According to a certain point of view, radiation remaining below a certain threshold value would not have injurious effects. In keeping with the precaution principle, it is, however, assumed in radiation protection that, for example, the likelihood of cancer is directly comparable to radiation dose without the threshold value. Concerning small doses, the International Commission on Radiological Protection (ICRP) uses a cancer risk factor equal to one-half (Table 8-5) of the observed risk factor for large doses (ICRP 1991, UNSCEAR 1994, 1993).

Radioactivity, ionising radiation and the health effects of ionising radiation are treated more extensively in booklets (Wahlström 1994, Toivonen et al. 1987), books published by the Finnish Centre for Radiation and Nuclear Safety (Paile et al. 1996, Toivonen et al. 1998) and publications by the International Commission on Radiological Protection (ICRP) and United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR (ICRP 1991, UNSCEAR 1994, 1993).

The sensitivity of organisms to ionising radiation varies considerably depending on the organism species. Knowledge of the sensitivity of different species also varies. Generally, mammals are the most sensitive animals, followed by birds, fish, reptiles and insects. The sensitivity ranges of plants and animals partially overlap. Figure 8-8 outlines the sensitivity of organism species to radiation. The most radiation-sensitive characteristic is the ability to reproduce, particularly important from the standpoint of maintaining the population. Regarding natural plant and animal populations, there is little evidence to suggest that a dose rate lower than 0.1 mGy/h (approximately 800 mGy/a) would have detrimental effects on the population level (UNSCEAR 1996).

Table 8-4. Certain threshold doses showing early effects of ionising radiation for adults. Numerical values signify doses accumulated over short periods, for example within a few minutes. The accumulation of equivalent doses over a long-term period significantly reduces several effects (ICRP 1991).

Location/Impairment	Dose (mGy)
Testicles	
Temporary sterility	150
Permanent sterility	3500–6000
Ovaries	
Permanent sterility (susceptibility increases with age)	2500–6000
Lens	
Observable blurring	500–2000
Loss of vision (cataract)	2000–10 000
Bone marrow	
Significant temporary interruption in formation of blood cells	500
Skin	
Reddening, loss of hair	3000–5000
Blisters and ulcers	20 000
Entire body	
Death of susceptible person	1000
Death of healthy person in 50% of cases without hospital care	3000–5000

Table 8-5. Nominal probability coefficients for stochastic effects of small radiation doses or small radiation dose rates to whole body for radiation protection (ICRP 1991). Values are conservative (overrated) and average (not, for example sex- or age-specific). The probabilities of other cancers and hereditary effects have been weighted according to their severity. For example the probability of fatal cancer (0.005%/mSv) means that if, for example, 100,000 persons each receive a dose of 1 mSv, it can be expected that approximately 5 persons will be afflicted with this kind of cancer.

Hazard probability per dose (%/mSv)	Working population	Entire population
Fatal cancer	0.004	0.005
Other cancer	0.0008	0.001
Serious hereditary effects	0.0008	0.0013
Total hazard	0.0056	0.0073

Table 8-6. Legal maximum values for radiation exposure in Finland (Radiation Act, Valtioneuvosto 1991a, 1991b and 1999).

Effective dose accumulated during one year in normal radiation-related work	50 mSv
Effective dose accumulated during five years in normal radiation-related work	100 mSv
Effective dose accumulated during one year caused by radiation elsewhere than in radiation-related work	1 mSv
Effective dose accumulated during one year by person living in area subject to emissions from nuclear power plant	0.1 mSv
Expectation value of effective dose accumulated during one year by person living in proximity to nuclear power plant's final disposal facility for spent nuclear fuel	0.1 mSv
Annual effective dose to person living in proximity to nuclear power station's final disposal facility for spent nuclear fuel caused by expected malfunctions	0.1 mSv

Table 8-7. Typical radiation doses and dose rates from certain sources and activities (Voutilainen 1998, UNSCEAR 1993).

Average annual dose of background radiation in nature (except radon in indoor air)	1 mSv
Average annual dose of radon in indoor air for Finns	2 mSv
Background radiation in Eurojoki, Kuhmo, Loviisa and Äänekoski, and annual dose caused by radon in indoor air estimated on basis of measured radon concentrations	3–220 mSv
X-ray examination of lungs	0.3 mSv
Dosage caused by background radiation (external radiation) at sea level in one hour	0.1 µSv
Cosmic radiation in aeroplane at altitude of 10 km in one hour	4 µSv

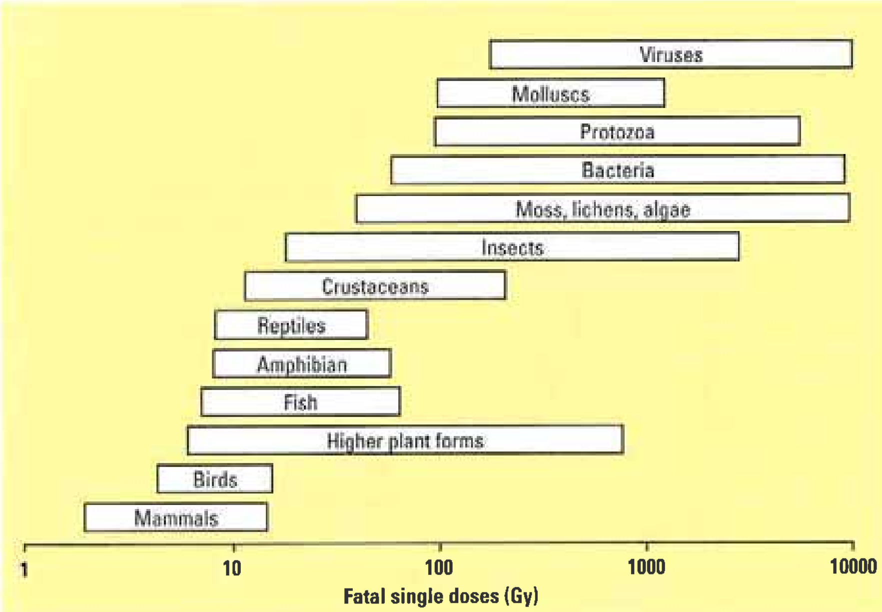


Figure 8-8. Approximate acute lethal dose ranges for various taxonomic groups (UNSCEAR 1996).

The International Commission on Radiological Protection (ICRP) believes that the present-day control of peoples' exposure to radiation ensures that other species will not be endangered, or that there will not be imbalances created between species, even though individual members of certain species might be harmed (ICRP 1991). The International Atomic Energy Agency (IAEA) has reached the same conclusion, except that special ecological conditions, such as rare or endangered species, or the manifestation of other stress factors along with radiation could mean an exception (IAEA 1992a). Within the IAEA, attention has been paid to the possible necessity for guidelines on the radiation protection of environment (IAEA 1997b).

Transport of spent nuclear fuel

Utilised methods and assumptions

Health detriments possibly caused by the transport of spent fuel were assessed based on the transport arrangements and routes described in Chapter 4, assuming that transport is implemented according to present requirements. From the standpoint of possible health effects, the maximum quantities of the most significant radionuclides in examined cask types are shown in Table 8-8.

According to regulations concerning the transport of hazardous materials, the transport casks of spent fuel should fulfil the requirements of so-called B-type packaging, correspondingly, the transport arrangements should fulfil the requirements for the transportation of such load. B-type packaging can contain more radioactive materials than so-called A-type packaging that applies to the certain radionuclide-specific upper limits A1 and A2. For this reason, along with endurance in normal situations, requirements for accident endurance (See section "Accident Situations") have been established for B-type packaging that differentiate them from A-type packaging.

Anticipated health effects

During the normal transportation of spent fuel, the amount of radioactive material leaking from the interior of the cask to the outdoors is not significant. Transport regulations specify an upper limit for leaks (one-millionth part of A_2 per hour) caused by the highest normal stresses on the cask. The exterior surface of the cask must be kept as free of radioactive materials as is practically possible. An upper limit of 4 Bq/cm^2 has been established for the quantity of radioactive materials possibly loosening from the surface, an exception being an upper limit of 0.4 Bq/cm^2 for certain nuclides emitting alpha radiation. The maximum allowable dose rate at a distance of one metre from the cask is 0.1 mSv/h. Dose rates in the transport under study were clearly dominated by gamma and neutron radiation originating from within the cask.

Figure 8-9 illustrates the dose rate at various distances from the horizontally positioned CASTOR-TVO cask caused by the maximum allowable dose rate. The dose rate originating from the cask decreases as the distance increases, and is 0.1 μSv/h (typical dose rate for external radiation in Finnish nature) at a distance of approximately 35 metres, and a tenth of that at a distance of approximately 100 metres (impact area). In reality the dose rate would be smaller.

The risks of transporting spent fuel have been examined in the report (Suolanen et al. 1999). Transported casks were assumed to contain a maximum amount of radionuclides in spent fuel and external dose rate was at the maximum permissible level.

The population's exposure to radiation penetrating cask walls was assessed according to the aforementioned transport modes and routes. The transport could normally be required to stop occasionally for various reasons. Only unusually long stops, for example caused by equipment failure or transport conditions, were considered transport malfunctions. In that case the cask's protective characteristics would

Radionuclide	Abbreviation	Half-life (y)	Quantity (Bq) CASTOR-TVO	CASTOR-VVER
Tritium (Hydrogen 3)	H-3	12.3	$7.4 \cdot 10^{13}$	$8.6 \cdot 10^{13}$
Krypton-85	Kr-85	10.7	$1.2 \cdot 10^{15}$	$1.2 \cdot 10^{15}$
Strontium-90	Sr-90	28.6	$2.1 \cdot 10^{16}$	$2.1 \cdot 10^{16}$
Rutenium-106	Ru-106	1.01	$2.1 \cdot 10^{11}$	$2.2 \cdot 10^{11}$
Iodine-129	I-129	$1.57 \cdot 10^{7}$	$1.6 \cdot 10^{10}$	$1.6 \cdot 10^{10}$
Cesium-134	Cs-134	2.06	$1.2 \cdot 10^{14}$	$1.2 \cdot 10^{14}$
Cesium-137	Cs-137	30.2	$3.2 \cdot 10^{16}$	$3.1 \cdot 10^{16}$
Cerium-144	Ce-144	0.779	$5.8 \cdot 10^{9}$	$5.9 \cdot 10^{9}$
Promethium-147	Pm-147	2.63	$2.0 \cdot 10^{15}$	$1.9 \cdot 10^{15}$
Plutonium-238	Pu-238	87.8	$2.3 \cdot 10^{15}$	$1.6 \cdot 10^{15}$
Plutonium-239	Pu-239	$2.41 \cdot 10^{4}$	$1.5 \cdot 10^{14}$	$1.6 \cdot 10^{14}$
Plutonium-240	Pu-240	$6.57 \cdot 10^{3}$	$2.4 \cdot 10^{14}$	$2.4 \cdot 10^{14}$
Plutonium-241	Pu-241	14.4	$2.4 \cdot 10^{16}$	$2.4 \cdot 10^{16}$
Americium-241	Am-241	$4.32 \cdot 10^{2}$	$1.2 \cdot 10^{15}$	$1.2 \cdot 10^{15}$
Curium-244	Cm-244	18.1	$1.6 \cdot 10^{15}$	$1.0 \cdot 10^{15}$

Table 8-8. From a safety standpoint, the maximum quantities of more significant radionuclides contained in CASTOR-TVO and CASTOR-VVER cask types during the transport of the spent fuel stored at the Olkiluoto and Loviisa Power Plants for a minimum of 20 years (Suolanen et al. 1999, Rossi et al. 1999). It was assumed that the CASTOR-TVO cask contained 48 Olkiluoto fuel assemblies with an average burnup of 45 GWd/tU and that the CASTOR-VVER cask contained 84 Loviisa fuel assemblies with an average burnup of 42 GWd/tU.

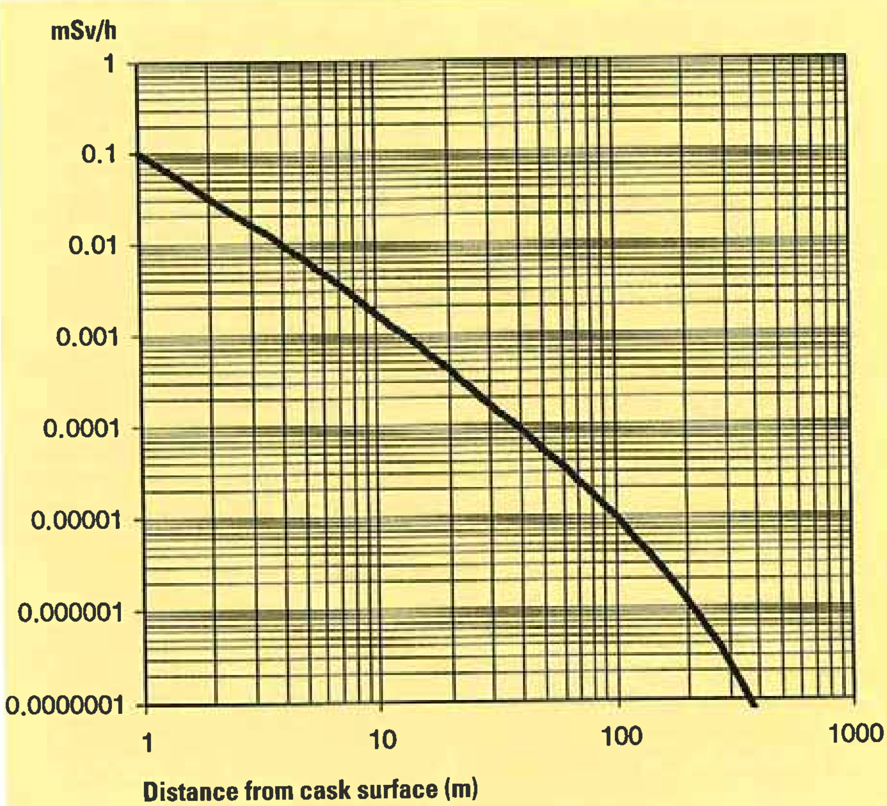


Figure 8-9. Approximate dose rate from the long edge of the CASTOR-TVO cask in transport position as a function of the distance from the cask surface (Suolanen et al. 1999). Dose rate at a distance of 1 metre from the cask surface is assumed to be a maximum allowable dose rate of 0.1 mSv/h.

not be weakened, but the environment could be exposed to additional radiation penetrating through the walls of the cask. Another type of malfunction studied was the situation in which radioactive substances on the surface of the cask, despite cleaning, might become more easily loosened during transport. Accident situations are extremely rare situations in which the cask's tightness and integrity could be threatened.

Upper values for annual doses and total doses for an individual (belonging to the population) subject to greatest exposure were calculated assuming that he or she:

- stays at a distance of 10 m from every passing cask transported by road (maximum 25 casks per year) and
- stays for 13 hours each year at a dis tance of 10 m from a stationary cask,

because land transport is also connected with rail and sea transport.

The results of the study are shown in Table 8-11. For the sake of comparison, the dose caused by the bypass of a single cask is shown in Table 8-12 as a function of bypass distance. Doses received by an individual (belonging to the population) most exposed, as well as the entire population resulting from stops considered to be malfunction situations, are shown in Table 8-13, assuming that 50 persons have been present for 8 hours at a distance of 10 m from the cask.

The health risk posed by the possible loosening of radioactive substances remaining on the cask surface is insignificantly small due to such factors as the minute quantities and the protective casing enclosing the cask.

The RADTRAN 4 computer program was used to calculate the total dose (the expectation value of the collective dose) caused to the population by transport and assumed malfunctions according to transport mode and route. In the model used by the computer program, the transport route is divided into sections for which can be specified factors such as average population densities, transport speed, number of passengers passing by, stopping time, the number of persons exposed to radiation and distance during stopovers. By selecting conservative values for the model's parameters, conservative values for calculated doses were also achieved with a high degree of certitude (upper values).

The results of calculations for overall doses received by the population are shown in Table 8-14 according to final disposal facility location alternatives, transport mode alternatives and route type (technically and economically advantageous or avoiding the population). Collective doses caused by normal transport predominate in doses' expectation values; the portion of doses caused by malfunction situations is minor.

For their part, doses caused by normal transport were dominated by doses resulting from stationary casks. For this reason, the total dose for the route aiming to avoid the population may even exceed the technically and economically advantageous route's dose.

The least radiation exposure to the population is caused by sea transport, the next least by railway and the most by road transport. If the final disposal facility were located in Kuhmo, sea transport to Raahe would reduce doses. Total doses are however minor in all cases, clearly under 1 manSv.

	Radiation dose from casks radiation (mSv)	Health risk from cask radiation, probability of serious illness (%)	Radiation dose from natural background radiation (mSv)	Health risk from natural background radiation, probability of serious illness (%)
Annual dose from bypass (25 bypasses)	$5 \cdot 10^{-5}$	$< 4 \cdot 10^{-7}$	3	< 0.02
Annual presence near cask (10 m distance for 13 h)	0.02	$< 2 \cdot 10^{-4}$	3	< 0.02
Annual total dose (25 bypasses and presence near cask at 10 m distance for 13 h)	0.02	$< 2 \cdot 10^{-4}$	3	< 0.02
Total dose (23 years)	0.5	< 0.004	70	< 0.5

Table 8-11. Spent fuel transport in the basic case, annual and 23 years' maximum radiation doses caused to an individual (belonging to the population) most exposed, and equivalent health risks (7.3 • 10^{-3} % / mSv). The cask's bypass speed is assumed to be 35 km/h and the distance is 10 m. For the sake of comparison, the doses and equivalent health risks posed by average levels of natural radiation (3 mSv/a) are shown.

Distance (m)	Dose (mSv)
2	$8 \cdot 10^{-6}$
5	$3 \cdot 10^{-6}$
10	$2 \cdot 10^{-6}$
20	$7 \cdot 10^{-7}$
40	$3 \cdot 10^{-7}$

Table 8-12. Maximum dose caused by the bypass of a single cask as a function of bypass distance. The bypass speed is assumed to be 35 km per hour.

	Radiation dose (mSv)	Radiation dose (manSv)	Health risk, probability of serious illness (%)
Individual	0.02		$< 2 \cdot 10^{-4}$
Population		0.0007	$< 5 \cdot 10^{-3}$

Table 8-13. Maximum radiation doses caused by stopped cask transport to an individual (belonging to population) most exposed and entire population. Fifty persons are assumed to be present at a distance of 10 metres from the cask for 8 hours. The annual dose from natural radiation (3 mSv/a) is 200 times greater.

Table 8-14. Expectation values or expectation values' ranges of variation for total doses caused to population by spent fuel transport and their malfunctions in the basic case, over a period of 23 years by candidate municipality, transport mode and route type (technically and economically advantageous or avoiding the population) and equivalent health risks (7.3 % / mSv).

For the sake of comparison, the doses and equivalent expectation values for the number of serious detriments posed at the same time by average levels of natural radiation (3 mSv/a) are shown for the population living within 0.5 km of the transport route.

The expectation value for the number of serious detriments caused by cask radiation is clearly less than one; for that reason the probability of a single serious detriment is shown in the table.

Final Disposal Facility at Olkiluoto in Eurajoki

	Radiation dose from cask radiation, expectation value (manSv)	Health risk from cask radiation, probability of serious illness (%)	Radiation dose from natural background radiation (manSv)	Serious health hazards from natural background radiation, quantitative expectation value (quantity)
Road from Loviisa				
Technically and economically advantageous routes	0.025–0.046	< 0.4	< 1200	< 88
Routes avoiding population	same route as above			
Road-rail-road from Loviisa				
Technically and economically advantageous routes	0.015	< 0.2	3300	< 240
Routes avoiding population	same route as above			
Road-sea-road from Loviisa				
Technically and economically	0.0020	< 0.02	81	< 6
Routes avoiding population	same route as above			

Compared to transport originating from Loviisa, doses caused by the road transport of the Olkiluoto Power plant's spent fuel are in this case very low due to the short transport distance and low population density; for that reason they have not been calculated. Other transport modes are not considered.

Final Disposal Facility at Romuvaara in Kuhmo

	Radiation dose from cask radiation, expectation value (manSv)	Health risk from cask radiation, probability of serious illness (%)	Radiation dose from natural background radiation (manSv)	Serious health hazards from natural background radiation, quantitative expectation value (quantity)
Road from Eurajoki				
Technically and economically advantageous routes	0.15–0.20	< 2	< 2600	< 190
Routes avoiding population	0.16–0.17	< 2	< 2100	< 150
Road from Loviisa				
Technically and economically advantageous routes	0.045–0.099	< 0,8	< 1800	< 130
Routes avoiding population	0.042–0.11	< 0.8	< 1300	< 95
Road-rail-road from Eurajoki				
Technically and economically advantageous routes	0.022	< 0.2	4400	< 320
Routes avoiding population	0.028	< 0.2	3300	< 240
Road-rail-road from Loviisa				
Technically and economically advantageous routes	0.0089	< 0.07	4000	< 290
Routes avoiding population	0.0064	< 0.05	3600	< 260
Road-sea-road from Eurajoki				
Technically and economically advantageous routes	0.069–0.079	< 0.6	< 1200	< 88
Routes avoiding population	0.054–0.079	< 0.6	< 1200	< 88
Road-sea-road from Loviisa				
Technically and economically advantageous routes	0.039–0.053	< 0.4	< 1200	< 88
Routes avoiding population	0.037–0.053	< 0.4	< 1200	< 88
Road-sea-road-rail-road from Eurajoki				
Technically and economically advantageous routes	0.0099	< 0.08	750	< 55
Routes avoiding population	same route as above			
Road-sea-road-rail-road from Loviisa				
Technically and economically advantageous routes	0.0071	< 0.06	830	< 61
Routes avoiding population	same route as above			

Final Disposal Facility at Hästholmen in Loviisa

	Radiation dose from cask radiation, expectation value (manSv)	Health risk from cask radiation, probability of serious illness (%)	Radiation dose from natural background radiation (manSv)	Serious health hazards from natural background radiation, quantitative expectation value (quantity)
Road from Eurajoki				
Technically and economically advantageous routes	0.070–0.071	< 0.6	< 900	< 66
Routes avoiding population	same route as above			
Road-rail-road from Eurajoki				
Technically and economically advantageous routes	0.024	< 0.2	3300	< 240
Routes avoiding population	same route as above			
Road-sea-road from Eurajoki				
Technically and economically advantageous routes	0.0031	< 0.03	81	< 6
Routes avoiding population	same route as above			

Compared to transport originating from Eurajoki, doses caused by the road transport of the Loviisa Power Plant's spent fuel are in this case very low due to the short transport distance and low population density; for that reason they have not been calculated. Other transport modes are outside consideration.

Final Disposal Facility at Kivetty in Äänekoski

	Radiation dose from cask radiation, expectation value (manSv)	Health risk from cask radiation, probability of serious illness (%)	Radiation dose from natural background radiation (manSv)	Serious health hazards from natural background radiation, quantitative expectation value (quantity))
Road from Eurajoki				
Technically and economically advantageous routes	0.087–0.18	< 2	< 4400	< 320
Routes avoiding population	0.087	< 0.7	1400	< 100
Road from Loviisa				
Technically and economically advantageous routes	0.031–0.066	< 0.5	< 1600	< 120
Routes avoiding population	0.028–0.059	< 0.5	< 620	< 45
Road-rail-road from Eurajoki				
Technically and economically advantageous routes	0.014	< 0.1	2400	< 180
Routes avoiding population	same route as above			
road-rail-road from Loviisa				
Technically and economically advantageous routes	0.0081	< 0.06	2800	< 200
Routes avoiding population	same route as above			

The total doses caused to the population by transport of the accumulated fuel from 60 years' operation of the present Olkiluoto and Loviisa Power Plants' would be approximately 50% greater than in the basic situation directly comparable to the growth in transported fuel quantities, when it is assumed that transport arrangements and environmental conditions remain the same. If fuel of two possible new units were to be transported in the same way, total doses would be approximately three times greater than in the basic situation. The annual dose for individuals most exposed does not significantly depend on the total quantity of fuel to be disposed of in the final disposal facility.

The transport of spent fuel to the candidate municipalities would not cause significant health risks in normal as well as malfunction situations with the transport modes and routes under study. This is because the annual radiation dose received by individuals is at the most (0.02 mSv) well below the average dose of 3 mSv resulting from natural radiation as well as the maximum permissible dose of 1 mSv specified in radiation regulations. Additionally, the population's collective dose from all transport is clearly lower than the equivalent dose caused to the population by natural radiation and is so minute that not a single health detriment can be expected. Individual and collective doses at the most are so insignificant that the selection of disposal site, transport mode and route will be more heavily influenced by factors other than radiation exposure during normal and malfunction transport situations.

Accident situations

The B-type casks currently used for the transport of spent fuel are subject to stringent technical requirements established in statutes and regulations of au-

Tests simulating accident conditions for B-type casks (IAEA 1990)

1. Drop from a height of 9 metres onto an unyielding surface
2. Drop from a height of 1 metre onto a steel punch bar 15 cm in diameter.
3. Drop of 500 kg steel plate 1 m^2 in area from height of 9 metres onto the cask.
4. Heating at an ambient temperature of +800°C for a period of 30 minutes following drop tests.
5. Immersion in water to a depth of 15 metres for 8 hours. Additionally for spent fuel casks: immersion in water to a depth of 200 metres for one hour.

Test stresses shall be concentrated on the casks' weakest sections.

After testing, radioactive substances may only leak slowly from the cask, and the dose rate at a distance of one metre from the outer surface of the packaging shall be no greater than 10 mSv/h. The cask and its contents shall remain sufficiently subcritical; in other words the fission reactions maintained by free neutrons shall be kept under control.

We can be fairly certain that stresses caused in accident tests exceed those to which the cask would be subject to in practice during transport. For example, in one test, the collision of a heavy locomotive travelling over 150 km/h with a B-type cask resulted in less damage that the drop from a height of 9 metres carried out according to test requirements .

thorities whose purpose it is to ensure that significant amounts of substances are not released into the environment even in accident situations.

Although the purpose of casks is to prevent human exposure to radiation in all conditions, the potential for accidents is taken into account when planning transport arrangements. For example, vehicles, personnel, routes and time schedules can be selected to reduce the possibilities and consequences of accidents. Actions necessary in accident situations are planned and simulated in advance, and the necessary equipment and staff resources are procured and maintained. Actions are described in emergency instructions. Planning, implementation and maintenance of these arrangements are reported in a emergency response plan, as well as in a security plan concerning intentional damage, to be attached to transport permit applications filed with the Radiation and Nuclear Safety Authority (STUK). Fire and rescue authorities, the Radiation and Nuclear Safety Authority (STUK), the police and other authorities are similarly prepared for emergency situations. Plans drawn up by the parties responsible for the project and authorities are coordinated and joint exercises are arranged if necessary.

The current duties and responsibilities of authorities are specified in statutes, including an act and decree for fire and rescue operations, and regulations such as the Ministry of the Interior's regulation (Sisäasiainministeriö 1997): "The Planning and Communication of Protective Measures in Radiation Emergencies". Responsibilities of authorities in accident situations have been clarified in the Ministry of the Interior's guidelines (Sisäasiainministeriö 1988): "Planning of General Rescue Services". The Ministry of the Interior's guidelines (Sisäasiainministeriö 1998) "Actions in Radiation Accident Situations" provide the principles for the planning and implementation of rescue operations for radiation situations under normal conditions.

According to the Ministry of the Interior's regulations (Sisäasiainministeriö 1997), radiation danger situations are to be considered as a single type of accident in co-ordination plans of all provinces and co-operative planning areas, as well as in municipalities' plans for rescue services. The risks and their causes, however, vary in different parts of the country. The Loviisa Power Plant's preparedness area (Loviisa, Pernaja, Pyhtää, Ruotsinpyhtää) and the Olkiluoto Power Plant's preparedness area (Rauma, Eurajoki, Luvia) must be prepared for nuclear plant accidents in a specific way. The Ministry of the Interior's guidelines (Sisäasiainministeriö 1998) "Actions in Radiation Accident Situations" treats various radiation accidents as support to the planning of emergency preparedness.

The International Atomic Energy Agency (IAEA 1996) has presented the following normative action levels to protect the population from the effects of radiation:

- Taking shelter indoors, if the radiation dose to be avoided exceeds 10 mSv for at most 48 hours.
- Temporary evacuation (temporary egress in the path of the emission) if the radiation dose to be avoided exceeds 50 mSv for at least one week.
- Temporary relocation if the radiation dose to be avoided exceeds 30 mSv for at least one month.
- Prohibitions on the use of a foodstuff if its concentration of radionuclides exceeds 1–1000 Bq/kg depending on the radionuclide; for example, the action level for Cs-137 alone is 1000 Bq/kg.

Normative action level refer to such radiation dose (or the derived concentrations of radionuclides) avoided by a protective measure that can be considered reasonable and justifiable compared to possible disadvantages of the measure.

Report by Suolanen (1999) et al. also examine radiation exposure caused in transport accident situations. It has been estimated that the B-type cask studied will not leak when subjected to possible single or multiple vehicular collisions, fires and submergence. Despite this, the results of various assumed leaks were assessed.

For the first accident type, it was assumed that, as a result of a collision at ground level, the cask would begin to leak so that radioactive substances emitted from the fuel would be released into the environment within a short time. The second accident type assumed a fire occurring at the same time as the aforementioned leak, and the third type examined equivalent accidents at sea, including the sinking of the cask and release of radioactive substances into the sea. The fourth type examined the consequences resulting from a cask subjected to wilful damage.

Radiation doses caused by accident-related emissions were assessed using the ARANO computer program. The model used by the program takes into account such factors as the transport of radioactive substances in the atmosphere under various weather conditions, settling on the ground or vegetation in dry weather or in the rain and accumulation in agricultural products along various pathways. Doses can be calculated from external radiation caused by the emissions cloud and the deposition on the ground of radioactive substances, or from internal radiation caused by radioactive substances passing into the human body through breathing and eating. Because very conservative values were selected for the model's parameters, the calculated doses represent the upper limits of possible radiation doses.

In accident scenarios featuring emissions propagation, various weather situations were used, as well as statistically weighted propagation statistics compiled over the period of one year. Weather condition is generally defined by stability class, wind speed and the presence or lack of rain. When calculating expectation value for the individual dose and the probability distribution of the population's collective dose, the annual distribution of weather conditions was taken into account. Population density was assumed to be 1,000 persons/km^2 at distances of 0–2 kilometres, 400 persons/km^2 at distances of 2–5 kilometres and 10 persons/km^2 at distances of 5–100 kilometres. It was assumed that the population was not particularly protected against radiation. Accumulated doses for one month, one year and 50 years were calculated for three exposure paths: direct external radiation from the emissions cloud and fallout, as well as internal radiation caused by radioactive substances passed into the human body through breathing. The monthly dose enables the occurrence of early effects to be gauged. For their part, doses accumulated over a long time can be used to estimate delayed effects, assuming that there has not been protection from radiation.

Concerning the first accident type, two different scenarios were assessed: 1) *Only a small number of fuel assemblies damaged* (a fairly realistic estimate), and 2) *All fuel assemblies damaged* (a very conservative estimate). It was assumed that 100% of the gaseous substances emitted into the interior of the cask would be released into the environment, as well as 10% of particulate substances, and that the emission would last 30 minutes. In the latter case, of the entire contents of the cask, 50% of tritium, 11% of krypton, 4.5% of iodine, 0.0014% of cesium and 0.0003% of other emitted substances, would be released into the environment.

When all fuel rods were damaged, the month´s dose of an individual for the selected weather situation (stability class D, wind speed 5m/sec, no rain) was estimated as remaining under 0.4 mSv at a distance of 100 m, and less than 0.04 mSv already at a distance of 1 kilometre. Rain would increase doses slightly in nearby areas. The early effects of radiation do not appear under these conditions. Equivalent doses for 50 years are less than 30 mSv and 3 mSv. The dose caused by respiration is clearly greater than the dose caused by radiation emitted directly from the emissions cloud. Over a long time span the dose caused by direct radiation from fallout is practically as significant. The upper value (99.5% probability) of the collective dose to the population over a period of 50 years was estimated as 13 manSv, from which would result one serious health detriment (0.073 detriment/manSv). Doses are small compared to doses caused by natural radiation (several millisieverts a year). Protective measures would reduce possible effects.

If a simultaneous fire is also involved, it was assumed that during 10 minutes 100% of the gaseous substances emitted into the interior of the cask would be released into the environment, as well as 50% of particulate substances, but the emissions cloud would rise higher as a result of the effects of heat. In this case the largest individual dose would be accumulated at a distance of one kilometre. The dose would be smaller than the dose at 100 metres in the previous situation.

From the standpoint of the population, accidents occurring at sea would generally be less severe than those occurring on the mainland, because there are fewer inhabitants in coastal and archipelago areas. The cask has been designed to withstand submergence in deep water. If radioactive substances are, however, released into the sea, the doses to the population caused through eating fish would be minor because radioactive substances would be diluted by the large quantity of water.

In the fourth accident type, it was assumed that the transport cask would lose its integrity as the result of an external factor (for example intentional destruction), approximately 1% of fuel would be seriously damaged, and emissions would occur suddenly. Of entire contents of the cask approximately 2% of gaseous substances, 0.09% of cesium and 0.008% of other substances would be released into the environment in breathable form. On the other hand, the dose rate caused by direct radiation was examined for a situation where fuel assemblies would be left partially or wholly unshielded.

In the selected weather conditions (stability class D, wind speed 5 m/s, no rain), the month's dose of an individual was estimated as remaining under 14 mSv already at a distance of 100 m, and less than 1.4 mSv at a distance of one kilometre. Rain would increase doses slightly in nearby areas. The early effects of radiation would not appear under these conditions. Equivalent doses for 50 years are less than 1400 mSv and 140 mSv. The dose caused by breathing is clearly greater than the dose caused by radiation emitted directly from the emissions cloud. Over a long time span the dose caused by direct radiation from fallout is practically as significant. The probability of serious health detriments caused by a dose of 1400 mSv is under 10% ($7.3 \cdot 10^{-3}$ %/mSv).

For the sake of comparison, it should be pointed out that the individual dose accumulated over a period of 50 years from natural radiation is approximately 150 mSv. The upper value (99.5% probability) of the collective dose to the population over a period of 50 years was estimated as less than 500 manSv, from which would result less than 36 serious health detriments (0.073 detriment/manSv). Protective measures would reduce possible effects, because the larger doses accumulate over a long time. The collective dose to Finns of natural radiation accumulated over a period of one year is approximately 15,000 manSv, more than thirty times the amount.

Unshielded fuel assemblies would cause high dose rates in nearby areas. For example, the dose rate caused by a bundle of thirty fuel assemblies from the Loviisa Power Plant exposed to the air would be attenuated to a value of 0.1 mSv/h at an approximate distance of 200 metres. The CASTOR-VVER type cask can accommodate 84 fuel assemblies. In actual situations, the spent fuel would be located at ground level, with the result that surrounding objects, such as the cask, terrain, vehicle and the fuel itself would attenuate radiation.

The probability and severity of traffic accidents involving different modes of transportation have been examined (Suolanen et al. 1999). The probability of serious accidents and particularly of those also with radiation consequences was estimated as being extremely low. Expectation values for radiation doses caused by traffic accidents (probability x dose) was estimated as being clearly lower than for the very small radiation doses caused in ordinary transportation.

Experience in the transport of spent fuel by road, rail and sea has been accumulated for decades abroad and over ten years in Finland. No accident with significant consequences of radiation has occurred.

Emissions of radioactive substances and their emitted radiation resulting from an accident might be detected by performing measurements in the surroundings. The extent and form of the affected area would depend on the magnitude of the emissions and prevailing weather. Naturally radioactive substances and artificial radioactive substances from other sources would hamper detection. For accidents previously examined, the first would affect an area extending no larger than approximately 5 km in the direction of propagation, and the second would reach approximately 30 km, assuming a dose rate of 0.1 mSv/a as a boarder (average 3 mSv/a from natural radiation).

In the event of accident, the objectives of emergency measures are to prevent and limit the spread of radioactive substances into the environment, predict and measure emissions of radioactive substances, as well as their environmental concentrations and dose rates, and protect, if necessary, the population from radiation exposure. The transport personnel are initially responsible for leading emergency measures until authorities are able to assume operational control. If an accident occurs, the party responsible for the project shall notify fire and rescue authorities immediately, the Finnish Radiation and Nuclear Safety Authority, and other parties as required.

Doses caused by accidents are probably so minor as to not require protective environmental measures, in earlier as well as later stages. Taking shelter indoors in nearby areas may, however, be required before the danger has passed. Dose rates and concentrations of radioactive substances in the environment, for example in the soil and agricultural products, are measured thoroughly. Based on measurement results and other factors, authorities decide if it is necessary to limit residence in certain areas, or limit the use of agricultural products, gathering products, fish and game for food.

If the cask were, however, seriously damaged as a result of, for example, an intentional act, the population near the accident location might have to be temporarily relocated elsewhere. A damaged cask and spent fuel might have to be covered suitably and be stored at the accident location until their removal and other further treatment is possible. If required, restoration of the environment could begin after the application of protective measures.

All in all, cask properties, transport arrangements and preparedness for emergencies ensure that the health risks for accidents involving the transport of spent fuel are extremely low.

Annual individual radiation exposure caused by transport does not normally depend on the total quantity of spent fuel intended for final disposal because the handling capacity of the final disposal facility would, in any case, determine the maximum quantity transported each year. Overall health risks can, however, be roughly assumed to increase in direct proportion to duration of the operational phase and thus the total amount of spent fuel. Due to the low health risk, even a tripled growth in fuel quantity would remain insignificant from the standpoint of the population's health.

Operation of the final disposal facility

Safety regulations during the final disposal facility's operational phase

The final disposal facility is designed, constructed and operated in compliance with the provisions of statutes and of authorities' regulations. Most detailed regulations concerning the operation of the final disposal facility are found in the Council of State's decision concerning the safety of final disposal of spent nuclear fuel (Valtioneuvosto 1999). According to these requirements, the final disposal facility and its operation shall be planned so that:

- during undisturbed operation of the facility emissions of radioactive substances are insignificantly small,
- because of anticipated malfunctions, the annual dose to the most exposed members of the population does not exceed a value of 0.1 mSv.
- as a result of postulated accidents, the annual dose to the most exposed members of the population does not exceed a value of 1 mSv.

An anticipated malfunction refers to an event affecting safety during the operational phase that has been estimated as occurring less than once a year, but likely to occur at least once during the operational phase.

An postulated accident refers to an event affecting safety during the operational phase unlikely to occur during the operational phase.

Besides specified dose limits, the decision contains a number of detailed instructions pertaining to the facility's planning, construction and operational mode itself.

Health effects when the facility functions normally

When the final disposal facility complies with the safety requirements radioactive substances pose no significant health risks to the surrounding population during undisturbed operation of the facility. For its part, the annual dose limit concerning malfunctions is a small quantity, approximately 3%, of the annual dose of natural radiation caused to Finns, including indoor radon, that is approximately 3 mSv. Using ICRP's nominal coefficient (Table 8-5), the probability that a dose limit-sized radiation dose causes a serious health detriment to an individual is less than 0.0007%. In the basic case, assuming that the operational and decommissioning phase lasts approximately 25 years, the overall probability would remain under 0.02%. For longer periods, the probability would remain under 0.1% due to the limitations of the human life span. The risk from natural radiation, calculated in the same way, is 30 times greater. In Finland, the probability of an individual contracting fatal cancer is statistically approximately 20% (Lautkaski et al. 1988). The health risk posed to individuals by operational malfunctions would therefore not be considered significant. The health risk posed to the entire population is also insignificant because doses received by individuals are at the most very small.

Structure and operation of the final disposal facility is described in Chapter 4. A more detailed description of the facility has been presented in reports by Kukkola (1999b) and Riekkola (Riekkola et al. 1999). The radiation safety of the final disposal facility's operational phase has been dealt with in a working report (Rossi et al. 1999) for the facility's preliminary design and EIA procedure. The assessment is based on definitions of normal use, malfunctions and accident situations presented by Kukkola (1999a). The consequences of excavating the repository for the final disposal facility, regarding radiation doses caused by increased radon emissions, were examined by Vesterbacka and Arvela (1998).

The most significant quantities of the final disposal facility's radioactive substances are contained in spent fuel. As regards the fuel itself, the greatest amount of radioactive substances are to be found within the solid fuel pellets contained in the hermetically sealed tube-like cladding. A significantly smaller amount is found on the surfaces of the fuel pellets and the inner surface of the cladding, as well as in the space between them, and in other components of the fuel assembly. Only a small part of radioactive substances are gaseous or otherwise easily released into the air, taking into account the temperatures for spent fuel maintained in the final disposal facility.

From the standpoint of the environmental effects of the final disposal facility's operational phase, maximum amounts for the most significant radionuclides in a single fuel assembly and final disposal canisters are shown in Table 8-15. Equivalent quantities for individual transport casks are shown in Table 8-8.

In the encapsulation plant, it is assumed that at any one time, the maximum number of transport casks containing fuel is eight (for example 4 CASTOR-TVO and 4 CASTOR-VVER casks), and that the maximum number of filled final disposal canisters is 12 (12 fuel assemblies/canister).

Radionuclide	Abbreviation	Half-life (y)	Quantity (Bq) Fuel assembly	Canister
Tritium (Hydrogen 3)	H-3	12.3	$1.6 \cdot 10^{12}$	$1.7 \cdot 10^{13}$
Krypton-85	Kr-85	10.7	$2.5 \cdot 10^{13}$	$2.6 \cdot 10^{14}$
Strontium-90	Sr-90	28.6	$4.5 \cdot 10^{14}$	$4.6 \cdot 10^{15}$
Rutenium-106	Ru-106	1.01	$4.4 \cdot 10^{9}$	$5.0 \cdot 10^{10}$
Iodine-129	I-129	$1.57 \cdot 10^{7}$	$3.4 \cdot 10^{8}$	$3.5 \cdot 10^{9}$
Cesium-134	Cs-134	2.06	$2.5 \cdot 10^{12}$	$2.4 \cdot 10^{13}$
Cesium-137	Cs-137	30.2	$6.7 \cdot 10^{14}$	$7.0 \cdot 10^{15}$
Plutonium-238	Pu-238	87.8	$4.7 \cdot 10^{13}$	$3.8 \cdot 10^{14}$
Plutonium-239	Pu-239	$2.41 \cdot 10^{4}$	$3.1 \cdot 10^{12}$	$3.5 \cdot 10^{13}$
Plutonium-241	Pu-241	14.4	$5.0 \cdot 10^{14}$	$5.8 \cdot 10^{15}$
Americium-241	Am-241	$4.32 \cdot 10^{2}$	$2.5 \cdot 10^{13}$	$2.9 \cdot 10^{14}$
Curium-244	Cm-244	18.1	$3.3 \cdot 10^{13}$	$2.1 \cdot 10^{14}$

Table 8-15. From the standpoint of the environmental effects of the final disposal facility's operational phase, maximum amounts for the most significant radionuclides in a single fuel assembly and final disposal canister (Rossi et al. 1999). Fuel assemblies are from the Olkiluoto Nuclear Power Plant stored for at least 20 years. It is assumed that the average burnup is 45 GWd/tU for a single fuel assembly, and the average burnup of the canister's fuel assemblies is 40 GWd/tU.

During the final disposal facility's operational and decommissioning phases, it is estimated that radioactive substances are released normally and in connection with malfunctions into the environment primarily through the air, with only a small quantity exiting with the plant's outflow water. For that reason, only airborne emissions will be examined in this context.

Normal emissions and direct radiation

In normal handling, radioactive substances accumulated during use and storage may loosen from the outer surfaces of fuel elements. A small number of the fuel rods in the assemblies may lose their tightness during normal transport and handling in the encapsulation plant, or a leak may have already originated at the nuclear power plant, in which case radioactive substances from within the cladding may also be released in connection with normal handling. Radioactive substances are initially released in transport casks, encapsulation rooms or within canisters.

Transport casks containing spent fuel are opened in a handling chamber in which the fuel is placed in canisters and full canisters are sealed shut. Radioactive substances released into the handling chamber are for the most part recovered so that no significant amounts of radioactive substances are released into the environment. Concerning the cleanliness of the outer surfaces of canisters containing spent fuel, care is taken to ensure that no radioactive substances are released from the surfaces of canisters into the final disposal repository when canisters are placed there. Table 8-16 shows the estimated upper limits for normal annual emissions of radioactive substances released into the atmosphere in the operational phase, assuming that 100% of the gaseous substances (hydrogen, krypton and iodine) released in the final disposal facility premises, as well as 0.3% of other substances, have passed into the environment.

Small quantities of radioactive substances originating in nuclear power plants can also be carried to the encapsulation plant on the surface of the transport cask and within the cask's protective covering (weather protection). If necessary, the transport cask's outer surface and weather protection covering are decontaminated at the encapsulation plant and radioactive substances are recovered like other radioactive substances.

Bedrock and groundwater seeping into underground rooms contain naturally radioactive substances of which, primarily radon gas is released into the air in the final disposal repository. Radon and its decay products pass with ventilation air into the environment. Radon also emits to a certain extent into the atmosphere from groundwater pumped to the surface and from piles of blasted stones and crushed rock at the surface. Radon's probable emission rate into the atmosphere is of $1 \cdot 10^{12}$ Bq/a at a maximum (Vesterbacka & Arvela 1998).

Techniques used to recover radioactive substances include negative pressure air conditioning, exhaust air filtration,

Radionuclide	Emission (% of maximum content in transport cask)		
	Normal operation	Malfunction situation	Accident situation
Tritium (Hydrogen 3)	$2.3 \cdot 10^{-1}$	$3.8 \cdot 10^{-2}$	$4.4 \cdot 10^{1}$
Krypton-85	$5.2 \cdot 10^{-2}$	$8.7 \cdot 10^{-3}$	$8.7 \cdot 10^{0}$
Strontium-90	$4.0 \cdot 10^{-9}$	$6.6 \cdot 10^{-10}$	$7.8 \cdot 10^{-7}$
Rutenium-106	$3.8 \cdot 10^{-9}$	$6.4 \cdot 10^{-10}$	$8.5 \cdot 10^{-7}$
Iodine-129	$2.2 \cdot 10^{-2}$	$3.7 \cdot 10^{-3}$	$3.5 \cdot 10^{0}$
Cesium-134	$2.2 \cdot 10^{-8}$	$3.6 \cdot 10^{-9}$	$2.9 \cdot 10^{-6}$
Cesium-137	$2.1 \cdot 10^{-8}$	$3.4 \cdot 10^{-9}$	$3.1 \cdot 10^{-6}$
Plutonium-238	$4.7 \cdot 10^{-9}$	$7.8 \cdot 10^{-10}$	$6.1 \cdot 10^{-7}$
Plutonium-239	$3.8 \cdot 10^{-9}$	$6.3 \cdot 10^{-10}$	$8.6 \cdot 10^{-7}$
Plutonium-241	$3.7 \cdot 10^{-9}$	$6.1 \cdot 10^{-10}$	$8.8 \cdot 10^{-7}$
Americium-241	$3.6 \cdot 10^{-9}$	$6.1 \cdot 10^{-10}$	$8.7 \cdot 10^{-7}$
Curium-244	$5.1 \cdot 10^{-9}$	$8.6 \cdot 10^{-10}$	$4.9 \cdot 10^{-7}$

Table 8-16. Final disposal facility's annual normal maximum emissions of radioactive substances released into the atmosphere during the operational phase, and the facility's maximum emissions of radioactive substances released into the atmosphere by assumed malfunction and accident situations during the operational phase. Quantities are shown as portions of maximum quantities contained within the transport cask (Table 8-8, CASTOR-TVO).

the vacuuming of surfaces and wastewater filtration. Collected radioactive substances are treated and stored in the encapsulation plant with other radioactive waste accumulated during the operational phase. Waste is packed for example by cementing it in drums which are placed in a separate rock chamber excavated in connection with the final disposal repository.

With decommissioning, equipment and materials classified as radioactive waste are removed from the encapsulation plant for final disposal with other nuclear waste created during the operational phase. With the removal, small quantities of radioactive substances may be released into the encapsulation plant premises, most of these substances are recovered using the same methods as during the operational phase.

Ionising radiation from spent fuel situated in the final disposal facility, as well as from other, significantly less radioactive sources, is attenuated to a sufficiently low level by radiation shields that include the transport casks, final disposal canisters and concrete structures. The dose rate near the final disposal facility buildings is generally of similar magnitude to the dose rate caused by natural background radiation, approximately 0.1 μSv/h, and no higher than 2.5 μSv/h. Outside the facility area direct radiation from the final disposal facility is insignificant compared to natural background radiation.

Emissions in malfunction situations

The final disposal facility's most significant malfunction situations were defined as follows:

- A fuel rod has lost its tightness during transport, and it has not been possible to recover radioactive substances released during the emptying of the transport cask by normal means.
- As a result of an operational error or equipment fault, a fuel assembly is knocked in the encapsulation plant and fuel rods are damaged.
- In connection with the possible drying of fuel assemblies, the tempera ture rises higher than usual due to equipment malfunction, in which case a fuel rod loses its tightness. This may have also occurred earlier.

From the standpoint of the release of radioactive substances, malfunction situations primarily differ from normal situations in that more fuel rods lose their tightness simultaneously or that a higher temperature increases releases from an individual rod.

Radioactive substances are also released in malfunction situations in the encapsulation premises and the equipment contained therein. The filtration of exhaust air is assumed to be functioning normally. Table 8-16 illustrates the largest estimated emissions of radioactive substances into the atmosphere in an individual malfunction situation, when it is assumed that 100% of gaseous substances and 0.3% of other substances released in the final disposal facility's premises pass into the environment.

Radiation doses and areas of impact in normal and malfunction situations

Radiation doses are caused by natural radon and its decay products primarily passing through into the body by respiration. Vesterbacka and Arvela (1998) have assessed the radiation doses caused by these. Other radiation doses caused by emissions in normal and malfunction situations have been assessed using the ARANO computer program (Rossi et al. 1999) according to the same principles as the effects of transport described earlier.

The probabilities of malfunction situations will be assessed with detailed planning. Operations will be planned so that malfunction probabilities will be low.

The dose to an individual belonging to the population from one year's normal emissions, accumulated over a period of 50 years, is less than 0.01 mSv (over 99.5% probability) in the immediate vicinity of the facility. In that case it has been assumed that the individual resides permanently just outside the facility site area, practises agriculture and uses food primarily from his or her own production. The most significant radionuclide is cesium-137.

Most part of the dose accumulates from radionuclides that have deposited on the ground and been transferred to agricultural products, for example milk, subsequently creating internal radiation through eating. The direct external radiation from fallout, and the inhalation of radioactive substances present in the air cause the next largest doses. Direct radiation from the emissions cloud causes a significantly lower dose. The dose is at least an order of magnitude lower at a distance of 5 kilometres compared to the immediate vicinity of the facility. Further away the dose is even lower. Doses caused by normal emissions are therefore insignificantly small compared, for example, to natural radiation (approximately 3 mSv/a). Doses caused by the passage of natural radon and its decay products into the environment would also remain insignificant.

The largest dose caused by an individual malfunction situation over a period of 50 years is less than 0.001 mSv (over 99.5% probability). Doses caused by malfunction situations therefore clearly remain under the upper limit of 0.1 mSv per year specified in regulations. Doses in neighbouring countries would be many orders of magnitude smaller because the distance at its shortest is approximately 18 km from Romuvaara in Kuhmo to Russia, about 80 km from Hästholmen in Loviisa to the Estonian mainland and over 200 km from Olkiluoto in Eurajoki to the Swedish mainland.

Doses would accumulate in the same way as those caused by normal emissions.

The characteristics of the final disposal facility surroundings, for example, population density, distribution, structure and living patterns, as well as climate, affect the resulting radiation doses and health risks. Due to the scarcity of health risks, there are no significant differences between site alternatives in this respect.

Radioactive substances in normal emissions might be detected as very small concentrations near the facility, and further away in malfunction situations. Naturally radioactive substances and artificial radioactive substances from other sources would hamper the detection of concentrations. The measuring of total dose rate would not detect changes in the environment's radiation situation.

If the quantity of fuel to be disposed of were larger than in the basic case, the duration of the operational phase and the resultant health risks would increase mostly in direct proportion to the growth in fuel quantity.

Accidents

Regarding compliance of the final disposal facility with safety requirements, radioactive substances resulting from the postulated accidents do not pose significant risks to the population in the environment during the operational and decommissioning phases. The annual dose limit concerning postulated accidents is a small fraction of the average annual dose caused to Finns by natural radiation (approximately 3 mSv), including radon present in indoor air.

Using ICRP's nominal coefficient (Table 8-5), the probability that a dose limit-sized radiation dose causes a serious health detriment to an individual is less than 0.007% for the first year, decreasing with successive years. When the low probability of these kinds of accidents is taken into account, a comparison of respective dose limits reveals that the overall probability for a health detriment caused by accidents remains lower than for those caused by malfunction situations. The health risk posed to the general population would also not be significant compared with, for example, the risk caused by natural radiation because the doses for individuals would remain lower the longer the person resides.

In case of nuclear power plants postulated accidents refer to situations that are used as a design basis for safety systems (Valtioneuvosto 1991a). It is assumed that the same definition can also be applied here to the final disposal facility. More serious accidents than design basis ones can also be conceived, but their probability is estimated as being lower than that of design basis one. Thus, it can be assessed that the total likelihood of a health detriment caused to individuals by these accidents, too, will remain insignificantly small, even though the radiation dose for a member of the population receiving the maximum radiation dose would be greater than 1 mSv/a if an accident occurs.

Emissions in accidents

The following situations are assumed to be the most serious accidents:

- The transport cask falls; all fuel rods are damaged and lose their tightness; the cask remains hermetically sealed; fuel is removed from the cask in a controlled manner.
- The canister falls; all fuel rods are damaged and lose their tightness; the canister remains hermetically sealed; fuel is removed from the canister in a controlled manner.
- The lid of the transport cask drops into the open cask; 1/10 of the fuel rods are damaged and lose their tight ness.
- A fuel assembly falls onto another fuel assembly; all fuel rods in both assemblies are damaged and lose their tightness.
- The canister lift drops into the water pool that serves as a shock-absorber; the canister and all the fuel assembly's fuel rods are damaged and lose their tightness.

In these accident situations, besides gaseous substances and other substances easily released into the air, fuel rods may also release particles of various sizes. Particles descend upon room surfaces at a rate that depends on their size; the smallest particles will float in the air for longer periods. If the canister is damaged in the water pool, primarily gaseous substances will be released into the air. Fuel does not heat up appreciably in these situations. In the postulated accident scenarios, radioactive substances are initially released in the encapsulation plant or lift shaft. The filtration of air exhausted from the premises is assumed to operate normally.

Table 8-16 shows the estimated upper limits for emissions of radioactive substances released into the atmosphere in postulated accidents when it is assumed that 100% of the gaseous substances released in the final disposal facility, as well as 0.3% of other substances, pass into the environment.

During the final disposal facility's operational and decommissioning phases, it is estimated that radioactive substances are released into the environment primarily through the air, with only a small quantity exiting with the plant's outflow water. For this reason, only airborne emissions will be examined in greater detail.

Radiation doses and areas of impact in accident situations

Radiation doses caused by emissions resulting from accident situations were assessed in the same way as the consequences of malfunction situations (Rossi et al. 1999). The probabilities of accident situations will be assessed with detailed planning. Operations will be planned so that probabilities of accidents occurring during the operational and decommissioning phases are extremely low.

The largest dose caused by a postulated accident situation to an individual belonging to the population within the first year is less than 0.5 mSv, and over a period of 50 years, is less than 0.8 mSv (over 99.5% probability). Doses caused by postulated accident situations therefore clearly remain under the upper limit of 1 mSv per year specified in regulations. The largest doses are experienced by those living near the facility area, assuming that the individual resides permanently, practises agriculture and uses food primarily from his or her own production. Main part of the dose accumulates from radionuclides that have deposited on the ground and have been transferred through the food chains in the same manner as with malfunction situations.

The dose is at least in an order of magnitude lower at a distance of 5 kilometres compared to the immediate vicinity of the facility. Further away the dose is even lower. Doses in neighbouring countries would be many times smaller because the distance at its shortest is approximately 18 km from Romuvaara in Kuhmo to Russia, about 80 km from Hästholmen in Loviisa to the Estonian mainland and over 200 km from Olkiluoto in Eurajoki to the Swedish mainland.

Emissions of radioactive substances and their emitted radiation resulting from accident situations might be detected by performing measurements in the surroundings. The extent and form of the affected area would depend on the magnitude of the emissions and prevailing weather. Naturally radioactive substances and artificial radioactive substances from other sources would hamper detection. The affected area of the assumed accident would extend no more than approximately 5 km in the direction of propagation, assuming a dose rate of 0.1 mSv/a as a boarder (average 3 mSv/a from natural radiation).

If the quantity of fuel to be disposed of would be larger than in the basic case, the duration of the operational phase and the resultant health risks would increase for the most part in direct proportion to the growth in fuel quantity. Due to the low health risk, even a tripled growth in fuel quantities would remain insignificant from the standpoint of the population's health.

Besides the aforementioned postulated accidents, other accidents that are in principle possible include earthquake, the impact of a heavy object, such as an aeroplane, with the encapsulation plant, fuel achieving criticality and intentional damage. The encapsulation plant is designed to withstand earthquakes generally occurring in Finland, as well as an impact by a light aircraft. The likelihood of impact by a large aircraft or meteorite is extremely small.

A criticality accident, in other words the uncontrolled chain reaction of fissions maintained by free neutrons, can occur in fuel if the fuel assemblies form a sufficiently large and dense pile-up. This kind of accident is prevented by planning fuel handling and storage facilities and equipment in such a way that the accident situation would be impossible in practice.

Sufficient security systems provide preparedness against intentional damage. Fuel in the encapsulation plant and the repository is well protected against sabotage.

Prevention and mitigation of adverse effects

Concerning normal, malfunction and accident situations, the adverse environmental effects of radioactive substances are prevented and mitigated during the operational and decommissioning phases according to the following design principles:

- Activity of spent fuel has been reduced by interim storage for 20 years before handling in the final disposal facility.
- Spent fuel is handled in spaces whose construction and equipment on one hand protect the stored fuel from adverse effects originating outside the final disposal facility, and on the other hand prevent or mitigate the spread of radioactive substances into the environment.
- Radiation emitted by spent fuel is attenuated to a sufficiently low level by radiation shielding.
- The release of radioactive substances into spaces of the plant accompanying the handling of spent fuel is held to a minimum. Released radioactive solid, liquid and airborne particulate substances are recovered and treated as radioactive waste. Removal of the decay-heat produced by spent fuel is taken care of to ensure that the fuel does not heat up excessively.
- Transport casks, fuel and canisters are handled in the final disposal fa cility in controlled areas where radiation levels, as well as the quantity of radioactive substances in the air, on surfaces, in water and in other materials, is monitored. If required, areas have their own ventilation, waste processing and other related systems.
- Functions important to safety are redundant (endangered safety would require several simultaneous faults or deficiencies).
- Transfer systems for transfer casks, spent fuel and canisters are planned so that the probability of excessive

acceleration of fuel caused by fall and crash is sufficiently low.
– An uncontrolled chain reaction of fissions maintained by free neutrons occurring in fuel (criticality accident) is prevented by structural means.
– The final disposal facility is designed so that the likelihood of fire is small, and that possible consequences would be minimal from the safety aspect.
– The final disposal facility is designed to reliably prevent explosions that might endanger the integrity of fuel, canisters and premises or devices containing radioactive substances.
– Structures, systems and equipment important to safety and disposal sites for spent fuel are designed to enable measures (security arrangements) against illegal actions to be implemented as effectively as possible taking requirements pertaining to nuclear and radiation safety into account. Security arrangements are based on the use of safety zones within each other so that the interfaces of the zones form sufficiently effective structural barriers that prevent unauthorized entry. The control centre has an assured connection to the police and the control room of the plant.
– Measures for a emergency situation include a radiation measurement system, a meteorological measuring system necessary to assess the spread of radioactive substances, a communications and alarm system, as well as premises and equipment reserved for mitigating environmental damage (emergency response arrangements).

The party responsible for the project maintains preparedness for accident situations by advance planning and training in simulated situations, and by acquiring and maintaining the resources necessary to cope with emergency situations. Measures are described in emergency instructions. Their planning, implementation and maintenance is described in an emergency response plan, and equivalently, regarding security arrangements in a security plan that are attached to the operating licence of the final disposal facility. The emergency response and security plans are developed during the operational phase according to the need. Fire and rescue authorities, the Finnish Radiation and Nuclear Safety Authority, the police and other officials are similarly prepared for emergency situations. Plans drawn up by the responsible party for the project and authorities are co-ordinated and joint exercises are arranged if necessary. Council of State decisions (Valtioneuvosto 1991b, 1991c) concerning the emergency response and security arrangements of nuclear plants are applied to the extent necessary.

Actions in accidents of the plant are governed by the same principles and instructions as in transport accidents. In the event of an accident, the objectives of emergency measures are to prevent and mitigate the spread of radioactive substances into the environment, predict and measure emissions of radioactive substances, as well as their environmental concentrations and dose rates, and protect, if necessary, the population from radiation exposure. The transport personnel is initially responsible for leading emergency actions until authorities are able to assume operational control. If an accident occurs, the party responsible for the project shall immediately notify fire and rescue authorities, the Finnish Radiation and Nuclear Safety Authority, and other parties as required.

Doses caused by postulated accidents are probably so small that they do not require protective environmental measures, in earlier as well as later stages. Dose rates and concentrations of radioactive substances in the environment, particularly in the soil and agricultural products, are measured thoroughly. Based on measurement results and other factors, authorities decide if it is necessary to limit residence in certain areas, or limit the use of agricultural products, gathering products, fish and game for food.

For their part, doses caused by malfunction situations are so small that they do not require any kind of protective measures in the environment.

Final disposal facility's post-closure phase

Principles of long-term safety

In the base alternative for final disposal:

– the spent fuel is packed in durable watertight canisters, and
– the canisters are emplaced deep in the bedrock where they are far from people and where they can remain intact without supervision until their contents pose no threat to the living nature.

The canister walls and a few metres of bedrock are sufficient to totally block the radiation emitted from spent fuel. The purpose of a durable and tightly sealed canister is to prevent the release of radioactive substances to the groundwater. The main purpose of the bedrock is to protect the canisters. However, if for some reason the canister does not perform as planned, the bedrock would retard and dilute the passage of radioactive substances into the living nature.

The starting point is the multibarrier principle described in Chapter 3. Radioactive substances are contained within several "protective walls" that are mutually supportive yet as independent as possible so that the failure of one barrier will not endanger isolation performance. Besides the canister and the bedrock, another important protective barrier is the bentonite clay that impedes the movement of water along the canister's surface, and in the case of leakage, retards the spread of radioactive substances to bedrock.

The radiotoxicity of nuclear fuel decreases rapidly for the first decade after it has been removed from the reactor (Figure 2-3). During the first 40 years, activity decreases to approximately one-tenth of what it was within a year after it had been removed from the reactor and the decrease continues so that after one thousand years, activity has decreased to one-thousandth of that after the first year. Generally, the more radiative materials also decay faster. Within a few thousand years, the gamma radiation that passes so easily through substances will have been reduced to a harmless level. Subsequently, the contents of the canisters would be hazardous to human health only if their contents were to be ingested into the human body by eating or breathing.

A small part of the radioactive substances contained in the canisters are, however, extremely long-lived and require long-term isolation from organic nature. For this reason, the final disposal canisters are planned so that they remain intact in their final disposal locations for as long as possible. In Finnish conditions, the natural place to store canisters is bedrock, where they will be least likely subject to rapidly changing conditions. Finnish bedrock obtained its present form more than a thousand million years ago, and changes in bedrock since then have been slow and, from the perspective of millions of years, extremely minute.

Canisters placed deep in the bedrock are protected from changes taking place on the earth's surface – from the coming ice age as well – and at the same time they are far removed from peoples' normal living surroundings.

When ordinary granite bedrock is selected as the disposal site, the probability of someone unknowingly penetrating into the immediate vicinity of the final disposal repository is small, even if there is no longer any knowledge of its location.

The investigations carried out to date

Conditions prevailing in the deep bedrock, as well as the heat produced by spent fuel are largely determined by the details of technical solutions. The canister must withstand any loads deep in the bedrock to which it might be subject over a long time span. The technical planning of final disposal alternatives largely depends on the information obtained regarding the conditions, as well as their fluctuations that prevail in deep bedrock.

From the final disposal aspect, the properties of Finnish bedrock have been studied since the late 1970s, initially at the general level to develop research methods. From 1987 onwards, investigations have focused directly on ascertaining the bedrock properties suitable for the final disposal of spent fuel, initially on five investigation sites, more recently on four alternative sites.

Detailed information has been obtained through deep drilling that has extended to a depth of approximately one kilometre at all investigation sites. So far 8-13 investigation boreholes many hundreds of metres deep have been drilled at each site.

A sizeable group of Finnish and foreign experts has participated in bedrock studies and in interpreting their accumulated findings. Joint foreign projects have been co-ordinated with domestic investigations. Of these the more important have been studies carried out in Sweden during the 1980s at the Stripa mine and currently at the Äspö Hard Rock Laboratory. Sweden's bedrock is largely similar to Finland's, and the general knowledge acquired by the Swedish Nuclear Fuel and Waste Management Company (SKB), is largely applicable to Finnish conditions. In Canada, investigations conducted by Ontario Hydro and AECL have focused on the same types of bedrock that are found in Finland. Posiva has also been able to benefit from the information acquired there in its own studies. Extensive cooperation has also been carried out with NAGRA, Switzerland's nuclear waste research organisation.

During the two decades of investigations carried out to date, a thorough understanding has been gained of the general properties of Finnish bedrock, as well as a detailed picture of the bedrock at the four alternative disposal sites. A list of the more significant investigation reports is appended to this report. Research results have also been published in a series of international publications and in connection with conferences. Concerning Finnish bedrock, there is also a wealth of information contained in numerous publications issued by the aforementioned SKB, NAGRA and AECL organisations.

From time to time, in connection with bedrock investigations aimed at finding final disposal sites for spent fuel, summaries complying with legal requirements have been prepared. These summaries include summation reports published in 1992 by the Nuclear Waste Commission of Finnish Power Companies (YJT) (TVO 1992a, 1992b), and Posiva's interim report (Posiva 1996c) concerning alternatives for disposal sites. Several summaries concerning prevailing bedrock conditions at alternative disposal sites have been published as separate individual site reports (Anttila et al. 1999a–d).

Additionally, Crawford and Wilmot (1998) have prepared a general overview of the anticipated future development in bedrock conditions in the sites studied.

The chemical properties and the pressure of the groundwater particularly influence technical planning of the final disposal concept. The bedrock's normal movements must not break the containers' integrity. Canister construction and materials have been chosen to enable the canister to withstand the compression caused by the high pressure as well as the corrosive effects of substances contained in groundwater. The normal groundwater pressure at a depth of 500 metres equals 50 atmospheres. Under ice age conditions, the pressure may increase.

The required mechanical strength is provided by the massive cast iron inner canister, while the outer canister's material is copper, selected for its chemical durability. Corrosion of copper canisters in deep bedrock could be effected primarily by the oxygen or sulphide dissolved in the groundwater. In deep bedrock, the groundwater is, however, normally oxygen-free, and its sulphide concentrations are low.

The compacted bentonite clay placed between the canisters and the bedrock attenuates the effects of normal bedrock movements and prevents the canisters from coming into contact with corrosive substances. To retain bentonite's excellent compaction properties, the repository shall be built in such a way that the bentonite is not exposed to unnecessarily high salt concentrations.

The technical properties of the final disposal concept and the effects of the materials and structures used on the bedrock environment have been researched concurrently with site characterisation since the early 1980s. These reports were also first published in YJT's series of reports, and later as Posiva's reports. Summaries of this research have been published in 1992 (TVO 1992a) and 1996 (Posiva 1996a). A wealth of material produced by SKB's investigations has also been available in respect of the properties and behaviour of final disposal canisters and the bentonite surrounding them. Currently SKB intends to use the same type of final disposal canisters as Posiva.

The general goal in research, development work and technical planning concerning final disposal was to find a solution in which the waste is isolated to prevent the emergence of any health risk, either within the coming decades or far into the future. An appreciable number of investigations have, however, been devoted to studying the situations and consequences in which isolation does not perform as expected. In particular, the studies in question have focused on the solubility and migration characteristics of radioactive substances in bentonite and bedrock environments, as well as the radiation exposure produced by these. The significance of possible emissions has been assessed in so-called safety analyses, carried out over a period of several years beginning in 1982. These analyses themselves have been reported in YJT and Posiva publications in 1982, 1985, 1992, 1996, and most recently in 1999 (Anttila et al. 1982, Peltonen et al. 1985, Vieno et al. 1992, Vieno & Nordman 1996, 1999). Besides these reports, summaries of completed investigations include those published in 1992 and 1996 (TVO 1992a, Posiva 1996b). In the safety analysis published in 1999, the point of comparison are the general safety regulations proposal by Radiation and Nuclear Safety Authority that was ratified by the government with only slight modifications in March 1999 (Valtioneuvosto 1999).

Safety requirements

According to general safety requirements for final disposal (Valtioneuvosto 1999):

"In any assessment period, disposal shall not cause health or environmental effects that would exceed the maximum level considered acceptable during the implementation of disposal".

Although the primary safety objective is the protection of the living nature and human life, the Radiation and Nuclear Safety Authority also requires that the final disposal concept has to prevent effectively the release of radioactive substances into the bedrock for thousands of years. Throughout the entire period, the multi barrier principle ensures that the isolation capacity of the final disposal concept does not depend on just a single release barrier.

The maximum acceptable level of impact is specified using the maximum permissible annual radiation dose and limits on average activity releases. The starting point is a value of 1 mSv, the maximum permissible annual dose for the population defined in radiation statutes. Because the maximum value in question covers everything else besides natural background radiation and medical radiation exposure, a single source of radiation exposure, e.g., the waste disposed of, may only contribute to a fraction of the maximum dose. On this basis, the annual upper limit for radiation doses caused by final disposal has been set at 0.1 mSv.

Because the assessment of radiation exposures to individuals becomes the more difficult the more distant the time of exposure is, the activity of radioactive substances (expressed in Bq units) released into organic nature from the final disposal repository is used instead of radiation doses to assess the effects caused to people and the environment. The Radiation and Nuclear Safety Authority (STUK) has established nuclide-specific limits for released substances, the aim being that any future radiation exposure to individuals would at its maximum remain at same level as currently approved exposure levels (STUK 1999).

The limits established by the Radiation and Nuclear Safety Authority are equivalent to an annual probability of $5 \cdot 10^{-6}$ that a serious health effect is caused to an individual, calculated according to the dose-effect relationship recommended by the International Commission on Radiological Protection. STUK has ascertained that the risks to society are typically of a magnitude of $10^{-5} - 10^{-4}$, expressed as the annual probability of death to individual. In Finland, the radiation doses from natural radiation sources are more than 30 times the maximum limit.

Safety requirements also demand that unforeseen events be taken into consideration when planning final disposal. Examination of the significance of these events takes into account the probability of their occurrence.

Assessment of long-term safety

The final disposal's planning objectives and compliance with safety regulations is assessed using safety analyses that combine information concerning:
- the characteristics of waste and changes therein.
- the materials and constructions used in the final disposal concept.
- the properties of the bedrock surrounding the final repository as well as phenomena and transformations taking place within the bedrock.
- the behaviour of radioactive substances in organic nature and the radiation doses arising to people.
- the interaction between different substances and phenomena.

In safety analyses, it is determined whether the final disposal concept complies with the established requirements, and what consequences for human life and the natural environment occur if one or more of the protective barriers isolating the nuclear waste were to fail, releasing radioactive substances from the repository, first to the surrounding bedrock, then possibly to organic nature.

When performing safety analyses, the key questions are:

- How to anticipate future changes in the final disposal repository environment.
- How to ensure that all factors affecting the final disposal alternative have been taken into account.
- How to ensure the reliability of information describing the behaviour of the repository environment and the technical final disposal concept.

The safety analyses make no attempt to predict how the world will change during succeeding millennia, or the exact future appearance of the terrain above the repository. From the aspect of the performance of the final disposal concept, it is essential to be able to assess what kinds of conditions could form in the repository itself and in its surrounding environment. The basis for these assessments is obtained from general geological knowledge as well as special geochemical and mineralogical investigations. The underlying assumption in this case is that despite the changes created by people - such as climatic changes caused by the greenhouse effect - information from the past can be used for future predictions. In other words, from a geological time perspective, the changes possibly achieved by humans will remain insignificantly transitory.

It is indeed considered more likely that conditions deep in bedrock will remain relatively stable over the next ten thousands or hundreds of thousands of years despite any possible climatic shifts or forthcoming ice ages. Possible changes in bedrock are, however, examined with the help of future scenarios. Additionally, sensitivity analyses and "what if" investigations are used to study how different phenomena deviating from normal development could affect the performance of the final disposal concept.

Extensive surveys have been conducted concerning the mapping of various phenomena and chains of events that might affect the final disposal solution in the future. The OECD Nuclear Energy Agency (NEA) has compiled reports prepared in different countries into a common database that, based on current knowledge, describes factors that could affect the ability of geological final disposal to isolate waste from the living nature. This database has also been utilised for safety analyses carried out in Finland.

However, safety analyses do not assume that our knowledge of nature and the functioning of technical systems is complete. Data-related uncertainty and omissions are compensated by making pessimistic simplifications, in which it is either assumed that development will be unfavourable for the final disposal solution, or at least, positive factors with significant uncertainties are ignored. Additionally, the significance of uncertainties can be assessed with the aid of sensitivity analyses. Overall, the final disposal concept must be planned so that its ability to isolate waste does not depend on the kinds of technical factors or bedrock properties whose relevant data is, as yet, incomplete.

The question of the reliability and thoroughness of safety analyses can in the last resort only be solved by a reliance on general scientific assessment principles. The source data, assumptions and the models used to describe processes and interactions in safety analyses are based on extensive theoretical, experimental and empirical information gathered in Finland and elsewhere. The operational performance of the final disposal solution over a long time span cannot be tested for the time scales for which isolation requirements must be met, but a picture of the whole can be built on the available information relating to the behaviour of different substances and their interactions.

Additionally, information concerning so-called natural analogies is available. These are locations in which the situation in nature has for a long time already been similar to that in planned objects or final repositories. Examples of these kinds of natural analogies include rich uranium deposits in which it has been possible to examine the behaviour of radioactive substances in bedrock, and deposits in which the materials used in final disposal, for example copper, are found in nature. In Finland this kind of analogical data has been sought from such locations as the Palmottu uranium deposits (Paananen et al 1998) and natural copper deposits at Hyrkkölä (Marcos 1996).

Throughout the world, other interesting analogical investigation sites include Cigar Lake's rich uranium deposits (Cramer & Smellie 1994), where conditions resemble the conditions for final disposal in many respects. Model forecasts prepared in safety analyses provide a comparison for the information obtained from these kinds of natural analogies.

From the aspect of safety analyses, the list of most important reports published by YJT and Posiva are appended to this document. To facilitate assessment by international experts, reports have for the most part been published in the English language.

The Ministry of Trade and Industry (KTM) and STUK have annually assessed the progress of investigations in statements and decisions about the research programmes. About the summary reports prepared in 1992 and 1996, STUK has made separate expert reviews (Ruokola 1994, STUK 1997; STUK was also assisted by foreign experts for evaluations in its 1992 review).

As investigations have progressed, Posiva has also assessed its own work with the aid of outside experts. Additionally, completed investigations have been evaluated in several international forums, including the NEA's expert groups. The research being carried out in Finland is equivalent to the highest level of current international knowledge.

It should also be pointed out that investigations related to final disposal in Finland have also been commissioned by STUK and KTM (the so-called publicly funded nuclear waste research, JYT). A summary of these studies was most recently published in 1997 (KTM 1997).

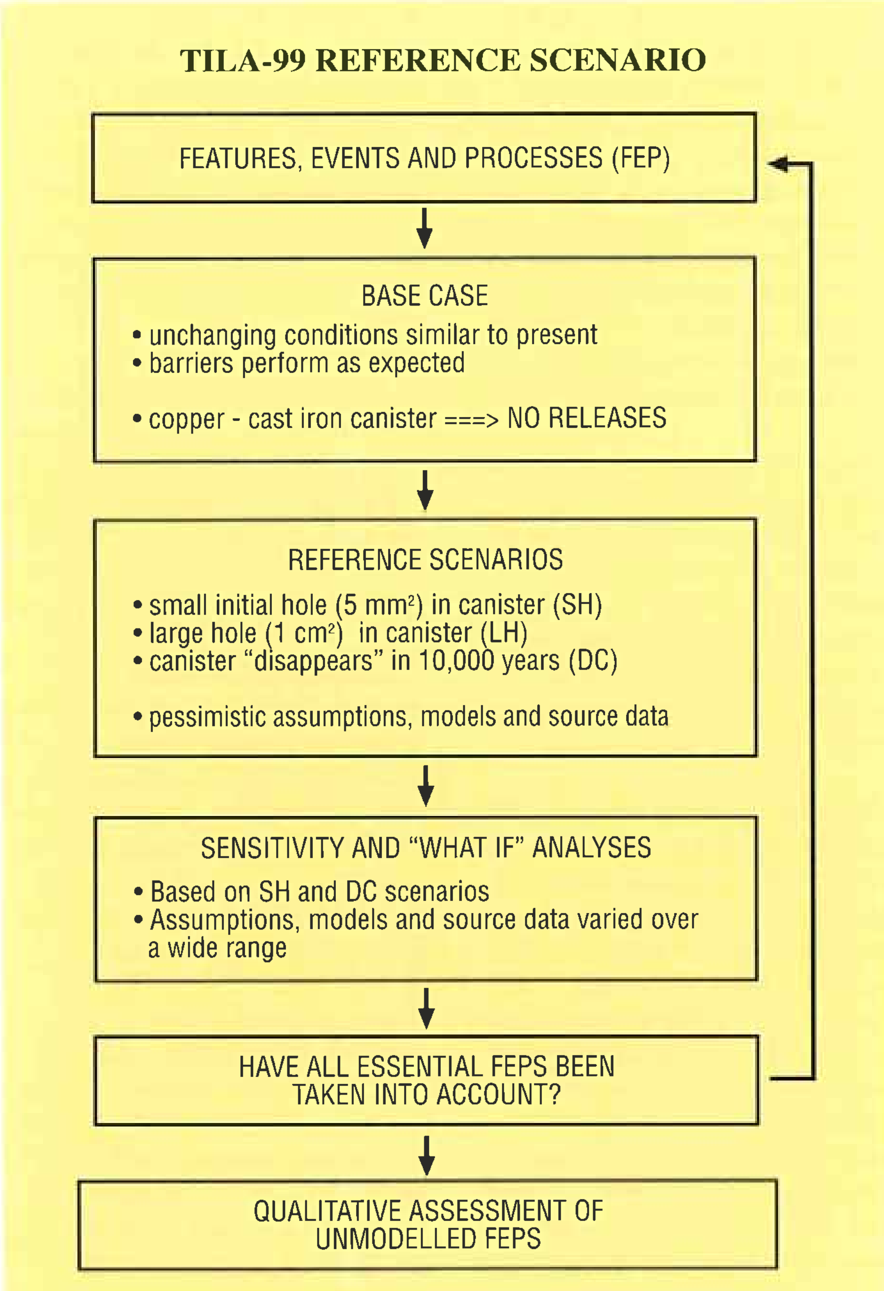
Estimated effects

The performance of Posiva's base alternative has most recently been assessed in the TILA-99 safety analysis report (Vieno & Nordman 1999) prepared by VTT Energy. The safety analysis is based on the same principles as the TVO-92 safety analysis published in 1992 (Vieno et al. 1992), and the TILA-96 safety analysis published in 1996 (Vieno & Nordman 1996).

TILA-99 examines the ability of the planned base alternative to isolate spent fuel according to STUK's safety requirements. Analyses take into account the latest information produced by final disposal investigations. Source data and assumptions about the bedrock have been selected to correspond to the properties of the alternative disposal sites under study.

In evaluating the possible long-term health effects of final disposal, the greatest attention has been paid to radioactive substances and their subsequent radiation effects. A separate study has, however, focused on the significance of disposed substances' chemical toxicity to human and environmental health. This study has been published as a separate Posiva report (Raiko & Nordman 1999).

TILA-99 is based on the scenario structure shown in the enclosed figure. The main objective was to ascertain how the conditions within the final disposal repository and the surrounding bedrock will develop after the repository has been permanently sealed, and what this would mean for the isolation capacity of the final disposal alternative and thus, the health and environmental protection of future generations (safety analysis base case). Additionally, a separate study focuses on what would happen if the canister's isolation capacity fails (so-called reference scenarios). In this connection, it is assessed, among other things, what would happen if a technical error or human negligence occurs in the technical implementation of final disposal, with the result that certain canisters would be leaking already from the start. Additionally, it has been ascertained what would happen if, for some reason, the copper canister were to lose its entire isolation capacity at a later date.



The purpose of reference scenarios is to assess the consequences of various unlikely but conceivably possible chains of events. Analyses have not attempted to formulate detailed predictions concerning all possible future factors that might cause a canister to leak; in reference scenarios, it has been simply assumed that at a certain point in time the canister has lost its integrity, either partially or completely. Using numerous sensitivity analyses, it has then been established how various assumptions concerning the spent fuel, the final disposal technique and the bedrock surrounding the facility would affect the outcome.

A detailed description of the safety analysis is contained in a separate English-language report published by Posiva (Vieno & Nordman 1999). Additionally, the background information for the report is contained in several other Posiva reports listed in the appendix attached to this document. Following is a summary of the content and results of the safety analysis by scenario.

Base case

The starting point for the base case is general geological knowledge and the assumption based on the bedrock investigations that conditions in the final disposal repository will, following final disposal, gradually revert to their original pre-disposal state, and that subsequent changes deep in the bedrock will be minor, at least for a period of tens of thousands or hundreds of thousands of years, at which point the disposed nuclear waste will no longer pose a threat to organic nature. The base case assumptions and the site-specific and general data underlying it are considered in greater detail in a separate report published by Crawford & Wilmot (1998).

Oxygen passing into the bedrock during the operational phase of the repository will be consumed in a few hundred years, and the only substance that could cause significant corrosion of the container is the sulphide dissolved in the groundwater. Groundwater turnover rate at the canister surface is slow, and the groundwater's sulphide concentrations at all investigation sites are so minor that millions of years would pass before the canisters would corrode through – even taking into consideration the possibility that in certain locations corrosion could occur more rapidly than average.

Over a long time, the compaction capacity of the bentonite clay protecting the canister may weaken to a certain degree. Under normal conditions this is not, however, of any significance for the canister life-time. Groundwater with a high degree of salinity may weaken the compaction capacity.

The salt concentrations observed at the investigation sites would not, however, cause any risks to the performance of the buffer between canisters and bedrock at the planned depths. Because of the significant salinities observed at Olkiluoto and Hästholmen, the backfilling of tunnels has been designed to consist of higher bentonite contents than at inland sites (backfilling with mixture of crushed rock and bentonite).

Helium produced by radioactive decay within the canister would, over a long time, cause increased pressure, but this could lead to a bursting of the canister only after tens of millions of years at the earliest.

The conclusion regarding the base case is that the final disposal of spent fuel will not produce any kind of health or environmental threat over a time span of millions of years. Further into the future, after millions of years, the contents of the canisters will resemble a rich uranium deposit. Even though canisters would no longer be intact, the entire activity quantities released from the final repository each year would be insignificant compared to nature's own natural background radiation (Vieno et al. 1992).

Reference scenario (1): Leaking canister

In reference scenarios it is examined what might happen if everything does not occur as assumed in the base case. Specifically, assessments have been carried out for cases where certain canisters might be leaking from the start. In the analysis, it has been assumed that the puncture could be a small "pin hole" (cross-sectional area approximately 5 mm^2) or a slightly larger hole (cross-sectional area approximately 1 cm^2).

The purpose of the quality control inspections and the quality assurance system is to prevent defect canisters from passing to the final repository. Because it is impossible to guarantee perfect faultlessness in practice, a conservative practical goal states that quality objectives established for canisters are to be achieved in no less than 99.9% of canisters. In that case, there would only be a few initially faulty canisters in the final repository.

Even taking the possibility of human error into account, it would appear practically impossible for a fingertip-sized puncture to escape undetected. Such a large hole might arise from a situation in which an initially small puncture or defective section has gradually opened, for example, as a result of local corrosion.

Water seeping through bedrock and the bentonite clay would come into contact with spent fuel. Although most of the spent fuel is solid and poorly soluble in oxygen-free water, a small part of the radioactive substances present in the fuel assemblies could be released fairly quickly if the water has penetrated inside the fuel rods. The majority of the radioactive substances could dissolve in the water only after the uranium forming the main part of the fuel would have dissolved or at least become oxidised. In oxygen-free groundwater, this would occur very slowly, even taking into account the possibility of the formation of oxidising substances by radiation (so-called radiolysis).

As water penetrates into the canister, it would however also cause the cast iron canister to rust. In investigations commissioned by SKB of Sweden, it has been observed that it is more probable that rusting would consume the water penetrating inside, and that the rust would fill the canister so that water would not seep outwards from it.

Nevertheless, the performed safety analysis has pessimistically examined the possibility that radioactive substances would be released from the canister. In this case, the radioactive substances dissolved in water would first pass into the bentonite clay surrounding the canister and then possibly either into a bedrock fissure or towards the tunnels.

Actual flow of water through the compacted bentonite will, however, not occur. Migration could be based only on diffusion slowly taking place within the bentonite's capillary water. Migration would be slowed by the sorption of radioactive substances to porous surfaces.

Those radioactive substances that would eventually penetrate through the bentonite layer could migrate with water flowing slowly through rock fractures. The substances in question could also first end up in the backfilling material of the tunnels, but eventually a portion of these substances could enter the bedrock's fracture network.

Studies of bedrock fracturing and the slow flow in fractures have been, besides the chemical properties of groundwater, a key part of the bedrock investigations. Only through groundwater can significant quantities of radioactive substances be released into organic nature. The chemical quality of groundwater affects the solubility of nuclides and their adhesion to bedrock fissures and porous surfaces. The flow of groundwater and its distribution in bedrock will largely determine the quantity of dissolved radioactive substances released into the living nature.

In all alternative sites, the quality of the groundwater in deep bedrock is reducing and slightly alkaline; in practice this means that the solubility of many radioactive substances is low. More significant differences between sites are found in salinities, which measured in chloride, are a maximum of 100 mg/litre at the investigated inland sites, compared with the dozens of grams per litre found at the coastal sites. The high groundwater salinities reduce the capacity of certain substances to sorb on rock. Groundwater properties and their variability at the investigation sites have been examined in reports by Pitkänen et al. (1998a–b) and Snellman et al. (1998). The solubility of radioactive substances in groundwater at the investigation sites has been dealt with in reports by Ollila & Ahonen (1998) and Vuorinen et al. (1998).

During the site characterisation several assessments based on modelling and measurements have been made for the groundwater flow at the investigation sites. Source data has relied primarily on information compiled from holes drilled at various points throughout the investigation sites. This consists of data regarding the groundwater table, precipitation, as well as measurements of flow and hydraulic conductivity made in deep drill holes (8-13 holes at each investigation site). The summary report of the investigations carried out until 1992 includes a preliminary summary of the flow investigations as well (TVO 1992b). The entire quantity of data accumulated over a period of ten years has formed the basis for more recent summary reports published in 1999 (Löfman 1999a-b, Kattilakoski & Koskinen 1999, Kattilakoski & Mészáros 1999, Poteri & Laitinen 1999).

In the site scale, the flow assessment is based on the so-called porous material assumption that provides a picture of the bedrock's average flow characteristics. In more detail the flows have been investigated in the scale of emplacement holes. In this case the starting point for modelling has been information concerning bedrock fracturing and its variability obtained directly from drill holes and rock surfaces. When generalising fracturing data, the use of stochastic modelling based on probabilities has been employed. The utilised methods have been considered more fully in reports by Taivassalo and others (1994), as well as Poteri & Laitinen (1996). Andersson and others (1998) have recently presented an assessment of the work carried out to the present, as well as of the further development needs.

Based on measurements and computer simulations, groundwater flow conditions at the final disposal depth have been estimated as being fairly similar at all alternative sites. The flow is primarily determined by the bedrock's hydraulic conductivity and the topography prevailing at the investigated sites, but it will also be affected by the salinity distribution of the groundwater. Compared to inland locations, the larger salt concentrations at Olkiluoto and Hästholmen suggest that the turnover rate for deep groundwater has been minimal. This has also been affected by the prevailing elevation differences, particularly at Olkiluoto Island, that are lower in coastal areas than at inland sites. On the one hand, because future coastal areas will increasingly resemble inland sites due to land uplift, differences in flow conditions related to salinity and topography are likely to subsequently diminish. The effect on flows of the bedrock warming due to deposited spent fuel is considered minimal. The final disposal canisters will be placed in locations where bedrock fracturing is low and anticipated flows are small. In these kinds of bedrock, the hydraulic conductivity can be assumed to remain under 10^{-7} m/s. Table 8-17 provides examples of values based on measurements and modelling calculations for the maximum quantity of water flowing into a single Olkiluoto fuel canister's disposal hole in this kind of bedrock. Figures are shown at different percentiles; for example the 50th percentile means that at least 50% of the flow at the measured location will remain under the stated value. The quantity of water flowing into the smaller emplacement holes of Loviisa fuel would be slightly less than the values shown in the table.

Based on performed site-specific flow analyses, values for flow assumptions have been selected for use in safety analyses. Table 8-18 gives a summary of these assumptions. Although there are differences in the pressure gradients that give rise to flow and in the extreme values of the hydraulic conductivity distributions, the situation at different sites is fairly similar on average. The rate of flow "flushing" one single deposition hole has, indeed, been estimated to be 0.5 litres per year on average for all sites (median value). At all sites and in all disposal holes the flow would probably (95% of all measurement locations) remain under 50 litres per year. At Olkiluoto, under present conditions, the flow would likely be one tenth of this. Even there, the flow in certain holes could rise to approximately 10 litres per year in the future.

Groundwater flow and chemical composition do not alone determine migration of nuclides. It is also important how flow is distributed; in other words the nature of the bedrock's fracturing is also important. In principle, a similar-sized flow can be concentrated in a few highly conductive "channels" or many poorly conductive fractures. The distribution of flow will determine to which extent the bedrock due to its porosity and sorption capacity is able to retard the movement of radioactive substances. Factors affecting migration and their consideration in safety analyses are considered in the aforementioned report by Andersson et al. (1998).

	Gradient (%)	Flow at difference percentiles (litre/a)* 50.	75.	95.
Hästholmen current situation (saline groundwater)	0.01–0.1	0.003–0.04	0.05–0.7	0.7–9
Hästholmen future situation (fresh groundwater)	0.1–0.8	0.03–0.3	0.4–4.1	6.1–55
Kivetty	0.7–4.0	0.07–0.4	0.3–1.8	1.8–10
Olkiluoto	0.5–2.0	0.02–0.1	0.1–0.3	0.4–1.4
Romuvaara	1.2–4.2	0.03–0.1	0.1–0.5	0.7–2.5

* For example, 0.04l/a at the 50th percentile means that 50% of flow values will be less than 0.04 l/a.

Table 8-17. Groundwater flows calculated by fracture network simulations for a cross-sectional area of 1x5 m^2 through bedrock outside fracture zones. The ranges of variation for flow at different percentiles are calculated using the minimum and maximum values of the hydraulic gradient in the bedrock surrounding the final disposal facility.

Case	Flow (litre/a)
Fresh groundwater	
All sites: "median"	0.5
Romuvaara and future Olkiluoto: 95th percentile	10
Kivetty and future Hästholmen: 95th percentile	50
"Extremely wet" disposal hole	200
Saline groundwater	
Current Hästholmen and Olkiluoto: "median"	0.5
Current Olkiluoto: 95th percentile	5
Current Hästholmen: 95th percentile	25
"Extremely wet" disposal hole	100

Table 8-18. Total groundwater flow quantity per disposal hole: Values selected to TILA-99.

The bedrock's ability to slow migration can be assessed using the so-called transport resistance, describing the flow distribution in the fracture network of the bedrock. Transport resistance cannot, however, be measured accurately in bedrock; it can only be estimated approximately based on flow measurements and fracture observations made in drill holes. Because it is not possible to obtain an accurate picture of the distribution transport resistance at the investigation sites, even with a large quantity of drill holes, and because, based on present information, the overall range of variation in transport resistance appears to be fairly similar at all investigation sites, the same values have been used initially at all sites, subsequently varied to ascertain the significance of site-specific and disposal hole-specific differences. The health effects arising as a result of radioactive substances passing into the groundwater will ultimately depend on where the groundwater coming from the great depth is discharged and how substances dissolved in groundwater behave in organic nature. Discharge areas have been estimated using flow models based on preliminary information on tunnel locations. At coastal areas, probable discharge areas take into account changes caused by land uplift.

Estimated discharge areas based on modelling are shown in Figures 8-10, 18-11, 8-12 and 8-13. These would probably be the places where the extra radiation exposure due to possible releases would be located. A portion of releases would finally migrate along waterways to the sea. Concentrations of radioactive substances in the uppermost soil layers would probably be diluted. On the other hand certain radioactive substances may accumulate in plants and animals. In most cases, the larger radiation doses would, however, result in the eventual passage of radioactive substances into wells, and from wells into the human body through drinking water. The radiation dose estimates of TILA-99 have been largely based on this assumption. Radiation doses arriving through other types of routes have been examined using sensitivity analyses. Besides the maximum dose caused to individuals, analyses have, according to safety regulations for final disposal, examined the quantity, measured in Bq units, of radioactive substances passing from bedrock into the living nature.

Figure 8-14 depicts an estimate, based on the average flow conditions on the alternative sites, of the maximum annual dose, measured in sieverts, caused to an individual by a small puncture in a single canister (curve SH). The estimate is valid regardless of the site selected for the final disposal facility. If there were several faulty canisters, the estimate for the maximum dose may be calculated by multiplying the dose by the number of faulty canisters. The individual dose limit established in the safety regulations is 0.1 mSv/a.

Curve LH describes the dose in the event that the puncture was already large in the beginning. It can be seen that the size of the puncture does not significantly affect the size of the maximum dose, but larger doses could be caused earlier than in cases with small punctures.

The graph reveals that even if there are several faulty canisters, the resultant maximum doses would remain minor compared to the established dose limit. Figure 8-15 examines activity quantities passing into organic nature in the case of small puncture. Quantities in the graph have been proportioned di-

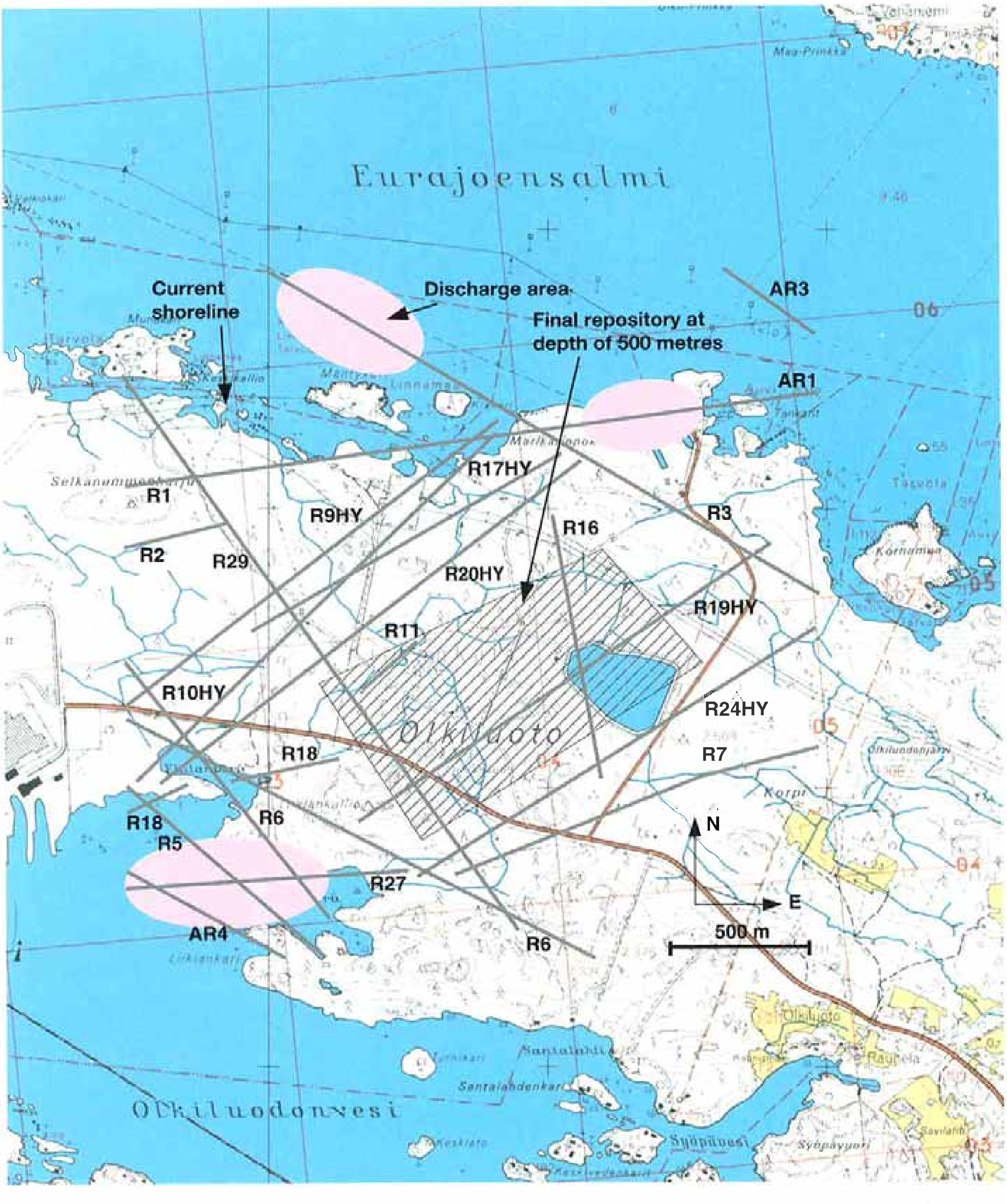


Figure 8-10. Estimated discharge areas of groundwater flows at Olkiluoto. The section with diagonal lines indicates the areas proposed for the final repository situated at a depth of 500 metres. Probable discharge areas at the ground surface are shown in colour. Also illustrated are the more significant fracture zones for flows.

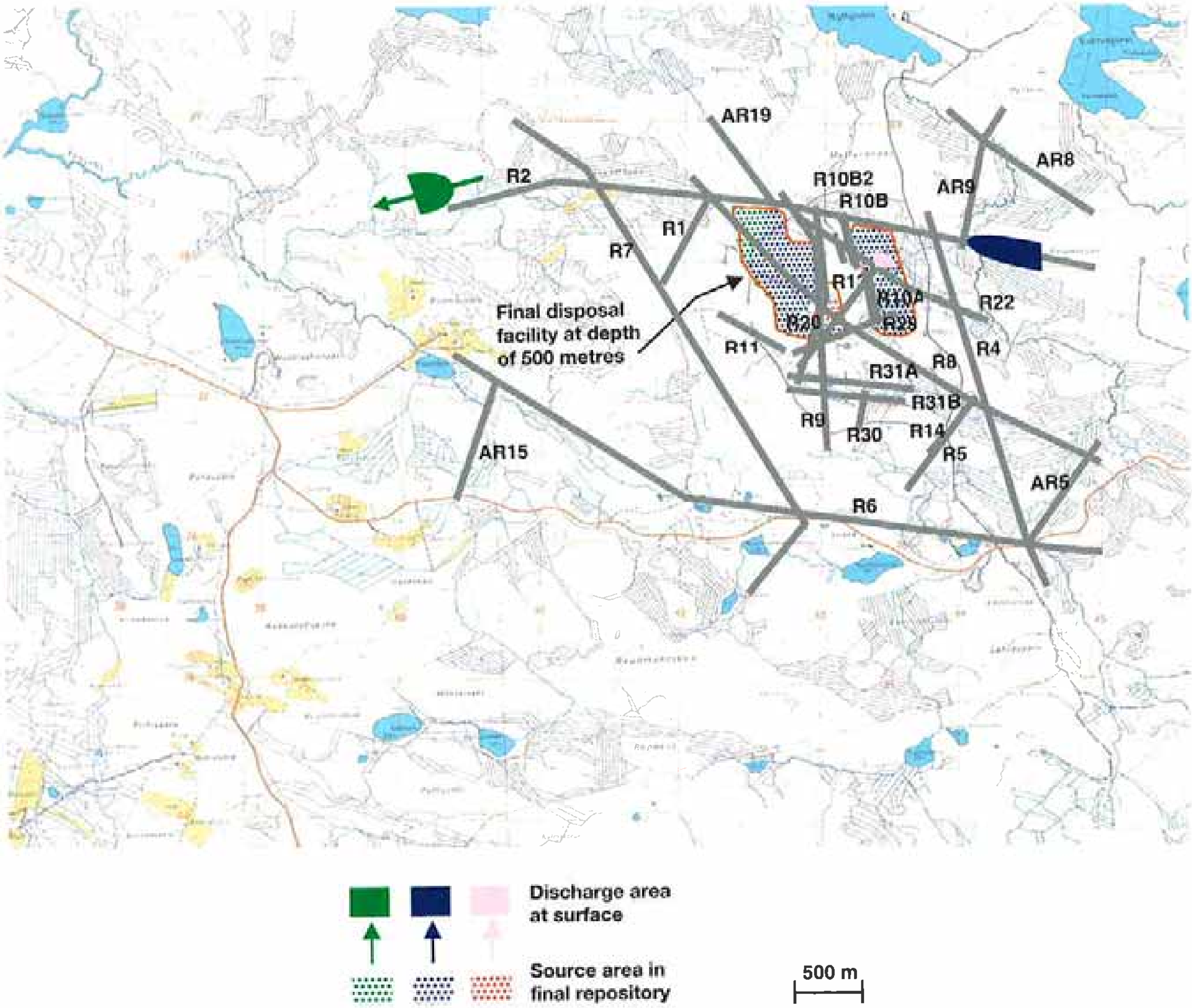


Figure 8-11. Estimated discharge areas of groundwater flows at Romuvaara. The section with diagonal lines indicates the areas proposed for the final repository situated at a depth of 500 metres. Probable discharge areas at the ground surface are shown in colour. Also illustrated are the more significant fracture zones for flows. According to the estimate, part of the discharge areas would lie outside the area illustrated.

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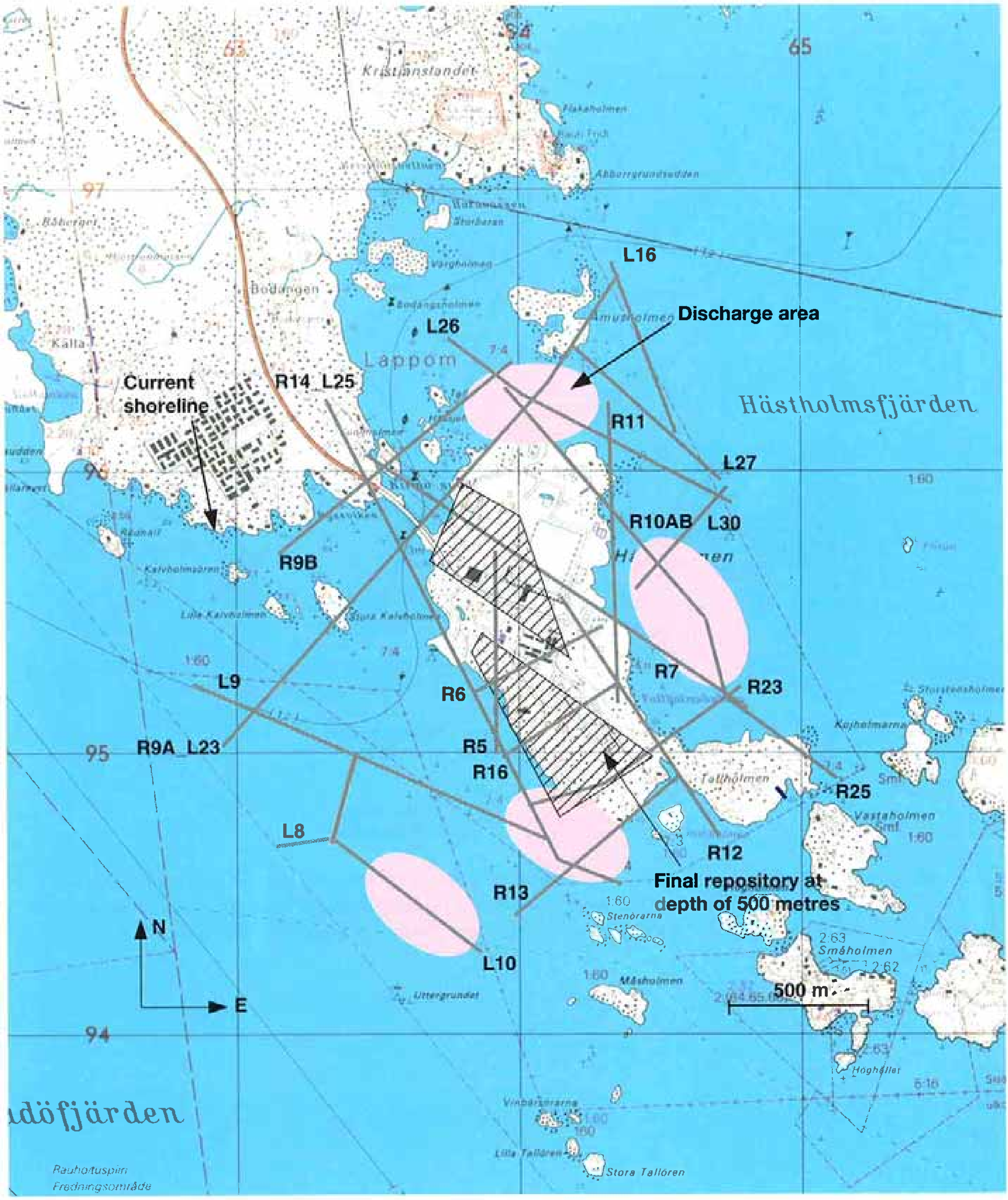

Figure 8-12. *Estimated discharge areas of groundwater flows at Hästholmen. The section with diagonal lines indicates the areas proposed for the final repository situated at a depth of 500 metres. Probable discharge areas at the ground surface are shown in colour. Also illustrated are the more significant fracture zones for flows.*

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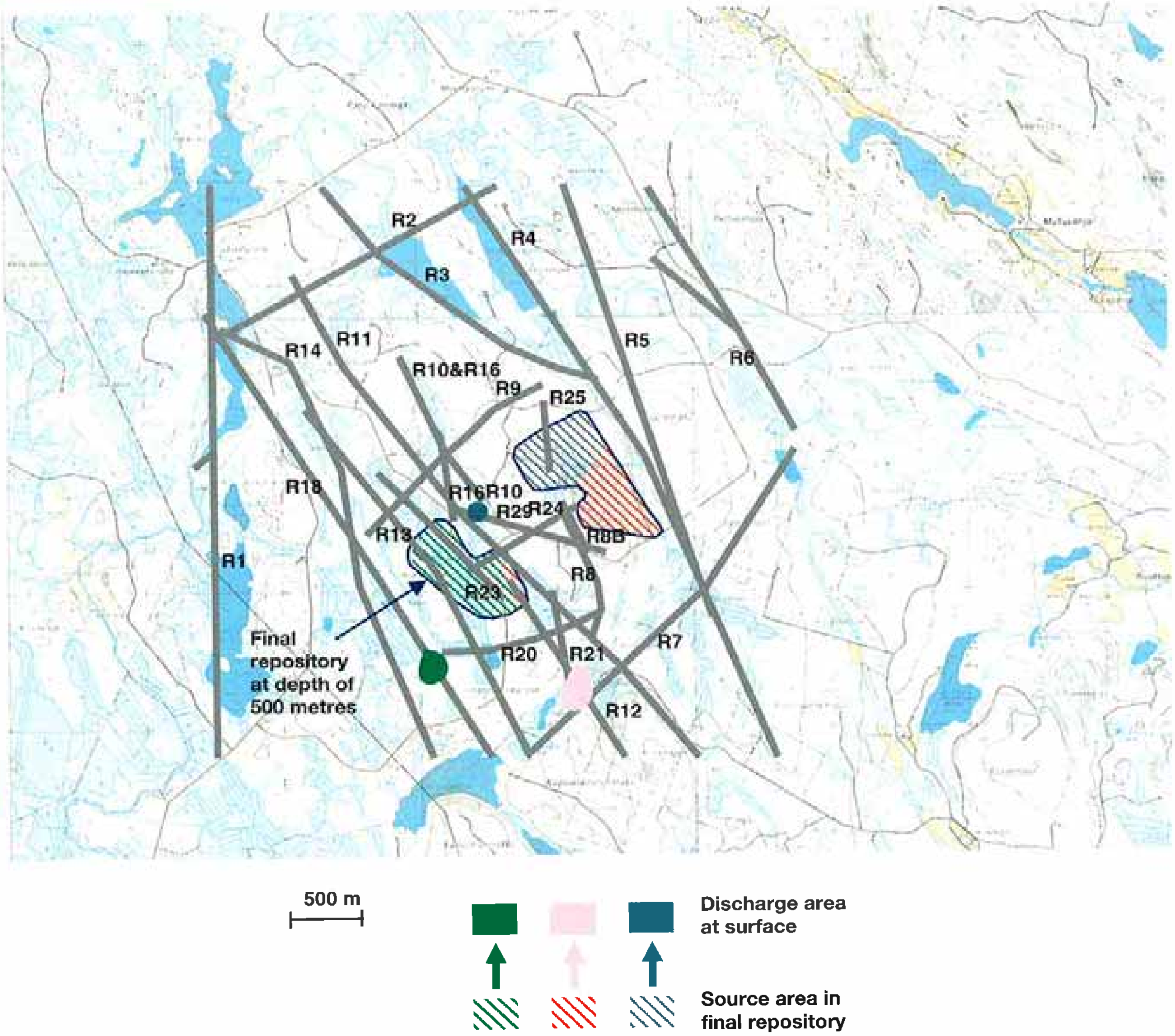

Figure 8-13. Estimated discharge areas of groundwater flows at Kivetty. The section with diagonal lines indicates the areas proposed for the final repository situated at a depth of 500 metres. Probable discharge areas at the ground surface are shown in colour. Also illustrated are the more significant fracture zones for flows. The following centrefold is a base map of the area and surroundings.

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rectly to STUK's proposed maximum nuclide-specific limits. The quantities released during the first few thousands of years would be less that one ten-thousandth of the allowable release limits.

Figure 8-16 shows the amount of nuclides released from a canister in the bedrock. In this case as well, the quantities are less than one hundredth of the limits set by STUK. According to this, the isolation capacity of the final disposal concept would be effective even without the retardation capacity and the diluting effect of the bedrock and organic nature.

Figures 8-14 and 8-15 reveal the maximum values valid at all four candidate sites. As described previously, flow conditions based on performed measurements and assessments are fairly similar at all four sites, and the average (median value) for flow rate flushing the deposition holes would probably be of the same magnitude at all sites. The probable range of variation could, however, be slightly different in different locations. Additionally, the quantity of radioactive substances released into organic nature would also be affected by the groundwater salinity. The significance of these differences is shown in Figures 8-17a and 8-17b. These depict the radiation doses for an initially defect canister (small hole) according to various flow assumptions. The curves identified as K95, R95, etc. describe the quantities under which the flow would remain in 95% of cases. The curve marked ns100 is equivalent to the "extremely wet" disposal hole of Table 8-18 in fresh water, the curve marked sal100 is equivalent to the situation in saline groundwater. For the sake of comparison, the cases are included under which the flows would remain under 50% in inland sites (ns50) and coastal sites (sal50). According to current conditions, the water flowing at coastal sites is assumed to be saline.

Figure 8-14. Maximum annual individual doses resulting from leaking canister shown for different periods. Curve SH indicates an assumed small hole and curve LH indicates a "large" hole.

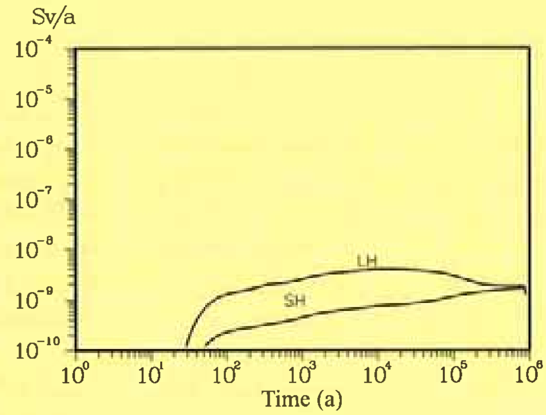


Figure 8-15. Quantities of released radionuclides passing into organic nature from a small hole in a single canister compared to release limits established by STUK. Release limits are 1 GBq/a for nuclides marked as solid lines and 10 GBq/a for C-14 marked as dotted line.

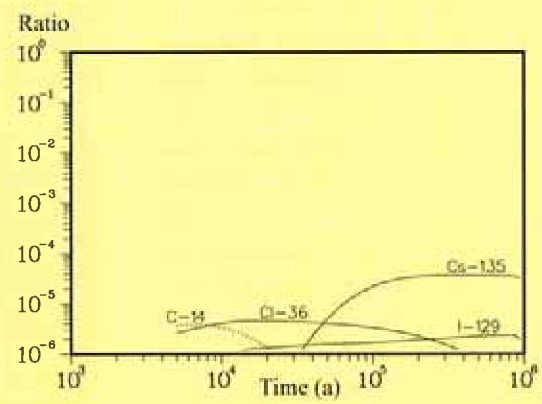
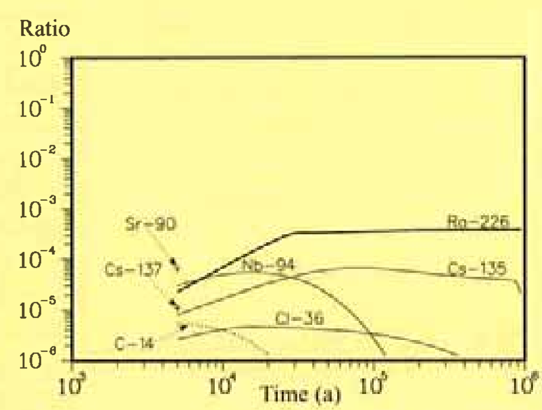


Figure 8-16. Quantities of released radionuclides passing into bedrock from a small hole in a single canister compared to release limits established by STUK. Release limits are 0.1 GBq/a for radium (bold line), 1 GBq/a for nuclides marked with thin solid lines (also for individual points marked for Sr-90 and Cs-137) and 10 GBq/a for C-14 marked as dotted line. The proportions of other nuclides remain under one part per million.



The peak appearing in values for coastal areas after approximately one hundred years is the result of weak retention of strontium by saline groundwater on rock fractures and porous surfaces. On the other hand, the peak dose is primarily theoretical because it is unlikely that saline water would be used for domestic water. It should also be pointed out that the maximum doses from a single canister indicated by curves H95 and O95 would remain less that one-thousandth of the established dose limits.

The significance of flow variations by themselves is relatively minor. The flow could be hundreds of litres in fresh water for a single hole without a significant increase in maximum doses. In saline water, the rise of the flow to hundreds of litres per hole would raise the maximum dose from the situation at the 95th percentile by a factor of ten – under the continued assumption that saline water would however be fit for use as domestic water. Despite that, the doses caused by releases from a single canister would remain less that one-hundredth of the dose limit. In practice, such bedrock location would not be accepted for emplacement of canisters.

Safety analyses have also examined situations in which, besides there being a puncture in the canister, the insulation capacity of the bentonite is lower than planned. This, however, would not have an appreciable effect on maximum doses because the passage of radioactive substances through the puncture would in any case be slow.

Reference scenario (2): Canister isolation capacity disappears completely

One reference scenario deals with the case in which it is assumed that, at a certain time, the canister isolation capacity would disappear completely and groundwater would freely come into contact with the fuel rods. It is difficult to imagine the reasons for this occurrence, but the intent has been to ascertain how the requirement for a multi-barrier principle is satisfied, or in other words: what significance does the canister generally have on the isolation capacity of the final disposal concept, and how effectively do the surrounding bentonite and bedrock themselves prevent detriments to the living nature?

In Figure 8-18, it has been assumed that the canister disappears in 10,000 years after final disposal. The diagram indicates the difference to the case of small hole: within a few years of canister disintegration, radiation doses may rise to levels that are on the whole at the same level as the peak levels shown in Figure 8-17a–b, but subsequently, maximum doses would decrease slowly towards the same values as in the cases of small hole. The dose peak would primarily be caused by the iodine (I-129) that would be released rapidly as the canister disappears. In this case, the retarding effect of the fuel cladding has not been taken into account.

If also the isolation capacity of the bentonite is significantly weaker than planned, maximum doses could grow by a factor of ten compared to Figure 8-18. If, in addition, there would be a very high flow of saline groundwater – in itself highly improbable – the maximum dose could rise to approximately one-

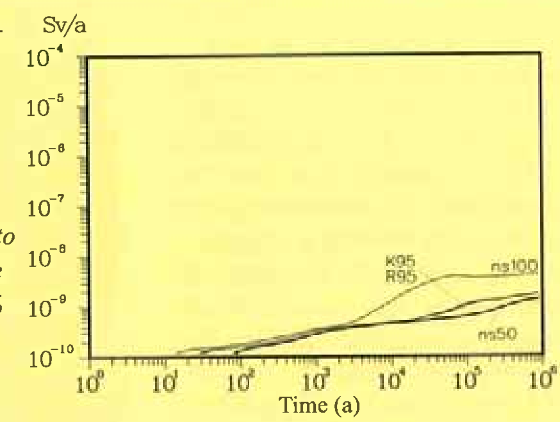


Figure 8.17a. Annual maximum doses for a small hole in a single canister for different flow assumptions at Kivetty (K) and Romuvaara (R). Curves K95 and R95 correspond to flow rates under which the flow would remain in 95% of estimated cases. The curve ns100 is equivalent to Table 8-18's "extremely wet" disposal hole in fresh groundwater. Curve ns50 corresponds to a flow rate, under which would remain at least 50% of checked cases on both sites.

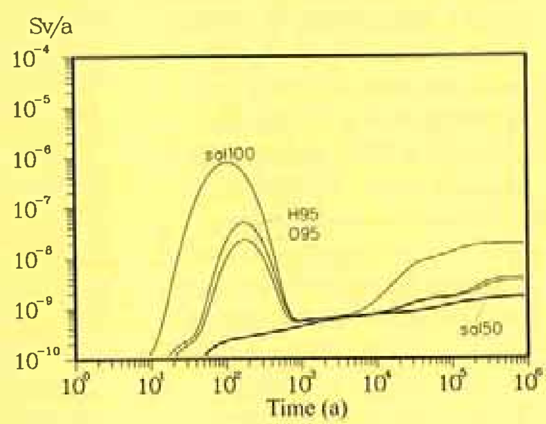


Figure 8.17b. Annual maximum doses for a small hole in a single canister for different flow assumptions at Hästholmen (H) and Olkiluoto (O). Curves H95 and O95 correspond to flow rates under which the flow would remain in 95% of estimated cases. The curve sal100 is equivalent to Table 8-18's "extremely wet" disposal hole in saline groundwater. Curve sal50 corresponds to a flow rate, under which would remain at least 50% of checked cases on both sites.

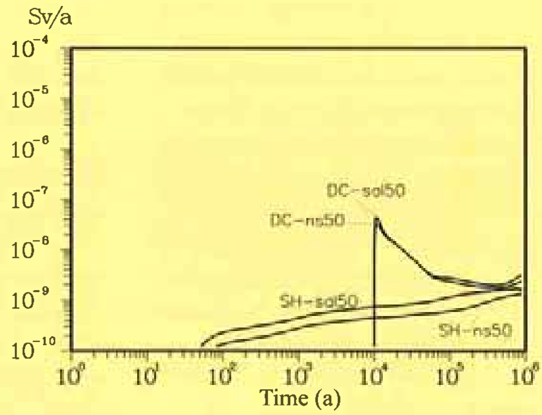


Figure 8-18. Annual maximum doses in cases where it is assumed that a canister disappears completely. Doses have been calculated separately for cases with saline groundwater (DC-sal50) and fresh groundwater (DC-ns50). Curves SH-sal50 and SH-ns50 represent leaks from small punctures.

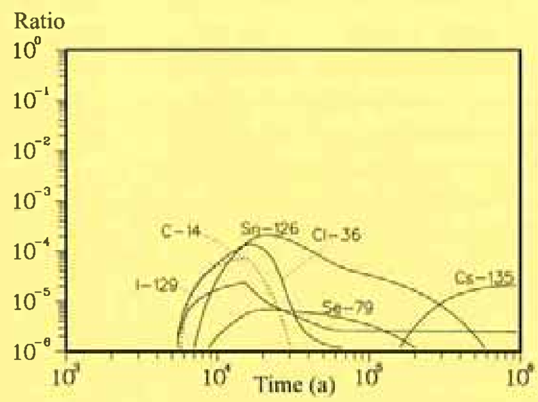


Figure 8-19. Quantities of radionuclides released into the living nature in the case of single disappearing canister compared to limits specified by STUK. Release limits are 1 GBq/a for nuclides marked with a solid line, and 10 GBq/a for the C-14 shown as a dotted line. Other nuclide proportions are less than one part in a million.

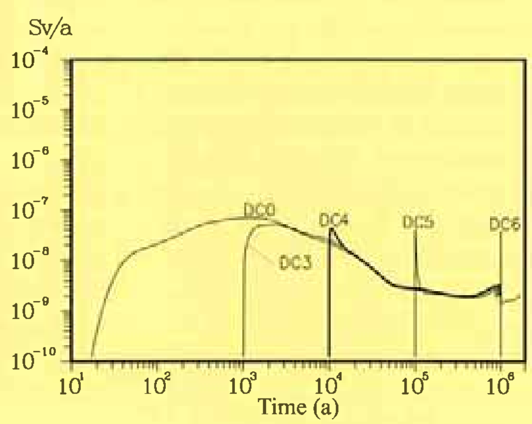


Figure 8-20. Effect of the time of disappearing of the canister on annual maximum doses. DC0 represents a case in which the canister disintegrates immediately following the sealing of the final disposal facility, DC3 one thousand years from the sealing, DC4 ten thousand years, DC5 one hundred thousand years, and DC6 one million years.

tenth of the dose limits presented in general safety requirements.

The radiation doses shown in Figures 8-17 and 8-18 were calculated for all periods on the same basis. As stated in the safety requirements for final disposal, actual radiation doses for persons living far into the future cannot be estimated reliably because of changing living and nutritional habits. The curves, however, provide an indication of the performance of the final disposal concept over long-term.

According to safety regulations for final disposal, the assessment criterion for long-term is the activity release to bedrock. Figure 8-19 shows the activity releases equivalent to the DC-ns50 case shown in Figure 8-18 compared to the limits specified by STUK. It can be seen that most releases remain at less than one-thousandth of limit values.

The moment of disappearing of the canister does not have an appreciable effect on maximum doses. Figure 8-20 shows a comparison of cases in which the canister completely disappears at different times.

Possibility of accidents

Planning of the final disposal concept is based on "passive safety". Its purpose is to protect organic nature and human life under all conditions regardless of peoples' desire and ability to take care of nuclear waste. Placing the waste deep in the bedrock keeps the solution independent of natural catastrophes occurring at the surface as well as from possible accidents caused by people. A solution aiming at the multiple isolation of radioactive substances also provides protection against unforeseen changes.

The principles on which the isolation capacity of the final disposal alternative are based are treated in the TILA-99 safety analysis, as well as in supporting research. Safety analyses have, however, also extensively examined cases in which isolation has not performed as anticipated, despite quality control and multiple inspections. In these cases it was directly assumed that one or more canisters would either leak or lose their isolation capacity completely, and that the isolation capacity of the bentonite would be poorer than planned. Analysis results indicate that even the complete disappearing of a few canisters would not yet lead to the exceeding of established limits.

Safety analyses have also investigated the possibility of many damaged canisters. Given present knowledge, only a rock displacement caused by an earthquake could cause this kind of accident. The picture is that a rock displacement of at least ten centimetres would hit the final disposal tunnel, breaking all the canisters in that tunnel.

A major earthquake could possibly cause this kind of displacement. Under prevailing conditions, the magnitude of the largest earthquakes occurring in Finland and nearby regions has been under five, nor have significant displacements occurred in present conditions (Saari 1996, 1997, 1998, 1999, Kuivamäki et al. 1998). In connection with coming glacial periods, earthquakes larger than today's are, however, possible. Rock displacements in Finland and Karelia studied by The Geological Survey of Finland seem to be the result of earthquakes whose magnitudes have ranged between 5.3 and 7.5 (Kuivamäki et al. 1998).

When searching for final disposal investigation areas, the aim has been, however, to eliminate, as far as possible, the likelihood of a rock displacement at the disposal site. Bedrock investigations and theoretical examinations indicate that movements in bedrock tend to be concentrated in existing fractures and faults. The movements seem to be connected with the fracture dimensions in a way that significant displacements occur only along major fault lines. All investigation sites have been selected so that the distances of planned tunnels from extensive fracture zones covering dimensions of hundreds of kilometres would be dozens of kilometres, and that the distance from smaller regional weakness zones would be at least several kilometres.

It is, however, most likely that the movements caused even by the large post-glacial earthquakes would result in only small movements in the fractures possibly hitting the final disposal tunnels, nor would they present any threats to the integrity of canisters. According to a preliminary study carried out for Posiva by La Pointe and Cladouhos (1999) the likelihood of dangerous movements affecting canisters would be very small.

Nevertheless, based on present knowledge, the possibility of a rock displacement at the emplacement hole in the future cannot be entirely eliminated. In safety analyses, projections have been made regarding the kinds of effects that might result. In these analyses, it has been assumed that the event would take place during the next ice age, or not earlier than 10,000 years following final disposal. Based on the assessment, the simultaneous breach of 60 canisters under one disposal tunnel could result under unfavourable conditions - assuming that the area was still inhabited - in the radiation dose of a few additional millisieverts per year to the most exposed individual. This assessment, however, does not take into consideration that in conditions following an ice age, most of the earth would be covered by water, and even elsewhere the quantity of water diluting the releases would be significantly greater than has been assumed. In fact, doses would remain minimal compared to the normal radiation exposure of people, nor would the releases have any important effects on nature regarding the amount of radionuclides already present in nature.

A second type of accident could be caused by human intrusion into the final disposal facility. Because the aim is to preserve information about the final disposal facility and the nuclear waste disposed of, and pass it on to future generations, the accidental or unintentional intrusion into the final disposal facility is unlikely as long as the present culture is preserved and continues. The potential for the occurrence of this kind of accident would increase only after knowledge of final disposal has disappeared. On the other hand, the radiotoxicity of the waste would have significantly decreased by then.

If the final disposal facility is entered without protective clothing within one hundred years of final disposal, the risk of a serious health detriment will exist. Acute health detriments would be possible if the intruders remained in close proximity to the exposed canisters for many hours. From the standpoint of the environment and the population at large, the occurrence would, however, become significant only if the canisters were opened and their contents either dispersed or spread through the environment. It is highly unlikely that the excavation of a tunnel to the final disposal facility and the opening of individual canisters underground would cause any significant increases in the natural radiation levels. The environmental effects of deliberately spread canister contents are fairly impossible to predict accurately because the consequences would largely depend on the time of the occurrence and the manner in which the waste is dispersed.

The prevention of these kinds of unintentional accidents due to lack of knowledge is achieved by placing the final disposal repository sufficiently deep in the earth so as to be outside the reach of people's normal lives. In any case, it is likely that if future generations are able to penetrate into the facility, they will also have the knowledge and skills to avoid the radiation emitted by the waste.

The uncertainty assessment in safety analysis

In safety analyses our general knowledge and future uncertainty are taken into account:
- in scenario selections
- by using conservatively chosen (overestimated consequences) assumptions
- by ascertaining the effects of assumptions used in the analyses on results with sensitivity analysis and "what if" assessments.
- by using outside experts to evaluate analysis performance and test results as the project progresses.

The cases assessed in TILA-99 scenarios and their sensitivity analyses have been selected so that taken together, they cover the logically conceivable future scenarios as well as possible situations in which technology or materials do not perform according to expectations. In this connection, particular attention has been paid to such factors as the possible effects of future ice ages. The uncertainty of information concerning bedrock conditions has been compensated by using pessimistic assumptions. Throughout experiments have been used to test hypothetical situations that might affect the performance of the final disposal concept.

Safety analyses, as well as the supporting research, has been open to scrutiny and evaluation by Finnish and international experts. Methods and assumptions of the analyses have been assessed in several international comparisons (Neall et al. 1994, Russell et al. 1997, SAM 1996, NEA 1997).

With these methods, care has been taken to ensure that the safety analysis represents the best available expertise and that uncertainty factors and their significance, from the aspect of result and conclusions, has been properly assessed. Before construction and operation of the final repository detailed bedrock investigations will be carried out at the selected site. The feasibility and quality of technical solutions will be demonstrated by tests and experiments. In this way, safety assessments will still be refined and revised before the actual final disposal operations are started.

Effect of spent fuel quantity

Examined from the standpoint of the safety and health effects on individuals or small self-contained communities, the quantity of finally disposed nuclear fuel is not essentially significant. According to safety analyses, it is most probable that radioactive substances will not be released from canisters for millions of years. Subsequently, the radioactivity of substances in the final disposal repository would in any case be extremely low.

Safety analyses have also examined the possibilities that certain canisters are initially defective, or damaged prematurely. The probability of these cases can be roughly estimated as increasing in direct proportion to the quantity of finally disposed fuel. As the number of canisters increases, the total length of final disposal tunnels also increases in fairly direct proportion. In this case, possible radioactive releases caused by faulty or damaged canisters would most likely be spread in different directions and the probability that they would, for example, end up at the same well is very low. It is most probable that the increased quantity of spent fuel to be disposed of would have no effect on the maximum individual dose.

Conclusions

The completed safety analysis demonstrates that the final disposal of spent nuclear fuel can be implemented according to radiation safety requirements at any one of the candidate sites. It is most likely that there would never be releases from the underground final repository that would be significant from the standpoint of the environmental protection. In even the worst cases, the largest radiation doses incurred by individuals would remain at most at the current level of natural background radiation, and the number of individuals exposed would be small and limited to the immediate vicinity of the final disposal facility. The cautionary principle has been applied in analyses, whereby pessimistic assumptions are made regarding future natural conditions and the performance of technological systems. The conclusions of the analyses do not, therefore, essentially depend on what exactly happens in the future.

Based on the analysis, none of the four alternative sites can be considered categorically superior or inferior than the others from the safety aspect, nor does the safety analysis provide any reason to abandon any candidate site.

The clearest differences between the candidate sites are found in the chemical quality of their groundwater: at coastal locations, the salinity of the groundwater in deep bedrock is significantly greater than at inland locations. Salinity limits the bedrock volume available for final disposal in the depth direction and affects the migration speed of substances possibly dissolved in groundwater. On the other hand, the salinity at coastal locations and the proximity of the sea reduce the probability that radioactive substances dissolved in groundwater would end up in peoples' food or drinking water in appreciable concentrations, causing genuine health detriments.

Certain differences in rock fracturing and flow conditions can also be observed at the different sites, but these variations are not essentially significant from the standpoint of long-term safety.

8.4.4 Psychosocial effects

Interview and questionnaire surveys carried out accompanying the assessment of the social impact of the final disposal project demonstrate that attitudes towards the project vary to a certain extent in all localities. In interviews, it has also become apparent that final disposal directly elicits fear in certain individuals (Chapter 8.5.5). For that reason the question has been raised if fears, anxieties and conflicts could lead to actual illnesses.

Establishing reliable links between illnesses and fears or anxieties is always difficult, and it is particularly difficult in this case because the effects under discussion will only manifest themselves after many decades into the future. In this connection detailed predictions are not made for future developments; instead the subject's mechanisms and interdependencies are assessed.

The assessment is based on a report prepared by the Department of Social Psychology at the University of Helsinki that reviewed the Finnish and international research as a basis for evaluating potential psychosocial effects incurred by the final disposal project (Paavola & Eränen 1999). Part of the same subject matter is also assessed in a recently completed doctoral thesis that investigated the contamination groundwater in Oitti(Lahti 1998).

Generally, stress is defined as an individual's behavioural, emotional or physiological reactions produced by various stimuli, or stresses, that threaten peoples' well being. Changes affecting behaviour and emotional life are termed *psychological stress*, while reactions affecting physiological and biochemical processes are referred to as *system stress*. It is fundamentally a question of the demands made on an individual as well as his or her ability to deal with imbalances. Stress factors can be caused by external events, but they can also result from individuals' self-inflicted ethical norms and behavioural demands.

An individual's stress management can be intrapsychic or cognitive, in which case the individual attempts to eliminate the imbalance through an intellectual or emotional redefinition. The individual can also attempt to influence external factors to eliminate or alleviate the cause of the stress (instrumental stress management). Regardless of the stress coping method employed, its failure will lead, from the individual's standpoint, to similar consequences. The resulting uncertainty may manifest itself as chronic depression, anxiety, a continuous feeling that the control of one's own affairs has been lost, or it may lead to somatic symptoms such as sleeplessness, headaches or recurring abdominal pains.

The community's possible support, or lack of it also influences stress management. Operating at the community level can create forms of stress management that could not be áccomplished by individuals acting alone. These kinds of communities can be, for example, the home municipalities as well as societal movements.

Accidents and catastrophes typically cause stress. Investigations indicate that people react differently to natural and man-made catastrophes. Technological catastrophes appear to be more powerful stress factors, and their psychosocial effects appear to last longer than those exerted by natural disasters. The reason for this difference may be that technological catastrophes are a demonstration of a loss of control or mismanagement, and that "guilty" parties can generally be blamed. Natural catastrophes are not expected to be fully under human control, so they are easier to accept. Another reason for the stress caused by technological disasters is that their consequential effects are not fully known, and that the subject itself may be a subject of debate, even at the expert level.

It has been found that natural catastrophes sometimes solidify communities and unite their members. This has not however been observed in technological catastrophes. A likely explanation for this is that the reasons for natural disaster are interpreted for the most part in the same way, whereas technological catastrophes and their consequences may be subject to differences of opinion.

Technological accidents do not necessarily divide communities. In Lahti's investigation (1998), it was observed that, despite the technological nature of groundwater accident in Oitti, the residents of Oitti viewed it as a natural disaster. These attitudes were viewed as a reflection of Oitti residents' confidence in the functioning of their municipal community. It was believed that municipal officials were doing their best and communications were not faulted.

When assessing nuclear waste-related stress factors, it must be borne in mind that nuclear waste and nuclear energy are often inseparably linked in the minds of the general public. Although the final disposal facility for nuclear waste would not pose the threat of a serious nuclear accident, people's knowledge and experience are unable to make these kinds of distinctions. For that reason the fears and anxieties possibly caused by final disposal may be somewhat related to attitudes towards nuclear energy itself. In that case the subject is affected by experiences and knowledge of, for example, the Three Mile Island and Chernobyl accidents. At the general level, an assessment of the probabilities and consequences of nuclear accidents including health impacts is associated in the minds of many with significant differences of opinion between experts.

Problems related to information provided by experts are dealt with more fully with social effects (Chapter 8.5). In cases of possible nuclear accidents, nuclear technology experts and authorities responsible for the supervision of nuclear plants are examples of so-called “outside groups”. From the aspect of assessing an accident’s stress factors, the core question is the confidence of the “inside group” (individuals or communities experiencing stress) in the abilities of the outside group. Trust can be weak if different groups’ resources have been distributed unequally, and, for example, if the information about stress-related matters is primarily in the hands of the outside group. For this reason, all measures that promote the exchange of information, consistency in information provided by experts and an empathetic response to the inside group’s concerns will alleviate the effects of stress factors.

Stress factors possibly caused by the final disposal project arise differently during the project’s various stages. Before and after the implementation of the final disposal decision, before actual operations, it will largely be a question of disagreements and attitudes resulting from differing points of view and opinions regarding the decision-making process (see also Viinikainen 1998). After operations have begun, the situation will be decisively influenced according to how smoothly the facility functions.

The presence of stress factors can be assessed through the so-called expectation value model. The starting points are the values internalised by individuals on which attitudes are largely based. Values for more directly practical operations are however often affected by attitudes that do not need to be in direct connection with individual values. In the expectation value model, the realisation of values into attitudes, as well as their prioritisation are viewed as a function of three component elements: cognitive, emotional and operational-motivational factors.

The cognitive factor alludes to information regarding the project and its environment received by the individual through learning and experience, while emotional factors are built from various positive and negative attitudes towards the project. Operational and motivational factors refer to the individual’s readiness to alter assimilated modes of behaviour.

The expectation value model clarifies individuals’ various reactions and opinions to the final disposal project. The model also explains why extensive communications and the use of rational arguments have only a limited effect on public attitudes. The controversial question regarding the final disposal of nuclear fuel is related to risk: the question is both the definition of the concept as well as its content in specific situations. Public attitudes concerning risks are rarely reduced to consequences and probabilities; perceived risks also depend on whether it is a question of voluntary exposure to danger or an external threat.

During decision-making stages, the importance of final disposal-related stress factors may significantly depend on individuals’ trust in their community (district of residence) and decision-making mechanisms. The question is two-sided: do the members of the community feel that they are in a position to influence the final disposal decision, and on the other hand, do they feel that the community would be also capable of supervising the situation’s development following the decision to locate the facility in the municipality in question.

In all alternative site locations final disposal-related concepts of finality, irreversibility and lack of control could create stress for certain local residents. Additionally, abnormal situations and possible import of foreign waste are preoccupations. The reasons for anxiety would appear to be uncertainty related to scientific data, as well as difficulties in understanding the information and its diversity.

The potential for stress management is similar in all municipalities. The least number of questions related to the project’s planning and decision-making process have been raised in Eurajoki. In other municipalities, greater doubt has been expressed regarding the ability of local residents to exert an influence: it has been claimed that residents have not been properly informed at a sufficiently early phase. This has been attributed to either the Nuclear Energy Act or municipal government and administration. Views concerning the impact of a public referendum are divided. The possibility of participation, essentially related to EIA procedures, has not however attracted the involvement of local residents. The attendance for arranged meetings was highest in Eurajoki. In all municipalities, civic leaders and decision-makers (Ponnikas 1999) believed that open communication is a prerequisite for an open and democratic final disposal process. In municipalities with power plants, there is faith in the workings of representative democracy and in the impartiality of the central government regarding the final disposal of nuclear waste. Seventy-nine per cent of Eurajoki's civic leaders and 60% of Loviisa's civic leaders believe that the final disposal decision should be made by community authorities. In municipalities without power plants, the preference is for direct public decision-making; 66% of Kuhmo's civic leaders and 51% of Äänekoski's civic leaders believe that a referendum is necessary to render the final disposal decision.

The development of the situation is also naturally influenced by the actions of experts. What is essential is not simply the quantitative assessments of risks by experts, but how well experts are able to respond to public perceptions of the essential nature and significance of risk. The ethical viewpoint is a particularly important part of this discussion.

Following the siting decision, the significance of the facility as a potential stress factor will depend to a large extent on the role assumed by the municipality: will it be passively adapted or will it become and active adapter. Adaptation means, for example, that the municipality includes the facility in its municipal planning and instigates dialogue between different parties.

When the final disposal facility has established its position in the selected location, its significance as a stress factor will likely decrease. If the facility operates without disturbances, it will gradually be accepted as a normal part of the community's functional surroundings. Within the public there may still be differences in attitudes towards the facility. These differences can be caused by, for example, direct proximity to the facility, whose employees generally tend to place a greater trust in its performance (Kivimäki & Kalimo 1993, Kivimäki et al. 1995). For some individuals the facility may however be a permanent stress factor.

A possible operational disturbance could revive the disagreements and uncertainties surrounding the project, even though the occurrence might in reality cause no physical consequences of any kind outside the facility. In these types of situations it is just the uncertainty itself that is the significant stress factor. It is possible that residents would be divided in their attitudes towards the disturbance: some would believe that there are no actual detriments posed to, for example, health, while others, despite reassurances issued by experts and public authorities, might consider their health endangered. This may include search for the quilty either inside or outside the community. In these kinds of cases, the Oitti case providing one example (Lahti 1998), the development of the situation is influenced by the community's (municipality's) faith in its operational culture.

In actual accident situations, behaviour could partially deviate from that found in disturbance situations. Perceptions of the content of events could be more congruent than in disturbance situations. Individual stress coping techniques could, however, differ from each other and some of these could lead to moving aside from the others. In these kinds of situations, the alleviation of stress could best be achieved by consistent communications and reassessment of emotions awakened by the event. It must, however, be pointed out that a serious reactor-type accident cannot occur in final disposal facility, nor for this reason would there be a need for accident-related evacuation situations that would damage the community's sense of solidarity.

The social effects of the final disposal facility have been treated more fully in Chapter 8.5. In that connection, questions of risk definitions and their nature, as well as meaning of expert information in formation of popular attitudes, are re-examined.

8.4.5 Summary of health effects

Given the completed safety analyses and other assessments, the effects of the project on human health remain insignificant, locally as well as on a larger scale, and it is most likely that no changes would be discerned at any time. The risk of health detriments caused by accidents, project-related uncertainties and unexpected future events is also extremely low. Impacts on the health condition would remain small and would possibly be limited to psychosocial effects.

Among the general public, the greatest concern regarding possible health effects is attached to the health risks possibly caused by radiation emitted by the radioactive substances contained in spent fuel. Under normal conditions radioactive substances are, however, kept strictly isolated from nature and human life. The greatest attention has been given to the consequences of various disturbance situations and accidents, as well as to assessments of the long-term safety of final disposal facility.

Although various fears and anxieties focus on the transport of spent fuel, both practical experience and completed safety analyses demonstrate that the health risks are minor. The minimum risk is attained when the number of shipments is minimised and the transport is carried out by sea. If it is only the spent fuel produced by existing plant units that is to be finally disposed, the risk is minimised when Olkiluoto is selected as the disposal location and transport from Loviisa is carried out by ship. The risk is however on the whole so low that the impact of the final disposal site or transport mode on health conditions or possible health risks is insignificant.

The safety regulations established in Finland for the final disposal facility are extremely strict by international comparison. In all situations, the radiation exposure created by the facility remains negligible, regardless of the fact that the intent has not been to restrict habitation near the plant. This being the case, the site location is also insignificant from the standpoint of health risks.

One of the most important starting points for the planning of the final disposal alternative has been long-term safety, and one of the main objectives in the research carried out during the past 20 years has been to acquire sufficient basis for the assessment of long-term safety. Based on completed safety analyses, it has been established that at all sites the solution will sufficiently protect nature and human life far into the future until the time when the waste can no longer be considered an essential threat.

Differences possibly affecting long-term safety at the candidate sites can be primarily reduced to differences between coastal and inland locations. On the other hand, from the aspect of long-term safety, coastal as well as inland locations have their advantages and disadvantages, nor do safety analyses provide a sufficiently clear basis for selecting the best site. At all sites, the final disposal facility can be built so that any significant quantity of hazardous substances would never be released into organic nature. Regardless of how the magnitude of risks is evaluated in safety analyses, the project will cause fear and anxiety in certain individuals, and this can be considered an effect on health conditions. The magnitude or seriousness of these effects is, however, difficult to assess. In any case, based on the questionnaire and interview studies conducted, it is apparent that their significance would probably be lower in municipalities with power plants than in Kuhmo and Äänekoski.

8.5 Social impacts

8.5.1 Starting points of the assessment

The assessment of social effects is based on the Environmental Impact Assessment Act (EIA), which states that the effects of an undertaking on, inter alia, people's living conditions and amenity must be assessed by the EIA procedure. Although various relatively objective scales and indicators can be used to measure people's living conditions and surroundings, assessing the social effects is ultimately a question of subjective conceptions and perspectives relating to the effects and these naturally vary from one individual and group of people to another. In addition, when the object of investigation is a project extending over several decades, there are considerable uncertainties associated with assessment. Although the people living within the sphere of impact of a project are experts on assessing the social effects on themselves, they are nevertheless unable to speak on behalf of those generations who will live there in the future. Therefore this assessment attempts to expound as many views as possible without trying to summarise the relations and weight between different views.

The EIA Act provides that 'the views of those parties whose circumstances or interests may be affected by the project are heard' in the assessment. Drafting the assessment programme gave priority to those factors that the residents of the candidate municipalities where the proposed facility would be located felt it important to examine. Moreover the assessment also takes into account the recent experts' debate and the guidelines on the assessment of social effects being prepared by the Ministry of Social Affairs and Health (STM 1998).

During and prior to its research into the location for the final disposal facility, Posiva – and previously TVO – were in constant contact with decision-makers, public officials and residents of the candidate localities. In most of the municipalities studied there has, throughout the investigations, been a cooperation or follow-up group on which there have been representatives of both Posiva and the municipality. These groups have dealt with the progress of the research and other factors relating to the project. Information and discussion events dealing with final disposal have been held in the municipalities. Local residents and Posiva have also conducted a lively debate in the letters pages of the local press.

The assessment of the social effects of the final disposal project covers socio-economic, cultural and psychological factors and also procedures directly affecting the living environment which could cause changes in and impacts on the quality of life, lifestyle, the living environment and how it is experienced and also well-being.

The following assessment the social effects starts from objectively observable changes and ends with effects whose significance is crucially dependent on the assessors themselves.

8.5.2. The general approach and material used

The general methods of social impact assessment were used in drawing up the programme (Sairinen 1998). These include: theme interviews, media analysis, a variety of participation arrangements and previous studies relating to the assessment of the social effects of a final disposal facility.

Assessment content was reviewed and monitored during the course of the assessment. Consideration was given to local residents' opinions and also to previous statements, questionnaires, interviews and other research on the impacts of a final disposal facility on living conditions.

Comments given on the EIA programme showed that it would have been a good idea to present the methods to be used in the social impact assessment in the programme. In its assessment, Posiva has, however, sought a problem-oriented study rather than method orientation. This means studying the matters held to be important by the residents and those making statements and choosing the methods applied in accordance with the issues to be investigated.

In selecting methods attention was, however, given to the views presented in the draft guidelines of the Ministry of Social Affairs and Health (STM 1998). Efforts were also made to develop and delineate assessment methods by participating in a research project to study the assessment of social effects in projects within the energy sector (Koivujärvi et al. 1998).

Work began on collecting the initial data on the socio-economic structure of the localities, its development and development prospects and the economic effects of the project in the 1980s (Aronen 1985, Suunnittelukeskus 1987a, 1987b, 1987c) and was continued in the 1990s (Nummenpää & Ollikainen 1996). The attitude of local citizens to final disposal was studied in the 1990s (Kurki 1995, Pirttikoski 1996). In addition to TVO's and Posiva's own research, the thoughts about final disposal among the inhabitants of the localities studied were also investigated under a publicly funded nuclear waste research programme (JYT).

There has also been monitoring of citizens' opinions of final disposal since the first half of the 1980s (e.g. Kiljunen 1998), previously at Tampere University and currently by Yhdyskuntatutkimus Oy (Community Research). In addition to earlier opinion polls, information on residents' thoughts, opinions, desires and anxieties has been acquired in many ways when the programme was drawn up and during the EIA procedure itself. The active collection of information began with an EIA bulletin with an attached feedback coupon. This not only provided an opportunity to give feedback, but also to start debate (Pasanen 1998). After this, theme interviews were launched for different interest groups in all the localities proposed (Viinikainen 1998).

Events open to the public and discussion working parties for representatives of local associations were also held later (Leskinen et al. 1997). Residents, however, were not very active in the assessment (Hokkanen & Kojo 1998). Residents' feedback was also collected in conjunction with EIA exhibitions. Newspaper articles dealing with the final disposal project and assessment of its environmental impacts were also interpreted as feedback (Pasanen 1998).

Identification and delimitation in respect of impact assessment have also been conducted in the joint cooperation and follow-up groups of the municipalities and Posiva. The municipal representatives on these are appointed either by the municipal council or the municipal board. As the assessment progressed, the groups dealt with the progress and direction of the research. In the final phase of the assessment an extensive separate opinion poll was conducted on the acceptability of the final disposal facility in different localities.

The choice of the residents' perspective as the starting point for the assessment programme initially resulted in a group of questions or issues that should be considered in the assessment. Secondly, interviews and questionnaires produced evaluations of the effects and their causes or area of impact, of the current situation and future prospects of the locality. The material brought out the conflicting views relating to the project. In particular, the socio-economic factors and thoughts about the project rose to the fore. Residents also put forward the need to evaluate the economic and other benefits of the project.

Scant attention was paid to the usual impacts directed at the living environment. This is only natural because when selecting candidate disposal areas, one principle had been that research and any construction would cause minimum disturbance to current activities. In selecting sites, attention was given to the location of dwellings and crops, etc. A condition of selection was that dwellings or cultivated fields should not be left in the area studied so that local living conditions would not deteriorate. The bases for selection are dealt with in section 1.3.

Both quantitative and qualitative methods were used in the assessment. Two seminars were held on the methods and approaches to be used, the first for the research community and a later one for those issuing statements (Kivinen & Turunen 1999). In the research seminar particular emphasis was placed on the need for several points of view.

Material generated from interviews, questionnaires, various statistics, expert assessments and experiences of other Finnish and foreign projects was used as initial data. Study of comparable projects was also brought out in the statements given on the assessment programme and in the seminars held during the assessment (Kivinen & Turunen 1999).

A number of final disposal facilities for nuclear waste have already been constructed both in Finland and elsewhere and the experiences gained from these can be utilised in evaluating the social effects. Existing final disposal facilities are, however, intended for the final disposal of low and medium level waste and, at least in Finland, clearly greater attention is paid to the final disposal of spent nuclear fuel than to other nuclear waste. This may be because the final disposal facilities already constructed are located in the immediate vicinity of power plants. A factor that may also have significance for the location of the final disposal facility for spent nuclear fuel. However, to date there are no facilities from which the experience gained could be directly used to assess social effects. Thus assessors have had to be content with cases which have only a few features in common with the final disposal project. Efforts have been made to utilise research carefully carried out in Finland and in other countries relating to the social aspects of nuclear power and nuclear waste.

The questionnaire data collected for the assessment has been published in various reports (Ala-Lipasti et al. 1999, Lehto 1998, Nystedt & Gango 1999, Pääkkönen 1998, Åberg & Viinikainen 1998, Varis 1999), as have the interviews (Kantola 1999, Koskinen et al. 1998, Viinikainen 1997, 1998). Other Finnish research information essential for the project can be found in the publications of e.g. Harmaajärvi et al. (1998), Kiljunen (1998), Koskinen et al. (1998), Laakso (1999), Litmanen (1994, 1996a, 1996b), Paavola & Eränen (1999) and Ronkainen & Ukkonen (1999).

Areas of uncertainty relating to methods and material include:

- *availability of municipal develop ment forecasts and the limitation of the time dimension in relation to the lifespan of final disposal.*
- *problems relating to comparative projects and information:* the lack of similar comparative projects and sys tematic research material; the material available does not indicate that people behave in accordance with their attitudes
- *questionnaires*: replies refer to gen-

eral attitudes towards nuclear power and do not tell about the possible effects; responses are detached from people's real decision-making situation
- *interviews*: access to groups was imperfect
- *discussion events*: the point of emphasis was on the views of more active people
- *access to young people was problematic*
- *poor participation by summer residents*
- *assessment of development independent of the project*: for instance the image reflects a constantly changing reality and not a permanent state
- *assessment of the activity of other social agents*.

8.5.3. Formation of social effects

The social effects of the project originate in part in the physical and economic changes caused by the activity in the project's sphere of impact. These can often be depicted or measured as quantitative magnitudes. This is partly a question of people's (construed) conceptions and experiences relating to the project and activity whose measurement and interpretation is rarely simply and objectively feasible.

The effects of the project on people's physical living environment would be restricted to the immediate vicinity of the facility. The facility would cause only minimal changes in the landscape and would not significantly restrict the use of land areas. Its operation would not give rise to odour impacts and noise and dust impacts would also be restricted, with the exception of a minor increase in traffic, to the immediate vicinity of the facility. Nor would activity in disruption or accident situations give rise to significant emissions of radioactive substances into the environment. All in all the changes caused by the construction and operation of a final disposal facility in the physical environment are small (sections 8.2 and 8.3).

Although the total amount of fuel for final disposal would not really affect the facility's annual activity, any increase would prolong its operation. However, this would only be of slight significance for the physical changes in the environment brought about by the operation of the facility. Neither does the amount appear to be a very crucial factor in people's thoughts about the final disposal project (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998). The main cause for anxiety has been whether the project could lead to the disposal in the locality of nuclear waste from other European Community countries, as well. However, expert investigations reveal that Finland has no obligation to accept nuclear waste from other countries (Hermunen 1998). *Posiva's project is restricted solely to the final disposal of spent fuel produced in Finland.*

In the study of the socio-economic effects, the central feature is the changes in the community and population structure, employment, wealth and the provision and distribution of services brought about through jobs and investments. On the other hand it is, however, estimated that conceptions associated with the project could affect the image of the locality and thus, indirectly, the above-mentioned socio-economic factors.

The starting point in the community structure impact is an assessment of how the construction of a final disposal facility and its actual operation would affect entrepreneurial activity and employment in the municipality and area of its location. These factors would be reflected in migration and thence in the population trend. Population changes would affect the local housing market, the community structure and property values. Employment and population changes would further affect the municipal economy via tax revenues, state subsidies and the demand for services.

Interview and questionnaire studies carried out reveal the multiplicity of residents' conceptions and opinions relating to the final disposal project. One problem in assessing the social impact is that it is the conceptions of the present inhabitants of the municipality preceding the project. It will, however, be about twenty years until the start of operations and over ten years until work starts on building the facility. American research shows that there is a clear difference between impacts assessed in advance and impacts observed afterwards (Koskinen et al. 1998). People do not, in fact, appear to act in the manner predicted by questionnaire surveys. No final disposal facility for spent nuclear fuel has been built anywhere in the world, so empirical data on people's behaviour in just this type of situation is not available.

The concept of *image* has come to be central in the assessment. People speak of the image of a final disposal facility, the image of the locality and their interaction. In some people's minds the conceptions relating to a final disposal facility would directly bring about changes in the general wellbeing and living conditions of the locality. Furthermore conceptions relating to the project would affect the conception created of the municipality (the municipal image) by interest groups which are important to the municipality, which in turn would affect their behaviour. The changes brought about in these conceptions are assessed as appearing in, for instance, the community and population structure, employment, wealth and the provision and distribution of services, demand for products produced in the locality, migration and thence in the population structure and house-building.

The feedback and statements relating to the EIA programme emphasised the importance of investigating the project's affects on image. As a concept 'image' is, however problematic, because neither the final disposal project nor the municipalities have any crystallised image; rather the idea is one of people's conceptions. In speaking of the image of a place, it is a question of the common features of the conceptions of individual persons relating to the place. An image – whether it is a question of the image of a person, an enterprise or a municipality – is constructed in the public domain and could change for many different reasons. An image can also be actively influenced (Karvonen 1997, Äikäs 1997).

An entire group of different conceptions of a municipality exist, depending on the assessor and the place assessed. 'Municipal image' generally means the conception created by local residents and other interest groups important to the municipality, and which comprises their experiences, knowledge, decisions, attitudes, beliefs, feelings and expectations (Yli-Kokko 1991). One and the same municipality has thus a variety of images depending, for instance, on the group whose conceptions are the object of interested (residents, tourists, entrepreneurs, Finns in general, etc.).

In evaluating social effects, image has been studied firstly by assessing extent to which the municipalities are known and the way in which different assessors consider that the project would affect the municipal image (Ala-Lipasti et al. 1999, Kankaanpää et al. 1999). Furthermore, studies have also been made of whether the project would stigmatize the locality and thence its economic conditions, such as the demand for agricultural products and tourism services (Koskinen et al. 1998, Laakso 1999).

The image of a final disposal project among different residents reflects those persons' conceptions of final disposal and is probably explained by that person's experiences, values and attitudes. However, conceptions relating to final disposal can often be difficult to distinguish from the most common conceptions relating to nuclear power, and broader societal or value-world attitudes may be reflected in them the further away from the candidate municipalities the person in question is (Koskinen et al. 1998, Paavola & Eränen 1999, Sjöberg 1998).

Both positive and negative conceptions are associated with the final disposal project (Ala-Lipasti et al. 1999, Kankaanpää et al. 1999, Koskinen et al. 1998, Viinikainen 1998). Positive conceptions generally relate to the local economic benefits of the project. People have usually tried to explain negative conceptions relating to the project by referring to the risks of final disposal (Viinikainen 1998). Thus, negative conceptions could be changed if it was possible to prove that the risk is sufficiently small. It is, however, apparent that negative conceptions are not directly linked to the concept of risk that is used at any rate in technology, but represent a more common and undefined experience of nuclear waste or nuclear power (Sjöberg 1998). On the other hand, it is also apparent that conceptions associated with a final disposal facility could in future be different from those that have come to the fore in the polls now conducted. The future is also crucially dependent on the modes of operation of the different parties. This will be made concrete only as the project proceeds.

People's attitudes to the final disposal project are now conflicting and on the basis of the interviews it is apparent that the project causes anxiety and fear in some people. Conflicts, anxiety and fears can reduce the enjoyment of the surroundings and in some cases may be reflected in interpersonal relationships. The situation would, however, appear to differ from one locality to another (Ala-Lipasti et al. 1999, Viinikainen 1998).

Attempts have been made to characterise the origin and essence of the conflicts by reference to sociological debate (Kantola 1999). This debate can also be used as a basis to evaluate the way in which the situation could develop in future. It seems that once the question of the facility location is resolved – and at the latest once the final disposal facility is in operation – confidence in the operation of these facilities will grow and conflicts and fears will decrease (Paavola & Eränen 1999, Ponnikas 1999).

Conflicts and fears can in principle lead to stress situations and thereby to actual health effects. The possible psycho-social effects of the project have been evaluated on the basis of recent studies conducted in Finland and elsewhere (Paavola & Eränen 1999). A summary of this assessment is presented in conjunction with the health effects in subsection 8.4.4.

8.5.4 Effects on community structure

Business activity

The impact on business activity has been assessed via employment (Laakso 1999). The initial data consists of Posiva's manpower estimates relating to construction and operation, on the basis of which indirect effects on industry and services have been calculated (Figures 8-24 a–d, 8-25 a–d). In distributing total employment in the locality, the area of impact and the province, attention has been paid to the size of the labour force, the number of enterprises and the business sectors in the localities. The initial data are set out in Figures 8-21 and 8-22.

Businesses' competitiveness and willingness and preparedness to offer products have been studied by entrepreneurs in Eurajoki, Kuhmo and Äänekoski (Lehto 1998, Pääkkönen

1998, Varis 1999) and in the Loviisa region (Nystedt & Gango 1999). Separate investigations commissioned by Posiva in 1997-1998 have also been used as material.

Input–output models have been used to assess the employment effects in different business sectors during construction and operation. This has made it possible to research interactive relations and mutual dependencies between business sectors. The business sectors are those that will supply products or services to the construction project or to the facility once it is in operation. A more detailed description of the business sectors can be found in Laakso 1999. The problem with the method is that of the generalisability of nationwide data for an area.

The change has been assessed by correlating employment effects with labour force data for 1995. These show that the number of persons employed at Eurajoki is 2,300 and in the area of impact 19,600, at Kuhmo 3,500, at Loviisa 2,900 and in the area of impact 7,100, at Äänekoski it is 5,000 and in the area of impact 13,600.

The area of impacts have been defined such that they represent the true estimated economically area of impact of the facility and correspond to the estimated commuting area of the final disposal facility (Laakso 1999).

For Eurajoki Kiukainen, Kodisjoki, Lappi and Rauma have been included in the area of impact. At the provincial level the area of impact is the province of Satakunta.

Kuhmo has been studied as its own entity, because there is little commuting from other municipalities. At the provincial level the area of impact is Kainuu.

For Loviisa the area of impact also includes Lapinjärvi, Liljendal, Pernaja and Ruotsinpyhtää. At the provincial level the area of impact is the Province of Eastern Uusimaa and the regional municipality of Kotka-Hamina.

For Äänekoski the area of impact also includes Kannonkoski, Saarijärvi, Suolahti and Viitasaari. At the provincial level the area of impact is the Province of Keski-Suomi.

The employment effects have also been evaluated using data from comparative projects from which the information gained is actual and observable. Information from the construction and operation period of the Olkiluoto and Loviisa nuclear power plants has been used to form sample cases. In addition, as comparison data, the mine at Enonkoski has been used to describe the effect on a small municipality of the commencement and termination of an operation and the study of the regional effects of the Rauma pulp mill has also been used. The difficulty lies in distinguishing indirect effects (Laakso 1999).

In assessing the employment effects, employment trends occurring in the municipalities or areas for other reasons have not been taken into account. Assumptions have been made using present-day data, assuming that conditions are unchanged. Efforts have been made to reduce uncertainties relating to the construction phase by using entrepreneur questionnaires to aid assessment. One uncertainty factor in the operating phase is the amount of Posiva employees living in the locality (Laakso 1999).

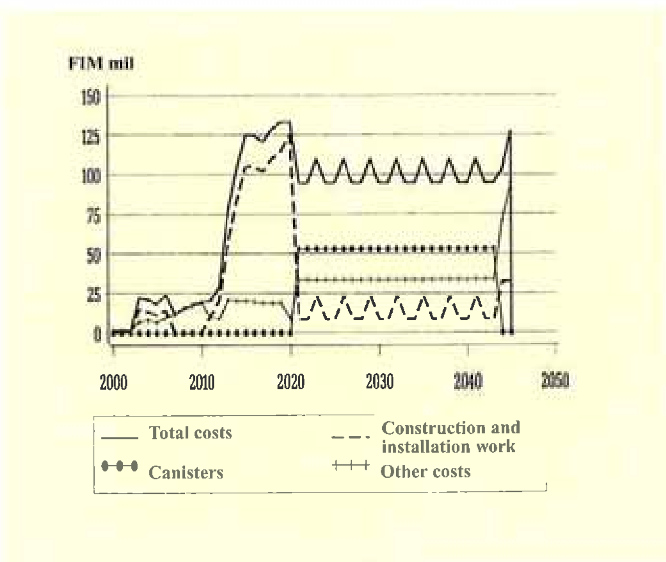


Figure 8-21. Costs of the final disposal facility (cash-flow excluding Posiva's personnel costs) for the years 2000–2046

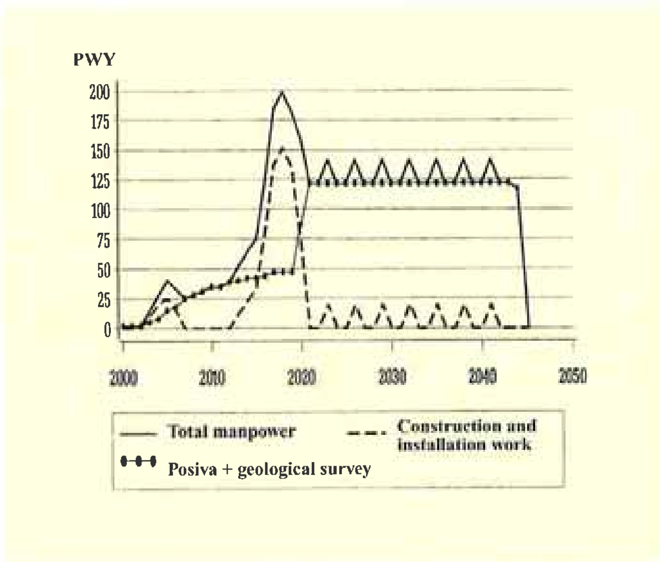


Figure 8-22. Manpower estimate for the final disposal facility in person-working years for 2000–2046

It is possible to assess the effects of the most significant factors because the plans for the final disposal facility are detailed as regards both construction and operation. The calculations obtained are indicative and represent orders of magnitude (Laakso 1999).

Uncertain areas in the calculations have been reduced by means of cooperation meetings of the cooperation or follow-up group of Posiva and the municipalities, in which the results of the calculations were presented and the initial data used and the borders of the area of impacts were assessed.

At the power plant localities and at Äänekoski, residents estimated that the directly and indirectly produced jobs might possibly change economic conditions somewhat and affect business life. At Kuhmo residents estimated that the effects as they were realised would be considerable and the change would be visible in the town's socio-economic structure and in the unemployment and population development trend. The changes are not expected to be large or decisive in the power plant localities in the entire nuclear power industry, nor at Äänekoski in relation to the town's other development (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

In no locality did residents think that the project alone would eliminate the prevailing unemployment from the municipality. On the other hand, the project was thought to cause unemployment if there was no steady work for the members of the migrants' families (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Residents felt that the construction phase jobs were important even though they only had a temporary effect on employment. It was thought that it would not be possible to find employees with appropriate training for the operating phase jobs near the site. Jobs involved with the final disposal facility would provide employment for construction workers and also directly or indirectly as a consequence of house-building. On the other hand it was thought, at any rate at Kuhmo, that the same number of jobs could be lost from agriculture and tourism as the project was expected to generate. In all localities residents estimated that the effects on employment would partly be focused on those moving in from elsewhere and also in the power plant localities on those currently working in the facility. The grounds for this were held to be previous experiences of the power plant localities and the inadequacy of education in the localities (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

In all localities residents estimated that the employment effects and the services and procurements needed by the facility would also be distributed throughout the economic area, the region and the province. It was estimated that the effects in the siting locality of the facility would be particularly concentrated on business life and entrepreneurial activity, such as transport, excavation work and maintenance and shop services. Those benefiting would thus be the local businesses, for whom the project would be 'a shot in the arm and a positive signal' (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Residents did not consider that the effects would automatically be focused on the facility site, rather that the change in the employment situation would require action in the local education system, promoting the business conditions and in seeking methods to promote the employment of local inhabitants (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Research (Laakso 1999) indicates that the jobs existing during construction and operation of the final disposal facility would both directly and indirectly affect construction and installation, and service sectors, in the municipality chosen and in neighbouring municipalities. At Kainuu the effects would mostly remain in Kuhmo, however. The effects in the construction and installation sector would last during construction, but in the service sector the effects would also continue during the operating phase. In industry the effects would be particularly directed at the province. The effects in the municipality chosen for disposal would be slight. Figure 8-24 a–d shows the distribution of employment effects by business sector.

In the construction phase the focusing of employment-creation effects on the location municipality would depend on companies' competitiveness and ability to exploit the advantage conferred by proximity. Figure 8-23 shows an estimate of the personnel employed at the final disposal facility.

Eurajoki is a small municipality in respect of its labour force and number of enterprises. The project would, in the *construction phase*, mean jobs for at most 30–70 persons. The effect on employment would primarily be directed towards other municipalities within the sphere of impact, which would mean employment for about 80 persons. The effect in the area as a whole would mean jobs for a total of 110–150 persons and, in the province of Satakunta as a whole, for a total of 170–230 persons.

Jobs:	no. of persons (approx.):
Administration	30
– office and finance work	
– communications	
– canteen	
Encapsulation	10
– reception	
– encapsulation	
– supervision	
Final disposal	30
– preparation	
– implementation	
– backfill	
– supervision	
Technical support	40
– quality control	
– geological survey	
– radiation protection	
– guarding, cleaning	
– storages	
Maintenance	10
– machines	
– systems	
– buildings	

Figure 8-23. Personnel at the final disposal facility

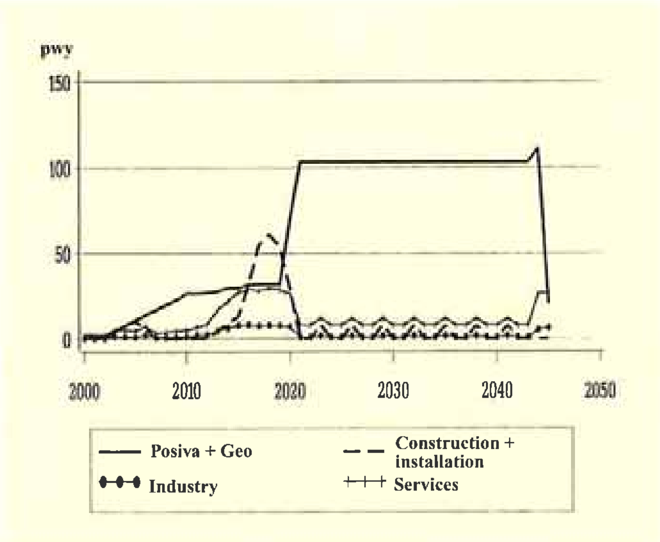
The effects of the final disposal facility are assumed to be similar to those of the Olkiluoto power plant during construction.

Kuhmo is large in area and commuting from other municipalities is minimal. The effect on employment would be jobs for a maximum of 90–125 persons during the construction phase. The effect on employment throughout Kainuu would mean jobs for a total of 150–215 persons.

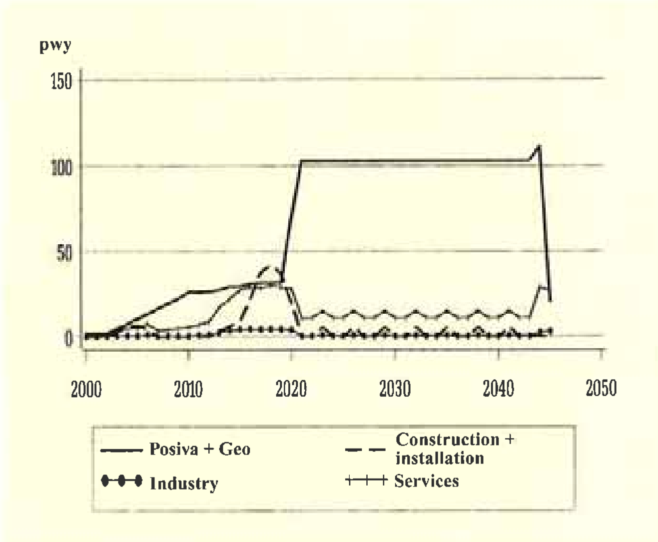
The effect on employment at Loviisa are considered as being similar to those of the power plants during construction. In Loviisa the effects on employment would be a maximum of 55–75 persons during construction. The effect on the area of impact would be jobs for a total of 100–130 persons, 45–55 of whom would be from other municipalities. At the provincial level the effect on employment would be to provide jobs for a total of 155–220 persons.

In respect of its labour force and number of businesses Äänekoski is a largish municipality compared to its neighbours. The effect on employment would mainly be focused on Äänekoski and would provide work for a maximum of 60–80 persons. The effect on employment focused on the entire area of impact would mean work for a total of 100–140 persons, 40–60 of whom would come from other municipalities. At the provincial level the effect on employment would be to provide jobs for a total of 170–225 persons (Laakso 1999).

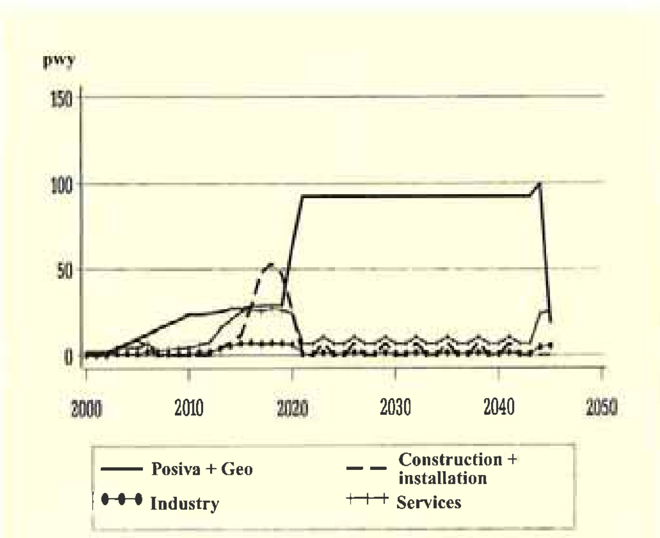
Figure 8-24 a–d. The effect of the final disposal facility on employment by business sector in the area of impact (person-working years of employed manpower)



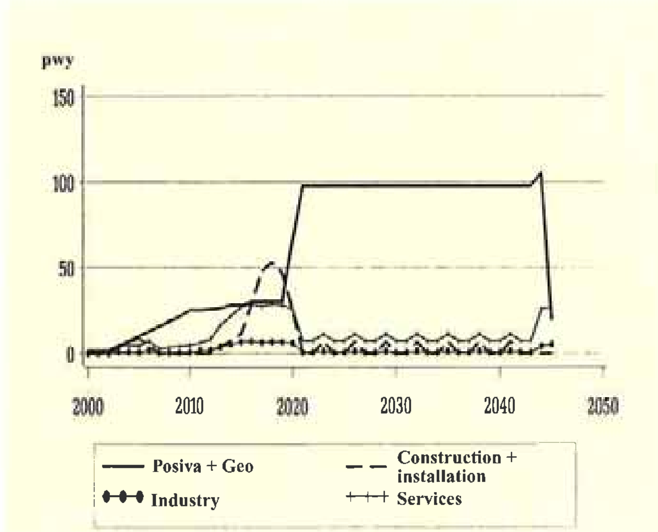
Effect on employment ***by business sector in the Olkiluoto*** *area of impact.*



Effect on employment ***by business sector in Kuhmo.***



Effect on employment ***by business sector in the Hästholmen*** *area of impact.*



Effect on employment ***by business sector in the Äänekoski*** *area of impact.*

In the *operating phase* the focusing the effect on employment on the location municipality would depend on the choices made by Posiva's personnel about where they would live. The effects are expected to remain within the province (Laakso 1999).

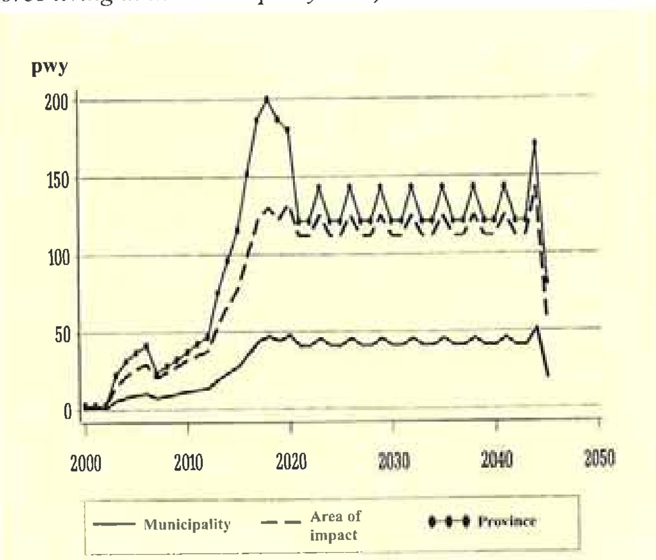
In *Eurajoki* the effect on employment would affect a maximum of 30–60 persons, 110–120 persons when the other municipalities in the area of impact are included and a total of 120–135 persons in the whole of Satakunta.

In *Kuhmo* the effect on employment would affect a maximum of 110–125 persons and 125–135 in the whole of Kainuu.

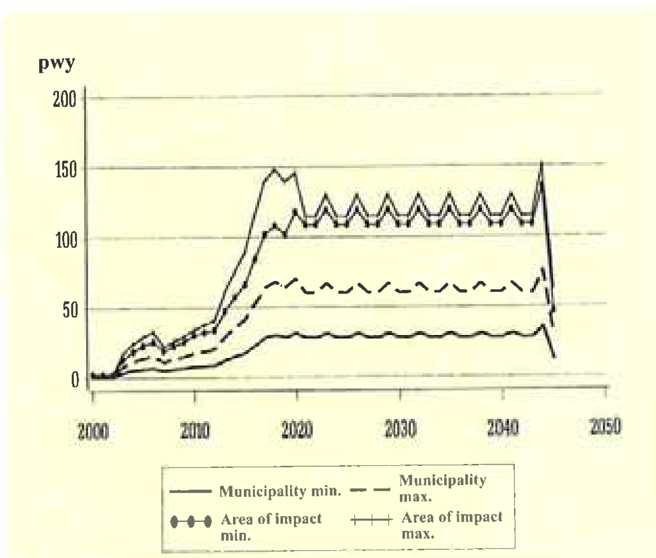
At *Loviisa* the effect on employment would affect a maximum of 70–85 persons, 100–110 persons when the other municipalities in the area of impact are included and 120–130 persons at the provincial level.

At *Äänekoski* the effect on employment would affect a maximum of 80–95 persons, a total of 105–115 persons when the other municipalities in the area of impact are included and a total of 125–135 persons at the provincial

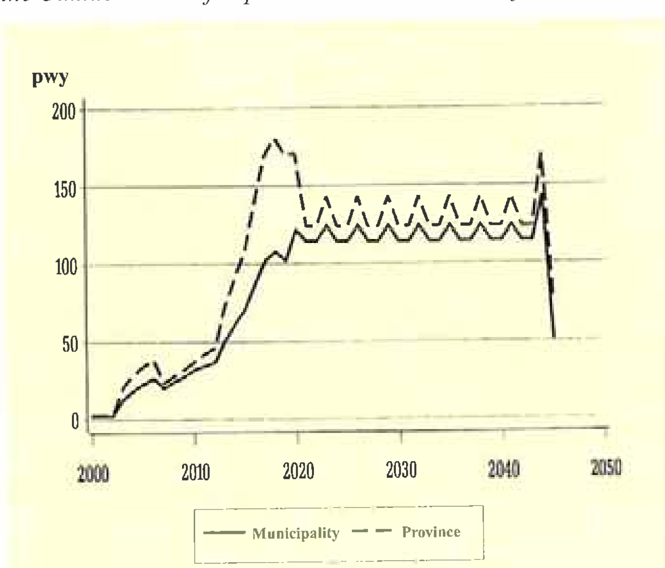
Figure 8-25 a–b. The employment effect by the final disposal facility by locality in the area of impact and in the province (left: manpower years of the employed labour force living in the municipality/area; right: minimum and maximum employed labour force living in the municipality/area)



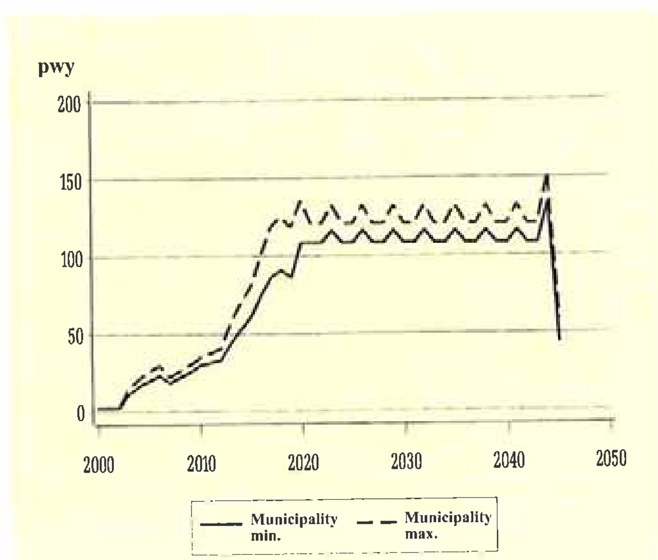
***Employment effect** by a final disposal facility at **Eurajoki**, in the Olkiluoto area of impact and in the Province of Satakunta.*



***Variation range of the effect on employment** by a final disposal facility at **Eurajoki** and in the Olkiluoto area of impact.*



***Effect on employment** by a final disposal facility at **Kuhmo** and in the Province of Kainuu.*



***Variation range of the effect on employment** by a final disposal facility at **Kuhmo**.*

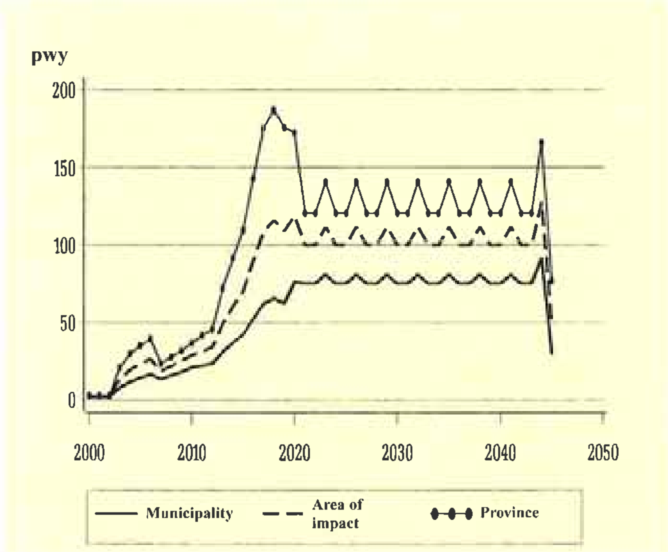
level. Figure 8-25a–d sets out the time and regional distribution of employment effects and the variation interval.

The effect on employment by a final disposal facility would be distributed evenly between the construction and operation phase. Construction of final disposal premises is a long-term project.

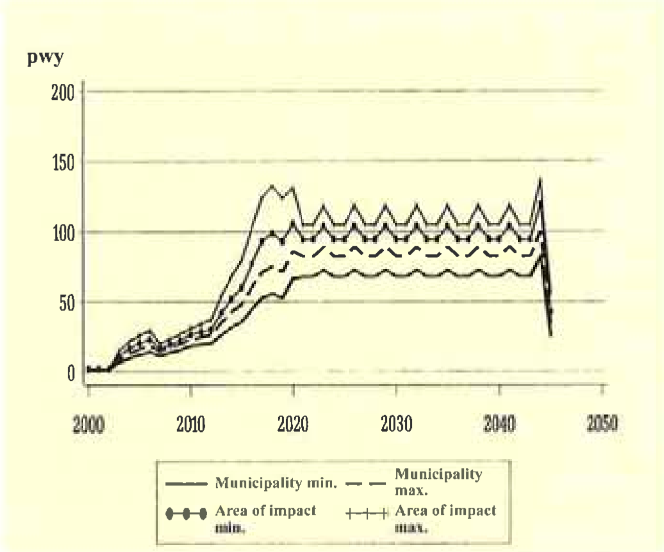
The canisters needed in the facility's operation phase would probably be manufactured outside the final disposal municipality, because the expertise and the equipment required are limited in Finland. Although the manufacturing method for the canisters has not been chosen, it is estimated that the effect on employment will be focused outside the municipality where the facility is located (Laakso 1999).

The methods available to Posiva of focusing the effect of employment in the municipality where the facility is located would be to use manpower living in the municipality and enterprises located there. As a private enterprise Posiva is not subject to the EU's Code on Competitive Tendering, which applies to public sector undertakings and would not thus impinge on the focusing of the employment effect in the locality.

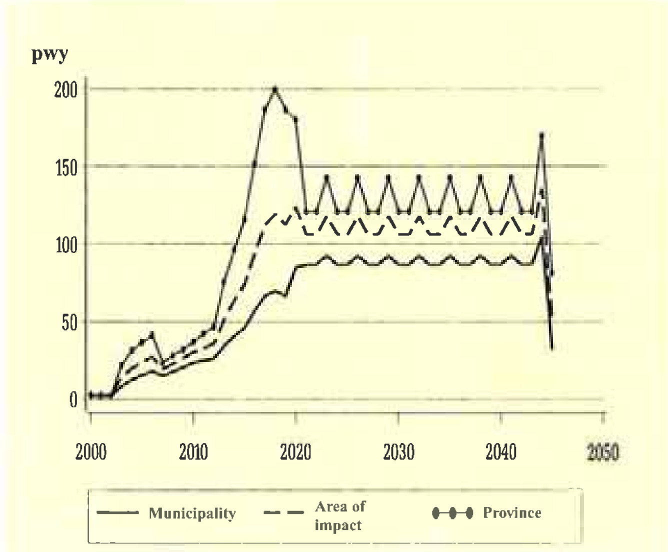
Fig. 8-25 c–d. The effect on employment by the final disposal facility by locality, in the area of impact and in the province (left: manpower years of the employed labour force living in the municipality/area; right: minimum and maximum employed labour force living in the municipality/area)



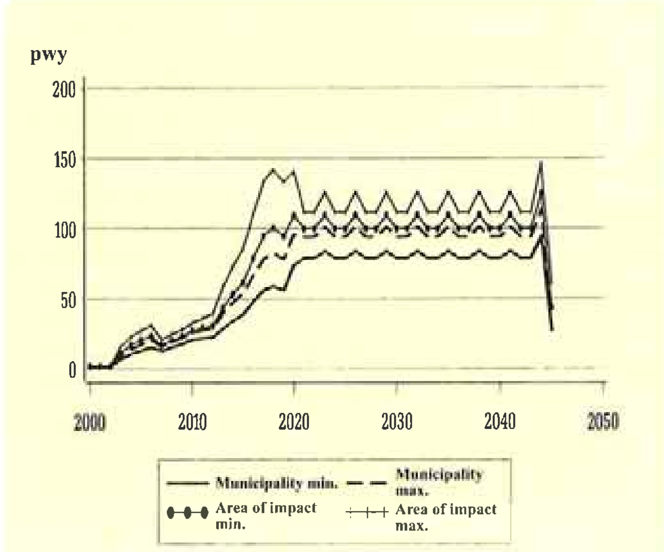
***Employment effect** at **Loviisa**, in the Hästholmen area of impact and in Eastern Uusimaa and the Kotka-Hamina joint municipal region.*



***Variation range of the effect on employment** by a final disposal facility in **Loviisa** and in the Hästholmen area of impact.*



***Effect on employment** by a final disposal facility at **Äänekoski**, in the Kivetty area of impact and in the Province of Keski-Suomi.*



***Variation range of the effect on employment** by a final disposal facility at **Äänekoski** and in the Kivetty area of impact.*

Agriculture

An evaluation (Koskinen et al. 1998) studied the role of the product chain in consumer behaviour and the decision-making and selection criteria in the product chain. The objective was to determine whether a final disposal facility could affect the conceptions relating to the municipality where it is located and whether these conceptions could affect the other activities of the municipality.

Agriculture and food production have major significance (on the basis of the main line of production of workplaces and farms) for the economy of the alternative municipalities involved and their neighbouring areas, because this could react with consumers perceptions of risk. The structure of food production also limits the scope of consumers to react to products produced in the municipality where the final disposal facility is located.

The object of investigation is industrial and non-industrial food production and the most important purchaser enterprises in the alternative siting localities. Production has been investigated together with the municipalities, research institutes and advice organisations and by using the available statistics. Research material was collected in late spring and early summer 1998 by interviews, with which it was possible to add to existing information.

The evaluation made use of foreign and domestic research into consumer reactions to food impurities. The comparison objects were industrial plants, which were known or claimed to cause effects on the community in their environment. Such objects included nuclear power technology facilities, problem waste installations and refuse dumps containing chemical waste. A list of the research used in the list is set out in a separate report (Koskinen et al. 1998).

Uncertainty in the evaluation is related to changes in the modes of operation of the market that could not be predicted. Uncertainty was reduced by studying legislation and statute projects being drafted to obtain a clear picture of enterprises' scope for refraining from purchasing the products of a particular locality. In addition, research into various exceptional situations (publicised accidents, emissions, malpractice, etc.) is difficult, because there have been no major industrial accidents in Finland that pollute wide areas (Koskinen et al. 1998).

In the municipalities where power plants are sited, residents estimated (Pasanen 1998, Viinikainen 1998) that a final disposal facility would not affect the success of agricultural production in the locality or its neighbouring area, because the present plant had no such effect. Ecological values or environment friendliness are not much used to market products. Some citizens of Eurajoki considered that final disposal could affect the cultivation of special plants.

In Kuhmo, the inhabitants' assessments of the effects of final disposal on agriculture varied (Pasanen 1998, Viinikainen 1998). Agricultural products, such as those of the Kainuu dairy and berry and mushroom processed foods, are marketed with reference to purity and ecological values and they would, based on their name, be identifiable as coming from a possible 'nuclear waste locality'. On the other hand the significance of the sector of original production will decline in future along with natural development and the significance of the final disposal of nuclear waste will not be crucial.

At Äänekoski, the inhabitants considered that final disposal would affect agriculture because final disposal and purity in agriculture conflict with one another (Pasanen 1998, Viinikainen 1998). The effects are not, however, assessed as being significant, because the processing and sales chains of products from Äänekoski area are long and products are not particularly identified as originating in the Äänekoski region.

As a physical building the final disposal facility would not affect the carrying out of agriculture, because no agricultural land would be covered by construction in any locality. This factor has been taken into account in the site selection process, because it was wished to ensure that the construction and operation of the facility would not detract from the living conditions of the inhabitants of municipality where the facility is to be located.

Research shows (Koskinen et al. 1998) that final disposal could, on account of the unpleasant concepts and perceptions of it, affect producers of organic products in the area and also those agricultural producers whose products are sold directly in markets (unprocessed berries or mushrooms) or from farms. There is no data available from the market trade in the locality. There are a few farms specialised in organic production in Eurajoki and Loviisa, in Kuhmo there are 5 (total cultivated area approx. 9 ha) and in the Äänekoski region there are 7 (total cultivated area approx. 4 ha) (Ollikainen & Rimpiläinen 1997a, 1997b, 1997c, 1997d).

The majority of agricultural producers in the alternative siting municipalities and provinces sell their products (grain, milk, vegetables) direct to the large domestic food industry, whose purchasing decisions are not affected by conceptions associated with final disposal. Because bakeries with a strongly local identity at Kuhmo purchase their raw materials from industry and the wholesale trade, final disposal would not affect their business conditions. An exception would be in the event of an accident or disturbance situation in the final disposal facility, as a result of which the authorities imposed a ban on the sale of the products from the area. Then the effects would be focused on other food producers and enterprises as well. The probability of such a situation is not great in Finland.

Tourism

An evaluation (Koskinen et al. 1998) studied the role of the product chain in consumer behaviour and the decision-making and selection bases in the product chain. The objective was to determine whether a final disposal facility could affect the conceptions relating to the municipality where it is located and whether this could in turn affect the municipality's tourist industry. The demand for tourism products reacts sensitively to consumers' perceptions of risk. On the other hand the structure of the provision of tourist services limits the scope of consumers to react to a final disposal facility.

The objects of the study were the tourism products of the alternative siting municipalities and material on this was collected with interviews in late spring and early summer 1998. The interviews sought to add to existing information. Some of the tourism entrepreneurs in the alternative siting municipalities and representatives of the sector in the area and nationwide were also studied.

No systematic research material available from Finland or abroad has been published to assess the effects on tourism. Visitor data from the Olkiluoto and Loviisa facilities has been used as examples and Sellafield in England has been used as a foreign example. Individual published research materials relate to accidents that have occurred abroad, and their comparison with Finnish conditions and with a final disposal facility is rather questionable.

As a physical building the final disposal facility would, like any industrial plant, have an effect on the landscape and on some of the conditions for tourism. The effects would be concentrated on the immediate vicinity of the facility, on those letting summer cottages, vendors of holiday home plots and persons arranging programme services.

Only at Romuvaara in Kuhmo are there a few wilderness and trekking routes in the vicinity of the facility area whose use might be affected by the facility in its implementation. There are no enterprises offering summer cottages for rent or vendors of holiday home plots in the immediate vicinity of the facility area in any locality (Koskinen et al. 1998).

The final disposal facility would bring about business and expert travel and the benefits from this would fall on the providers of accommodation and restaurant services as well as those arranging programme services and events in all localities.

In all the localities, residents' assessments of the effects of final disposal on tourism vary. According to some assessments the locality's interest as a tourist destination would not change significantly or it could increase, because the facility would be a tourist attraction and in any case business trips would increase. The benefits are assessed as falling on the providers of accommodation and restaurant services in all localities except Eurajoki, where there are few tourism services (Pasanen 1998, Viinikainen 1998).

According to certain other assessments the interest in the locality would decline, because the facility would conflict with natural values or with the locality's present tourism marketing. It is thought nature tourism and programme service entrepreneurs would be the main sufferers. (Pasanen 1998, Viinikainen 1998).

The final disposal facility could affect tourism through association. It could increase the scope of activity or the risks of some entrepreneurs. Unpleasant associations could affect the operating conditions of some wilderness and farm tourism entrepreneurs and of those letting holiday cottages. Actual emergence of effects is uncertain, because it would require farms, wilderness routes and holiday cottages to be located in the immediate vicinity of the facility area and that tourists considered that nature and naturalness had changed as a consequence of construction. If they materialised, such disadvantages would focus on wilderness, nature and farm tourism entrepreneurs, of which there are a few at Kuhmo and Äänekoski. At Eurajoki and Loviisa there are no entrepreneurs is this sector and there is no holiday cottage rental operation in the vicinity of the planned facility area in any locality.

It is difficult to assess the significance of conceptions relating to a final disposal facility on tourist behaviour, because research carried out abroad and in Finland does not support the concept that tourism would decrease in normal circumstances (Koskinen et al. 1998). For instance, nuclear power stations and the final disposal caverns for power plant waste at Eurajoki and Loviisa are among the most important visitor attractions in their localities, and so the final disposal facility could similarly become a tourist attraction in the municipality where it is located, as it would have no competitors in the same sector. It is also difficult to assess the significance of conceptions relating to final disposal on tourism in the municipality where it is located for the following reasons:

- The attraction of events would be greater than the risk arising from the facility and this attractiveness is not based solely on nature, tranquillity or purity (e.g. Chamber Music at Kuhmo).
- A good standard of service (at Kuhmo and Loviisa) would be a counterweight to the risks involved in the facility.
- The localities have irreplaceable tourist attractions not existing anywhere else, such as the nuclear power plants at Eurajoki, the Kalevala village at Kuhmo, the nuclear power plants and fortifications at Loviisa. These are not present at Äänekoski.

The same uncertainties are linked to the assessment as in the Agriculture section, where they are described in more detail. The extent to which the municipality is known is dealt with in subsection 8.5.5: Effects on living conditions and general wellbeing.

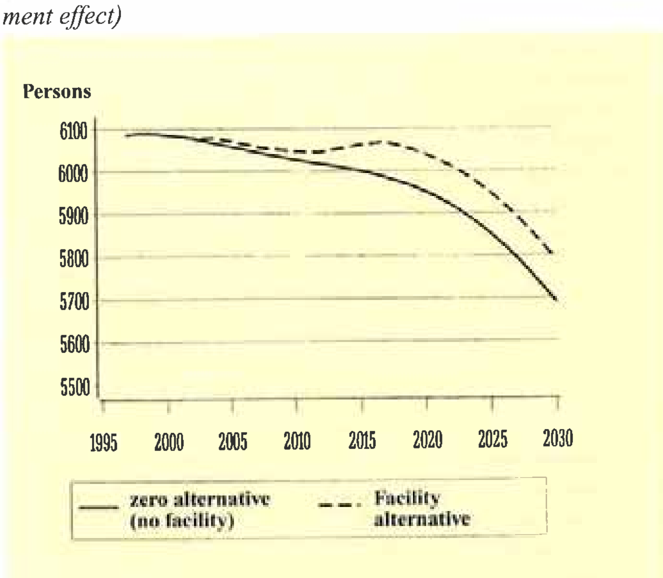
Population size and structure

Migration was used to assess the effects on the size and structure of the population. Jobs in final disposal would affect migration in particular during the intensive building phase and in the initial phase of operation. Migration would in turn affect the population size and structure. The assessment assumes that 70% of the manpower needed by the facility would move into the municipality where the site is located and that for every ten migrants seven other people (spouses and children) would move in.

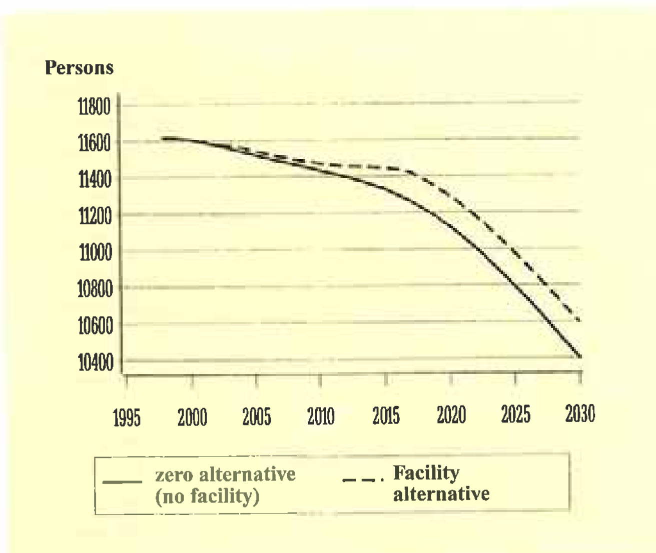
A demographic projection model (figs. 8-26 a–d) was used to assess the effect of migration on the population size and age structure in the years 2000–2030 in the municipality of the final disposal facility. The material comprises population data relating to migration from each municipality, which has been obtained from the statistics maintained by Statistics Finland. Numbers of residents at the beginning of 1998 were as follows: Eurajoki 6,086, Kuhmo 11,913, Loviisa 7,679 and Äänekoski 13,770.

The assumptions in the assessment are based on Finnish research on migration and on data on the effects of migration during construction and operation of the Olkiluoto and Loviisa plants. The change in the number of residents has been compared to a situation in which the facility does not come to the municipality in question. The age structure is assumed to be similar to that in the first half of the 1990s in small urban

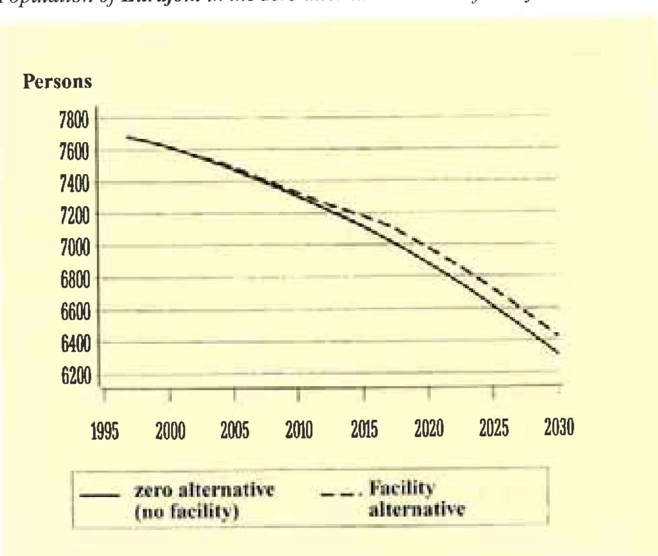
Figure 8-26 a–d. Population of the proposed municipalities in the zero alternative and the facility alternative (maximum employment effect)



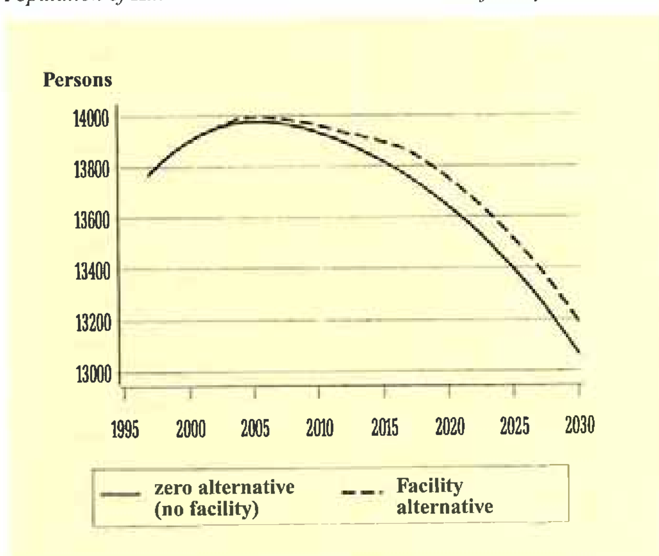
*Population of **Eurajoki** in the zero alternative and the facility alternative.*



*Population of **Kuhmo** in the zero alternative and the facility alternative.*



*Population of **Loviisa** in the zero alternative and the facility alternative.*



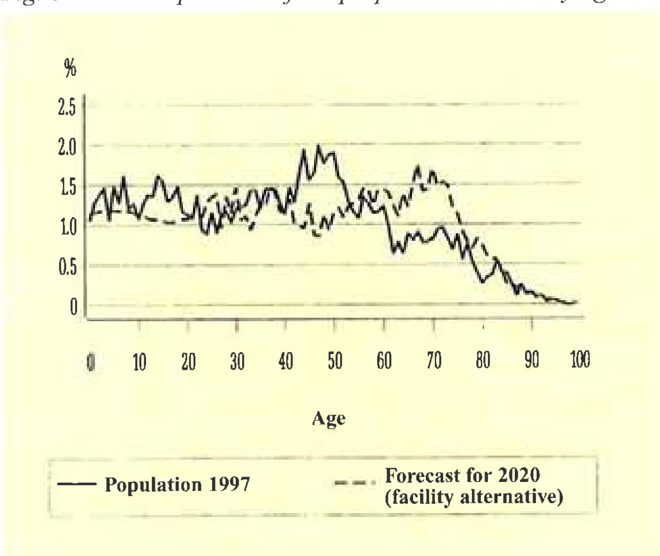
*Population of **Äänekoski** in the zero alternative and the facility alternative.*

areas and changes have been estimated using the average fertility and mortality rates for the country as a whole in 1995-1997 (Laakso 1999).

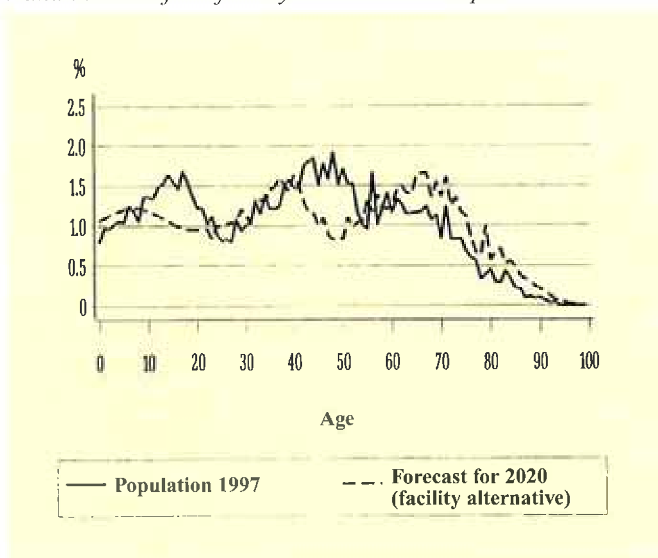
The assessment gives a picture of the magnitude with which the final disposal facility could affect the population trends in a municipality. In assessing population effects, no allowance has been made for population development occurring in the municipalities or areas for other reasons, because innumerable other factors affect this (including the living environment of the municipality or area, the level of service, availability of housing and municipal taxation). The assumptions are made using current data, assuming that conditions are unchanged. In the operating phase there is uncertainty as to how many of Posiva's personnel live in the locality (Laakso 1999).

The bases for assessment were reviewed in autumn 1998 in meetings of the joint cooperation and monitoring group of Posiva and the municipalities, in which calculations of preliminary results were presented and the source data used and borders of the area of impact were assessed. Population effects have only been studied in the municipalities stated below. The effects on population size and structure have not been calculated for a larger area, because the effect of the facility can be considered minimal when it is correlated with the population of more extensive areas (Laakso 1999).

Fig. 8-27 a–d Population of the proposed localities by age in 1997 and in 2020 if the facility alternative is implemented.

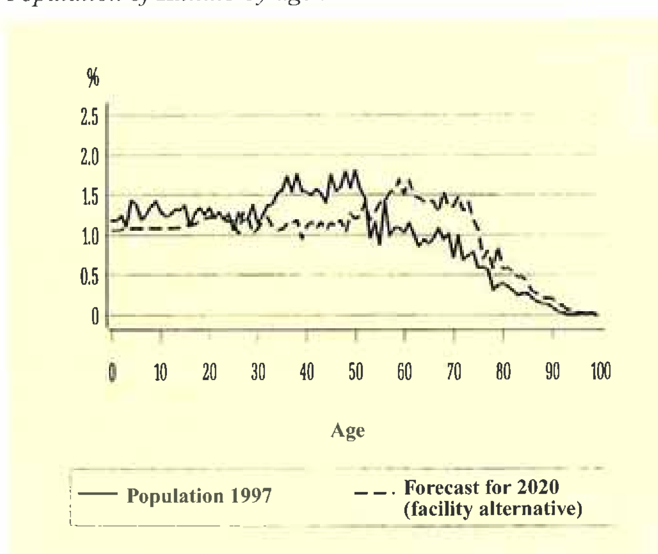


*Population of **Eurajoki** by age in 1997 and 2020.*



*Population of **Kuhmo** by age in 1997 and 2020.*

*Population of **Loviisa** by age in 1997 and 2020.*



*Population of **Äänekoski** by age in 1997 and 2020.*

Inhabitants' views are divided in respect of the effect of a final disposal facility on other migration in all localities, with the exception of Kuhmo (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

At Eurajoki it is estimated that the facility would have no effect on the choice of a place to live, because the municipality's service level would have greater significance on choice than the facility. During the existence of the current power plants, Eurajoki has had a net migration gain. On the other hand, if the final disposal facility were to have an effect, this might be that a neighbouring municipality of Eurajoki would be chosen as a dwelling place.

At Kuhmo the effects of final disposal on emigration would be minimal, because emigration is otherwise great. Those born in Kuhmo would probably not move away; rather, the decision to move would be made by a small group of people who had come from outside.

At Loviisa, as in Eurajoki, it is estimated that the facility would have no effect on the choice of where to live, because people would move on the basis of job location and not on the basis of conceptions. If there were to be an effect, then the place of their home would be considered most carefully by the highly educated.

At Äänekoski it is thought, as in the localities of power plants, that the facility would have no effect on the choice of dwelling place. If the facility had any effect, then the place of the home would be considered most carefully by the highly educated, as was the case in Loviisa.

As a physical building, the final disposal facility would have no effect on residence and thence on the population size, because no homes would be in the way of construction in any locality. The reason for this has been the site selection process, because one condition for the selection and elimination of a site was that there should be no homes in the area selected. In this way, it was desired to ensure that the possible construction and operation of the facility would not detract from the living conditions of the inhabitants of the municipality of its location.

The construction and operation personnel of the final disposal facility would affect the number of inhabitants of the municipality where it is located in choosing it for their home. Net migration, calculated using the effect on employment (Fig. 8-28 a–d) at the beginning of the operating phase would be: 35–75 persons in Eurajoki, 130–150 persons in Kuhmo, 80–100 persons in Loviisa and 95–115 persons in Äänekoski. In the year 2030 it is forecast that the number of inhabitants at Eurajoki would be 5,700, at Kuhmo 10,700, at Loviisa 6,300 and at Äänekoski 13,100.

In no locality would there be a change in the predicted age structure development prospects. According to these the numbers of children and young people would decline and that of pensioners would increase. Thus the final disposal facility would have no effect on the current need for the construction of daycare and school premises nor on services for old people, old people's housing or on the development or construction of other social and health care services. In Loviisa the number of those whose mother tongue is Finnish might increase as a consequence of both migration and the natural population trend (Laakso 1999). Figures 8–26, 8–27 and 8–28 show the predicted population size and age structure in each locality.

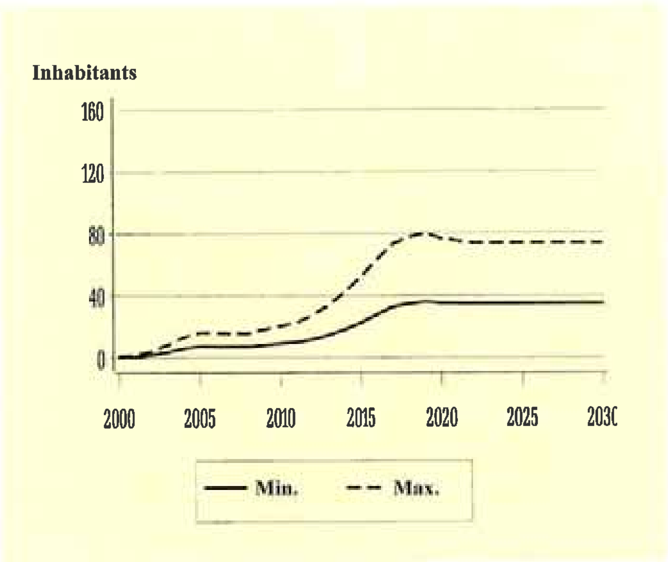
Growth in population could be reflected in Eurajoki and Kuhmo in the production of new housing, because there are very few unoccupied houses. On the other hand, the lack of housing could restrict immigration. Population immigration would probably not be reflected in the building of new homes in Loviisa or Äänekoski because 10% of existing houses now stand empty. Demand might be focused on single-family houses, because it is assumed that the migrants would be young and well-educated, with good incomes in comparison with current the average salary-level of those already living in the municipality (Laakso 1999).

Any negative conceptions which might be associated with final disposal could mean that emigration was not compensated for by immigration. Such a development would be unlikely on the basis of population trends of the 1970s and 1980s at Eurajoki and Loviisa (Koskinen et al. 1998, Laakso 1999). Conceptions would not in themselves affect the selection of a place to live nor the majority of migrants, because choices are affected by numerous other factors relating to the phase of life, labour and housing markets and the living environment (Laakso 1999).

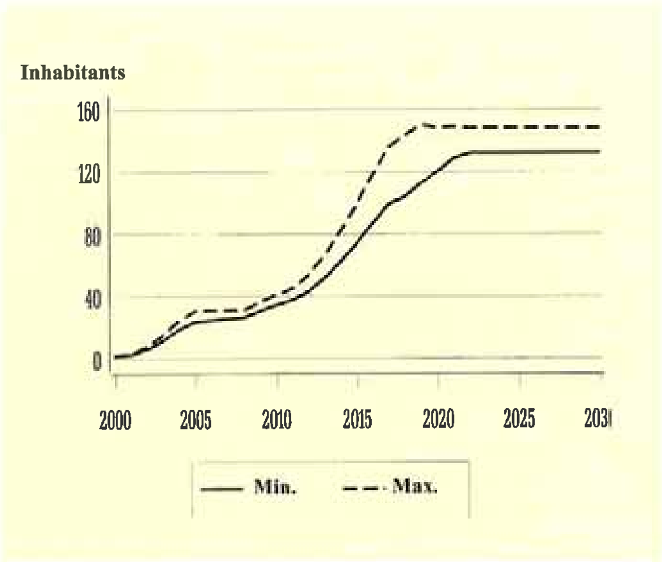
Questionnaires (Kiljunen 1998) indicate that final disposal would not affect emigration in the localities of existing power plants, because few people are worried about the risks and are considering moving away in either locality (14% at Eurajoki and 18% at Loviisa in 1995). The reason may be that the residents of Eurajoki and Loviisa are accustomed to the existence of the present nuclear power plants and that the plants are of major economic importance to the locality. Another reason could also be that construction of the power plants has, in its time, increased the exchange of inhabitants and some of the residents who experience the risk as serious have moved elsewhere and been replaced by residents who do not think that the risk is significant.

The questionnaires indicated (Kiljunen 1998) that final disposal could, to some extent, affect the turnover of inhabitants of Kuhmo and Äänekoski, because in these municipalities more people are worried about the risk and seriously considering moving away than in the power plant localities (25% at Kuhmo and 29% at Äänekoski in 1995). On the other hand, the weight given to individual environmental risk factors in the choice of a place to live is not necessarily great, even though it is of major significance as an individual issue (Koskinen et al. 1998, Laakso 1999). The effect would be reversed if the municipality of the site were able to use the greater economic strength brought about by the facility to increase its attractiveness and e.g. improve services and cut taxes. This could increase a migration gain or reduce a migration loss. The effects of municipal economy are dealt with separately in the section on Municipal Economy.

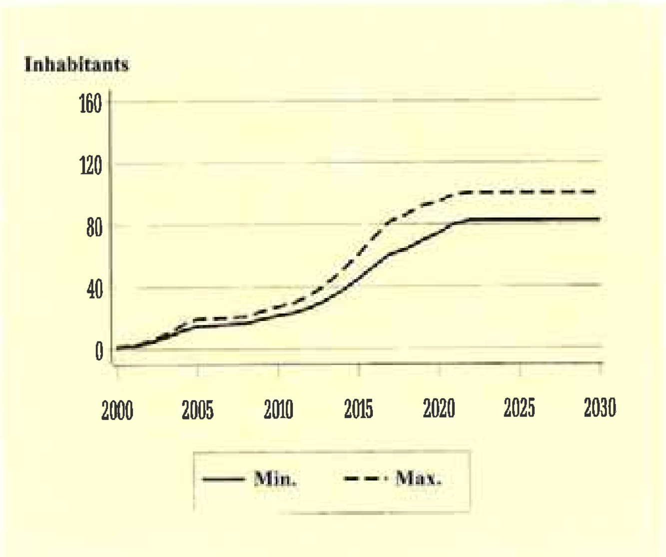
Figure 8-28 a–d. Effect of the final disposal facility on migration in the candidate municipalities (cumulative net migration).



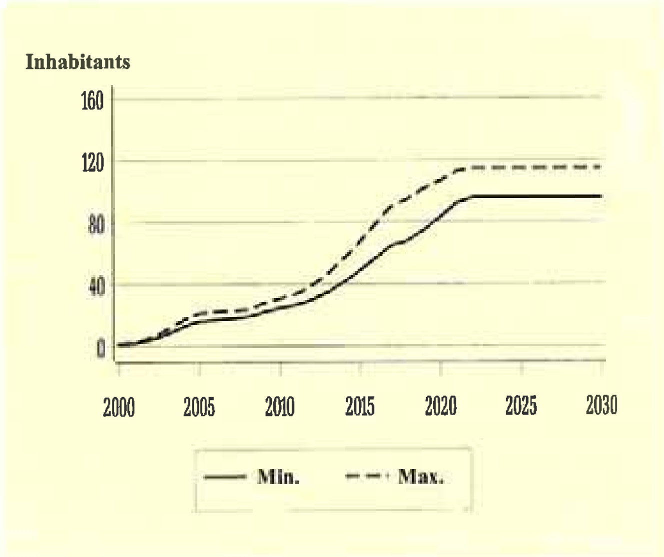
Eurajoki



Kuhmo



Loviisa



Äänekoski

Other community structure and infrastructure

The effects on other community structures have been assessed via construction related directly and indirectly to the final disposal facility (Laakso 1999). Statistics Finland's housing stock and house-building statistics, Posiva's plans and the results of its employment calculations relating to construction of the final disposal facility have been used as material.

The municipal engineering associated with the final disposal facility has been studied as a direct effect. Construction of business premises associated with changes in business activities and service construction and housing production associated with population changes have been studied as indirect effects.

The assessment (Laakso 1999), has not taken into account employment and population trends occurring for other reasons in the municipalities or areas. In addition an uncertain factor relating to indirect construction is Posiva personnel's choice of a place to live. The effects have only been studied within the candidate municipalities, because the effect would be slight in a wider area.

As a physical building the final disposal facility would affect transport communications and municipal engineering of its immediate environment. The effects on other infrastructure would be slight at Eurajoki and Loviisa, because the facility would be constructed in the vicinity of the existing power plants and would not alter present transport communications. In Kuhmo and Äänekoski the effects would be focused on link roads because the facility would be built in a commercial forest area. In the Romuvaara and Kivetty areas it would be necessary to build a new road, but present rail links would be adequate. In all places it would be necessary to construct water and waste water maintenance in conjunction with the facility. Traffic and noise volumes are dealt with in subsection 8.2.

The final disposal facility, with its jobs and the related migration effects, could affect the other infrastructure of the municipality where it is located. The growth in population would add to the demand for housing and the structural change would affect the type of housing on which demand would be focused. The construction and operation of the final disposal facility would have an indirect effect on the construction, industrial and service enterprises of its own municipality and neighbouring municipalities, which could in turn be further reflected on the demand for business premises and their construction.

The effect of migration associated with the final disposal facility would mean a net growth in households of 20–45 at Eurajoki, 75–90 at Kuhmo, 50–60 at Loviisa and 60–70 at Äänekoski.

Because there are few empty dwellings at Eurajoki and Kuhmo, the increase in immigration would be directly reflected in the production of new homes, which would increase by the same amount as the net growth in households. Demand would be geared towards single family dwellings, because the migrants would be young and well-educated, with good incomes compared with the average income level of the present inhabitants of the municipality. Because 10% of homes at Loviisa and Äänekoski are unoccupied, the increase in immigration would probably not be fully reflected in new housing production, but would increase it somewhat. In the longer term growth in the demand for housing might focus on high-quality single-family housing. The indirect affect on the growth in demand for business premises brought about by the impacts on business activities would remain slight and be mainly implemented within the framework of the old stock of business premises. It would not lead to construction of business premises in any of the proposed municipalities (Laakso 1999).

The final disposal facility could have an effect on the change in population size and structure, which in turn would affect the need and demand for municipal services. It would not, however, affect the current population forecasts for the localities (the number of children would decrease or remain the same, the number of pensioners would grow), because the effects of the facilities would be focused on those of working age and children. The facility would thus not affect the need for building daycare and school premises or services for old people, old people's housing or other development and construction for services relating to social and health care in the alternative siting municipalities (Laakso 1999).

In Eurajoki, the inhabitants assessed that the construction of a final disposal facility would increase traffic volumes so that movement, by schoolchildren in particular, would be endangered. Widening roads and crossings and increasing lighting would improve safety of movement. The inhabitants of other localities estimated that the effects on their living environment would be minimal. In Loviisa the inhabitants thought that blasting work during construction would cause noise pollution. In Kuhmo and Äänekoski residents assessed that the road network would improve because of increased traffic volumes. At Äänekoski the increase would only constitute a small part of otherwise heavy traffic (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Property values

Assessment of the affects of the construction and operation of a final disposal facility on the property values in the candidate areas is based on previous research results and on material relating to the alternative municipalities' property stock and price data (Laakso 1999). Separate investigations of the development and current situation of the property markets (Ridell & Raak 1997, 1998a, 1998b) and Statistics Finland's statistics on the housing stock and housing production were used as material.The assessment took into account the effects on different types of property, i.e. houses and residential properties, business premises and business and industrial properties, leisure-time properties (Figures 8-29, 8-30, 8-31, 8-32) and agricultural and forestry properties.

At Eurajoki and Kuhmo most property sales are in sparsely populated areas. At Eurajoki the properties sold are detached houses and plots for these and agricultural and forest land; at Kuhmo the properties sold are plots for holiday homes and agricultural and forest land. Price variation is typical of properties sold to private individuals, mainly because of differences between plots. In Eurajoki prices are comparable to the prices paid in similar municipalities. In Kuhmo sales are marked by plentiful supply and scant demand and stagnant prices. In Loviisa, most sales of property occur in areas for which a town plan exists. The properties sold are detached houses and plots for these. Prices correspond to the general trend in costs. At Äänekoski property sales are both in areas with a town plan and in sparsely populated areas. The properties sold are plots for detached houses, whose prices are at the same level as in similar localities elsewhere. In sparsely populated areas the vendors are private individuals, prices vary and the emphasis is on differences between plots (Ridell & Raak 1998a).

Property market data for Eurajoki and Loviisa have been collected from decisions by municipal councils, legal entries in the land register and from sale price statistics and registers. Statistical indicators (median, average) have been calculated from completed sales. As regards Eurajoki and Loviisa the annual variation in prices has been studied from the decision to build and site selection of the current power plants up to the mid 1990s. Property market data for Kuhmo and Äänekoski have been collected from sale price registers since the 1980s. Statistical indicators and the price level for the locality and its development have been calculated from completed sales. In addition data has been collected in all localities with vis-

Figure 8-29 Location of Olkiluoto, indicated with a line

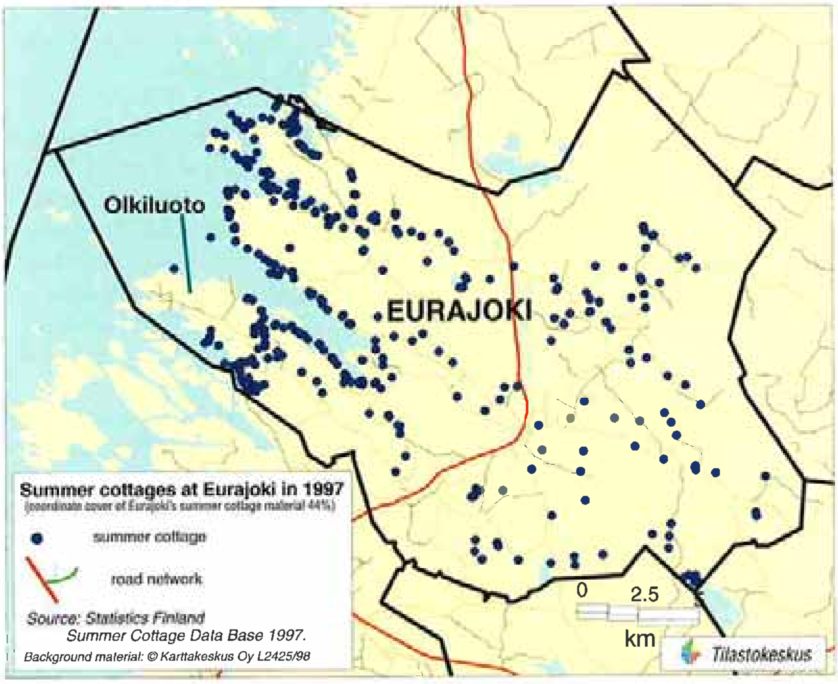
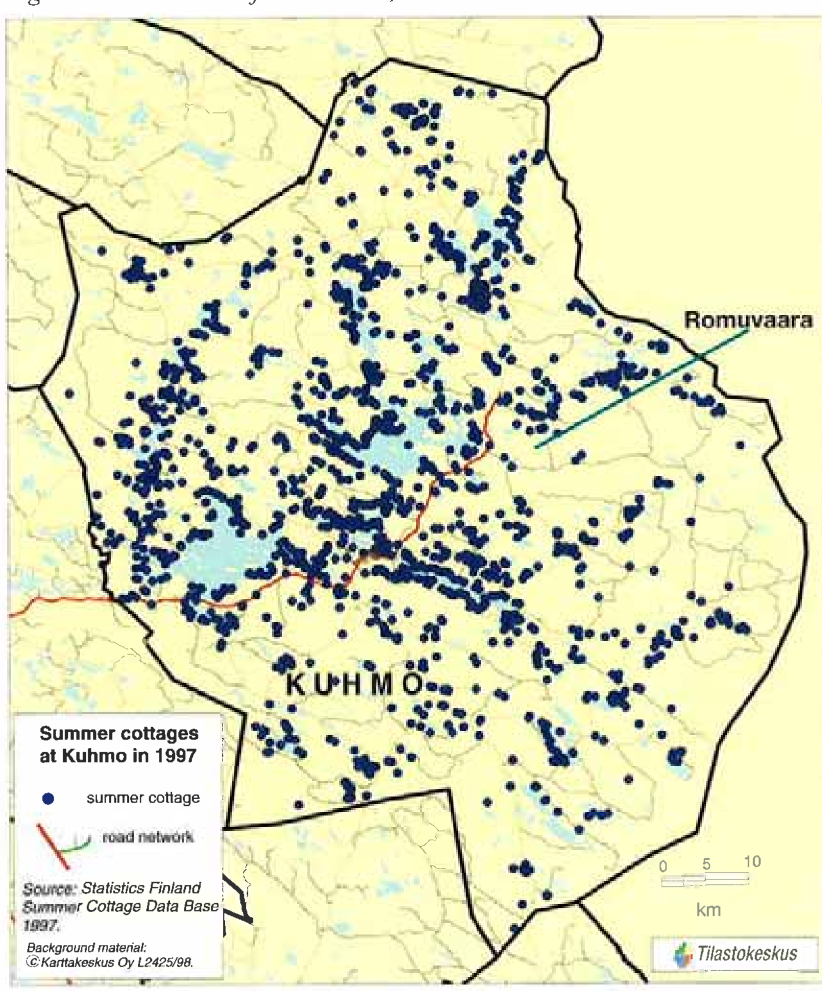


Figure 8-30 Location of Romuvaara, indicated with a line



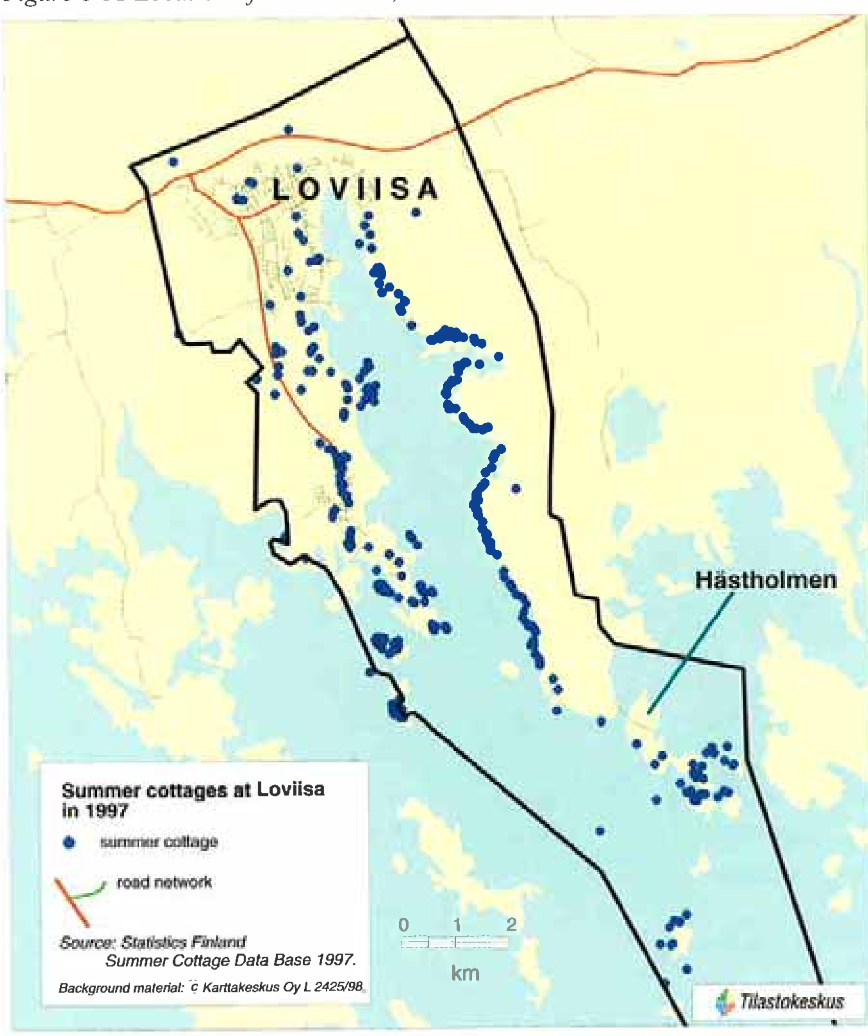
its to the terrain and by interviewing property experts in the municipalities. These experts have also participated in checking the material. Data on the population and business structure, on unemployment and construction have also been used in the analysis. It must be pointed out that the results are only indicative, because the material is too limited to determine a clear price level. Price data have also been investigated in neighbouring municipalities where applicable.

A survey carried out in Sweden on the affects of the proximity of a nuclear power plant on the values of leisure-time properties, a survey of the affect of the Olkiluoto and Loviisa plants on property values and data on the affect of Ekokem (a problem waste processing company) on property values in Riihimäki were used as comparison material (Koskinen et al. 1998, Ridell & Raak 1997, 1998b).

Inhabitants of the power plant localities estimated that the final disposal facility would affect property values in the same way as any industrial plant, in which case visibility of the facility would be the most significant factor affecting price (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Experiences of the present power plants give no reason to assume that the effect of the final disposal facility would be any different to that of other industrial installations.

Figure 8-31 Location of Hästholmen, indicated with a line.



With the exception of Kuhmo, the localities thought that the effects could be focused on leisure homes in that demand for them would be weakened and the value would fall. The effects are expected to be felt in the immediate vicinity of the facility. Property value factors did not come to the fore in the assessments by the inhabitants of Kuhmo (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

As a physical building the final disposal facility – like any other industrial installation – would reduce the price of (holiday) homes situated in its immediate vicinity, if the facility caused noise or landscape impacts. At Olkiluoto and Hästholmen the nearest buildings are located in the immediate vicinity of the planned facility area. At Romuvaara the nearest residential buildings are located approximately one kilometre from the planned facility area. At Kivetty the nearest residential buildings are located about two kilometres away. The facility has been planned in all locations to be constructed such that no habitations would remain in the noise impact area and that the completed buildings could not be seen behind fully grown trees (Figures 8-2, 8-3, 8-4, 8-5, 8-6 and 8-7). The studies show that the final disposal facility could affect property prices if the buildings are located on the shore at Olkiluoto and Hästholmen, with no protective woodland, as then they would be visible from the sea. Because of land ownership and location of settlement the facility will not however affect the property values in its immediate planned location (Koskinen et al. 1998).

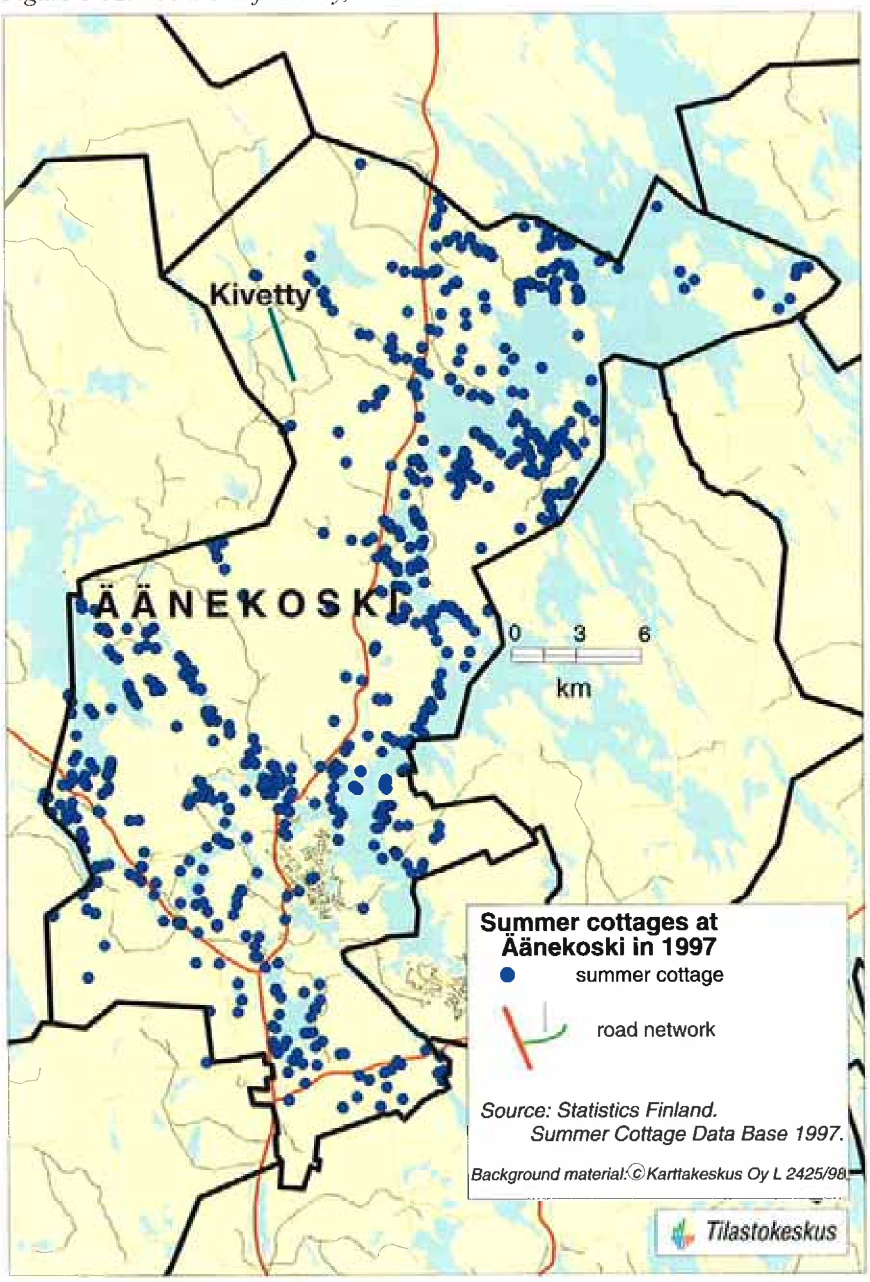
The effect of the final disposal facility on demand and prices for residential properties in all localities would be relatively slight and would be divided over a long period. This would be because increased immigration brought about by the facility would occur in the years 2010–2020 and it would not cause noticeable population growth; rather it would slow the reduction occurring for other reasons or possibly halt the reduction for about 10 years.

In addition there is a fairly large reserve of 'Arava' subsidised housing at Loviisa and Äänekoski which would cushion the effects of the growth in demand on the old stock of housing (Laakso 1999).

Investigation of the effects of the existing power plants at Olkiluoto in Eurajoki and at Hästholmen in Loviisa on the value of local properties – residential real estate, fields, forests, dwellings – it was found that prices in both localities have, since the 1960s, followed general price trends and that there have been no upward or downward divergencies, with the exception of plots for detached houses. In the 1970s, migration contemporaneous with the building of the nuclear power plants increased the demand for plots for detached houses and raised the price of individual plots in particular (Ridell & Raak 1997, 1998b).

The effect of a final disposal facility on demand for business premises or on unbuilt properties would be slight in all municipalities, because the growth in employment brought about by the facility in other business sectors directly associated with the project would be minimal. Therefore the facility would have no effect on the level of rents or prices (Laakso 1999).

Figure 8-32. Location of Kivetty, shown with a line.



It is unlikely that the final disposal facility would affect the prices of leisure-time properties in any of the localities, because, for instance, the construction and operation of the nuclear power plants have not significantly affected these prices at Eurajoki or Loviisa (Ridell & Raak 1997, 1998b). Similar results have been obtained in Sweden (Laakso 1999). The final disposal facility might increase the demand for holiday cottages in its municipality along with the new inhabitants. The location of Olkiluoto and Hästholmen near to major urban areas (Rauma, Pori and the Helsinki metropolitan area) might result in there being no reaction to the final disposal facility in the demand for holiday cottages (Koskinen et al. 1998).

If the conceptions associated with the final disposal facility were to affect the values of homes and residential properties at Eurajoki, Kuhmo, Loviisa and Äänekoski, there would have to be major population emigration. Research (Laakso 1999) gives grounds for considering this improbable. Most potential purchasers or renters would need to consider that the location of a property in the municipality of the final disposal facility was a risk factor before the conceptions associated with the final disposal facility had an effect on the values of leisure-time properties in the locality.

Research indicates that the final disposal facility could affect the value of agricultural land in organic food production if the facility brought about a fall in sales of such production (Laakso 1999).

The amount of cultivated land in organic production in each locality is shown in the section on Agriculture. Experience from the Ekokem problem waste installation at Riihimäki shows that conceptions associated with a facility do not affect the sale of wood or ordinary agricultural production, nor the value of forests (Koskinen et al. 1999).

Municipal economy

The effect of a final disposal facility on a municipality's economy would be brought about by both the facility itself and by the resulting employment and population changes. The facility would pay property tax. The effect on employment and population changes as a result of the facility would affect local income tax. The change in tax revenues would affect national tax revenue equalisation and this would cut part of the increase in tax revenues. The changes in population size and age structure brought about by migration would affect state subsidies and municipal service production and also other costs.

An assessment investigated the effects of local taxes paid by the final disposal facility workers and of the property tax paid by the facility on municipal economy. In addition a study was also made of the net effect of the final disposal facility on municipal economy taking into account the effects of both income and expenditure. In municipal income attention is paid to local income tax, corporation tax, property tax, tax revenue equalisation, the general state subsidy and the share of value added tax (Laakso 1999, Ronkainen & Ukkonen 1999).

In assessing the effects on expenditure, a study was made of those services dependent on and independent on age, with attention being paid to the effects of the project on service quantity and cost. Efforts were made to set the result out clearly as a change in the municipality's annual margin (Laakso 1999, Ronkainen & Ukkonen 1999).

The assessment used planning data for the base alternative, i.e. estimates of the number of employees and the amount of annual investment (Figures 8-21, 8-22).

The municipalities' financial statement data for 1997 and budget for 1998 were used as data for each municipality. The tax percentages approved for 1999 were used as the local income tax rate (Eurajoki 16%, Kuhmo and Loviisa 18.5% and Äänekoski 18%).The municipalities' financial plans for 1999–2001 were used to depict the municipalities' own estimates of future trends. Assessments of the effects on the annual margin are based on the municipalities' financial statement data for 1997 (Ronkainen & Ukkonen 1999).

Assessments are based on employment and population estimate calculations. In line with the findings of other research in the sector, assessments of the effect on employment assume that 70% of jobs will be filled by those moving into the locality and 30% by local people. In addition, for every ten migrants seven other persons will move into the locality. One third of these will be employed in other local enterprises (Laakso 1999).

The tax yield estimate is based on the assumption that the average income of persons employed in the final disposal facility is FIM 156,000 pa. The average income level for those accompanying immigrants who are employed is assumed to correspond to the average of FIM 127,000 pa for the country as a whole. It is assumed those employed in the locality will increase the tax revenue yield by an amount equal to the difference between the average income level at the final disposal facility and the previous income level. The previous income level is assumed to be FIM 76,000, which corresponds to the average income of unemployed people throughout the country (Laakso 1999).

Assessments drawn up for the years 2003–2030 (Ronkainen & Ukkonen 1999) are based on the Ministry of the Interior's trend calculation to the year 2002. The assessments assume that the municipalities' tax revenue, independent of the final disposal facility, will remain the same as in the year 2002. The total cost of services would change in consequence of the final disposal facility in line with the number of inhabitants and age distribution. Assessments of the effect of migration on municipalities' expenditure development and employment are based on experiences gained from construction for other municipal economy sectors and nuclear power plants. The amount of tax revenue per head of population in the years 2003–2030 is the same as in the Ministry of the Interior's forecast for the year 2002.

The assessments used current data for determining property tax and on corporation tax reform, with attention being paid to the share for each job in the state subsidy scheme, reclaiming value added tax and municipalities' other income statement items including depreciation. Depreciation relating to the project would commence when the facility is ready in the year 2020 and the facility's minimum taxable value would be 40% of the total cost. Calculations are based on data for 1998 increased by the amount of the rise in general costs to the year 2002. Assessment for the years 2003–2030 assumes that the municipalities' own financing contribution will remain unchanged, but a rise in the cost level has not been allowed for (Ronkainen & Ukkonen 1999).

The assessment method and its reliability have been developed in interaction with municipal finance and tax administration experts. Finance and planning personnel in the candidate municipalities have assessed the applicability of the accounting principles and made it possible to take the special features of the municipalities into account in assessment. In this way efforts have been made to outline uncertainty involved in the assessment. Thus the assessment has also been able to take into account the latest information on any changes to the system.

The uncertainties involved in the assessment are state actions, parliamentary and government decisions governing municipal economy and interpretations relating to the imposition of property tax. Experience has, however, been gained of these in conjunction with the setting of property tax for the power plant waste caverns at Eurajoki and Loviisa. Since, on one hand it is impossible to assess the development of the cost level up to 2030, and, on the other hand, the current change in the cost level is rather low, no assumptions have been made in the assessments for general trends in the cost level (Laakso 1999, Ronkainen & Ukkonen 1999).

The inhabitants in all localities estimated that the project would bring additional tax revenue to the locality. In the municipalities where there are existing power plants, this was considered an additional benefit alongside the decreasing tax generated by the current plants. In Kuhmo tax revenues are needed to service the town's debts. In Äänekoski the tax revenues were felt to be an additional benefit that could be used to safeguard the city's current level of service and area development. In addition, the inhabitants in all localities estimated that the tax revenue effect would also focus on neighbouring municipalities, because of the facility's procurements and the choice of dwelling place of its employees. On the other hand it was thought that the benefits would remain small, because of the state subsidy equalisation system or if tax bases were altered so that property tax in its present form would not be in use in the future (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

The property tax yield would commence with the construction of underground investigation premises and the tax would be 2.2% of the property's taxable value. In 2010 the property tax would be FIM 1.3 million, in 2021 it would be about FIM 10.7 million and in 2030 about FIM 8.7 million.

The property taxes and local income taxes in the candidate municipalities would affect the tax yield as follows (Laakso 1999, Ronkainen & Ukkonen 1999):

In the municipality of **Eurajoki** the total yield from property tax would rise from FIM 22 million to a maximum of approximately FIM 33 million. In the 2030 the municipality's yield from property tax would be FIM 32 million. If the project were not implemented, the municipality's annual yield from property tax would remain at FIM 22 million.

In the town of **Kuhmo** the total yield from property tax would rise from FIM 3 million to approximately FIM 14 million. In 2030 the town's property tax yield would be approximately FIM 13 million. If the project were not implemented, the town's annual yield from property tax would remain at FIM 3 million.

In the town of **Loviisa** total property taxes would rise from FIM 16 million to a maximum of approximately FIM 27 million. In 2030 the town's property tax yield would be FIM 26 million. If the project were not implemented, the town's annual yield from property tax would remain at FIM 16 million.

In the town of **Äänekoski** the total yield from property tax would rise from about FIM 7 million to a maximum of FIM 17 million. In 2030 the town's property tax yield would be FIM 16 million. If the project were not implemented, the town's annual yield from property tax would remain at FIM 7 million.

The employment and population change brought about by the final disposal facility varies in the different candidate municipalities. Therefore the local tax yield and the expenditure caused by population changes vary.

In Eurajoki the increase in local tax yield would be FIM 0.1 million in 2003 and in 2018 it would be about FIM 1.0 million. When the facility begins operating in 2020, the increase would be about FIM 1.0 million per annum.

In Kuhmo the increase in local tax yield would be about FIM 0.3 million in 2003 and in 2018 it would be about FIM 2.0 million. When the facility begins operating in 2020, the increase would be about FIM 2.5 million per annum.

In Loviisa the increase in local tax yield would be FIM 0.2 million in 2003 and in 2018 it would be about FIM 1.3 million. When the facility begins operating in 2020, the increase would be about FIM 1.7 million per annum.

In Äänekoski the increase in local tax yield would be FIM 0.2 million in 2003 and in 2018 it would be about FIM 1.4 million. When the facility begins operating in 2020 the increase would be FIM 1.8 million per annum.

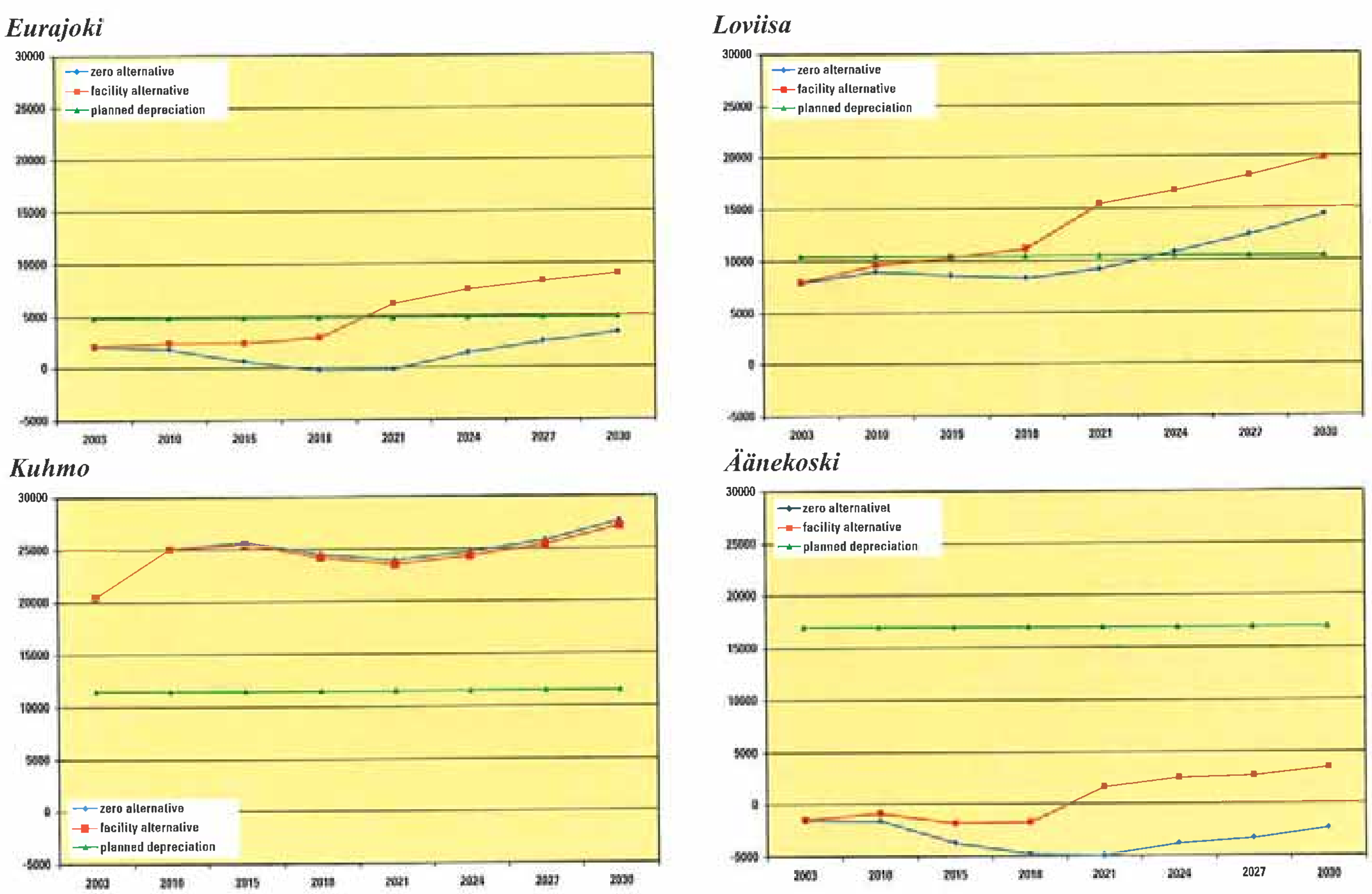
In all the alternative location municipalities population changes would result in state subsidies increasing and value added tax decreasing every year, irrespectively of whether the final disposal facility is constructed or not. By the year 2030 the increase in state subsidies would be almost FIM 10 million in Eurajoki, over FIM 20 million in Kuhmo, over FIM 13 million in Loviisa and over FIM 20 million in Äänekoski. The reason for this is the increase in the number of old people, irrespective of the facility. On the other hand the facility would bring with it young migrants of working age. Value added taxes would decrease in Eurajoki by about FIM 0.3 million, in Kuhmo by about FIM 1.0 million, in Loviisa by about FIM 1.0 million and in Äänekoski by about FIM 0.7 million (Ronkainen & Ukkonen 1999).

The final disposal facility would affect the corporation tax yield of the municipality via population changes. The effect would be indirect, because Posiva would not itself generate a profit from its activities. The yield would arise from stimulating the local business environment, from the indirect effect on employment and from the increase in the taxable income of local enterprises. Because the effects of income change vary from one municipality to another, the indirect effects on the yield from corporation tax are of different magnitudes. The effect on corporation tax would be slight in all cases (Laakso 1999, Ronkainen & Ukkonen 1999).

The yield from property and local income tax brought about by the final disposal facility would affect municipal finances in various ways in the different municipalities. In Eurajoki, Loviisa and Äänekoski less than half of the increase in tax revenues and in Kuhmo almost the entire increase would go to tax revenue equalisation. Thus tax revenues during the construction phase would increase by FIM 0.1–4.2 million at Eurajoki, FIM 0.1–2.0 million at Kuhmo and FIM 0.1.–4.5 million each at Loviisa and Äänekoski. During the operating phase the growth in tax revenues would be FIM 7 million at Eurajoki, FIM 2 million at Kuhmo and FIM 8 million each at Loviisa and Äänekoski (Ronkainen & Ukkonen 1999).

The effect on income and expenditure brought about by the final disposal facility on municipal finances up to the year 2030 has been assessed as an indicative change in the annual margin, which is shown in Figures 8-33 a–d. The figure also shows the zero alternative, i.e. that the final disposal facility is not built. The municipal economy is considered good when the annual margin covers planned depreciation.

Figure 8-33 a–d Annual margin in zero and facility alternatives and planned depreciation (FIM 1000) over the years 2003-2030 in the proposed municipalities.



8.5.5 Effects on living conditions and general wellbeing

Inhabitants' conceptions of final disposal

The impact of the project on the physical environment would mainly be restricted to the immediate vicinity of the facility and assessments indicate that these would remain minor (Chapters 8.2 and 8.3). Anxiety, fears, negative perceptions and conflicting conceptions relating to the project might, however, affect inhabitants' pleasant surroundings, interpersonal relationships and even people's health. In conjunction with drawing up the assessment programme, particularly emphasis was given to the importance of the effect of project image.

The research material comprised residents' views and conceptions of risk (Viinikainen 1998). The material also consisted of data collected in telephone interviews on the municipalities' present internal and external image among one thousand Finnish consumers and entrepreneurs (Ala-Lipasti et al. 1999) and also data collected using a questionnaire among almost one thousand tourists (Åberg & Viinikainen 1998). In addition, group discussions at Kuhmo and Loviisa formed the basis of a study of the views of residents and entrepreneurs on the effect of a final disposal facility on image (Ala-Lipasti et al. 1999). Material collected in publicly funded nuclear waste research circles was also available in the assessment (Harmaajärvi et al. 1998, Kankaanpää et al. 1999). Consumers' views and evaluations of their own behaviour were also collected in group interviews (Koskinen et al. 1998). Interviews were used to complement previous questionnaire studies (see subsection 8.5.2.) which lacked various situation-linked factors relating to everyday life which would have a central effect on the way consumers took the risks into account.

In addition to the fresh material, the conceptions of the inhabitants of the candidate final disposal municipalities had already been studied previously in an opinion poll conducted by Kurki (1995), the material from this was also utilised in interpretations made by Litmanen (1996a, 1996b). The University of Tampere and Yhdyskuntatutkimus Oy (Community Research) have carried out long-term monitoring of the development of opinions (Kiljunen 1998). Uncertainties relating to different materials are dealt with in subsection 8.5.2.

Conflicting conceptions, fears and anxiety relating to the safety of final disposal and transports of spent nuclear fuel, as well as positive expectations relating to the project are clearly apparent in themselves in the letters pages of the press (see e.g. Pirttikoski 1996, Pasanen 1998). The available interview and questionnaire studies attempt to analyse the backgrounds behind these conceptions.

Some inhabitants of the candidate municipalities assessed the risks relating to final disposal which would be caused by e.g. sabotage, changes in the conditions of the bedrock, or inadequate research into final disposal and its safety. In addition, it is feared that the final disposal alternative would also bring foreign nuclear waste into the final disposal site. On the other hand some other people think that safety would not be a problem. In the municipalities where there are power plants, final disposal was considered to be part of the nuclear power industry as a whole and people are accustomed to the safe operation of the power plant. The final disposal facility would not be subject to the same risks as interim storage and would thus enhance general safety (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

Figure 8-34. Distribution of opinions within the municipalities. Those interviewed replied to the question: "In the event that the investigations and safety assessment by the authorities indicated your own residential community to be safe as a final disposal site for nuclear wastes, would you accept the placement of nuclear wastes produced in Finland within the confines of your home municipality?"

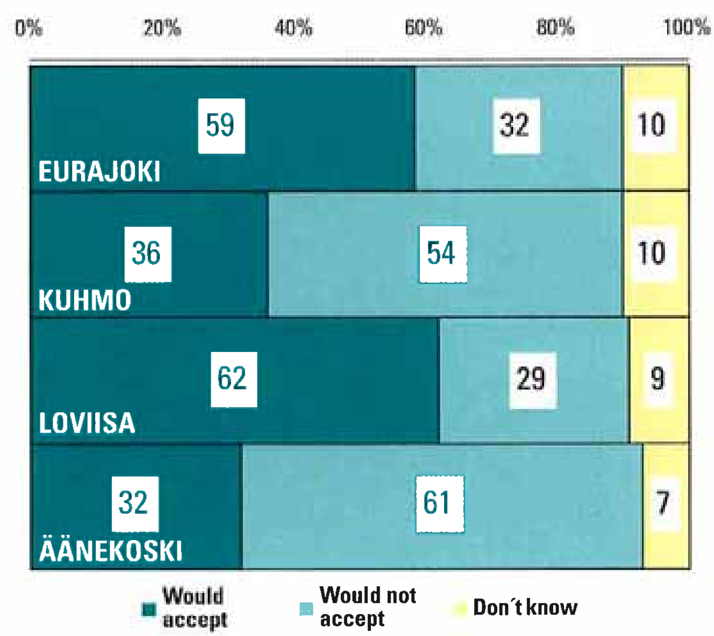
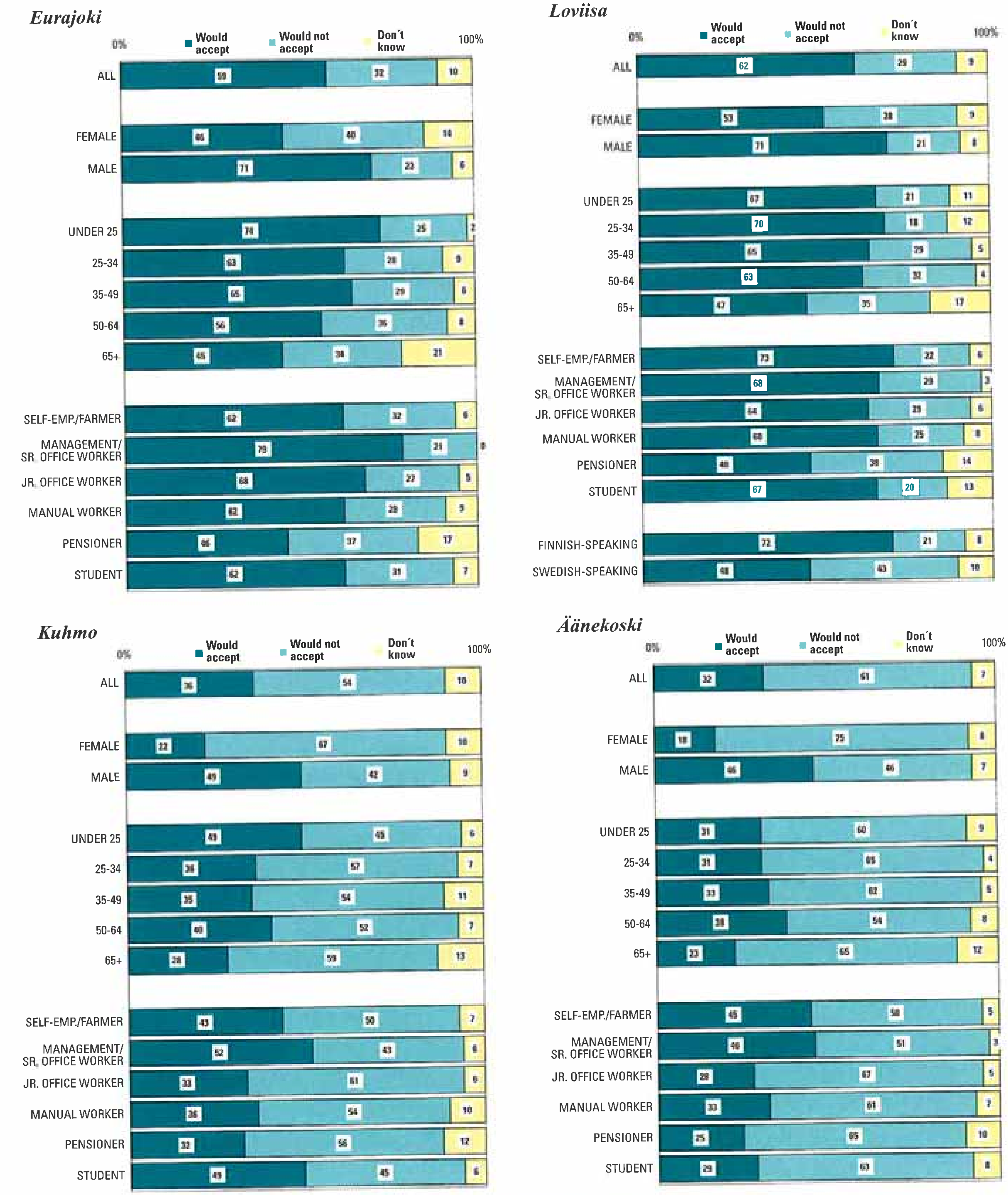


Figure 8-35 a–d. Acceptability of final disposal in the municipalities, classified by respondents' sex, age and occupation. The question posed was: "In the event that the investigations and safety assessment by the authorities indicated your own residential community to be safe as a final disposal site for nuclear wastes, would you accept the placement of nuclear wastes produced in Finland within the confines of your home municipality?"



On a nationwide basis, some residents associate final disposal with health risks, the possible effects of which would emerge after a long period. On the other hand there is confidence in nuclear technology, because this field is felt to be well managed and supervised in Finland. Final disposal is generally believed to be safe in normal circumstances, but there is fear of exceptional occurrences and risks from possible changes occurring in the future. These are held to be rare occurrences such as earthquakes, nuclear war or an ice age, as well as situations in which different groups of people terrorise their fellow citizens. Nevertheless, the actual occurrence of such situations is considered unlikely in Finland. Risk would, however, also be caused by human error (Koskinen et al. 1998).

One cause for anxiety is also the assessed irreversibility of final disposal. Many residents thought that it should, if necessary or if desired, be possible to open the final disposal repository and retrieve the fuel to the surface. Although Posiva considers that this would be possible at all phases (Saanio & Raiko 1999), in previous Posiva reports the possibility of retrieval is not really dealt with.

Conflicting conceptions relating to transport are similar, regardless of the assessor's relation to the siting locality. Some people believe that transports will increase the safety risk, because transportation is assessed as being vulnerable to sabotage, human error and road accidents, even though the technology itself is safe.

In some people's opinion there is, however, already plenty of experience of transporting nuclear waste and of trouble-free transportation. Other dangerous substances are also constantly being transported by road and rail across large cities. There is confidence in the safety of transportation, particularly when it is known that under the pressure of publicity it would be necessary to carry out transportation with great care.

Some residents consider the nature of nuclear technology (including the processing and final disposal of nuclear waste) to be completely different from other industry. Nuclear technology is thought of as a sector which is unknown and uncontrollable, and residents are unable to influence the possible consequences of its operation; neither are experts able to predict all the risks involved or these risks are not comparable to known risks. The possibility of disaster is then often also associated with nuclear technology (Koskinen et al. 1998).

In the opinion of some residents nuclear technology is technology like any other. When it is well managed they consider it relatively clean and offering many advantages. In these cases the risks of nuclear technology are also thought of as only a minor added risk. Today's technology is felt to be safe in developed societies and particularly in Finland (Koskinen et al. 1998).

Locally, there are anxieties concerning the residential community in relation to final disposal. Some people consider final disposal would make the municipality better known, others dwell on the negative stigma brought by final disposal (Leskinen et al. 1997, Pasanen 1998, Viinikainen 1998).

In the municipalities where there are nuclear power plants, some people assess that their community will not necessarily become better known, because the final disposal facility would be only part of the nuclear technology already under way. On the other hand some people assess that their community will become better known, because the project would be unique and managing waste would mean accepting responsibility and conserving the environment, which would be worthy of note.

Outside the power plant localities, it is thought the municipality could be stigmatized owing to the negative image relating to final disposal. The project would result in the disposal municipality becoming a 'garbage centre'. This idea could conflict with current activities: in Kuhmo the municipality's wilderness image would be the conflicting factor. In Äänekoski the project is considered as retarding the municipality's efforts to rid itself of previous images relating to industrial emissions.

The effects of image and stigma are thought to focus mainly on agricultural production, tourism, other business activities and population placement and property values. Thus the effects are seen as both beneficial and harmful.

An opinion poll conducted in early 1999 studied the general acceptability of the final disposal project among the inhabitants of the research areas, with a sample of over ten per cent of the population in each municipality. The poll was conducted by Suomen Gallup Oy. The sample can be held to be representative of residents' current opinion distribution. The poll was conducted by telephone. Respondents were requested to give their views on the question: 'In the event that the investigations and safety assessment by the authorities indicated your own residential community to be safe as a final disposal site for nuclear wastes, would you accept the placement of nuclear wastes produced in Finland within the confines of your home municipality?' The response options were 'Yes' or 'No'; other responses were classified as 'Don't know'. A summary of the results of the opinion poll is set out in Figures 8-34 and 8-35 a–d.

The findings from the questionnaire show that the majority of the inhabitants of Eurajoki and Loviisa would be prepared to accept the facility. In Kuhmo and Äänekoski the majority opposes the construction of the facility in the municipality area. The percentage of people declining to give an opinion was rather small in all municipalities. Similar results have also been obtained in research investigating the attitudes of Finnish people (Kiljunen 1998) and in a questionnaire investigating the present image of the municipalities (Ala-Lipasti et al. 1999).

In all the municipalities women's opinions to the project are more negative than those of men. The difference between the sexes was least in Loviisa. A similar division of opinions by sex is also apparent in relation to nuclear power (Kiljunen 1998). One explanation might, in accordance with the model put forward by Paavola & Eränen (1999), be the different weight given to the cognitive, emotional and functional factors underlying attitudes in different people and groups. The background might perhaps be men's greater confidence in technical systems.

At Kuhmo negative opinions were also correlated with the respondent's age: almost half of those aged under 25 would be prepared to accept the facility, although the majority of the group of all inhabitants opposed the facility. The explanation might be young people's concern for the preservation of the viability of the municipality and their effort to stress the positive benefits of the project.

Social science perspectives

The nuclear power industry primarily considers nuclear waste management a techno-economic problem, which ought to be solved on the basis of expert information. Many citizens, however, have suspicious or negative opinions to nuclear waste management solutions, citing, e.g. the danger of the waste. At the same time they often cast doubt on the expertise of the nuclear power industry. The differences in views can be explained by different conceptions relating to information and science. Litmanen (1994, 1996a, 1996b, Lidskog & Litmanen 1997) has shown that a conflict already appears in the definition of the problem. The nuclear power industry strives to keep the debate within the sphere of technical expertise, while the local population holds such a definition to be too narrow. The interpretations set out in the following are to a great extent based on the report of Kantola (1999), which sets out the social science perspectives on the nuclear waste debate.

The assessment of experts and the perception of citizens are two different ways of emphasising matters, defining situations and characterising concepts. The experts on final disposal base their views on technical information and on the conception that the risks and consequences of final disposal can be objectively assessed with scientific methods. From the residents' perspective, information is formed and gains significance only in conceptualisation occurring by way of public debate. Conceptualisation is affected on the one hand by residents' own values, beliefs and attitudes and on the other hand by the parties and discussion channels of public debate.

For technology experts, 'risk' is a strictly defined mathematical entity, which describes the consequence and its probability. Such a definition makes possible the mutual comparison of very different technical alternatives. Citizens have a different way of conceiving of risk. In everyday conversation the word 'risk' is taken to mean more or less the same as 'danger' or 'threat'; although it is generally associated with situations in which the question is one of decisions or choices. The residents' conception of risk is illustrated, for example, by the expressions in the EIA feedback 'long-term risks which are difficult to determine and understand', 'final disposal is based on assumptions which involve uncertainties', 'there is no experience of final disposal' or 'the consequences are not known for certain' (Leskinen et al. 1997, Pasanen 1998).

The concept of expertise in technology is based on a conception of information, in which there exist objective facts, which only have to be discovered. Residents, on the other hand, have emphasised their right to their own conceptions, regardless of the 'facts': 'if a person is afraid, then he or she is afraid and the experienced fear is real' (Kivinen & Turunen 1999). In matters relating to nuclear waste it is fairly generally accepted that people's conceptions are significant, irrespective of whether they are justified in some objective sense or not. Great power of decision in the matter has been left to politically elected bodies (municipal councils, parliament), and so the opinion of citizens is also emphasised by this way. The question is then one of accepting what is known as the 'constructionist perspective'.

In the sociological perspective in the debate the question is also one of the difference between the modern and postmodern analysis: the modern, enlightened, conception defends expertise, while the postmodern conception stresses scientific relativism and the equality of different conceptions.

Debate on the relation of the power of experts to the citizens' society encounters the problematic nature of the concept of 'risk'. In the view of Niklas Luhmann the concept of risk used by technological experts is a construction into which techno-economic experts attempt to concentrate the uncertainty of the future and threats caused by the unknown. Other societal 'subsystems' are not, however, ready to accept the all-inclusiveness of the concept of risk of the techno-economic subsystem and this, in practice, has led to a breakdown of communication between different subsystems and thence to conflict situations in society.

Ulrich Beck considers that contemporary society differs radically from previous societies precisely because societies are increasingly dependent on systems which contain risk, and the information for their control is in the hands of only a few experts. In Beck's view this type of risk society culminates in nuclear power. On the other hand, it could be suggested in reply to this that there has not been an increase in danger, but in awareness of the dangers and of the opportunities for avoiding them (Kantola 1999, Sjöberg 1998). According to Zygmunt Bauman, technical choices can no longer be evaded: if we leave unexploited some opportunity permitted by modern technology, we must assess the consequences of this 'zero alternative' (see, e.g. Lahti 1998).

Conflicts between conceptions thus arise in particular out of confidence or distrust felt towards information or the producers of information. In the risk society information relating to nuclear technology - particularly that relating to safety - is centred on a few experts. People often declare that the only producers of information are power companies and active opponents of a project and so the information produced by such interest groups is unavoidably partial and biased. In addition information on nuclear technology is felt to be difficult to understand. Lack of interest has also been a barrier to the distribution of information.

Differences in peoples' views are also explained by the relations between data, feelings and motivation and actions (Paavola & Eränen 1999). Positive or negative feelings about final disposal affect the way in which the information offered is used and how motivated people are to act in favour of the project or against it. This also explains the different attitudes of citizens to the final disposal facility. Although it would be possible to justify the acceptability of risks at the scientific level, there might be an encounter with the level of feelings. The thought of final disposal is unpleasant in spite of solid factual information. On the other hand, the opposite may also occur: final disposal is accepted, even though people's own information is not adequate to assess acceptability.

Observations and research results

No systematic Finnish or foreign research on the effect of final disposal on knowledge or stigma of a municipality is available (Koskinen et al. 1998). In investigating the current knowledge of the localities proposed for the final disposal facility, it was observed that the municipalities in question are little known (Ala-Lipasti et al. 1999, Kankaanpää et al. 1999). Eurajoki is neither known in general nor as the locality of a power plant. Loviisa is better known than Eurajoki and Loviisa is known precisely for its nuclear power plant. Investigations show that becoming either positively known or negatively stigmatized require several different parties and procedures. The municipality itself is one crucial agent. Public debate and events relating to the sector occurring elsewhere (for instance operating disruptions in power stations) also have significance for the impact of the project. It would in practice be impossible to take account of all these factors in assessing the effects.

Research results and empirical observations partly conflict with one another. On the basis of questionnaire studies it would be possible to assess that the final disposal facility would particularly affect consumers and the choices of some consumers, such as the choice of a holiday resort or place to live (Ala-Lipasti et al. 1999, Åberg & Viinikainen 1998). The final disposal facility would place a negative stigma on its locality and conceptions would be visible in consumers' choices. The respondents' attitude to nuclear power is also reflected in the responses to questionnaire studies (Ala-Lipasti et al. 1999).

An assessment made by the National Consumer Research Centre (Koskinen et al. 1998) reveals that consumers and entrepreneurs do not behave in real choice and decision-making situations in accordance with the attitudes they report. There is no evidence of a reduction in the sales of foods or the use of tourist services from industrial localities.

The development of property prices in Eurajoki and Loviisa has followed the general price trend (Ridell & Raak 1997, 1998b). The price of homes and holiday homes is reduced by any industrial installation located in the immediate vicinity of the dwelling. Elsewhere prices are not reduced for this reason; they might even rise. The views of consumers would not affect the general preconditions for other products and business activity.

Interviews show that consumers have faith in the quality control of the Finnish food sector and in the supervision of the authorities (Koskinen et al. 1998). Consumers consider that the choice of a holiday resort is in itself such a complex process that they are not willing to load their decision-making with an additional risk survey. There is generally considered to be, as an acceptable element related to travelling, a higher level of risk than in everyday normality. As reasons for rejecting a tourist resort, consumers cite crime, riots and natural disasters. On this basis it could be assessed that tourists would come to a locality regardless of the final disposal facility.

It is in principle possible that tourists considering acquiring a leisure-time home in the final disposal locality would react to the building of the facility. If they estimated that the value of the home would decline, they might withdraw from the sale. Wilderness travellers and farm holidaymakers might decline to travel in the final disposal locality if they assessed that the locality's cleanliness and natural conditions had changed. In order for tourists to commence avoiding the final disposal locality it would, however, be necessary that the tourist sites (e.g. cottages or farms) were located in the immediate vicinity of the final disposal area. About one in ten consumers (Koskinen et al. 1998) might refrain from coming to the final disposal locality, because the attitude to nuclear power and final disposal stamps all behaviour. This would come about if the negative relationship does not remain at the purely attitudinal level.

Because the possibility of stigma of the municipality can, from the point of view of entrepreneurs, only be related to food production, tourism services and holiday home rental activity on certain conditions, the majority of firms would continue their operation as before, independently of the final disposal facility. Decision-making and the factors affecting it vary by business sector in such a way that the tourist sector bases its assessments on the possible reactions of consumers and the food industry, for its part, relies on quality control and tests (Koskinen et al. 1998).

Conflicting conceptions can be explained by differences in attitudes. People who are not residents of the locality examine the final disposal solution via general attitudes on the environment and then no information specific to the locality is related to it. Local people examine final disposal from the angle of the multiple dimensions of local attitudes and attach information specific to the locale to their assessments. Their views are not constituted on the basis of general attitudes, but on bases relating specifically to e.g. nature, the local economy and well-being. Views are also affected by the locality's industrial base, the existence of nuclear technology, and the size, wealth and cohesiveness of the community (Koskinen et al. 1998, Viinikainen 1998).

Of the candidate municipalities, Eurajoki is characterised by a fairly positive attitude to the project. In the background to these attitudes there is probably the influence of the existing power station and the experiences gained from this. There is no organised opposition at Eurajoki, although there are also opponents of the project among the municipal citizens. A multiplicity of views is typical of the other localities. In Kuhmo the debate is influenced by the small industrial base and prolonged high unemployment. The opponents of final disposal have organised themselves into the Romuvaara Movement and its supporters into the Kuhmo for Opportunity Association. In Loviisa bilingualism has provided a sounding board for the exchange of opinions for and against the facility. Opponents of final disposal have organised themselves into the Loviisa Movement and its supporters into the Pro Loviisa Association. The nuclear power plants and the experiences gained from them and the town's slow recovery from the recession lie in the background to debate. At Äänekoski the debate is influenced by the size and wealth of the town, as well as its ability to recover from the recession of the 1990s and its strong industrial base. Opponents of final disposal have organised themselves into the Kivetty Movement. No group supporting final disposal has been formed (Koskinen et al. 1998, Viinikainen 1998).

Although conflicts involved in nuclear waste are related in part to generally contentious societal questions and in some cases even symbolise them, the conflicts could in time disappear or be alleviated. Ponnikas's questionnaire study (1999) conducted among municipal opinion-leaders indicates that the effects of the conflicts would remain smaller at Eurajoki and Äänekoski than at Loviisa and Kuhmo. According to Paavola & Eränen (1999) and Lahti (1998), the key position is held by citizens' views of the community's – in this case the municipality's – ability to manage its inhabitants' well-being and by general confidence in this ability.

One starting point in reducing the negative effects caused by fears, anxiety and conflicts is admitting the existence of different points of view and continuing the interaction between the different parties on this basis. Technical experts have striven to offer their own expertise for the use of citizens. For a comprehensive and high-quality final result an open dialogue between both the instances opposing and those supporting the project is important.

Some people take the view that the implementer or the state should pay compensation in some way for social impacts which may be caused by the project. Compensation procedures planned in some countries have been cited in this matter.

8.5.6 Summary and conclusions

There are many uncertainties, both methodological and informational, involved in assessing the social effects linked to a final disposal facility. Peoples' conceptions and experience are very different and in part conflict with one another. A variety of views are related to the environmental impact of the project and the implementation alternatives on offer. The views do, however, represent the conceptions of the present inhabitants of the municipalities, and do not in themselves describe the way in which the effects experienced over the decades will be formed. Some of the effects of the project are direct, that is, brought about by jobs and investments or arising via physical construction. These changes may also include indirect effects, which are in conjunction with conceptions relating to the project. Because to date there is no experience of a final disposal project for spent nuclear fuel either in Finland or elsewhere, analogies are perforce deficient. For this reason a variety of perspectives, views and uncertainties must be accepted in the assessment.

Locally, the most discussion and interest is aroused by, on the one hand, the positive effects of the project (e.g. the effects on employment and business activity, population development, municipal finances and on the general conditions for economic activity) and, on the other hand, the negative conceptions associated with the project. Anxiety about the safety of the project and its effects on health generally come to the fore. In Loviisa opinions for and against the undertaking are also to some extent weighted according to language: among Swedish-speakers opposition to the project is more widespread than among Finnish-speakers. Significance of impacts from the inhabitants' point of view is shown in table 8-19.

Both in the locality and in general discussion the implementation alternatives are assessed on the basis of the safety and finality involved in the final disposal solution. The design of the facility and supervision of this design and also complete freedom from monitoring after completion would guarantee safety both in normal and in exceptional conditions. Abnormal situations in society would mean risks if the continued interim storage was decided on in our country. It is assessed that supervision and publicity relating to the transportation of spent fuel would guarantee transport safety, although on the other hand some people assess that there is a possibility of human error involved in their implementation. It is assessed that there are uncertainties relating to the claimed finality and lack of supervision. The lack of experience is also assessed as reducing the safety of the alternative.

At Eurajoki and Loviisa the effects are compared to the effects of the present power stations. In the assessment by inhabitants the effects of the final disposal facility do not diverge from the effects of the power stations. However, some of the inhabitants thought that the installations were of a different nature: finality and permanence were associated with final disposal, while the operation of the power plants was held to be temporary. At Kuhmo no point of comparison was found for the effects of the project, because there was no large industry in the municipality before. At Äänekoski the effects of the project are related to the present forest and wood processing industry.

Peoples' views are affected by familiarity or unfamiliarity with nuclear power technology, the employment situation in the municipality, general development (municipal economy, population) local political perspectives and the compatibility of nuclear waste with the cultural, natural and production base of the locality. The employment, population and municipal economy effects arising via the project jobs and procurements are related to the current situation, history and development forecasts of the localities.

In all localities residents consider that the tax revenues arising from the project are important. In Eurajoki, Kuhmo and Loviisa new jobs are held to be important, but they are assessed as being directed at a wider area than the municipality of the site.

The effect on employment during construction would be smallest at Eurajoki and greatest at Kuhmo. At Loviisa and Äänekoski the effects would be similar. When related to the amount of manpower during construction and operation the effects would be greatest at Kuhmo and least at Äänekoski. The greatest effect on employment would be directed at the area of impact at Loviisa. The effect in employment effects in the area of impacts at Eurajoki and Äänekoski would be of the same extent in relation to the quantity of manpower. At the provincial level the employment effects would be greatest during construction and operation at Kuhmo.

The effect on population would not be great in any of the candidate municipalities in relation to current population size. This would mean a slowing or halting for a few years of population decline occurring for other reasons. The greatest effects in terms of quantity would be focused on Kuhmo and the least on Eurajoki. At Loviisa and Äänekoski the effects would be of a similar magnitude.

The rise in population would to some extent increase the demand for homes in the localities, which could then be visible as a temporary rise in the prices of old houses and housing plots in private ownership, as well as stimulation of house-building. The construction of the facility would have no effect on other property markets in any locality.

As a consequence of disparities in the employment and population effects the net effects on municipal economy would vary in the candidate municipalities. The municipal tax yield would be smallest at Eurajoki, greatest at Kuhmo and of similar dimensions at Loviisa and Äänekoski. Similarly, the expenditure caused by migrants would be smallest at Eurajoki and greatest at Kuhmo. Property and corporation taxes would be similar in all the municipalities. State subsidies would increase in all localities irrespective of the final disposal facility, owing to population trend forecasts. The tax revenue equalisation system would cut the tax revenue yield in all municipalities. Tax revenues would grow the most at Loviisa, Äänekoski and Eurajoki and the least at Kuhmo.

The effects of conceptions relating to the project are assessed in all localities in relation to the current situation and living environment. At Eurajoki image problems do not really come to the fore in the assessments of the inhabitants, because the final disposal facility is not considered as essentially changing the current situation. At Loviisa the significance of conceptions is assessed on the same bases as at Eurajoki, but on the other hand it is thought that final disposal would strengthen the share of nuclear power in the municipal picture, while at present many other things are also considered to be part of the conception. Research shows, however, that Loviisa is known precisely for its nuclear power station.

Expected size and significance of the effects	Safety worries and their consequences: effects on image, the character and pleasantness of the place	Direct and indirect economic effects and the significance of the project for the development of the municipality	Questions and conflicts relating to the planning and decision-making process
Eurajoki	small	small	small
Kuhmo	great	great	great
Loviisa	great/small	great/small	great/small
Äänekoski	great	small	great

Table 8-19. Significance of the effects of the project in different municipalities assessed from the inhabitants' perspective (Viinikainen 1998).

At Kuhmo the conceptions relating to the project are assessed as particularly affecting the carrying out of occupations based on nature. At Äänekoski it is assessed that conceptions would affect the extent to which the town will be known. Investigations reveal that of all the candidate municipalities Kuhmo is best known and Eurajoki is least known. The power station localities are little known and where they are known it is precisely for their nuclear power.

The final disposal facility might affect entrepreneurs in the nature, wilderness and farm tourism sectors, because conceptions linked to final disposal – often as a part of nuclear power – could affect the attitudes of some tourists and thence affect their behaviour. In the candidate municipalities enterprises specialised in this type of tourism and their labour force are few. Therefore the significance for a municipality's employment development is slight, although the significance for individual enterprises could indeed be great. There is more of this type of entrepreneurial activity at Kuhmo and Äänekoski. Studies show that the final disposal facility could also affect organic production and farm and market sales in all municipalities via conceptions.

The significance of this in the alternative siting locations is slight in comparison with main agricultural production.

At the present time the conceptions of the inhabitants of different municipalities vary very clearly. In Loviisa and Eurajoki the clear majority would, according to opinion polls, be prepared to accept the final disposal facility in their municipality, while at Kuhmo and Äänekoski the clear majority opposes the project. In all municipalities there is a clear statistical difference between the opinions of women and those of men, such that men would be more prepared than average to accept final disposal in their own municipality.

The social effects are dependent both on the way in which the facility is implemented and on the changes in the municipality and in society as a whole. Both citizens and experts have the conception that the effects could be influenced by measures taken by the different parties. If required it would be possible to reduce the negative effects on citizens' living conditions of any fears, anxiety and conflicts which may relate to the project. The key position is occupied on the one hand by interaction between the various parties and on the other hand by confidence in the efforts of the various parties to find positive solutions. Interaction between the different parties should be in both directions.

Clarity and ease of understanding is expected of expert information on safety and people also wish for information about possible risk factors and accident and disruption situations. The information should be impartial, for instance produced by the scientific community, research institutes and the information media. Information should also focus on places other than the municipalities proposed as locations for the facility.

The owner of the facility could also influence its socio-economic effects. There would be a possibility of favouring local options in procuring the manpower, substances and services needed. Some people also expect action from the state which would compensate for any social effects which may be caused by the facility.

9. ENVIRONMENTAL IMPACT RESULTING FROM NON-IMPLEMENTATION

Non-implementation, or the 'zero option' would mean the continuation of storing spent nuclear fuel in water pools in interim storage facilities at the nuclear energy plants in Eurajoki and Loviisa. This would mean postponing the final solution for spent fuel management to some undefined future date.

The following is an examination of the environmental impact resulting from non-implementation of the final disposal facility.

9.1 Releases of radioactive substances and their impact

More detailed descriptions of the interim storage facilities for spent fuel, the bases for the storage designs, the concentrations and inventories of the radioactive materials used in calculations and their passage into the various parts and systems of the storage facilities, incident and accident analyses prepared all appear in the safety reports on the interim storage facilities in Olkiluoto and Loviisa. The environmental impact of continuing interim storage of spent nuclear fuel and of possible extensions are discussed in the EIA reports prepared for upgrade of the power of the nuclear energy plants (TVO 1996 and IVO 1996).

Releases of radioactive substances from the existing interim storage facilities for spent nuclear fuel at the Olkiluoto and Loviisa plants are insignificant compared to the already minimal emissions from the nuclear power plants as such. Consequently, neither continuation of interim storage nor an extension to the fuel storage facilities in Olkiluoto and Loviisa would noticeably increase the power plants' radioactive releases. Any gaseous releases are channelled, after filtering if required, to the power plant ventilation stack. Radioactive water is fed into the power plant's active water treatment system.

During the normal storage operations, the total radiation dose from spent nuclear fuel for the population is estimated to be a maximum of 10^{-2} manSv the most exposed being those working in the storage facility. The estimate applies to both the Loviisa and Olkiluoto interim storage facilities.

In the safety analysis prepared for the Loviisa storage facility, the most serious fuel handling accident is if a transfer basket full of spent fuel fell and all the 30 fuel assemblies in it became damaged. The doses arising from such accident have been estimated for individual living in the vicinity of the power plant. The whole body dose is estimated to be below $1 \cdot 10^{-3}$ Sv and the thyroid dose from breathing the air $1 \cdot 10^{-4}$ Sv.

According to the safety analysis, for the Olkiluoto storage the worst situation in Olkiluoto would be created if a spent fuel transfer cask were to fall as it is being lowered into the loading pool with the lid unlocked. In this case, it is assumed that all 41 fuel assemblies in the transfer container break, in which case, at a distance of 300 metres, the maximum individual whole body dose would be $4.4 \cdot 10^{-3}$ Sv and for the thyroid dose $1.7 \cdot 10^{-4}$ Sv.

9.2 Impact on safety from continued interim storage

Continued interim storage of spent nuclear fuel in Olkiluoto and Loviisa and the possible extensions to the storage facilities would result in more radioactive materials being stored at the facilities than today. Most of the stored spent fuel is old, cooled for more than five years. From the safety aspect, the older the spent fuel is the easier it is to treat it safely, because with time the heat generation and activity of the fuel decrease. During the next few decades, increasing storage of fuel older than five years at the facilities will not considerably affect the safety factors or accident risks.

The most important mechanism impairing the condition of the fuel assemblies when storing them in water pools is corrosion of the fuel cladding. Based on theoretical forecasts and over 30 years of operation experience, the corrosion of a zirconium cladding is very slow. Corrosion of fuel assembly structures made of Inconel and stainless steel is not significant, either. Hence, the final report (IAEA 1997a) of a research programme co-ordinated by the International Atomic Energy Agency states that, technically speaking, the storage in water pools of the fuel assemblies with zircalloy cladding seems to be practically fine unlimited for the fuel itself provided that the chemical and other properties of the pool water are of sufficiently good quality and that the fuel does not come into contact with unsuitable materials. Very long-term storage in water pools may, however, require additional studies, e.g., in case of the high burnup fuel. A more probable limiting factor is the technical and commercial lifetime of the actual water pool storages than the problems resulting from the fuel itself.

The safety of interim storage requires active control and maintenance of the storage facilities and the fuel. If, for any reason, maintenance were to end, the storage facilities would pose a considerable threat to the environment. History shows that the possibility of such a situation cannot be ruled out, neither can its probability be assessed. Consequently, the long-term safety of interim storage is vitally dependent on human action. It would thus require commitment by future generations to continue using resources to take care of the waste storage facilities.

In comparing the safety of interim storage to final disposal, it can be stated that during the operation similar safety and release standards apply to both interim storage facilities and final disposal facilities. However, the standards proposed by STUK for the final disposal facility are more stringent than those for interim storage facilities. Both alternatives provide good protection from radioactive materials for human life and the environment.

9.3 Social impacts resulting from continued interim storage

A partial assessment of the social impact resulting from the 'zero alternative' was already made in conjunction with the impact assessment of the base alternative. The discussion is presented in point 8.5.2, "The general approach and material used". The reports discussed deal with regional and municipal economy which compare, on the one hand, the construction of a final disposal facility in the municipality, and, on the other hand, a situation where no facility is to be constructed.

As long as the plants are in operation it is difficult to differentiate the social impacts resulting from interim storage from those resulting from the nuclear power plants. The social impact is hardly likely to change immediately even after the plants have been decommissioned, but might emerge later on, e.g., when improvements or a replacement of structures in the water pool storages are required.

The social impact resulting from interim storage would in part be different to those resulting from the final disposal facility. This is because it would be a case of continuing existing operations in the present nuclear power plant municipalities. As the interim storage facilities are already in operation in these municipalities, there would only be minor changes to people's current physical living environment. Non-implementation of the final disposal facility would mean an extension to the interim storage facilities and prolonged operation. An interim storage facility would in no way change local business, demographic trends or the forecast for municipal economy. Neither would an interim storage facility and its extension have an impact on other infrastructure or the value of real estate.

The opinions and images associated with an interim storage facility differ from those linked to a final disposal facility. An interim storage facility is mainly not considered a threat to living conditions and business activities. Local people estimate that interim storage facilities would have no impact on the demand for agricultural products or tourism in the power plant municipalities.

By continuing interim storage, possible negative impacts on the image would be avoided. On the other hand, for instance in Kuhmo, estimates have been presented that non-implementation of a final disposal facility in Kuhmo would hamper the position of entrepreneurs, erode the position of agriculture and increase the relative share of income transfers. The 'zero alternative' would also leave the question of a final disposal facility location open. This in turn might foster conflicts and worries.

Opinions as to the impact of interim storage on the environment and human life and of their time-related dimensions vary. According to some estimates, an interim storage facility would not pose a threat to human life or the environment as the storage facility could be controlled for possible emissions and leakage. Nevertheless, other estimates, see an interim storage facility as posing a threat to human life or the environment because there would be no guarantee of the continuous undisturbed functioning of the society. In the long term, it is also possible that social anxiety about the safety of storage and the fears surrounding it may increase as the storage facilities age.

9.4 Other impacts resulting from continued interim storage

Other environmental impacts resulting from the interim storage of spent nuclear fuel and continued interim storage are of practically no significance. As the amount of spent fuel increases, the heat conducted to the sea increases somewhat but is still very minute compared to the temperature of the cooling water of the power plant. Compared to the power plant buildings, the interim storage facilities are small; hence, the impact on the present landscape even after extension work would not be significant.

As regards ground construction works, an extension of the interim storage facilities does not differ from other construction projects of a similar size. Only small quantities of land and rock mass are removed, e.g., in case of an extension to the interim storage facility at the Loviisa plant, the quantity involved is around 1,800 m^3.

Every effort is being made to use the land and rock mass profitably. As earlier, the bedrock forms the foundation of an extension to interim storage facilities. Mainly crushed rock will be used for building ground and for external fillings. Drainage pipes connected to the power plant rain water sewage systems will isolate those parts of the buildings below groundwater level. Given the above, extending and operating the interim storage facilities does not give rise to hazardous impacts on the neighbouring soil, bedrock or groundwater.

The environmental impacts from extending the interim storage facilities are typical impacts resulting from land and rock excavation work in the form of pressure, vibration, and dust. The formation of dust is estimated to remain local. Noise during the construction work corresponds to the noise from normal construction work. Explosions, handling broken rock and the operation of working machines would cause temporary significant incidences of noise disturbances. Detonation work is estimated to last a few weeks during the initial stage of the construction work. During the construction phase, the incidences of noise disturbance would be minimal compared to the strongest background noise during the day, mainly from traffic. During construction work, the traffic flow will increase somewhat and this will cause temporary noise and dust on the sides of the roads leading to the area. No extraordinary waste would be generated during the construction phase. Ordinary unusable waste would be taken to the dumping area.

However, a possible future extension to interim storage facilities would require its own EIA procedure to ascertain in greater detail the environmental impact resulting from such an extension.

10. ASSESSMENT OF ALTERNATIVES

10.1 Structure of assessment

When deciding the future proceeding in the management of spent nuclear fuel, the first choice must be between continuing the preparations for final disposal and the zero alternative (postponement of decision). Should it be decided to implement the project, a site for the facility must also be chosen.

The following chapters examine these alternatives with respect to the decision situation. The difficulty in assessing the environmental impacts of the different alternatives lies in the long lifespan of the project, making it hard to evaluate matters far into the future. This concerns particularly the social effects, which largely depend on future generations, their decisions and the practical measures taken. On the other hand, any changes of attitudes taking place in society, particularly in attitudes towards nuclear power in general, can influence the social effects and especially approval of the final disposal facility.

10.2 Implementation or non-implementation of the final disposal project

The implementation or non-implementation of the final disposal project presented by Posiva can basically be assessed using the same criteria used in chapter 3 to evaluate the different technical options for final disposal.

These aspects are

- the protection of human health and the environment
- the protection of future generations
- the avoidance of burden on future generations
- the safety of nuclear waste plants

The evaluation can be used as a basis to compare the environmental impacts of the different alternatives and to compare the technical feasibility and costs of the different alternatives.

The enclosed table shows a summary of the comparison made on the basis of the grounds above. The zero alternative and implementation of the project both meet the requirements to protect human life and the environment. However, the safety of the zero alternative calls for continuous supervision and maintenance of the storage pools. The safety of the facilities while in operation is not a problem in either of these two alternatives.

The avoidance of the continuous maintenance obligation speaks in favour of implementing the final disposal project. Adoption of the base alternative (or a variant thereof) to dispose of the spent fuel would mean that future generations would not have to undertake any measures to protect their health or the environment. Nevertheless, future generations would be left with an option of being able to retrieve the spent fuel to the surface if they so wanted.

Ignoring social or possible psychosocial effects, neither alternative poses significant environmental impacts. It is hard to assess social and psychosocial effects. As long as the interim storage facilities are well managed, their impact can hardly be separated from that of the power plants. In the final disposal alternative most attention has been paid to the radiation safety of the project. Evaluations indicate that final disposal will not affect the radiation conditions of the environment or human health at any stage.

The most important environmental effects of the final disposal project seem to concern our social environment. Since this is a question of a facility that would not start operations until some twenty years hence and then operate for many decades to come, it is impossible to reliably predict the social effects of the project. Wherever it is located, the final disposal facility would have some positive socio-economic effects. According to the understanding of the present population and expert evaluations it would seem there are contradictory attitudes towards the project. Even plain fear and anxiety have been expressed. In particular, there has been much debate about the possible negative image generated by the project. Evaluations suggest that any social problems would, however, be smaller in places with existing nuclear power plants than in others. On the other hand, continued interim storage could, in time, give rise to conflicts and fears particularly among people living near such facilities.

Although the final disposal of spent nuclear fuel could be carried out using available technology, some development work is still required, for example, in canister manufacturing technology to enable production on an industrial scale industrial scale. To optimise the entire solution, it would also be worth studying different variants of the base alternative. The zero alternative does not require the development of new storage solutions.

As far as the costs are concerned, the zero alternative would be cheaper during the next few years. Nevertheless, in time the costs of continuous storage would exceed the cost of the base alternative.

At the stage of decision about the final disposal facility, the basic question is one of the present-day decision situation. A decision to implement the project does not mean that actual final disposal would start forthwith or even within the next few years. According to the plans a fairly long research period would precede actual construction work and the operations proper would start only after a couple of decades. In any case, separate safety permits will still be required to both build and operate the facility. The main question is whether to progress with preparations for final disposal: how important is it in view of the safe management of spent nuclear fuel if the decision is made to proceed with research and planning work or if the decisions are postponed?

There are currently no ways of eliminating nuclear waste entirely. It is unlikely that there will be any such means in the future either. According to present understanding nuclear waste would still remain even if some of the nuclide partitioning and transmutation methods being currently researched were to prove feasible. The requirement of nuclear energy legislation to permanently dispose of nuclear waste in Finnish ground or bedrock must therefore sooner or later be solved in one form or another. The zero alternative postpones the taking of the decision into the future.

A decision in favour of the final disposal project would mean a commitment to continue R&D along the lines of which, based on present knowledge, provide the best means for a permanent solution to nuclear waste management. The method can be further developed and improved and it is likely that the technical plans will be honed during prototype and demonstration projects that are either already running or being set up. The decision would mean that bedrock studies could effectively be continued from within the underground investigation tunnels and concentrated expressly on the bedrock of the intended final disposal site. This would enable the plans to be adapted to local conditions and any important safety issues could be taken into consideration when deciding on locating the facilities.

Apart from postponing the decision, the zero alternative would also cause serious problems in further studies. Bore holes alone are not expected to yield any major new information on the bedrock to develop the final disposal alternatives. Building a research tunnel separately from the actual site would make little sense because information is needed explicitly from the vicinity of the planned final disposal site. There is plenty of general information available on rock properties from underground tunnels in the existing rock laboratories, e.g. in Äspö, Sweden.

To summarise, in comparison of the zero alternative with the final disposal alternative on the one hand,
- storage in water pools passes the obligation for continuous supervision and maintenance to future generations
- storage in water pools offers no protection against the long-term risks arising from social circumstances
- postponing decisions will not end the conflicts relating to this issue, but even deepen them in time

and on the other hand

- the decision in respect of final disposal gives decades to further develop the final disposal method and to consider any change of plans
- all in all further work on preparations for final disposal gives future generations more freedom of choice than interrupting the preparations.

No significant impacts emerged in the environmental impact assessment of the final disposal alternatives to justify non-implementation of the project. It is therefore important to proceed to the choice of site and to detailed studies on the rock environment of the planned final disposal site from the underground research facilities.

10.3 Evaluation of alternative sites

10.3.1 Preferred properties of the final disposal site

Basis provided by the site selection process

The target schedule of site selection with interim targets is based on a government decision concerning nuclear waste management (Valtioneuvosto 1983) and on subsequent decisions by the Ministry of Trade and Industry. The idea was to choose the site on the basis of long-term characterisation programme. Long-term working was designed to ensure that when deciding the location, the decision-makers would have access to comprehensive research material helping them to assess the safety and feasibility of implementing final disposal.

In the early 1980s, there was still insufficient data available on the properties of deep bedrock. It was considered important to carry out investigations in several areas in different parts of the country to ensure the site chosen would represent typical properties prevailing in the bedrock.

It was also considered important that the suitability of the site for construction of the facility is ensured through investigations carried out at underground research facility at the chosen site. The findings of these investigations could then be used to ensure the suitability of the conditions and to plan the final disposal alternative in detail.

Chapter 1 explains the Finnish site selection process advancing in stages from extensive general reports to detailed study summaries. The general principle was that the methods became

Comparison of implementation and non-implementation

	Base alternative and derivatives	Continuation of water pool storage
A. Ethical and ecological principles		
1. Protection of man and nature	Dangerous materials are isolated in such manner that no active maintenance is required.	Dangerous materials are maintained in active operation, separate from nature and man.
2. Protection of future generations	Safety analyses indicate that adequate isolation shall function as long as the wastes are a danger to man or nature.	As long as the storage areas are supervised and maintained, no danger shall be posed to man and nature. Neglect of care could lead to environmental contamination.
3. Avoidance of burden on future generations	Does not require action from future generations but at the same time does not prevent it.	Continued maintenance of storage areas, supervision and renewal are relegated to future generations.
4. Safety of facilities while in operation	Safety can be guaranteed by means of strict release criteria.	Safety can be guaranteed by means of currently available principles of operation.
B. Environmental impact as assessed		
1. Effects on nature and utilization	Effects would be minimal and restricted to the immediate vicinity of the facility.	Do not deviate from present power plant -related impact.
2. Effects on land use and landscape	Requires a few dozen hectares of land. Effects on landscape quite limited.	Do not deviate from present power plant -related impact.
3. Effects on human health	Aside from possible psychosocial influence, the project has no significance in respect to human health. The effect of stress would evidently be the most minimal in the current power plant sites.	Does not affect human health as long as the storage areas are maintained and supervised. Neglect of care could with time also result in health risks.
4. Social effects	The project would exert positive socio-economic influence. Fears, worries, contradictions and image problems would be at their minimum at the power plant sites	No substantial positive impact. Concern for the condition of storage areas as well as their maintenance could, with time, result in social conflicts.
C. Technical implementation		
1. Technical development level	Does not require the development of new technical methods, but room is allowed for procedural development and optimization.	The technology is available in Loviisa and Olkiluoto.
2. Disposal site: readiness for selection	The investigations required in respect to site selectionare, in the main, complete and allow assessment.	The current storage sites are appropriate for the purpose.
3. Costs	Costs are moderate and they have been anticipated in the price of electricity.	Cheaper than the base alternative, but over the long term the uncertainty of financing rises.

increasingly more detailed as the number of subjects being investigated decreases and the area becomes smaller. Assessment and selection of candidate sites for the next stage and further studies was based on data obtained at different stages of investigation and on the safety analyses and technical plans drafted on the basis of this data.

The site selection process was based on regional screening investigations covering the whole country in 1983–1985. These investigations assessed geological suitability by e.g. the following factors taking international recommendations into consideration (Salmi et al. 1985):

- Topography revealing the fracturing of the bedrock, significant with respect to the hydraulic gradient causing the movement of groundwater. Finnish topography is predominantly gently sloping.

- Stability of the bedrock influencing the steadiness of the waste packages in the bedrock. The Fennoscandian shield is calm as far as earthquake activity is concerned and no considerable changes are expected in the prevailing conditions. Considerable bedrock movements can be assumed to concentrate mainly on existing crush zones.

- Size, homogeneity and depth of the final disposal formation is significant in view of locating the repository. There are enough large homogenous formations to be found in the Finnish bedrock. Most large homogenous areas are found in the granitic rock type areas.

- Fracturing of the bedrock's significant in view of the hydraulic conductivity as well as the amount of groundwater flow and the flow routes. Fracturing of the bedrock also affects the possibilities to construct the underground repository within the bedrock. Investigations sought to identify the fracture zones so that these can be avoided, if necessary, when selecting locations for the final disposal repository.

- Amount and movement of groundwater is minimal in intact bedrock. Groundwater mostly moves in the crush zones of the bedrock. These should be avoided in site selection.

- Natural resources could be important with respect to future use of the area. Certain Finnish rock types contain more ore minerals and are therefore more potential for exploration and mining activities in the future. A large groundwater deposit that can be used to provide for the water supply also comes under natural resources.

Initially, attention was paid to the structure of the bedrock and especially to the avoidance of large crush zones or other fractures when selecting areas for investigation. At this stage environmental factors were also examined and were found important when considering the suitability of the location (Äikäs 1985). The use of land and land-use plans in the areas screened on geological grounds were examined in order to assess the overall environmental impact. Also the transportation possibilities of spent fuel were examined from the aspect of transportation technology. Based on these reports e.g. some densely populated areas, agricultural and protected areas were eliminated from the list of candidates.

In preliminary site characterisation, borehole studies and various logging and sampling methods were used to collect information about rock types, fracturing and the groundwater. The results showed that the areas under investigation do not differ greatly from each other as regards properties. Similarly it could be concluded that there are no factors such as major crush zones in the bedrock in the areas which would be unfavourable with regard to final disposal or its long-term safety (TVO 1992b). Detailed site characterisations added to the information collected and some uncertainty factors were eliminated (Posiva 1996c, Anttila et al. 1999 a–d).

The characterisation of several areas provided and extensive evaluation basis on which to build safety analyses and technical plans for the base alternative. Investigations ensure that the bedrock at all site options consists of typical Finnish bedrock. There is minimum variation in properties between the site alternatives and in some cases the variation within one site is comparable to variation between different sites.

Ideas concerning the preferred properties of the bedrock have developed during the years with the site selection research and safety analyses carried out in different countries. The site selection process can, with good reason, be considered a kind of learning process continuously changing and developing the understanding of bedrock properties and their significance to the final disposal system. This process has enabled the base alternative to be constantly developed, evaluating at the same time also the significance of the remaining uncertainties.

General criteria and recommendations for site selection

Bedrock properties

The purpose of the final disposal implemented in keeping with the base alternative is to isolate the spent fuel permanently from organic nature and to store it in a geological environment where the changes are minimal and take place very slowly and predictably compared to the conditions prevailing on the earth's surface. A thick layer of hard crystalline bedrock would not only isolate the spent nuclear fuel from organic nature but also protects the final disposal system from external effects and prevents the copper canisters from breaking long into the future. A thick layer of bedrock also shields against all direct radiation to the earth's surface. Ultimately, the task of the bedrock is to prevent the release of nuclear substances from their final disposal depth even though some of the canisters might get broken for some unexpected reason and the spent nuclear fuel come into contact with the groundwater.

A final disposal system like the base alternative based on a multibarrier principle can be adapted for implementation in many geological formations. For this reason no detailed criteria should be placed in advance on the bedrock properties of the disposal site. General criteria concerning the bedrock properties in respect of the selection of a disposal site were developed already in the late 1970s and 1980s (NEA 1977, DOE 1982, IAEA 1989 a–b). These have been used when studying the suitability of the Finnish bedrock for final disposal and when planning studies for the selection of the disposal site. International recommendations such as the IAEA's "Siting of Geological Disposal Facilities" (IAEA 1994) provide general guidelines on the level and quality of information needed during the different phases of characterisation and on the factors that should be taken into account during the site selection process. The geological criteria of these guidelines are much the same as earlier ones. Anttila (1995) has gone through the guidelines for the selection of the final disposal site. The most significant changes as compared to earlier guidelines deal mainly with the consideration of the factors concerning environmental and social effects. The Swedish Nuclear Fuel and Waste Management Company (SKB) also developed some guidelines in Sweden concerning site selection (SKB 1998).

In Finland the criteria concerning the properties of the disposal site were recorded in the Council of State's decision on the safety of the final disposal of spent nuclear fuel (Valtioneuvosto 1999).

The safety regulations are based on the fact that *"the geological characteristics of the disposal site shall, as a whole, be favourable for the isolation of the disposed radioactive substances from the environment. An area having a feature that is substantially adverse to safety, shall not be selected as the disposal site"*. Favourable conditions mean stable mechanic and chemical conditions, where technical barriers perform efficiently and retain their performance as long as possible. The bedrock also works as a barrier by preventing and retarding the radioactive substances possibly released from the deep repository.

Factors indicating the unsuitability of a final disposal site could include the proximity of exploitable natural resources, unusually high rock stress, seismic or tectonic anomalies and exceptional values in ground-water characteristics (STUK 1999).

Another condition for a suitable disposal site mentioned in the safety regulations is the requirement that the final disposal repository could be built so deep in the bedrock that the effects of superterranean events, operations and changes of conditions on long-term safety are minimal. Human intrusion into the final disposal facilities should also be made as difficult as possible.

The safety regulations require that the long-term safety of final disposal should be based on multiple barrier system. In this way, if one barrier fails or a predictable geological change takes place, this does not jeopardise long-term safety. This means that site properties should not only be considered from today's perspectives. Climatic changes tens of thousands of years hence may also cause changes deep down in the bedrock. These changes can affect the flow conditions of groundwater, groundwater chemistry and rock movement.

Other properties

Other properties relating to the site largely relate to project feasibility. Site property recommendations can be applied provided that the site alternatives otherwise meet the requirements of the safety requirements above.

As regards feasibility, it would be useful if the final disposal facility can be based on the existing infrastructure and other services at the disposal site and the surrounding area. Public discussion about site selection also favours nuclear power plant areas as the most suitable sites to construct the final disposal facility.

In Finland, under the Nuclear Energy Act, the final disposal facility requires the Council of State's decision in principle. For the government's decision, it is essential for the municipality concerned to accept location of the final disposal facility in its area. Decision-making highlights the acceptability of the project by the local community and the acceptability of the social effects of the final disposal facility. This is considered as meaning that the project should bring overall benefits to the area, whereas the negative social effects would be minimised (IAEA 1994).

10.3.2 Assessment criteria for the suitability of the disposal sites

Site selection is a research and investigation process aimed both at locating a site fulfilling the safety and environmental criteria and site assessment. Besides the geological conditions related to long-term safety, the aspects related to implementation of the final disposal facility must be considered during the site selection and evaluation process. Local support for the project is one of the essential factors in view of the implementation.

The most important criteria relating to site selection are presented below. These are not listed in any order of importance. Nevertheless, it is obvious that long-term safety and local acceptance of final disposal are prominent in the ranking order.

Long-term safety

- A stable geological environment enables the base alternative to be implemented in the manner planned. Larger crush zones or exploitable ore or mineral deposits should not appear at the disposal site. In this kind of environment hydrogeological and geochem-ical processes take place slowly and so that the change factors affecting them are sufficiently well understood.

- A suitable geochemical environment where the engineered barriers retain their special properties for as long as possible. This kind of environment is characterised by conditions free from oxygen, low Eh value, pH value near neutral and low sulphide concentration. The salinity of the groundwater must not be too high (TDS-value below 100g/l).

- A suitable hydrogeological environment where the groundwater circulation is sufficiently low around the final disposal canisters. This kind of environment is characterised by a small hydraulic gradient and low hydraulic conductivity value.

- A suitable rock mechanical environment where the repository can be located deep enough in the bedrock. This kind of environment is characterised by sufficiently low rock stress and also by the ratio between the rock stress and the strength of the rock type.

Constructability

- A suitable rock mechanical environment where the repository can be built by normal construction methods and the stability of the underground facility is good without any special measures. This kind of environment is characterised by the fact that a sufficient amount of the rock type of suitable rock classification is to be found in the depth planned so that disposal tunnels can be built at this depth.

With the rock type of the lower rock classification the construction and operation of the repository require special measures, reinforcing and grouting. These could cause additional uncertainty in assessing the long-term safety. At worst, the stability problems of the rock could prevent final disposal if even a variant of the base alternative cannot be implemented owing to the tendency of the tunnels or disposal holes to collapse.

- The flexibility in positioning the repository, meaning that with the aid of further characterisation it is possible to find a rock type suitable for excavation and final disposal so that disposal tunnels can be located in a bedrock volume classified suitable for construction.

Possibilities to expand the repository

The repository would need to be expanded in anticipation of handling and final disposal of larger amounts of spent fuel than expected from the present power plant units.

Present research findings obtained from the ground surface should enable characterisations of larger rock volumes and make it possible to find the rock type needed for any enlargement

Operation of the final disposal facility

As far as the encapsulation plant is concerned the operational safety depends more on the design and construction rather than the properties of the site. It should be possible to plan and build the plant and to operate it at the site so that it complies with the safety requirements provided by statutes and regulations. The safety risks of the use of repository are linked to the criteria presented above in the constructability aspects described earlier.

The transport of spent fuel forms an integral part of the operational (final disposal) phase. Transport safety essentially depends upon the transport casks. Site alternatives affect the transport need and forms.

Social acceptance

The objective is to minimise or mitigate any contradictions or conflicts caused by the project to an acceptable level. This is best achieved when characterisation confirming the site properties, construction work and the operation and decommissioning of the final disposal facility can be implemented in cooperation with the municipality concerned and its residents.

Land use and environmental loading

The facility needs a land area with proper plans in view of its future operation. The land area cannot be used for any other purposes. Traffic and transport to the facility add to present environment loading.

Infrastructure

The final disposal facility needs practical traffic connections, municipal engineering and industrial services.

Costs

The construction and operating costs of the facility (including transport) vary according to location. A crucial factor when evaluating costs is the uncertainty concerning the underground final disposal repository.

10.3.3 Assessment of the alternatives

The suitability of the site alternatives for the final disposal facility according to the assessment criteria presented above is examined below.

Long-term safety

Present characterisation from ground surface and the safety analysis indicate that final disposal can be implemented in the bedrock of the four sites (Vieno & Nordman 1999, Anttila 1999 a-d). Rock volumes applicable for final disposal can be shown to exist in the bedrock all the areas.

Studies on groundwater chemistry show that the stable geochemical conditions prevail at the planned final disposal depth in the bedrock in all the areas. This means that the conditions exist for the engineered barriers to maintain their performance and that they will function as planned. Groundwater deep in the bedrock is reducing and contains no oxygen.

At Olkiluoto and Hästholmen groundwater deep in the bedrock is saline, but fresh in Kivetty and at Romuvaara. Observations of the isotope composition of saline groundwater indicate that the groundwater in question does not interact with the meteoric groundwater circulation. Salinity does not jeopardise the safety of final disposal as long as it remains well below a level of 100 g/l (TDS) at the final disposal depth. High salinity can limit the disposal depth of the repository at Hästholmen and Olkiluoto. In addition, salinity must be taken into consideration when selecting the backfill materials. On the other hand, salinity and the coastal location mean that it is extremely unlikely that deep groundwater would be used for household water, because the use of saline groundwater for household water is normally out of the question.

Exceptionally high pH values (pH 10) were measured in the samples taken at Romuvaara, where dikes of a basic rock type occur locally. Also the sulphide content of these samples is slightly higher than normal (3 mg/l). Rather high sulphide contents (2–3 mg/l) were measured also at Olkiluoto. This is probably due to the solubility limitation of iron, in other words iron sulphide does not precipitate as pyrite.

The hydraulic gradient affecting the groundwater flow is rather small in Finnish conditions and the areas studied do not deviate from the typical conditions in that respect. In coastal areas such as Olkiluoto and Hästholmen, the gradient is more favourable compared to Kivetty or Romuvaara, but continuous isostatic uplift will result in the coastline moving further away from where it is today and the conditions between these two areas will become similar.

Measurements indicate that the hydraulic conductivity of the bedrock affecting groundwater flow varies little between the different areas. A slightly greater than average hydraulic conductivity is more typical for the rapakivi granite at Hästholmen than for the bedrock in the other areas. On the other hand there are only few fractures conducting water well and these can mostly be taken into consideration when positioning the tunnels and disposal holes.

Taking into account long-term changes in the prevailing conditions, no considerable differences are expected between the alternative sites. Before the start of the next ice age, the continuous uplift in groundwater conditions will cause changes in the bedrock at Olkiluoto and Hästholmen, which are on the coastline, in a different manner than in the bedrock at Kivetty and Romuvaara, which are inland. At Olkiluoto and Hästholmen changes in groundwater conditions are largely linked to changes in the depth relations of fresh and saline groundwater. These changes should be considered in the positioning the final disposal repository and planning the disposal depth.

During the ice age the conditions will remain more or less the same in all areas for very long periods and the uncertainties associated with these conditions are similar in all areas.

Findings show that no ore deposits are located in any of the studied sites or in the immediate vicinity. The bedrock in all areas consists of the commonly found rock type not used for any particular purpose. For this reason the chances of disturbance or unintentional human intrusion are small in all areas.

Constructability

On the basis of the site characterisation carried out at Hästholmen, Olkiluoto, Romuvaara and Kivetty and the technical plans made for final disposal, it would seem the final disposal facility with its deep repository could be built in all areas in line with the base alternative. The study findings (Anttila et al. 1999 a–d) indicate that rock suitable for the construction is generally found in the bedrock of the sites. This would enable the final disposal repository to be positioned at the planned depth of 400–700 meters at one or more levels.

The final disposal repository could be built in all four sites using normal methods currently in use. Local bedrock structure can be taken into consideration in all areas by dividing the final disposal repository into numerous different parts or by locating the facilities at two levels if necessary.

Mica gneiss is found at Olkiluoto and Romuvaara. At greater depths (600–700 metres) increasing rock stress state might require major steps to reinforcement when constructing and operating the repository. In these areas, rock stress and strength require more detailed further investigation. In rock stress state at Hästholmen, there is a significant anisotropy between the principal stresses. This must be considered when planning the underground excavations and orienting the tunnels.

At Olkiluoto and Hästholmen, flexibility in locating the final disposal facilities is somewhat restricted by the occurrence of saline groundwater. Detailed further studies on the occurrence and properties of saline groundwater are needed.

Possibilities to expand the final disposal repository

It would be possible to enlarge the repository in all areas. If the volume of spent nuclear fuel increases than at present, further investigations can locate more rock volume suitable for the construction of final disposal tunnels. At coastal sites the positioning of the underground galleries was based on the presumption that the disposal tunnels are not constructed outside the shoreline. At Hästholmen in Loviisa, enlargement would require the excavation of additional space under the mainland instead of Hästholmen island. At Olkiluoto, the repository could be extended both to the west and to the east from the central part of the island.

Operation of the final disposal facility

The final disposal facility is planned, constructed and operated so that it complies with the requirements provided by statutes and regulations. According to the safety analysis (Rossi et al. 1999) the encapsulation plant planned for implementation of the base alternative meets safety requirements. As far as safety is concerned, the properties of the disposal site do not play a significant role during the operation of the plant. Safety depends on the design and technical solutions of the plant. Although the number of inhabitants and nature of the candidate municipalities vary, the safety regulations are so strict that the releases of radioactive substances are insignificantly small in all municipalities.

Its corrosion qualities mean saline groundwater must be considered separately in the repository. At Olkiluoto and Hästholmen the underground systems must be fitted with corrosion resistant materials.

According to the transport report (Jakonen et al. 1998) and safety analysis (Suolanen et al. 1999) spent nuclear fuel can be safely transported between the interim storage facilities of Olkiluoto and Hästholmen and the alternative sites for final disposal. The construction of totally new transport routes is not needed in principle. Some stretches of roads might have to be improved or bridges strengthened.

As regards transport, the site alternatives are in a different position. If final disposal took place at Olkiluoto, the transport needed would be least in the present nuclear power plant situation, since the majority of the spent fuel is already at Olkiluoto. Transport between Hästholmen and Olkiluoto can be carried out using the most suitable method, i.e. transportation by sea, land or rail or a combination of these three. If the final disposal site were located at Hästholmen, slightly more transports would be required than for Olkiluoto.

The radiation from radioactive substances during the transportation would cause no significant health effects to the public. Theoretical risks are fewest in sea transport because there are less people along the route. There are most people along the road transport routes. Accidents damaging the transportation casks are extremely unlikely. Even if a cask were damaged, the health risk would be minimal due to transportation cask structure and the provision for accidents. In the event of accident, the health risks are lowest in connection with sea transport, because the sea would dilute any releases.

Spent fuel has been transported safely for several decades in the world and in Finland, too, for over ten years. Although technical and safety studies prove that the transport is rather safe, people believe, however, that the transportation of nuclear fuel increases the safety risk considerably.

On the one hand the residents of Kuhmo and Äänekoski in particular, consider transportation susceptible to sabotage, errors and especially road accidents due to the long distances involved. On the other hand, the inhabitants of Loviisa and Eurajoki consider transportation as rather safe. Since transportation of spent nuclear fuel would not start until at least 2020, it is difficult to predict how people will react to it at that time.

Social acceptance

Generally speaking, the environmental impacts of the final disposal facility on the social structure are similar in all the alternative sites. On a local level, the final disposal facility would have a positive effect on employment and benefit local business and municipal economy. Estimates as to the significance of the effects vary according to the assumptions used. The effect on employment is likely to be greatest in Kuhmo and smallest in Eurajoki. Because the effects would not be felt until far into the future they would, therefore, ultimately depend on the many steps taken by the municipalities and business concerned to guide the direct and indirect effects and steer employees to move to the disposal locality.

On the basis of the studies and reports carried out, it has become evident that the project would cause considerable benefits to Eurajoki, Loviisa and Äänekoski. Their municipal economy would clearly benefit from the final disposal facility. Changes in the population, and changes in general, as compared to the present situation would be smallest in the power plant municipalities. Special arrangements or changes in present legislation would be needed to bring some benefits to the municipal economy in Kuhmo. Otherwise the benefit to the municipal economy of Kuhmo would remain minimal. On the other hand, it is precisely in Kuhmo that the effects on employment and the development of the population base would be greatest. This is because the town area is so large, the effects would not reach outside the district.

The reports indicate that in normal conditions the activity of the final disposal facility would probably not affect the image on the disposal site and through that on the demand of local products or on tourism. Although certain types of tourism (such as wilderness tours in Kuhmo) could, however, suffer as a result of the facility, it might generate other types of travel centred on the final disposal facility itself. Excluding Kuhmo, none of the other candidate municipalities is a tourism district or a place where a lot of image-marketed products are currently produced.

Negative images and conflicting opinions have been associated with the final disposal facility. These images and opinions are thought to influence the amenity, the interpersonal relations and through that even human health. Estimates concerning social effects represent the present state of affairs and the present attitudes and values of the local population. It is impossible to predict the significance of these factors in the future. It is unclear how people would, in fact, react in the future when final disposal becomes a more familiar and routine. Moreover, the project could be implemented in cooperation with local inhabitants and efforts made to consider any negative effects in advance and even prevent them altogether or at least alleviate them.

Reports show that negative images are often attached to the final disposal facility irrespective of where the assessor lives. The final disposal facility is often thought to erode the interest in its locality as a place to live. The effects could appear mainly through population change, people who would move in and replace those who have left the locality would not consider the image concerned as being important.

Studies show that the population of the power plant localities of Eurajoki and Loviisa reacts more positively to nuclear power and final disposal than the population of Kuhmo and Äänekoski. According to the resident poll made in Eurajoki and Loviisa the majority of the population would accept the facility. The residents of the power plant localities are used to nuclear energy and the general level of knowledge concerning nuclear energy and final disposal is higher than in other municipalities. For this reason the indirect adverse effects on some businesses or the appearance of fears and conflicts would most probably be the smallest in Eurajoki and Loviisa. Moreover, the municipality of Eurajoki has drafted a municipal strategy indicating that nuclear energy will also be a part of the future everyday life of the municipality. The town of Loviisa has started to develop future projects building heavily on nuclear energy know-how.

Land use and environmental loading

Today Olkiluoto and Hästholmen are nuclear power plant areas and have valid land use plans for this purpose. The final disposal facility does not change the use of land much during the construction and operational phase.

Kivetty and Romuvaara are forestry areas. A decision by the Metsähallitus (Forest and Park Service) has marked a small part of the potential construction area in Kivetty as recreational forest area. Construction of the final disposal facility in these areas would change the present land use of the areas and building plans for this particular purpose would have to be drafted for the areas. However, there is nothing to prevent a change in the purpose for which the land is used.

The planned final disposal facility would not cause any major restrictions on land use in the immediate vicinity. As power plant localities Olkiluoto and Hästholmen already have restrictions on land use owing to the operations of the nuclear power plants. The final disposal facility, therefore, would not result in any new restrictions.

There is, however, reason to impose restrictions on some operations in the final disposal area and its immediate vicinity during the final disposal phase and after the decommissioning. Such operations would include extensive excavation of rock and drilling deep boreholes. Such restrictions should be included in the appropriate building plan and land register.

The structures above ground and yard areas of the final disposal facility cover approximately 15 ha of land area. At Äänekoski and Kuhmo, a new road would require an additional 10 ha. At potential construction areas and new alternative road routes, there are no provincially or nationally significant natural features, Natura 2000 areas or nationally endangered species. At Kivetty and Romuvaara, the areas are more forested compared to Hästholmen and Olkiluoto, where there is also industry.

Most plants take their water from water above the groundwater table. In this respect lowering of the groundwater table caused by underground facilities would not affect plants. Groundwater-influenced natural features are so far away from potential construction areas that there would probably be no effects. There are no groundwater-influenced features at Olkiluoto.

At Kivetty the buildings would not be visible behind fully grown trees. At Romuvaara, the top of the heating plant chimney would only be visible from Särkkä esker. At Hästholmen and Olkiluoto, the buildings would be visible from the sea if there are no stretches of protective trees. In both cases the landscape is dominated by the existing power plants. If buildings near shore locations are placed behind fully grown trees, only the top of the heating plant chimney will be visible from the sea.

Surface excavation resulting in vibration, dust and noise at the construction phase would last for less than a year. Vibration and dust could be discernible at distances of 200–300 metres. At Loviisa and Eurajoki, the proximity of existing structures may require vibration monitoring. The sound of blasting could be heard one kilometre away; in sea areas as far as two kilometres away. Noise may disturb nesting birds at a distance of 100–300 metres and one kilometre away in sea areas. Excavations will not take place at night.

Blasted rock is crushed for about one month every other year. Crushing is not carried out at night. When the pile of blasted rock and crushing plant are positioned in the area correctly, buildings or local ornithological areas do not remain in noise and dust-specific locations. In Kuhmo, the buildings are situated so far away that there is no need to take noise protection into account.

Transport resulting from the plant would extend the noise zone relevant to roads on the Olkiluodontie road in Eurajoki and the Saaristotie road in Loviisa by about 10 metres (from the present 40 metres to 50 metres) and on Murontie road in Äänekoski and Riihivaarantie road in Kuhmo by about 20 metres (from the current 10 metres to 30 metres). Transport on new stretches of road in Äänekoski and Kuhmo could disturb the nesting birds within a radius of 100–200 metres.

Infrastructure

According to local plans, the encapsulation plant and auxiliary premises could be located at all sites. In the present power plant areas at Olkiluoto and Hästholmen the encapsulation plant could optionally be located in connection with the interim storage facilities of spent nuclear fuel, when some of the spent fuel could be transferred for encapsulation straight from the storage facilities.

As regards the existing road network and municipal engineering, the plant could utilise the solutions made for the nuclear power plant at Olkiluoto and Hästholmen and the services already available in the area. At Romuvaara the final disposal facility would be fully independent and all operation units would be built for it separately. At Kivetty it is moreover possible to use the municipal engineering of the town of Äänekoski.

Costs

Considering the uncertainties associated, there is little difference between the alternative sites in the cost of the final disposal solution implemented in accordance with the base alternative. This is mainly due to the uncertainty of the construction costs of the underground repository system in view of e.g. the length of the central tunnels. Some savings could be achieved at

Olkiluoto and Hästholmen where the final disposal facility could make use on the existing infrastructure. On the other hand, the salinity of the groundwater can correspondingly result in additional costs compared to other localities because of the more expensive material demands due to corrosion factors.

10.3.4 Summary

Assessment indicates that the environmental impact of the final disposal facility will be minimal in all candidate municipalities. Generally speaking, the disposal municipality and its population will benefit economically from the facility. The changes as compared to the present situation would be least in Eurajoki and Loviisa, where the areas of Olkiluoto and Hästholmen are in nuclear power plant use and the operation of the nuclear power plants plays a major role in the everyday life of the population.

In Kuhmo and Äänekoski the facility would cause a change as compared to the present situation. On the other hand, Äänekoski is already now an industrial locality and the final disposal facility does not differ greatly from any other industry. In Kuhmo, however, there is comparatively little industry.

The conflicts related to final disposal could deepen the gulf between the opponent and proponent factions of the population in Kuhmo and, to an extent, also in Äänekoski. Nevertheless, it is obvious that especially during normal operation, people would grow accustomed to the facility, conflicts would gradually subside and no expected stress impacts would emerge.

On the whole, the residents of Eurajoki and Loviisa have a more positive attitude to final disposal. The differences of opinion concerning nuclear energy and final disposal have eased off over the years, along with the operation of the nuclear power plants and the final disposal facilities for low and medium radioactive plant waste. Nevertheless some polarisation of the population was already found earlier in the Loviisa region in relation to nuclear power issues.

11. MEASURES TO BE UNDERTAKEN AFTER EIA

11.1 Required plans, licences and decisions

The required plans, permits and related decisions (LT-Konsultit Oy 1997) to implement the project can be divided as follows:

- EIA procedure
- land use plan, or planning procedure
- decision in compliance with the Nuclear Energy Act
- transport licences
- other licences and
- international statutes

Environmental impact assessment procedure

Before applying for the licences required for the final disposal of nuclear waste, as provided by the Act on Environment Impact Assessment Procedure, an environmental impact assessment procedure of the project and its alternatives must be carried out. The procedure includes giving citizens an opportunity to express their views about the assessment programme, i.e. what alternatives or environmental impacts are to be assessed and how assessment is to be carried out.

Citizens can also express their opinion about this assessment report. The Ministry of Trade and Industry will give public notice of the assessment report and collect opinions and statements.

Planning

The planning procedure comprises two-stage consultation with citizens. During the drafting stage citizens are consulted before any binding planning decisions are made and the planning proposal is on public display once it has been almost finalised. Before any building permit can be granted a regional plan, a master plan and a building or urban plan are required. These plans must be submitted either to the Ministry of the Environment or to Regional Environment Centres.

Decisions in compliance with the Nuclear Energy Act

Under the Nuclear Energy Act, a final disposal facility for spent nuclear fuel requires three separate decisions. The first stage is to apply for a decision in principle if a final disposal facility for nuclear waste in Finland would be constructed. Before the Council of State considers the decision, a public hearing in respect of the application is organised. The Council of State requests a statement from the candidate municipalities for final disposal and from the neighbouring municipalities stated in the application, as well as a preliminary safety assessment from the Centre for Radiation and Nuclear Safety Authority (STUK). It is an absolute requirement that the statement made by the candidate municipalities gives support to the project. The Council of State's decision in principle must then be submitted for consideration by Parliament, which decides whether it will be approved or repealed as such.

Under the Nuclear Energy Act, a construction license can be applied for the final disposal facility once Parliament has approved the decision in principle for the project. By this time a plan of the area and detailed plans for the final disposal facility must be ready. Before the final disposal facility can begin to operate, under the Nuclear Energy Act a separate application must be made to the Council of State for an operating licence. When the construction or operating licence is being considered, STUK inspects the final disposal facility to ensure it fulfils the prescribed safety requirements. Final disposal of nuclear waste is completed once STUK has verified that the nuclear waste has been permanently disposed in the approved manner.

Transport licences

Under the Nuclear Energy Act, a licence is required to transport spent nuclear fuel. This licence is granted by the Radiation and Nuclear Safety Authority (STUK).

Other licences

A final disposal repository for nuclear waste and an encapsulation plant in particular require several parallel environmental licences including a building permit, environmental permit, permits granted by the Water Court to alter the groundwater environment and for the water and sewage systems. These licences are considered through their own procedure and they include the hearing procedures in compliance with the legislation concerned. To build a public road to Kivetty or Romuvaara would require ratification in line with the Road Act.

International statutes

In addition to national statutes, the final disposal of nuclear waste is also subject to several international agreements and recommendations. These agreements include the European Atomic Energy Community (EURATOM) Treaty and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, an international treaty signed in autumn 1997. Furthermore, based on the United Nations' Economic Commission for Europe, the treaty on the transboundary environmental impact assessment procedure, the environmental impact assessment phase includes international information dissemination.

Under Article 37 of the EURATOM Treaty, each Member State must submit to the Commission general information about any plans for the final disposal of radioactive waste to enable an assessment to be made of whether the plan will cause radioactive contamination of water, soil or air in another Member State's territory.

An annex to the Commission's recommendation regarding the application of Article 37 provides that each Member State inform any aspect linked to the project. The Ministry of Trade and Industry will decide on how and when notification is made.

Furthermore, in line with Article 77, the Commission is responsible for maintaining Safeguards to ensure that the spent fuel is not transferred to any location other than that notified. The International Atomic Energy Agency (IAEA) also carries out similar safeguards.

Since the ECE's Espoo Convention (Convention on Environmental Impact Assessment in a Transboundary Context, 25 February 1991) applies to the project, under Section 14 of the Act on the Environmental Impact Assessment Procedure, neighbouring states must be also notified of the project. Notification must disclose at least information about the project, information about any possible transboundary environmental impact, information about the assessment procedure and decision essential to implementation of the project. Notification should also mention a reasonable deadline by which officials, citizens or communities of neighbouring countries intending to take part in the assessment procedure should notify the Finnish Ministry of the Environment of their intention to do so. The deadline in earlier similar cases was two months.

After the project was launched, the contact authority submitted the assessment programme to the Ministry of the Environment. Sweden, Russia, and Estonia were informed that the assessment procedure was under way and provided with the entire or a partial assessment programme translated into that country's language. The Ministry of the Environment notified the neighbouring countries and enquired about their willingness to participate in the assessment procedure. Every country gave a statement about the assessment programme and expressed their desire to take a limited part in the procedure.

11.2 Environmental impact follow-up programme

Based on this Environmental Impact Assessment Report, a proposal was prepared to monitor the environmental impacts in the final disposal locality chosen.

Follow-up of impacts resulting from radiation

The follow-up of impacts resulting from radiation is based on measuring emissions and concentrations of radioactive materials and radiation dose rate. Concentration and dose rate are assessed also by calculation methods using emission and weather data. This is because it is expected that amounts of radioactive materials originating from the facility are so minute they cannot be detected in the environment. The expected radiation impacts are so small that it is not considered necessary to monitor especially the public health. Possible health detriments could not be detected among the general incidence of illness. However, if necessary, it is possible to compare the health of the population to that of the population living farther away by using, for instance, the National Public Health Institute's cancer register.

Work on monitoring the concentration of radioactive materials and radiation dose rate is to start already before final disposal operations to obtain comparative information for various directions and distances. Concentrations will be measured from the air, water, soil, organisms, agricultural products, gathered products and game. Work will also start on collecting weather and other data necessary for calculatory assessment.

During the operational phase, emissions of radioactive materials into the environment will be measured. Typical measuring sites are ventilation air outlets and sewage discharge routes. Work already under way on measuring of concentration and dose rate will continue.

Other follow-up

The following list complements the proposal for the follow-up programme:

- measurement of natural radon gases in the facilities within the bedrock
- monitoring the groundwater surface level in the rock facility environment
- monitoring the distribution of vegetation in the areas affected by the groundwater
- measurement of surface excavation-related vibration in the buildings in the immediate vicinity of the construction site at Loviisa and Eurajoki
- sampling of effluent at the new water purification plant in Romuvaara

– follow-up of municipal image
– follow-up of fears concerning radiation
– follow-up of socio-economic impacts.

Other follow-up requirements may be determined in conjunction with considering the licences, e.g. with regard to noise and dust.

Post-sealing follow-up

Posiva will cease monitoring measurements once the facility has been sealed in the manner approved by the Radiation and Nuclear Safety Authority (STUK). During the sealing phase, Posiva will prepare a proposal for a post-sealing follow-up programme and remit once–for–all compensation to the State. The authorities will use this sum to conduct follow-up and monitoring operations as they want. Final disposal, however, must be carried out so that it is safe enough not to necessitate post-monitoring.

During the post-closure phase it is crusial to follow up how the properties of the bedrock revert to the pre-construction state. The monitoring of bedrock conditions has been discussed in several international meetings (e.g., NEA 1993, NEA 1996).

Post-closure follow-up could include measuring radioactivity on ground surface and in deep boreholes. Groundwater table levels, flow, chemistry, temperature, etc. could be monitored in holes. The incidence of micro earthquakes can be observed by geophysical measurements on ground surface. To obtain nuclear material, for instance, for terrorists would require action visible on ground surface. Such activities could be detected and monitored internationally via satellite.

12 SUMMARY

Studies of the alternatives and necessary measures for spent nuclear fuel management commenced already when the nuclear power plants were being built. The long-term R&D programme now under way is largely based on the R&D objectives stated in the decision of the Council of State made in 1983. One of the principal objectives has been to develop a concept for final disposal. Work on selecting a suitable location for the final disposal facility started in 1983 and has advanced stage by stage together with the technical planning and the safety assessment for final disposal. The candidate sites for final disposal are Olkiluoto in Eurajoki, Romuvaara in Kuhmo, Hästholmen in Loviisa and Kivetty in Äänekoski. The decision on the final disposal site should be made by the end of the year 2000. It is intended to build a final disposal facility based on verifying investigations and on detailed plans to be prepared based on the investigations in the decade beginning 2010 and to start actual final disposal operations in 2020.

The construction of a nuclear facility of public significance requires a decision in principle of the Council of State on whether the construction of the plant is in the interests of society as a whole. Before any decision can be made, the party in charge of the project must prepare an EIA report to be appended to the application for a decision in principle. An EIA procedure does not replace other required studies or licences. To make the decision, the government also obtains many other reports.

When considering an application for a decision in principle, the government requests a preliminary assessment of the safety of such a facility from the Radiation and Nuclear Safety Authority (STUK) and asks for the opinions of the candidate municipalities' councils on locating the facility in the municipality. The Council of State may only make a favourable decision if the municipality where it is intended to locate the facility approves of the facility being located in its area and if there are no other issues emerging which would make it unsafe to implement the project. The decision in principle of the Council of State must be submitted to the Parliament for ratification.

Under the Nuclear Energy Act, the nuclear waste produced in Finland "must be handled, stored, and permanently disposed of in Finland". The Nuclear Energy Decree specifies disposal in the Finnish ground or bedrock as permanent disposal. According to the Council of State's decision on the safety of final disposal, the concept must be one that requires no supervision or maintenance. Nevertheless, the final repository must be capable of being opened in the event developing technology renders it expedient. As things stand, only geological final disposal concepts based on passive safety are to be considered in respect of any decision concerning the final disposal of spent fuel or reprocessing waste in compliance with the Nuclear Energy Act. Postponing the decision would mean the continued interim storage of spent fuel for an indefinite period (the so-called zero alternative).

The EIA programme dealing with the final disposal facility for spent fuel was completed during 1997 and was submitted to the contact authority, the Ministry of Trade and Industry, in February 1998. Drafting the EIA report took into account the Ministry of Trade and Industry's requirements outlined in its statement about the EIA programme and the issues brought up by local residents at the interactive events held in the candidate municipalities.

The report also gives a general overview of such basic alternatives for the management of spent fuel, the feasibility of which is uncertain or which does not meet valid legal provisions. Ignoring the requirements of the law does not in reality increase the alternatives available almost at all. Despite R&D into nuclide partitioning and transmutation, there are no realistic alternatives to geological final disposal, in other words disposing of the waste deep in the Finnish bedrock. At the time of writing, there are no means available to completely eliminate the spent fuel or the nuclear waste accumulating from reprocessing. In practice, too, an alternative based on nuclide partitioning and transmutation would return to the zero alternative because it is impossible to assess the real technical and industrial feasibility of such a solution using existing knowledge.

Non-implementation of the final disposal facility would mean that spent nuclear fuel would continue to be stored in water pools at the nuclear power plants at Olkiluoto and in Loviisa as at present. The interim storage facilities are so designed that fuel assemblies can be stored in them for tens of years. According to the experts, there is no absolute deadline in sight for the continuation of interim storage into the indefinite future. If the project were not to be implemented, nuclear waste would not be permanently disposed of in Kuhmo or Äänekoski at the moment. The spent fuel would remain in Eurajoki and Loviisa, at least for the time being.

A decision in favour of the final disposal project would mean a continuation of committed R&D along the lines of which, based on present knowledge, provide the best means for a permanent solution to nuclear waste management. The method can be further developed and improved and it is likely that the technical plans will be honed during prototype and demonstration projects that are either already running or being set up. The decision would mean that bedrock investigations could effectively be continued from within the underground investigation tunnels and concentrate specifically on the bedrock of the intended final disposal site. This would enable the plans to be adapted to local conditions and important safety issues be taken into consideration when locating the facilities.

Detailed technical plans and assessment of the safety of final disposal have been based on the final disposal of spent fuel from existing plant units. Planning the bedrock facilities has taken into account the uncertainty relating to the length of the operating life and the properties of the fuel. Planning has also considered the possibility that new nuclear power plant units would be built in Finland and that the spent fuel from these would be finally disposed of in the same facilities. Detailed estimates have been made of the expected fuel accumulation from present facilities. The changes to environmental impacts have been identified in respect of final disposal of additional amounts of spent fuel arising from any new nuclear power units.

This report deals with the impacts on nature, the exploitation of natural resources, land use, cultural heritage, landscape, and buildings in each candidate disposal site. The superterranean structures of the final disposal facility, including yards, would require some 15 ha of land. In Äänekoski and Kuhmo, a new road would require approximately an additional 10 ha of land. There are no provincially or nationally valuable natural sites, Natura 2000 areas or nationally endangered species on the potential construction sites or where new roads would need to be built. Regional ecological links would not be broken.

Compared to Hästholmen and Olkiluoto, the areas of Kivetty and Romuvaara are heavily forested. There is also industry located in Olkiluoto and Hästholmen. Local nature sites have been identified and will be taken into account in further planning.

All in all, the impact on landscape is minimal. In Hästholmen and Olkiluoto, the buildings would be visible from the sea if they were located on the shore without being screened by trees, in which case, the present power plants would dominate the landscape.

Activities causing vibration, dust and noise can be carried out so as not to cause environmental impacts. The traffic required by the facility would widen the noise areas of the roads to some extent. Statistically, the additional traffic would have only a minor impact on municipal road accidents.

Safety analyses were used to assess the impact of the project on human health. Analyses were drawn up for the duration of the facility's operation, for spent fuel transport and for the post-closure period. A separate analysis has been carried out of psychosocial impacts.

Based on the safety analyses and other reports, the project's impact on human health would remain insignificantly small, both locally and when examined from a broader perspective. It is highly likely that no changes will ever be detected. The risk of incurring health detriments from accidents and from the uncertainties and unprecedented future events involved in the project is also estimated to remain negligible. The impacts on health conditions in the surrounding area will remain insignificant and be limited to possible psychosocial impacts.

The greatest concern expressed by the public at large is about the possible health risks resulting from any radiation of the radioactive materials in the spent fuel. However, under normal conditions the radioactive materials are tightly isolated from living nature and human life. Therefore, the main concern has focused on the consequences of various types of malfunctions and accidents and on assessing the long-term safety of final disposal.

Although various worries and fears were expressed about the transport of spent fuel, both practical experience and accident analyses show the health risk to be minimal. The risk is the smallest when the amount of transport is minimised and sea routes are used for transport. However, all in all, the risk is so minimal that the significance of the location of the final disposal site or mode of transport on health conditions or health risks is insignificantly small.

By international comparison, the safety requirements in Finland for the operation of a final disposal facility are very stringent. Radiation exposure in a facility will consequently remain insignificant in all situations. This being the case, the site location is also irrelevant from the standpoint of health risks.

The long-term safety of final disposal has been the most important starting point in planning the final disposal concept. One of the core objectives in research carried out over the past 20 years or so has been to obtain sufficient grounds on which to assess long-term safety. Safety analyses carried out indicate that the concept can adequately guarantee to protect the environment and people's health in each site as far into the future as possible detriments from the waste could ever emerge.

Differences possibly affecting long-term safety at the candidate sites can be primarily reduced to differences between coastal and inland locations. On the other hand, from the aspect of long-term safety, coastal as well as inland locations have their advantages and disadvantages, nor do safety analyses provide a sufficiently clear basis for selecting the best location. At all sites, the final disposal facility can be built so that a significant quantity of hazardous substances would never be released into living nature.

Regardless of the kinds of risks assessed in safety analyses, the project will cause fear and anxiety in certain individuals, and this can be considered an effect on health conditions. The magnitude or seriousness of these effects is, however, difficult to assess. In any case, based on the questionnaire and interview studies conducted, it is clearly apparent that their significance would probably be lower in municipalities with power plants than in Kuhmo and Äänekoski.

People's understanding and experiences of the final disposal vary quite extensively and also partially conflict with each other. The opinions refer to the environmental impacts resulting from the project and the implementation alternatives being offered. However, these opinions represent the views of the present residents of the municipalities and, as such, do not tell how the impacts experienced would be formed decades hence. On the one hand, some of the impacts are direct, i.e., generated by jobs and by investments or changes brought by physical construction. On the other hand, these changes may also include indirect impacts related to the images associated with the project. As there are no experiences about any final disposal facilities for spent fuel in Finland, or for that matter anywhere else, analogies from other institutes are bound to be insufficient. Therefore, the existence of the diverse viewpoints, various opinions and considerable uncertainties appearing in the assessments must be accepted.

The opinions of local residents are influenced by the familiarity or non-familiarity with nuclear power technology, the local job situation, general trends (economy, population), regional policy viewpoints and the compatibility of nuclear waste with the culture, nature and basis of production in the locality. The impact of jobs and purchases created by the project on employment, the population and municipal economy become proportional to the current situation, history and development forecasts in those localities.

The impacts of images associated with the project are being assessed in all localities in relation to the present situation and to the living environment. In the estimates of the residents of Eurajoki, the problems of image hardly emerged as the final disposal facility is not expected to essentially change the present situation. In Loviisa, although the importance of image is estimated on the same grounds as in Eurajoki, final disposal is estimated to strengthen the emphasis of nuclear energy in the context of municipal image, whereas present images are considered to include many other features, too. Surveys, however, show that Loviisa is well known especially because of its nuclear power plant.

The opinions of residents in the candidate municipalities vary in regard to the final disposal. Polls show that a clear majority in Loviisa and Eurajoki would be willing to accept the final disposal facility in their municipality, whereas most of the residents in Kuhmo and Äänekoski are opposed to the final disposal project. A distinct statistic variation between the opinions of men and women was noted in all municipalities. On average, men are more willing to accept disposal.

The studies carried out show that the environmental impacts in all candidate municipalities would be minimal. In general, a municipality and its residents would derive economic benefit from the facility. The facility would bring least changes to the present situation in Eurajoki and Loviisa, where the Olkiluoto and Hästholmen areas are the sites of nuclear power plants. Nuclear power plant operations are already an important factor in the life of those communities. The facility would bring a change to life in Kuhmo and Äänekoski compared to the present situation. In fact, Äänekoski already is an industrial municipality. The operation of a final disposal facility differs very little from other industrial business. But, the municipality of Kuhmo has very little industry at present.

The conflicts related to final disposal could deepen the gulf between the opponent and proponent fractions of the population in Kuhmo and, to an extent, also in Äänekoski. On the other hand, it is obvious that especially during normal operation, people would grow accustomed to the facility, conflicts would gradually subside and no expected stress impacts would emerge. On the whole, the residents of Eurajoki and Loviisa have a more positive attitude to final disposal. The differences between opinions concerning nuclear energy and final disposal have eased off over the years, along with the operation of the nuclear power plants and the final disposal facilities for low and medium level operating waste.

GLOSSARY AND ABBREVIATIONS

activation
Transform of atoms of material into radioactive, for example, when neutrons hit the atomic nuclei.

activity
The number of disintegrations occurring in atomic nuclei of radioactive material in a given time interval, expressed in becquerels (Bq). One becquerel equals a disintegration of one nucleus per second.

alpha radiation, alpha particle
Particle radiation consisting of alpha particles or helium nuclei (2 protons + 2 neutrons). Radioactive atomic nucleus emits an alpha particle and transforms into a different nuclide.

atomic nucleus
Central particle of an atom consisting of protons and neutrons.

background radiation
Natural radiation, except for that from radon.

becquerel (Bq)
Unit of activity, 1 Bq = a disintegration of one nucleus per second.

bentonite
Bentonite clay is natural clay.

beta radiation
Particle radiation consisting of electrons or positrons. A radioactive atomic nucleus emits an electron or positron transforming into a different nuclide.

biotope
Organic environments, of which the most important environmental factors are similar, belong to the same biotope or type of environment, for example, forest and swamp types.

breeder reactor
A reactor which produces more fissionable material than it consumes.

building plan
Detailed instructions concerning the use of an area other than a city municipality.

burnup
The thermal energy per fuel mass unit produced during the operation of the fuel assembly. Often expressed as MWd/kgU.

capacity coefficient
The percentage of the actual amount of energy the power plant has produced during a year of the amount of energy the power plant can produce operated at full power during one year of operation.

cladding, see fuel rod.

contamination
Radioactive impurity which can be transferred as any other impurity.

Council of State
(or Government – in Finnish: Valtioneuvosto) consists of the Prime Minister and up to 17 ministers. The term is also applied to the whole formed by the Government and ministries.

crush zone
A large, densely fractured zone in the bedrock.

criticality
Nuclear fuel (or more correctly the whole formed by the fuel itself and its surroundings) is said to be critical if one fission releases enough neutrons to produce another fission at the same time, i.e. the number of fissions in a unit of time remains constant. In subcritical fuel the number of fissions in a unit of time tends to decrease in time, in overcritical fuel the opposite occurs.

daughter nuclide
A new nuclide which is created as result of radioactive decay of a parent nuclide. The daughter nuclide can be radioactive or stable.

delayed effects
Delayed effects of radiation are cancer and hereditary detriment which can occur, with small probability, after a long period from having been ex-posed to radiation.

diffusion
Transport from one place to another as a result of random movements. In water diffusion is the transfer of matter from a region of high concentration to a region of low concentration as the result of the random thermal movements of small particles, molecules or atoms even though there is no flow of water in the direction concerned.

direct final disposal
Final disposal of spent nuclear fuel without reprocessing.

early effects
Detrimental effects of large radiation dose; will appear soon after exposure.

ECE
United Nations Economic Commission for Europe.

ecological fragmentation
Fragmentation of natural environments in which their surface area decreases and they get isolated from each other.

electromagnetic wave motion, radiation
The name and properties of electromagnetic radiation depend on the wave length. Gamma, X-ray and ultra violet radiation, visible light, infrared radiation, micro and radio waves listed from shorter to longer wave length are electromagnetic wave motion. Gamma, X-ray and short waved ultraviolet radiation are ionizing radiation.

electron
An elementary particle moving around the atomic nucleus having a negative electrical charge.

EURATOM
European Atom Energy Association of European Union. Finland is one of its members.

expectation value
The average value of a random variable. E.g. the average value of wind speed observations for the year.

fast breeder
A nuclear reactor in which fast neutrons have a significant role in maintaining a chain reaction. More fissionable material is produced than the reactor uses.

fast reactor
A nuclear reactor in which fast neutrons are not moderated and fissions are induced predominantly by fast neutrons.

fission
Splitting of a heavy atomic nucleus into two parts with a simultaneous release of fast neutrons.

fission products
Medium-sized, and generally radioactive, atomic nuclei created in a fission.

flow channel
The channel surrounding the fuel rod assembly made of metal plate with a function to direct the water flow through the bundle.

flow rate
The volume of a substance flowing through a surface per unit of time. A unit, e.g. m^3/a.

fracture zone
A zone of fractured rock in the bedrock.

fuel rod
A fuel rod is a long tight metal tube closed at its ends loaded by fuel. The tube (cladding) is of zirconium alloy. The fuel is ceramic uranium dioxide which has been made in cylindrical pellets and packed one after another inside the cladding.

fuel rod assembly
A bundle consisting of fuel rods which holds its shape due to the spacers and the end plates.

full profile boring technique
A technique enabling to bore a full-scale tunnel in a single operation.

fusion
The merging of two light atomic nuclei into a heavier nucleus.

gamma radiation
Electromagnetic radiation with a smaller wave length than X-radiation.

general shore plan
The general shore plan specifies the general guidelines for the use of the shore areas if not otherwise stipulated by a general plan in effect.

gradient
The change of a variable in relation to a very small change of place. For example, if the groundwater pressure rises steadily by 4 bars when passing from point A to point B and the distance between the points is 2 m, the gradient of the groundwater pressure is 2 bar/m in between. Groundwater flows towards the lower pressure. The lower the pressure gradient the slower the flow.

half-life
The time required for a decay of half of the same type of radionuclides into other nuclides.

high-level waste
The high-level waste contains radionuclides to the extent that special radiation protection is needed during its handling and its cooling down must be taken care of.

IAEA
International Atomic Energy Agency.

ICRP
International Commission on Radiological Protection founded in 1928 as the International X-Ray and Radium Protection Committee.

infrastructure
Infrastructure comprises e.g. roads and railroads, media, telephone and post services as well as energy and water supply facilities.

ionization
One or several electrons are loosened from the electron cloud of an atom with the result that the atom becomes electrically charged.

ionizing radiation
Electromagnetic or particle radiation causing directly or indirectly ionization.

isotope
Nuclides of the same chemical elements having different number of neutrons in their nucleus.

IVO
Imatran Voima Oy. From 1 March 1999 Fortum Heat and Power Oy (Fortum).

JYT
Publicly governed and funded nuclear waste research. Nuclear waste studies commissioned by the Ministry of Trade and Industry.

lattice
The lattice of a fuel rod assembly is its cross sectional structure (i.e. number of fuel rods and their mutual distances).

low-level waste
Handling of low-level waste does not require any special radiation protection.

master plan
General features of the use of a municipal area are outlined by master plan.

medium level waste
Medium level waste contains radionuclides to the extent that radiation shielding is required but it does not produce enough thermal energy to be especially cooled down.

Natura 2000
A network of natural protection areas in accordance with the EU directives on nature aimed especially to protect endangered, rare or characteristic natural environments, both fauna and flora.

natural radiation
Radiation from natural radioactive materials and from outer space.

natural uranium
Uranium having the isotopic composition occurring in nature.

NEA
Nuclear Energy Agency of OECD.

neutron
Electrically uncharged elemental particle, a structural part of an atomic nucleus.

neutron flux
A quantity explaining density and velocity of free neutrons.

neutron radiation
Particle radiation consisting of neutrons.

nuclear energy
Type of energy relating to the forces between the particles in an atomic nucleus

nuclear reaction
Reaction occurring in an atomic nucleus.

nuclear reactor
A device in which nuclear reactions can be maintained and controlled.

nuclide
A species of atoms or nuclei characterized by its proton and neutron number.

OECD
Organization for Economic Cooperation and Development. An organization promoting to development of international economic cooperation as well as economy. Finland is a member country.

parent nuclide
A parent nuclide of a nuclide is any radioactive nuclide which in the decay chain gives rise to a nuclide.

partial regional plan
A part of regional plan to be separately drafted.

particle radiation
Radiation consisting of particles in movement.

positron
Antiparticle to electron, positive by its electrical charge.

probability
With the probability of 1 the event is sure to occur. If the probability is, for example, 0.001 the event is not sure to occur, in other words the event occurs on the average only once if the situation could be repeated 1000 times in a similar way. With a probability of 0 the event does not occur at all.

proton
An elementary particle having a positive electrical charge, a structural part of the atomic nucleus.

radioactive
Radioactive material includes atomic nuclei which can transform or decay by themselves into other nuclei. Ionizing radiation is created (e.g. alpha, beta and gamma radiation) in a decay. See radioactivity.

radioactivity
A quality of an atomic nucleus to transform by itself into another nucleus. The radioactive nucleus may emit an alpha or beta particle transforming into another nucleus which, for its part, can emit electromagnetic radiation. The transformation is called radioactive decay.

The decay is a random phenomena so that no one can predict when a single nucleus will decay. There are, in general, a great number of similar nuclei and it can be predicted that half of them has decayed after the half-life which is characteristic to them and half of those remaining after the next half-life.

radiation dose
A quantity describing the effect of radiation. The amount of energy transferred from radiation per mass unit, unit gray (Gy) = 1 J/kg or if the biological effects are considered by a weighting coefficient, sievert (Sv) = 1 J/kg. It is often used one thousandth part of sievert i.e. mSv.

radionuclide
Radioactive nuclide.

regional plan
The regional plan contains a general plan concerning the use of the area in two or several municipalities.

reprocessing
Separation of fertile nuclides from spent nuclear fuel. Fission products and part of transuranic elements are remaining.

risk
A risk means a combination of the probability of an event and its consequences (most simply a risk = probability x consequence), in every day language often related to the probability of hazardous events.

safeguards
Supervision of nuclear technological equipment and material in peaceful use.

scenario
A postulated future. Assumptions as to certain future events and, for example, of bedrock properties in the future.

shore plan
Detailed instructions are given by a shore plan to organize recreational residence and other use for the area relating to the shore areas which are not under a town plan or a building plan in effect.

sievert (Sv)
A radiation dose unit which takes the biological effects of radiation into consideration. Usually its thousandth part, the millisievert (mSv), is used as the dose unit.

sorption
The attachment of a solute onto a solid matter. In absorption attachment takes place within the solid matter and adsorption on the surface. Substances in the groundwater can be sorbed to the rock.

spallation
E.g. a proton with high velocity collides with an atomic nucleus which results in the release of many neutrons from the nucleus.

STUK
The Radiation and Nuclear Safety Authority. The Finnish authority and expert whose principal idea of activities is to prevent and limit hazardous effects of radiation in an effective and determined manner without unnecessarily complicating the functions of society.

subcritical reactor
A subcritical reactor is a reactor where the number of free neutrons and the amount of fissions caused by them declines of its own accord unless more neutrons come from somewhere.

town plan
Detailed instructions concerning the use of an area are given by a town plan.

transmutation
In this connection, a change of long-lived radionuclides into shorter-lived or stable caused by nuclear reactions induced by neutrons.

transuranic element
An element the atomic nuclei of which consists of more protons than uranium.

TVO
Teollisuuden Voima Oy, a nuclear power company.

YJT
The Nuclear Waste Commission of Finnish Power Companies set up by Teollisuuden Voima Oy and Imatran Voima Oy in 1978. YJT has coordinated the companies' research into nuclear waste management.

REFERENCES

Ahokas, H. & Sallasmaa, O. 1998. Kalliotilojen vaikutus pohjaveden pinnankorkeuteen ja kasvillisuuteen. Helsinki, Posiva Oy. Työraportti 98-73.

Ala-Lipasti, J., Karjalainen, P. & Pohjola, J. 1999. Kuntaimagotutkimus. Helsinki, Posiva Oy. Työraportti 99-23.

Andersson, J., Ahokas, H., Koskinen, L., Poteri, A., Niemi, A. & Hautojärvi, A. 1998. A working group's conclusions on site specific flow and transport modelling. Helsinki, Posiva Oy. POSIVA 98-02.

Anttila, M. 1992. TVO:n käytetyn ydinpolttoaineen koostumus, aktiivisuus, lämmöntuotto ja muut radioaktiiviset ominaisuudet jäähtymisajan funktiona. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-92-03.

Anttila, M. 1995. Characteristics of Loviisa NPP spent fuel. Helsinki, Nuclear Waste Commission of Finnish Power Companies. Report YJT-95-21.

Anttila, M., Björnberg, M. & Vuori, S. 1999. Käytetyn ydinpolttoaineen huollon vaihtoehdot – Pitkäaikaisvarastointi ja transmutaatio. Helsinki, Kauppa- ja teollisuusministeriö. Tutkimuksia ja raportteja 10/1999.

Anttila, M., Halonen, O., Holopainen, P., Korhonen, R., Kätkä, M., Meling, K., Noro, A., Peltonen, E., Rasilainen, K., Savolainen, I. & Vuori, S. 1982. Käytetyn polttoaineen loppusijoituksen turvallisuusanalyysi. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-82-41.

Anttila, M., Halonen, O., Holopainen, P., Korhonen, R., Kätkä, M., Meling, K., Noro, A., Peltonen, E., Rasilainen, K., Savolainen, I. & Vuori, S. 1982. Käytetyn polttoaineen loppusijoituksen turvallisuusanalyysi. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-82-41.

Anttila, P. 1995. Käytetyn ydinpolttoaineen loppusijoitus – loppusijoituspaikan valintaperusteet. Helsinki. Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-95-07.

Anttila, P., Ahokas, H., Front, K., Hinkkanen, H., Johansson, E., Paulamäki, S., Riekkola, R., Saari, J., Saksa, P., Snellman, M., Wikström, L. & Öhberg, A. 1999a. Final disposal of spent fuel in Finnish bedrock - Hästholmen site report. Helsinki, Posiva Oy. POSIVA 99-08.

Anttila, P., Ahokas, H., Front, K., Heikkinen, E., Hinkkanen, H., Johansson, E., Paulamäki, S., Riekkola, R., Saari, J., Saksa, P., Snellman, M., Wikström, L. & Öhberg, A. 1999b. Final disposal of spent fuel in Finnish bedrock – Kivetty site report. Helsinki, Posiva Oy. POSIVA 99-09.

Anttila, P., Ahokas, H., Front, K., Hinkkanen, H., Johansson, E., Paulamäki, S., Riekkola, R., Saari, J., Saksa, P., Snellman, M., Wikström, L. & Öhberg, A. 1999c. Final disposal of spent fuel in Finnish bedrock – Olkiluoto site report. Helsinki, Posiva Oy. POSIVA 99-10.

Anttila, P., Ahokas, H., Front, K., Hinkkanen, H., Johansson, E., Paulamäki, S., Riekkola, R., Saari, J., Saksa, P., Snellman, M., Wikström, L. & Öhberg, A. 1999d. Final disposal of spent fuel in Finnish bedrock – Romuvaara site report. Helsinki, Posiva Oy. POSIVA 99-11.

Aronen, K. 1985. Käytetyn polttoaineen loppusijoituspaikan taloudelliset vaikutukset sijaintikunnalle. Helsinki, Teollisuuden Voima Oy. TVO-KPA-Loppusijoitus, työraportti 85-07.

Autio, J. 1990. Syväreikäratkaisun tekninen soveltuvuus TVO:n käytetyn polttoaineen loppusijoitukseen. Helsinki, Teollisuuden Voima Oy. TVO/KPA - Turvallisuus ja tekniikka, työraportti 90-17.

Autio, J. 1992. Vaakasijoitusratkaisujen tekninen soveltuvuus TVO:n käytetyn polttoaineen loppusijoitukseen. Helsinki, Teollisuuden Voima Oy. TVO/KPA - Turvallisuus ja tekniikka, työraportti 92-08.

Autio, J., Saanio, T., Tolppanen, P., Raiko, H., Vieno, T. & Salo, J-P. 1996. Assessment of alternative disposal concepts. Helsinki, Posiva Oy. POSIVA-96-12.

Birgersson, L., Skagius, K., Wiborgh, M. & Widén, H. 1992. Project alternative systems study - PASS. Analysis of performance and long-term safety of repository concepts. Stockholm, Swedish Nuclear Fuel and Waste Management Co (SKB). Technical Report 92-43.

Cramer, J. & Smellie, J. (toim.) 1994. Final report of the AECL/SKB Cigar Lake analog study. Stockholm, Swedish Nuclear Fuel and Waste Management Co (SKB). Technical Report 94-04.

Crawford, M.B. & Wilmot, R.D. 1998. Normal evolution of a spent fuel repository at the candidate sites in Finland. Helsinki, Posiva Oy. POSIVA 98-15.

DOE 1982. National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment. Public Draft. U.S. Department of Energy.

Eggert, U., Kvamsdal, O. & Johansson, A. 1987. Lager för förvaring av miljöfarliga ämnen. Svensk patentansökan. Patentverket, Patentansökningsnummer 8704781-7.

Harmaajärvi, I., Litmanen, T. & Kaunismaa, M. 1998. Ydinjätehuollon ympäristövaikutukset. Kysely Eurajoen, Äänekosken ja Kuhmon asukkaille 1996. Espoo, VTT Yhdyskuntatekniikka. Tutkimusraportti 434.

Heinonen, P., Hallila, H., Koivurinne, J., Oikarinen, A., Saarikoski, P., Salmi, O., Soinne, H. & Tanninen, T. 1997. Länsi-Suomen alueen luonnonvarasuunnitelma. Helsinki, Oy Edita Ab. Metsähallituksen metsätalouden julkaisuja 12.

Hermunen, P. 1998. Ydinjätteiden tuonti ja loppusijoittaminen. EU-oikeudellisia näkökulmia. Helsinki, Helsingin yliopisto. Kansainvälisen talousoikeuden instituutin julkaisuja KATTI 32.

Hokkanen, P. & Kojo, M. 1998. Ydinjätteiden loppusijoituksen YVA-ohjelman laadintavaiheen yleisötilaisuudet osallistumisen näkökulmasta. Tampere, Tampereen yliopisto Politiikan tutkimuksen laitos. JYT 2001 tutkimuksia, työraportti 1/1998.

IAEA 1989a. Guidance and Regulation of Underground Repositories for Disposal of Radioactive Wastes. Vienna, International Atomic Energy Agency. Safety series No 96.

IAEA 1989b. Safety Principles and Technical Criteria for the Underground Disposal of High-level Wastes.Vienna, International Atomic Energy Agency. Safety series No 99.

IAEA 1992a. Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards. Vienna, International Atomic Energy Agency (IAEA). Technical Report Series No 332.

IAEA 1992b. The Process for Selection and Characterization of Sites for Geological Disposal of Radioactive Waste, Experiences in Member Countries. Vienna, International Atomic Energy Agency.

IAEA 1994. Siting of Geological Disposal Facilities. Vienna, International Atomic Energy Agency. Safety series No 111-G-4.1.

IAEA 1996. International Basic Safety Standards for Protection against Ionizing Radiation and for Safety of Radiation Sources. Vienna, International Atomic Energy Agency. Safety Series No 115.

IAEA 1997a. Further analysis of extended storage of spent fuel. Final report of a Co-ordinated Research Programme on the Behaviour of Spent Fuel Assemblies during Extended Storage (BEFAST-III) 1991-1996. Vienna, International Atomic Energy Agency. IAEA-TECDOC-944.

IAEA 1997b. Radiation Protection Guidelines for the Environment: Principles and Concepts, A Discussion Paper, Draft from the Meeting 10–13 November 1997, Vienna, International Atomic Energy Agency.

ICRP 1991. Recommendations of the International Commission on Radiological Protection. In Annals of the ICRP, Publication 60, Vol. 21, No 1–3. Oxford, Pergamon Press.

IVA 1998. Why research on accelerato-drive transmutation technology? Proceedings from an international conference arranged by the Royal Swedish Academy of Engineering Sciences (IVA) in 1997. Stockholm.

IVO (Imatran Voima Oy) 1996. Loviisan voimalaitoksen modernisointihankkeiden ympäristövaikutusten arviointiselostus. Vantaa, Imatran Voima Oy.

IVO (Imatran Voima Oy) & TVO (Teollisuuden Voima Oy) 1978. Ydinjäteselvitys.

Jakonen, J., Lehto, H., Raekallio, M., Terävä, S., Pitkänen, R., Kuisma, A., Kähkönen, S. & Santala, J. 1998. Käytetyn ydinpolttoaineen kuljetusvaihtoehdot mahdollisille loppusijoituspaikoille. Helsinki, Posiva Oy. Työraportti 98-48.

Kala- ja Vesitutkimus Oy, Mikkola-Roos, M. & Hirvonen, H. 1996. Toukolanranta. Rakentamisen ympäristövaikutukset. Ekologinen näkökulma II. Helsingin kaupunkisuunnitteluviraston julkaisuja 1996:20.

Kankaanpää, H., Haapavaara, L. & Lampinen, T. 1999. Tutkimus loppusijoituslaitoksen vaikutuksista kuntien imagoon. Helsinki, Kauppa- ja teollisuusministeriö. Tutkimuksia ja raportteja 1/1999.

Kantola, I. 1999.Ydinjätteiden loppusijoitus yhteiskunnallisena kiistakysymyksenä. Helsinki, Posiva Oy. POSIVA 99-06.

Karvonen, E. 1997. Imagologia. Tampere, Tampereen yliopisto. Acta Universitatis Tamperensis 544.

Kattilakoski, E. & Koskinen, L. 1999. Regional-to-site scale groundwater flow in Romuvaara. Helsinki, Posiva Oy. POSIVA 99-14.

Kattilakoski, E. & Mészáros, F. 1999. Regional-to-site scale groundwater flow in Kivetty. Helsinki, Posiva Oy. POSIVA 99-13.

Kiljunen, P. 1998. Suomalaisten suhtautuminen ydinjätteisiin. Valtakunnallinen ja kunnittainen asennekehitys 1983-1997. Helsinki, Energia-alan keskusliitto Finergy. Tutkimusraportti 5.

Kivimäki, M. & Kalimo, R. 1993. Risk Perception Among Nuclear Power Plant Personnel: A Survey. Risk Analysis, Vol. 14, No 4, 421-424.

Kivimäki, M., Kalimo, R. & Salminen, S. 1995. Perceived Nuclear Risk, Organizational Commitment, and Appraisals of Management: A Study of Nuclear Power Plant Personnel. Risk Analysis, Vol. 15, No 3, 391-393.

Kivinen, K. & Turunen, J.-P. 1999. Asiantuntijaseminaarit käytetyn ydinpolttoaineen loppusijoituslaitoksen ympäristövaikutusten arvioinnista. Helsinki, Posiva Oy. Työraportti 99-13.

Koivujärvi, S., Kantola, I. & Mäkinen, P. 1998. Energia-alan sosiaalisten vaikutusten arviointi. Vantaa, Imatran Voima Oy. Tutkimusraportti IVO-A-03/98.

Koskinen, I., Niva, M. & Timonen, P. 1998. Ydinjätteen loppusijoituslaitoksen mahdolliset vaikutukset kuluttajien valintoihin ja loppusijoituspaikkakunnan tuotteiden menekkiin markkinoilla. Helsinki, Posiva Oy. POSIVA 98-17.

KTM 1997. Final Report on Publicly Administrated Nuclear Waste Management Research Programme 1994 - 1996 (JYT2). Helsinki, Kauppa- ja teollisuusministeriö. Tutkimuksia ja raportteja 22/1997.

Kuivamäki, A., Vuorela, P. & Paananen, M. 1998. Indications of postglacial and recent bedrock movements in Finland and Russian Karelia. Espoo, Geologian tutkimuskeskus. Tiedonanto YST-99.

Kukkola, T. 1999a. Loppusijoituslaitoksen normaalikäytön, käyttöhäiriöiden ja onnettomuustilanteiden määritys päästö- ja annoslaskentaa varten. Helsinki, Posiva Oy. Työraportti 99-17.

Kukkola, T. 1999b. Kapselointilaitoksen ja -prosessin kuvaus. Helsinki, Posiva Oy. Työraportti 99-29.

Kurki, O. 1995. Ydinjätteiden loppusijoittamista koskevan informaation vastaanotto ja hankinta Eurajoella, Kuhmossa ja Äänekoskella. Helsinki, Teollisuuden Voima Oy. Työraportti TIETO-95-02.

La Pointe, P. R. & Cladouhos, T. T. 1999. An overview of possible approach to calculate rock movements due to earthquakes at Finnish nuclear waste repository sites. Helsinki, Posiva Oy. POSIVA 99-02.

Laakso, S. 1999. Käytetyn ydinpolttoaineen loppusijoituslaitoksen aluetaloudelliset vaikutukset. Helsinki, Posiva Oy. POSIVA 99-05.

Lahti, V.-M. 1998. Riskiyhteiskunta vesilasissa. Helsinki, Yliopistopaino.

Lautkaski, R., Pipatti, R. & Vuori, S. 1988. Suomalaisen terveysriskit. Espoo, Valtion teknillinen tutkimuskeskus. Tiedotteita 875.

Lehto, M. 1998. Eurajokelaisten yritysten perustietoselvitys. Helsinki, Posiva Oy. Työraportti 98-78.

Leskinen, A., Paldanius, J. & Turunen, J.-P. 1997. Vuorovaikutus käytetyn ydinpolttoaineen loppusijoituksen ympäristövaikutusten arvioinnissa – Arviointiohjelman laadintavaiheen tilaisuudet. Helsinki, Posiva Oy. Työraportti 97-67.

Lidskog, R. & Litmanen, T. 1997. The Social Shaping of Radwaste Management: The Cases of Sweden and Finland. Current Sociology, Vol. 45, No 3, 59-79.

Litmanen, T. 1994. Kallion uumenissa, satojen metrien syvyydessä. Paikalliset ydinjätekonfliktit Suomessa. Jyväskylän yliopisto. Sosiologian lisensiaatintyö.

Litmanen, T. 1996a. Ydinjätteet - kiitos, ei tänne! Paikkakuntalaisten suhtautuminen ydinjätteisiin Äänekoskella, Eurajoella ja Kuhmossa. Teoksessa Konttinen, E. & Litmanen, T. (toim.): Ekokuntia ja ökykuntia. Tutkimuksia ympäristöhallinnan paikallisesta eriaikaisuudesta. SoPhi, Yhteiskuntatieteiden, valtio-opin ja filosofian julkaisuja 6, Jyväskylän yliopisto.

Litmanen, T. 1996b. Ympäristökamppailun sosiaalinen rakentuminen. Ydinjätekamppailut Kuhmossa, Äänekoskella ja Eurajoella. Sosiologia 4/96, 299-311.

LT-Konsultit Oy 1997. Käytetyn ydinpolttoaineen loppusijoituksen vaatimat ilmoitukset, suunnitelmat, luvat ja niihin rinnastettavat päätökset. Helsinki, Posiva Oy. Työraportti 97-55.

LT-Konsultit Oy 1998. Loppusijoituslaitoksen ympäristövaikutuksia. Helsinki, Posiva Oy. Työraportti 98-74.

Lunabba, R. & Vira, J. 1990. Uraanipolttoaineen jälleenkäsittelyn ja jälleenkierrätyksen tila maailmalla 1990-luvun vaihteessa. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-90-12.

Löfman, J. 1999a. Site scale groundwater flow in Olkiluoto. Helsinki, Posiva Oy. POSIVA 99-03.

Löfman, J. 1999b. Site scale groundwater flow in Hästholmen. Helsinki, Posiva Oy. POSIVA 99-12.

Marcos, N. 1996. The Hyrkkölä native copper mineralization as a natural analogue for copper canisters. Helsinki, Posiva Oy. POSIVA-96-15.

Mayer, E. & Palmu, J. 1995. Loviisan voimalaitoksen käytetyn polttoaineen varastokapasiteetin lisäys. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-95-22.

NAS 1995. Underground repository still needed despite radioactive waste processing technologies. News from the National Research Council, August 24, 1995. National Academy of Science (Luettavissa http://www.nas.edu).

NEA 1977. Objectives, concepts and strategies for the management of radioactive waste arising from nuclear power programmes. Nuclear Energy Agency, Organisation for economic co-operation and development (OECD).

NEA 1993. Long-term Observation of the Geological Environment: Needs and Techniques. Paris, Nuclear Energy Agency, Organisation for economic co-operation and development (OECD).

NEA 1996. Characterisation of Long-term Geological Changes for Disposal Sites. Paris, Nuclear Energy Agency, Organisation for economic co-operation and development (OECD).

NEA 1997. Lessons learnt from ten performance assessments studies. Working group on integrated performance assessments of deep repositories. Nuclear Energy Agency, Organisation for economic co-operation and development (OECD).

Neall, F. B. (toim.), Baertschi, P., McKinley, I. G., Smith, P.A., Sumerling, T. J. & Umeki, H. 1994. Kristallin-I results in perspective. Wettingen, National Cooperative for the Disposal of Radioactive Waste (NAGRA). Technical Report 93-23.

Niini, S., Halenius, L. & Myllyvirta, I. 1998. Loppusijoituslaitoksen vesihuollon yleissuunnitelma Romuvaaran ja Kivetyn tutkimusalueille. Helsinki, Posiva Oy. Työraportti 98-75.

Nummenpää, J. & Ollikainen, T. 1996. Loviisan kaupungin yhdyskuntaselvitys. Helsinki, Posiva Oy. Työraportti LOVIISA-96-01.

Nystedt, H. & Gango, H. 1999. Loviisan seudun yritysten perustietoselvitys. Helsinki, Posiva Oy. Työraportti 99-14.

Ollikainen, T. & Rimpiläinen, A. 1997a. Eurajoen aluekuvaus. Helsinki, Posiva Oy. Työraportti-97-14.

Ollikainen, T. & Rimpiläinen, A. 1997b. Kuhmon aluekuvaus. Helsinki, Posiva Oy. Työraportti-97-12.

Ollikainen, T. & Rimpiläinen, A. 1997c. Loviisan aluekuvaus. Helsinki, Posiva Oy. Työraportti-97-15.

Ollikainen, T. & Rimpiläinen, A. 1997d. Äänekosken aluekuvaus. Helsinki, Posiva Oy. Työraportti-97-13.

Ollila, K. & Ahonen, L. 1998. Solubilities of uranium for TILA-99. Helsinki, Posiva Oy. POSIVA 98-13.

Paananen, M., Blomqvist, R., Kaija, J., Ahonen, L., Ruskeeniemi, T., Suksi, J. & Rasilainen, K. 1998. The Palmottu natural analogue project, Progress Report 1998. Espoo, Geologian tutkimuskeskus. Tiedonanto YST-100.

Paavola, J. & Eränen, L. 1999. Käytetyn ydinpolttoaineen loppusijoituksen psykososiaaliset vaikutukset. Helsinki, Posiva Oy. POSIVA 99-04.

Paile, W., Mustonen, R., Salomaa, S. & Voutilainen, A. 1996. Säteily & terveys. Helsinki, Säteilyturvakeskus ja Oy Edita Ab.

Pasanen, T. 1998. Kuntalaispalaute käytetyn ydinpolttoaineen loppusijoituksen ympäristövaikutusten arvioinnissa: Kirjallinen palaute, pienryhmät ja lehtikirjoittelu. Helsinki, Posiva Oy. Työraportti 98-64.

Peltonen, E., Vuori, S., Anttila, M., Hillebrand, K., Meling, K., Rasilainen, K., Salminen, P., Suolanen, V. & Winberg, M. 1985. Käytetyn ydinpolttoaineen loppusijoituksen turvallisuusanalyysi – Perustapaus. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-85-22.

Pirttikoski, R. 1996. Pelko on voimaa - kahden paikallislehden mielipidepalstat ydinjätekamppailun areenoina, Kuhmolaisessa ja Sisä-Suomen Lehdessä vuosina 1987-1994 julkaistujen mielipidekirjoitusten sisällön erittelyä. Helsinki, Posiva Oy. Työraportti TIETO-96-01.

Pitkänen, P., Luukkonen, A., Ruotsalainen, P., Leino-Forsman, H. & Vuorinen, U. 1998a. Geochemical modeling of groundwater evolution and residence time at the Kivetty site. Helsinki, Posiva Oy. POSIVA 98-07.

Pitkänen, P., Luukkonen, A., Ruotsalainen, P., Leino-Forsman, H. & Vuorinen, U. 1998b. Geochemical modeling of groundwater evolution and residence time at the Olkiluoto site. Helsinki, Posiva Oy. POSIVA 98-10.

Pitkänen, P., Snellman, M., Vuorinen, U. & Leino-Forsman, H. 1996. Geochemical modelling study on the age and evolution of the groundwater at the Romuvaara site. Helsinki, Posiva Oy. POSIVA-96-06.

Ponnikas, J. 1999. Millä ehdoilla ydinjätteet meidän kuntaan? Tampere, Tampereen yliopisto, Politiikan tutkimuksen laitos. JYT2001 tutkimuksia, työraportti 1/1999.

Posiva 1996a. Käytetyn polttoaineen loppusijoitus Suomen kallioperään. Tekniikkatutkimukset vuosina 1993-1996. Helsinki, Posiva Oy. Raportti POSIVA-96-14.

Posiva 1996b. Käytetyn polttoaineen loppusijoitus Suomen kallioperään; paikkakohtaisen turvallisuusanalyysin edellytykset ja mahdollisuudet. Helsinki, Posiva Oy. POSIVA-96-16.

Posiva 1996c. Käytetyn polttoaineen loppusijoitus kallioperään. Yksityiskohtaiset sijoituspaikkatutkimukset 1993-1996. Helsinki, Posiva Oy. POSIVA-96-19.

Poteri, A. & Laitinen, M. 1996. Fracture network model of the groundwater flow in the Romuvaara site. Helsinki, Posiva Oy. POSIVA-96-26.

Poteri, A. & Laitinen, M. 1999. Site-to-canister scale flow and transport at the Hästholmen, Kivetty, Olkiluoto and Romuvaara sites. Helsinki, Posiva Oy. POSIVA 99-15.

Pääkkönen, M. 1998. Kuhmolaisten yritysten perustietoselvitys. Helsinki, Posiva Oy. Työraportti 98-50.

Raiko, E. & Nordman, H. 1999. Kemiallinen myrkyllisyys käytetyn ydinpolttoaineen loppusijoituksessa. Helsinki, Posiva Oy. Työraportti 99-18.

Raiko, H. 1996. Käytetyn ydinpolttoaineen loppusijoituksen lämpötekninen optimointi. Helsinki, Posiva Oy. POSIVA-96-03.

Raiko, H. & Salo, J.-P. 1999. Design report of the disposal canister for twelve fuel assemblies. Helsinki, Posiva Oy. POSIVA 99-18.

Reivinen, M., Freund, J. & Eloranta, E. 1996. A theoretical and numerical consideration of rock mass behaviour under thermal loading of radioactive waste repository. Helsinki, Säteilyturvakeskus. STUK-YTO-TR 112.

Ridell, H. & Raak, S. 1997. Selvitys kiinteistöjen hintakehityksestä Loviisan alueella. Helsinki, Posiva Oy. Työraportti 97-48.

Ridell, H. & Raak, S. 1998a. Selvitys kiinteistöjen hintakehityksestä ja -markkinoista Eurajoen, Kuhmon, Loviisan ja Äänekosken alueilla. Helsinki, Posiva Oy. Työraportti 98-79.

Ridell, H. & Raak, S. 1998b. Selvitys kiinteistöjen hintakehityksestä Eurajoen alueella. Helsinki, Posiva Oy. Työraportti 98-80.

Ronkainen, I. & Ukkonen, A. 1999. Käytetyn ydinpolttoaineen loppusijoitushankkeen kunnallistaloudellisten vaikutusten arviointi. Helsinki, Posiva Oy. Työraportti 99-24.

Rossi, J., Raiko, H., Suolanen, V., & Ilvonen, M. 1999. Käytetyn ydinpolttoaineen loppusijoituslaitoksen normaalikäytön, käyttöhäiriöiden ja onnettomuustilanteiden aiheuttamien säteilyannosten arviointi. Helsinki, Posiva Oy. POSIVA 99-16.

Rubbia, C., Buono, S., Kadi, Y., & Rubio, J.A. 1997. Fast Neutron Incineration in the Energy Amplifier as Alternative to Geologic Storage: The Case of Spain. CERN/LHC/97-01 (EET).

Ruokola, E. (toim.) 1994. Review of TVO's spent fuel disposal plans of 1992. Helsinki, Säteilyturvakeskus. STUK-B-YTO 121.

Russell, S. B., Goodwin, B. W., Villagran, J. E., Jensen, M. R. & Kempe, T. K. 1997. Performance assessment plan for the used fuel disposal project. Toronto, Ontario Hydro. Report 06819-REP-01200-0018-R00.

Saanio, T. & Raiko, H. 1999. Käytetyn ydinpolttoaineen loppusijoituskapseleiden palautettavuus. Helsinki, Posiva Oy. Työraportti 99-21.

Saari, J. 1996. Loviisan alueen seismisyys. Helsinki, Posiva Oy. Työraportti PATU-96-67.

Saari, J. 1997. Olkiluodon alueen seismisyys. Helsinki, Posiva Oy. Työraportti 97-61.

Saari, J. 1998. Kivetyn alueen seismisyys. Helsinki, Posiva Oy. Työraportti 98-43.

Saari, J. 1999. Romuvaaran alueen seismisyys. Helsinki, Posiva Oy. Työraportti 99-15.

Sairinen, R. 1998. Ihmisen ja luonnon välissä: SVA:n vaikeudet käytännön työssä. Alustus valtakunnallisilla YVA-päivillä 10.-11.2.1998.

Salmi, M., Vuorela, P. & Kuivamäki, A. 1985. Käytetyn ydinpolttoaineen loppusijoituksen geologiset aluevalintatutkimukset. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-85-27.

SAM 1996. An international comparison of disposal concepts and post-closure assessments for nuclear waste disposal. A report prepared by Safety Assessment Management for Atomic Energy of Canada Limited (AECL), Whiteshell Laboratories. TR-M-43.

Siitonen, M. 1996. Äänekosken Kivetyn luontoselvitys 1996. Helsinki, Posiva Oy. Työraportti PATU-96-24.

Siitonen, M. & Ranta, P. 1997a. Eurajoen Olkiluodon luontoselvitys 1997. Helsinki, Posiva Oy. Työraportti 97-66.

Siitonen, M. & Ranta, P. 1997b. Kuhmon Romuvaaran luontoselvitys 1997. Helsinki, Posiva Oy. Työraportti 97-65.

Siitonen, M., Sipari, J. & Ranta, P. 1997. Loviisan Hästholmenin luontoselvitys 1997. Helsinki, Posiva Oy. Työraportti 97-64.

Sisäasiainministeriö 1988. Yleisen pelastuspalvelun suunnittelu, ohje 1184/701/88, sarja A:26.

Sisäasiainministeriö 1997. Säteilyvaaratilanteessa tarvittavien suojelutoimenpiteiden suunnittelu ja niistä tiedottaminen, sisäasiainministeriön määräys 1/97.

Sisäasiainministeriö 1998. Toiminta säteilyonnettomuustilanteissa, ohje 10/011/98, sarja A:57.

Sjöberg, L. 1998. Avfallet är kärnfrågan. Nucleus 17, 3/98, 28-35.

SKB 1992. Project on alternative systems study (PASS) - Final report. Stockholm, Swedish Nuclear Fuel and Waste Management Co. Technical Report 93-04.

SKB 1996. Annual report. Stockholm, Swedish Nuclear Fuel and Waste Management. TR-96-25.

SKB 1998. FUD-program 98. Kärnavfallets behandling och slutförvaring. Program för forskning samt utveckling och demonstration av inkapsling och geologisk djupförvaring. Stockholm, Svensk Kärnbränslehantering AB.

Snellman, M., Pitkänen, P., Luukkonen, A., Ruotsalainen, P., Leino-Forsman, H. & Vuorinen, U. 1998. Summary of recent observations from Hästholmen groundwater studies. Helsinki, Posiva Oy. Working Report 98-44.

STM 1998. Sosiaali- ja terveysministeriön ohje ympäristövaikutusten arvioinnista annetun lain (468/94) soveltamisesta; ihmisiin kohdistuvien vaikutusten arviointi (ihmisten terveys, elinolot ja viihtyvyys).

STUK (Säteilyturvakeskus) 1997. Käytetyn ydinpolttoaineen loppusijoitusta koskeva väliarviointi, lausunto A811/17 kauppa- ja teollisuusministeriölle 31.10.1997.

STUK (Säteilyturvakeskus) 1999. Valtioneuvoston päätös käytetyn ydinpolttoaineen turvallisuutta koskevista yleisistä määräyksistä. Perustelumuistio 29.3.1999.

Suolanen, V., Lautkaski, R. & Rossi, J. 1999. Käytetyn ydinpolttoaineen kuljetusten terveysriskien arviointi. Helsinki, Posiva Oy. POSIVA 99-17.

Suunnittelukeskus Oy 1987a. Käytetyn ydinpolttoaineen loppusijoituspaikan valintaan vaikuttavien yhdyskuntarakenteellisten tekijöiden kuntakohtainen tarkastelu. Helsinki, Teollisuuden Voima Oy. TVO-Paikkatutkimukset, työraportti 87-06.

Suunnittelukeskus Oy 1987b. Käytetyn polttoaineen loppusijoituksen taloudelliset vaikutukset - Sijaintivaihtoehtona Konginkangas. Helsinki, Teollisuuden Voima Oy. TVO-Paikkatutkimukset, työraportti 87-09.

Suunnittelukeskus Oy 1987c. Käytetyn polttoaineen loppusijoituksen taloudelliset vaikutukset - Sijaintivaihtoehtona Kuhmo. Helsinki, Teollisuuden Voima Oy. TVO-Paikkatutkimukset, työraportti 87-10.

Taivassalo, V., Koskinen, L. & Meling, K. 1994. Groundwater flow analyses in the preliminary site investigations – modelling strategy and computer codes. Helsinki, Nuclear Waste Commission of Finnish Power Companies. Report YJT-94-04.

Tielaitos 1993. Asfaltti- ja murskausasemien melun leviäminen. Helsinki, Tielaitos. Tielaitoksen selvityksiä 43/1993.

Toivonen, H., Rytömaa, T. & Paile, W. 1987. Säteily, ihminen ja terveys. Helsinki, Säteilyturvakeskus ja Valtion painatuskeskus.

Toivonen, H., Rytömaa, T. & Vuorinen, A. 1988. Säteily ja turvallisuus. Helsinki, Valtion painatuskeskus ja Säteilyturvakeskus.

Tolppanen, P. 1998. Louhitun kiven käyttökohteet ja murskaus. Helsinki, Posiva Oy. Työraportti 98-40.

Tolppanen, P. & Kokko, M. 1998. Räjähdystarvikkeiden käyttö, varastointi ja kuljetus käytetyn polttoaineen loppusijoitustilojen louhinnassa. Helsinki, Posiva Oy. Työraportti 98-41.

TVO (Teollisuuden Voima Oy) 1992a. Käytetyn ydinpolttoaineen loppusijoitus Suomen kallioperään, tekniset suunnitelmat ja turvallisuusarvio. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-92-31.

TVO (Teollisuuden Voima Oy) 1992b. Käytetyn ydinpolttoaineen loppusijoitus Suomen kallioperään, alustavat sijoituspaikkatutkimukset. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-92-32.

TVO (Teollisuuden Voima Oy) 1996. Olkiluodon ydinvoimalaitoksen modernisoinnin ympäristövaikutusten arviointiselostus. Olkiluoto, Teollisuuden Voima Oy.

UNSCEAR 1993. Sources and Effects of Ionizing Radiation, UNSCEAR 1993 Report to the General Assembly, with Scientific Annexes. New York, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

UNSCEAR 1994. Sources and Effects of Ionizing Radiation, UNSCEAR 1994 Report to the General Assembly, with Scientific Annexes. New York, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

UNSCEAR 1996. Sources and Effects of Ionizing Radiation, UNSCEAR 1996 Report to the General Assembly, with Scientific Annexes. New York, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Uudenmaan ympäristökeskus 1997. Uudenmaan ympäristöohjelma 2005. Tampere, Tammer-Paino.

Wahlström, B. 1994. Säteileekö? Säteilytietoa arkikielellä. 3. painos. Loviisa, Itä-Uudenmaan Paino Oy.

Valtioneuvosto 1983. Valtioneuvoston tekemä periaatepäätös ydinjätehuollon tutkimus-, selvitys- ja suunnittelutyön tavoitteista. 10.11.1983.

Valtioneuvosto 1991a. Valtioneuvoston päätös ydinvoimalaitosten turvallisuutta koskevista yleisistä määräyksistä. 395/1991, 14.2.1991.

Valtioneuvosto 1991b. Valtioneuvoston päätös ydinvoimalaitosten turvajärjestelyjä koskevista yleisistä määräyksistä. 396/1991, 14.2.1991.

Valtioneuvosto 1991c. Valtioneuvoston päätös ydinvoimalaitosten valmiusjärjestelyjä koskevista yleisistä määräyksistä. 397/1991, 14.2.1991.

Valtioneuvosto 1991d. Valtioneuvoston päätös ydinvoimalaitosjätteiden loppusijoituslaitoksen turvallisuutta koskevista yleisistä määräyksistä. 398/1991, 14.2.1991.

Valtioneuvosto 1999. Valtioneuvoston päätös käytetyn ydinpolttoaineen loppusijoituksen turvallisuudesta. 25.3.1999.

Varis, J. 1999. Äänekoskelaisten yritysten perustietoselvitys. Helsinki, Posiva Oy. Työraportti 99-10.

Vesterbacka, K. & Arvela, H. 1998. Käytetyn ydinpolttoaineen loppusijoituslaitoksesta ympäristöön pääsevän luonnon radonkaasun aiheuttamat säteilyannokset. Helsinki, Posiva Oy. Työraportti 98-62.

Vieno, T., Hautojärvi, A., Koskinen, L. & Nordman, H. 1992. Käytetyn ydinpolttoaineen loppusijoituksen turvallisuusnanalyysi TVO-92. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-92-33.

Vieno, T. & Nordman, H. 1996. Interim report on safety assessment of spent fuel disposal, TILA-96. Helsinki, Posiva Oy. POSIVA-96-17.

Vieno, T. & Nordman, H. 1999. Safety assessment of spent fuel disposal in Hästholmen, Kivetty, Olkiluoto and Romuvaara, TILA-99. Helsinki, Posiva Oy. POSIVA 99-07.

Viinikainen, T. 1997. Käytetyn ydinpolttoaineen loppusijoituksen sosiaalinen ulottuvuus, Väliraportti. Helsinki, Posiva Oy. Työraportti 97-59.

Viinikainen, T. 1998. Käytetyn ydinpolttoaineen loppusijoituksen sosiaaliset vaikutukset kuntalaisten näkökulmasta, Haastattelututkimus. Helsinki, Posiva Oy. POSIVA 98-16.

Voutilainen, A. 1998. Käytetyn ydinpolttoaineen loppusijoituspaikkavaihtoehtojen ympäristön radioaktiiviset aineet ja ionisoiva säteily. Helsinki, Posiva Oy. Työraportti 98-63.

Vuori, S. 1996. Käytetyn ydinpolttoaineen suoraan loppusijoitukseen ja jälleenkäsittelyyn perustuvien huoltovaihtoehtojen säteily- ja ympäristöturvallisuus. Helsinki, Kauppa- ja teollisuusministeriö. Tutkimuksia ja raportteja 8/1996.

Vuorinen, U., Kulmala, S., Hakanen, M., Ahonen, L. & Carlsson, T. 1998. Solubility database for TILA-99. Helsinki, Posiva Oy. POSIVA 98-14.

YEL 1987. Ydinenergialaki 11.12.1987/990.

Yli-Kokko, P. (toim.) 1991. Kokkolakuva, raportti Kokkolan kaupungin kuntakuvasta ja sen tutkimuksesta. Jyväskylän yliopiston täydennyskoulutuskeskuksen tutkimuksia ja selvityksiä 10/1991.

Yrjölä, R. 1997. Eurajoen Olkiluodon, Kuhmon Romuvaaran, Loviisan Hästholmenin ja Äänekosken Kivetyn linnustotutkimus 1997. Helsinki, Posiva Oy. Työraportti 97-44.

Åberg, J. & Viinikainen, T. 1998. Matkailijoiden suhtautuminen käytetyn ydinpolttoaineen loppusijoitukseen. Helsinki, Posiva Oy. Työraportti 98-01.

Äikäs, T. 1985. Käytetyn ydinpolttoaineen loppusijoituksen aluevalintatutkimusten ympäristötekijöitä koskevat selvitykset. Helsinki, Voimayhtiöiden ydinjätetoimikunta. Raportti YJT-85-28.

Äikäs, T. A. 1997. Imagodiskurssit ja kaupunki - käsitekritiikkiä ja kaupunkisuunnittelun uudet työkalut. Yhteiskuntasuunnittelu 4/97, 4-16.

Öhberg, A. 1992. WP-Cave-ratkaisun tekninen soveltuvuus TVO:n käytetyn polttoaineen loppusijoitukseen. Helsinki, Teollisuuden Voima Oy. TVO/KPA - Turvallisuus ja tekniikka, työraportti 90-23 rev. 1.

APPENDIX 1

Statement by the Ministry of Trade and Industry (KTM) on the environmental impact assessment programme in respect of the final disposal facility for spent nuclear fuel

KTM 1/815/98
24.6.1998

Posiva Oy submitted to the Ministry of Trade and Industry an environmental impact assessment programme in respect of the final disposal facility for spent nuclear fuel in accordance with the Act on Environmental Impact Assessment Procedure (EIA Act). Under the EIA Act, the Ministry of Trade and Industry acts as the contact authority in the assessment procedure. Posiva Oy prepares the environmental impact assessment report on the basis of the assessment programme and the statement thereon issued by the contact authority. The procedure continues with public proceedings of the assessment report.

Under the Nuclear Energy Act, the final disposal facility for spent nuclear fuel requires a decision in principle of the Council of State. The environmental impact assessment report is appended to the application submitted to the Council of State for a decision in principle.

Body responsible for the project

The body responsible for the project is
Posiva Oy
Mikonkatu 15 A
00100 Helsinki.

Owned jointly by Teollisuuden Voima Oy and Imatran Voima Oy (Fortum Power and Heat Oy since 1 March 1999), Posiva Oy is principally responsible for the research, planning and execution of the final disposal of spent nuclear fuel generated by the two companies mentioned.

Project

The purpose of the project is the final disposal of spent nuclear fuel from Finnish nuclear power plants, in other words permanent disposal deep in the Finnish bedrock. The final disposal facility will comprise an encapsulation plant and auxiliary premises built above ground and a subterranean final disposal repository to be excavated at a depth of 300–700 metres in the bedrock. Final disposal operation would require an area of about 40 ha above ground. Additionally an approximately 20-metre wide road area and a strip 30 metres wide maximum should be reserved for power lines.

The assessment programme presents the environmental impacts of the project to be assessed in the EIA procedure when the final disposal facility is dimensioned for the spent nuclear fuel from existing nuclear power plants in Finland. In the basic case, this would involve a maximum of around 2,600 tonnes of uranium, which is equivalent to the volume of fuel accumulating at existing nuclear power plants in Finland during 40 years of operation. Moreover, a case is outlined involving a maximum of 4,000 tonnes of uranium to be finally disposed of, equivalent to 60 years of operation by existing nuclear plant. Technical planning of the final disposal facility also took into account use of the facility for the disposal of spent fuel from any new nuclear power plants built in Finland.

The assessment programme presents four candidate locations for examination under the EIA procedure:

1. the municipality of Eurajoki, where the final disposal facility would be sited in the central part of Olkiluoto island. The encapsulation plant could either be located within the existing power plant area or in the final disposal area.
2. the town of Kuhmo, where the final disposal facility and encapsulation plant would be sited at Romuvaara, 20 km to the northeast of the centre of Kuhmo.
3. the town of Loviisa, where the final disposal facility would be sited on Hästholmen island and partly in the bedrock at Källaudden. The encapsulation plant would be sited within the existing power plant area on Hästholmen island.
4. the town of Äänekoski, where the final disposal facility and encapsulation plant would be located at Kivetty, in the northern part of Äänekoski.

Posiva Oy's operations programme is committed to choosing a site for the final disposal facility during the year 2000. Work on building the facility is scheduled for the decade beginning 2010, with final disposal commencing in 2020. The extent and duration of final disposal depend on the amount of fuel involved.

The EIA procedure also examines the mode of transport and route options for the transport of spent nuclear fuel. The final mode of transport and routes will be chosen once the plant begins operations in line with the transport equipment and routes available when the time comes.

Contents of the assessment programme

The environmental impact assessment programme for the final disposal facility for spent nuclear fuel contains a description of the project, an examination of the project alternatives, a review of the licences and plans required by of the project, a description of the environmental impacts studied, a review of earlier environmental impact studies carried out, an information plan and a schedule for projects and the assessment procedure. The body responsible for the project specifies the assessment methods used and areas of impact to be studied during the assessment procedure. The assessment programme deals with the construction and operating phases of the encapsulation plant, the investigation shaft and final disposal repository and the long-term safety subsequent to sealing and the transport and transfer of spent fuel in connection with final disposal.

Status of the environmental impact assessment procedure in decision-making concerning final disposal in accordance with the Nuclear Energy Act

Under the provisions of Nuclear Energy Act (990/1987), a generator of nuclear waste shall be responsible for all steps relating to nuclear waste management and for the preparation thereof and shall also be responsible for the costs of nuclear waste management. The Act considers spent nuclear fuel as nuclear waste.

Under the 1994 amendment to the Nuclear Energy Act, nuclear waste produced in Finland must be handled, stored and finally disposed of in Finland.

In Finland, the outlines, interim objectives and schedule of the programme aimed at choosing a site for final disposal were originally defined in a decision in principle of the Council of State on the objectives of nuclear waste management, investigation and development on 10 November 1983. Since the entry into force of the present Nuclear Energy Act, decisions by the Ministry of Trade and Industry (7/815/91 KTM and 11/815/95 KTM) have legally bound Teollisuuden Voima Oy and Imatran Voima Oy to the objectives contained in the decision in principle. In keeping with these decisions, the power companies should carry out a research programme aimed at final disposal of nuclear waste in the Finnish bedrock. This programme should progress so that a site on which to build the final disposal facility, if required, has been studied and chosen by the end of 2000. The practical work relating to the research, planning and implementation of the final disposal facility is carried out by Posiva Oy, a company jointly owned by Teollisuuden Voima Oy and Imatran Voima Oy. The two latter power companies have legal and financial responsibility for the management of spent nuclear fuel.

Under the Nuclear Energy Act, the final disposal facility for spent nuclear fuel is a nuclear facility of considerable general significance, the construction of which requires a decision in principle of the Council of State for the project, so that building it is in line with the overall good of society. An application for the decision in principle is submitted to the Council of State. The application may apply to one or several alternative disposal sites. Under the Nuclear Energy Decree, an environmental impact assessment report in accordance with the Act on EIA should be appended to the application.

Environmental impact assessment procedure in accordance with the Act on EIA is part of the safety and environmental impact assessment of the final disposal facility relating to the decision in principle in accordance with the Nuclear Energy Act. In the EIA procedure, the body responsible for the project presents the project and its alternatives taking into account existing legislation and decisions made by the authorities. Examination of the application for a decision in principle under the Nuclear Energy Act is based on the overall good of society. Those providing statements, including the municipality where it is planned to site the facility, examine the project from their own perspective. Consideration of the application is not based solely on material submitted by the applicant. The authorities also obtain other studies provided for in the Nuclear Energy Decree and other reports they deem necessary, where the project is examined from more general aspects.

The environmental impact assessment report proper is a publication for wider distribution. To avoid unreasonable length, the report cannot be too detailed. Exact descriptions of the basic assumptions used, the assessment methods and findings are given in the reports and references appended to the assessment report. These reports and references will also be public. Quite an extensive amount of background material has been accumulated in the research and site selection programme carried out under the Nuclear Energy Act in particular. Consideration by the authorities and expert assessments will be based expressly on the detailed information given in the appendices and references. If the application for the decision in principle in respect of the final disposal facility is submitted for consideration together with the EIA report, both shall be based on the same information.

At the same time as the EIA procedure, work is also under way on a more detailed assessment of Posiva Oy's technical plans and site selection investigations aimed at final disposal. On 31 December 1996, Teollisuuden Voima Oy and Imatran Voima Oy submitted an interim report drafted by Posiva Oy to the Ministry of Trade and Industry concerning final disposal research. The Radiation and Nuclear Safety Authority (STUK) gave a statement (A811/17, 31.10.1997) on the interim report to the ministry.

To consider the application for a decision in principle, the Ministry of Trade and Industry must request a statement from the municipal council of the municipality in which it is proposed to site the facility, from neighbouring municipalities, from the Ministry of the Environment and from other authorities mentioned in the Nuclear Energy Decree. Furthermore, the ministry must obtain a preliminary safety assessment on the project from the Radiation and Nuclear Safety Authority.

Requirements in respect of the safety of the final disposal facility are based on the Nuclear Energy Act and Radiation Act and on the decrees and decisions issued by virtue thereof. The Radiation and Nuclear Safety Authority has drafted the general safety requirements concerning the final disposal of spent nuclear fuel. It is intended to bring into force these requirements by a decision of the Council of State.

Before the decision in principle is made, the applicant must publish an overall description of the facility project, the estimated environmental impacts and safety of the facility drawn up according to the guidelines of and inspected by the Ministry of Trade and Industry such that the description is generally available.

Interaction with the residents in the area of impact is part of the EIA procedure and also continues when the application for the decision in principle is being considered. Before a decision in principle is made, the Ministry of Trade and Industry must afford an opportunity for the residents and municipalities in the vicinity of a nuclear facility and local authorities to present their written opinion of the project. Moreover, the ministry shall, in a manner more precisely defined, hold a public meeting in the locality where the plant is to be sited at which opinions may be expressed orally or in writing. The opinions presented must be brought to the notice of the Council of State. Under Section 26 of the Nuclear Energy Decree (161/1988), the Ministry of Trade and Industry must submit to the Council of State a special review of existing and planned methods of nuclear waste management methods and their applicability to Finnish conditions in order for the Council of State to make a decision.

Before the Council of State can make a positive decision, it must, under the Nuclear Energy Act, prove that the municipality in which it is proposed to site the facility has issued a statement in favour of building the facility and that there are no factors in the statement by the Radiation and Nuclear Safety Authority or otherwise emerging in connection with consideration of the application to indicate that there are insufficient conditions to build and operate the plant so that it is safe and does not result in harm to human life, the environment or property.

The Council of State must immediately submit its decision to parliament for examination. Parliament may reject the decision as such or decide that it can remain in force as such.

The Council of State's decision is followed by the licence procedure proper. Construction of the final disposal facility requires a construction licence issued by the Council of State. Granting a construction licence, requires that plans for the facility are adequate from the safety aspect, that occupational safety and health, the safety of the population and environmental protection have been duly taken into account in the operating plan and that the site of the disposal facility is expedient with regard to the planned activities.

An operating licence is required before the facility can be used. This licence is issued by the Council of State provided that occupational safety and health, safety and environmental protection have been properly taken into account. The municipalities, authorities and citizens concerned will be consulted when considering construction and operating licences.

Decision-making and the licence system under the Nuclear Energy Act operate on the principle of ongoing safety assessment and assessment review throughout the entire procedure. Final safety assessments are not made until the operating licence stage.

Information and consultation about the assessment programme

The pending assessment programme was announced on the bulletin boards of the following municipalities and towns: Eurajoki, Eura, Kiukainen, Lappi, Luvia, Nakkila, Rauma, Kuhmo, Hyrynsalmi, Lieksa, Nurmes, Ristijärvi, Sotkamo, Suomussalmi, Valtimo, Loviisa, Lapinjärvi, Liljendal, Pernaja, Pyhtää, Ruotsinpyhtää, Äänekoski, Kannonkoski, Konnevesi, Laukaa, Saarijärvi, Sumiainen, Suolahti, Uurainen, Vesanto, and Viitasaari.

Statements were requested from the aforementioned municipalities and also the Ministry of the Environment, Ministry of Social Affairs and Health, Ministry of Transport and Communications, Ministry of Defence, Radiation and Nuclear Safety Authority, Finnish Environment Institute, Technical Research Centre of Finland, Geological Survey of Finland, Finnish National Road Administration, provincial governments of South Finland, West Finland and Oulu, the Government of the Åland Islands, regional environment centres of Uusimaa, Central Finland, Satakunta and Kainuu, East Uusimaa Regional Council, Central Finland Regional Council, Satakunta Regional Council, and Kainuu Regional Council. The water courts and the Provincial Government of the Åland Islands were afforded an opportunity to give a statement.

There was also a public announcement about the matter in the following newspapers: Länsi-Suomi, Satakunnan Kansa, Uusi-Rauma, Kuhmolainen, Kainuun Sanomat, Karjalainen, Loviisa Sanomat, Uusimaa, Östra Nyland, Borgåbladet, Keskisuomalainen, Sisä-Suomen Lehti, Keski-Suomen Viikko, Hufvudstadsbladet, Helsingin Sanomat and Kansan Uutiset.

Opinions and statements were requested to be forwarded to the contact authority by 23 April 1998. Answer forms and stamped addressed envelopes for people to give their opinions were available near where the EIA programme was on view.

In March 1998, the Eurajoki municipality, the towns of Kuhmo, Loviisa and Äänekoski respectively organised information and discussion events about the EIA programme. Representatives of the body in charge of the project, the contact authority and the Radiation and Nuclear Safety Authority were also present at these events. The topics discussed were the project and the EIA procedure. No official minutes were kept, so it was also requested that any opinions intended for the authorities were put in writing.

The Ministry of the Environment sent notification of the pending environmental impact assessment programme of the project to the authorities in Sweden, Estonia, and Russia. The Ministry requested these states to announce whether their authorities or citizens intended to participate in the environmental impact assessment procedure and to give a possible statement about the assessment programme being considered. Notification is based on the United Nations' (UN) Economic Commission for Europe (ECE) convention on the transboundary environmental impact assessment procedure between member states (SopS 67/1997) which entered into force in September 1997 and on the Act (468/1994 Sections 14 and 15) and Decree (792/1994 Section 16) on Environmental Impact Assessment Procedure. Estonia and Russia have not ratified the convention, although in the declaration drawn up in connection with signing, the parties undertook to comply with the convention as far as possible before the convention entered force.

Statements and opinions

The statements requested about the environmental impact assessment programme were obtained from the authorities of the aforementioned candidate municipalities, from many of their neighbouring municipalities and from the Swedish, Russian and Estonian authorities. Societies, civic movements and individuals presented a total of 120 opinions. Moreover, Teollisuuden Voima Oy presented an opinion concerning the assessment programme.

The Ministry of Trade and Industry

submitted copies of all the statements and opinions on the assessment programme to Posiva Oy. The originals are being kept at the Ministry of Trade and Industry.

Virtually all the statements consider the assessment programme as largely being properly and carefully prepared. Nevertheless, many statements considered that the alternatives for the disposal of spent nuclear fuel should be examined more comprehensively. Otherwise, very few additions proper to the programme were presented. On the other hand, many statements highlighted the importance of some of the topics included in the programme and wished for specification in the assessment plans.

Opinions brought up shortcomings in the EIA programme and ways of procedure more strongly than in statements issued by the municipalities and authorities.

The principal objective of hearing the EIA programme is to bring out any needs to supplement the programme. Nevertheless, many opinions and statements took a stand on the final disposal project itself and on factors which, as the ministry sees it, have more to do with the decision in principle procedure under the Nuclear Energy Act. In its capacity as contact authority, the ministry has nevertheless striven to evaluate all the views presented to it as to whether they are important from the aspect of EIA procedure.

The following examines the main views expressed in the statements and opinions by topic, and gives the Ministry of Trade and Industry's views on them (indented text). The content of the statements and opinions are described in more detail in the summary of the statements appended. A summary of the additions and specifications to the environmental impact assessment programme considered necessary by the Ministry of Trade and Industry appears in this statement under the heading "Statement by the contact authority".

Alternatives to be examined

In their statements, many authorities and certain municipalities have examined the necessity of dealing with the geological final disposal alternatives in the environmental impact assessment programme. The alternatives mentioned in the statements are:

- non-implementation of the project, the so-called zero alternative, which would in practice mean a continuation of present interim storage in storage pools
- various implementation alternatives for geological final disposal
- long-term supervised interim storage
- the elimination or utilisation of radioactive substances by new methods developed some time in the future.

The Ministry of the Environment considers that the various final disposal alternatives described in point 3.5 of the EIA programme, their safety, environmental impacts and costs should be examined in more detail. The Finnish Environment Institute notes that it is open to various interpretations if the solutions made relating to the principle of final disposal limit the examination only into the alternatives presented in the assessment programme. Moreover, the Finnish Environment Institute considers that from the aspect of openness and public participation, it is essential that the procedure also examines alternatives, the unreality of which is not unanimous and that, for example, further studies should be made of the alternatives based on long-term interim storage.

The Radiation and Nuclear Safety Authority considers that there is no zero alternative for final disposal, neither does long-term supervised interim storage satisfy the criteria of the Nuclear Energy Act. In respect of alternatives, in a statement (A811/17, 31.10.1997) issued earlier on Posiva Oy's interim report for 1996 the Radiation and Nuclear Safety Authority noted that, among other things, there were grounds to continue studies on horizontal disposal variants of the base alternative despite the fact that, to date, the base alternative has been shown to be the most expedient, taking into account all points of view.

A statement by the Ministry of Social Affairs and Health notes that final disposal in the bedrock is, in the light of existing knowledge, the best alternative. This, however, does not exclude the possibility of another solution before commencement of the planned final disposal in 2020.

The Technical Research Centre of Finland (VTT) considers that it is not expedient to seek to carry out assessment of detailed quantitative environmental impacts for the alternatives in the EIA procedure to the same extent as for the base alternative. So that there are sufficiently comprehensive grounds to make a decision on nuclear waste management, Finland should nevertheless prepare general reviews of alternatives to the base alternative such as long-term supervised interim storage and transmutation.

Some dozen civic organisations including the Finnish Association for Nature Conservation, Romuvaara-liikkeen tuki, Kivetyn puolesta-liike and Loviisaliike and other private individuals considered that limited consideration of the alternatives posed a serious shortcoming in the EIA programme. Many opinions highlighted the benefits in principle of long-term supervised interim storage. One example of alternative methods mentioned was dry rock storage (DRD method) proposed in Sweden.

The Geological Survey of Finland drew attention to the fact that the possibilities to retrieve the waste to the surface, if required, could also be examined in connection with final disposal in the bedrock.

The Ministry of Trade and Industry notes that under Section 10, Subparagraph 2 of the EIA Decree (792/1994) the assessment programme should present a suitable number of feasible alternatives to the project. One of these alternatives should be non-implementation of the project, unless for some special reason, this kind of alternative is unnecessary. Under Section 11 subparagraph 5 of the EIA Decree, the assessment report should, to a necessary extent, present an evaluation of the environmental impacts of the project and its alternatives, any shortcomings and main uncertainties in the information used including an evaluation of any environmental accidents and their consequences.

In addition to final disposal in the bedrock, the assessment programme also briefly presents certain alternatives to spent nuclear fuel management that are noted to be in violation with Finnish legislation or international agreements or which in practice are hardly technically feasible. As far as, the programme notes that continued storage in storage pools cannot come into question as an alternative to final disposal because the Nuclear Energy Act requires spent fuel to be disposed of in a manner considered as being permanent. Given this, Posiva Oy has deemed that in the assessment programme, non-implementation of the final disposal project should not come into question.

Nevertheless, the ministry notes that the Nuclear Energy Act makes no provision in respect of the schedule for final disposal. Requirements in respect of schedule appear in the government resolution of 1983 and in decisions (7/815/91 KTM and 11/815/95 KTM) issued by the Ministry of Trade and Industry. The requirements with regard to the objectives of research and planning and schedule given in valid Ministry of Trade and Industry decisions bind the companies responsible for nuclear waste. Nevertheless, the requirements imposed on these companies do not bind the Council of State or parliament in connection with considering the decision in principle. The municipality in which it is planned to locate the facility and any other entities providing statements can form their opinion on the application for the decision in principle irrespective of the requirements mentioned above. As the ministry understands it, the decision will assess whether Finland's nuclear waste management principles are justified and acceptable based on the knowledge at that time.

The ministry is not aware of any new aspects that would give cause to amend the objectives or schedule for spent fuel management. In order for the environmental impact assessment report to describe the project and the alternatives as comprehensively as possible for decision-making, the report should nevertheless examine a situation in which the final disposal project is not implemented. As the ministry understands it, in present circumstances non-implementation would mean continued storage in pools into the indefinite future.

The Ministry of Trade and Industry concurs with the Ministry of the Environment's view that the environmental impact assessment report should also deal in more detail with the alternative final disposal concepts (horizontal disposal, hydraulic cage, deep hole disposal) described in point 3.5 of the EIA programme and their safety, costs and environmental impacts. Examination could also include the land areas required and the suitability of the various alternatives to conditions in Finland. The environmental impact assessment report should also consider the possibility to retrieve the fuel to the surface in respect of both Posiva Oy's base alternative and the other alternatives presented.

According to the programme presented by Posiva Oy, the EIA procedure is not intended to assess the alternatives in principle to the management of spent nuclear fuel such as reprocessing and reuse or the destruction of nuclear fuel by some future methods. In principle, the ministry considers Posiva Oy's starting point acceptable in this respect. As the ministry understands it, the body responsible for the project may limit the alternatives to be examined in the EIA procedure to those that are acceptable under present legislation and technically feasible using existing knowledge.

Nevertheless, the ministry notes that the EIA procedure has a crucial role to play in disseminating information about the project and in public debate. For this reason, the ministry proposes that the body responsible for the project considers that the EIA report also generally examines such alternatives in principle to spent fuel management that, given today's knowledge, are perhaps not technically feasible or that do not comply with existing legislation.

The Ministry of Trade and Industry intends to commission studies (so called state-of-the-art reviews) in Finnish and possible foreign research institutions to support decision-making applying to the principles of nuclear waste management. These studies would look at existing and planned methods for spent fuel management and any future solutions. Topics to be examined include alternative ways of implementing long-term supervised storage in interim facilities for several hundreds of years and the possibility to destroy nuclear waste in transmutation plants.

Project scope

In its statement, Teollisuuden Voima Oy considers that the EIA procedure should take actively into account that, if required, the facility could also process spent nuclear fuel produced elsewhere in Finland. After drafting the programme, Teollisuuden Voima Oy submitted to the ministry an environmental impact assessment programme of a new nuclear power plant unit. Imatran Voima Oy has publicly announced that it has commenced preparation of EIA procedure in respect of a new nuclear power plant unit.

In the case of the final disposal facility, project scope as the ministry understands it primarily means the amount of spent nuclear fuel to be finally disposed of. It is expedient to express this amount in tonnes of uranium (tU). According to the assessment programme, the assessment procedure examines a basic case of the amount of uranium generated by Finland's present nuclear power plants over an operational lifespan of 40 years. This would produce a maximum of 2,600 tonnes of uranium. Furthermore, assessment examines a case whereby the useful life of existing plants is extended to 60 years. This would produce a total amount of uranium not exceeding 4,000 tonnes. According to the EIA programme, technical planning of the facility took into account the possibility that the same final disposal facility would also be used for the final disposal of spent nuclear fuel generated by any new power plant units.

The ministry notes that taking into account spent fuel from any new nuclear power plant under the EIA procedure now under way is a matter between Posiva Oy, Teollisuuden Voima Oy and

Imatran Voima Oy. Nevertheless, the application for the decision in principle in respect of the final disposal facility should not apply to a more extensive project than that in the EIA report appended. However, should the application apply to a more extensive project, the EIA report should be supplemented accordingly. As the ministry understands it, on the basis of the environmental impact assessment programme submitted by Posiva Oy, environmental impact assessment of a final disposal facility could also be made for a greater amount of spent fuel than that presented in the programme.

Safety assessment and the health risks posed by radiation

Several statements and opinions drew attention to the fact that whilst the assessment programme did show how to prevent the spread of radioactive substances and the health risks from radiation, not sufficient information was given about what the health and environmental risks might be, what is known about them, how information is to be given about them, what is necessary to study in connection with the final disposal project or what assessment of the health risks from radiation in connection with the final disposal project means in practice.

In its statement, the Ministry of the Environment notes that the programme fails to indicate to what extent the findings of safety assessments would be described in the report. Because radiation safety issues are vital when assessing the health and environmental risks, the ministry considers that the environmental impact assessment report should deal with them in sufficient detail.

The Ministry of Social Affairs and Health considers that it would be advisable for the assessment programme to mention that it is also intended to carry out a safety analysis taking into account local differences in the bedrock. Certain other statements and opinions wanted site-specific safety assessments to compare the different municipalities.

Statements by Regional Environment Centres of Southwest Finland and Central Finland considered that monitoring the impacts of the final disposal facility should continue long into the future and not end when the state assumes responsibility for the waste.

Certain municipalities drew attention to the intake of communal drinking water in the vicinity of the final disposal facility. For this reason even small pollution risks to the waterways were deemed unacceptable. For example, it was noted that the waterways in the Äänekoski region flow into Lake Päijänne, from where the Helsinki Metropolitan Area takes its drinking water.

A statement by the Ministry of Social Affairs and Health noted that it is only in Eurajoki and Loviisa that the present radiation situation is known sufficiently well. A measurement programme would be needed to ascertain the normal state in Äänekoski and Kuhmo.

The Ministry of Trade and Industry draws attention to the fact that in order to assess the health risks attributable to radiation, it is necessary to examine the chain of events which, in respect of long-term safety can be divided into the following stages:
1) possible loss of final disposal canister tightness and the release of radioactive substances from the spent nuclear fuel into the bedrock,
2) the transport of radioactive substances from the bedrock to food, drinking water or the air we breathe and thus into the human or animal organism,
3) the behaviour of radioactive substances in the organism and the radiation doses they cause to different organs,
4) the link between radiation doses and health risks, especially cancer.

In the latter two stages, the question is one of general knowledge about radiation protection and radiation biology that is not limited to the final disposal of spent fuel. Even though there are still uncertainties about the behaviour of radioactive substances and the health risks of radiation, decades of ongoing global research into the health risks associated with radiation have provided a fairly good overall picture serving as a basis for internationally accepted limits applying to the concentration of radioactive substances and radiation doses.

Assessment of the health risks from radiation in connection with the final disposal facility project in practice means assessing the radiation doses in various assumed situations during the project and comparing these doses with the acceptable limit values.

The first two phases apply particularly to the final disposal project and require project-specific and site-specific studies. A long-term research programme applying to final disposal and site-specific geological investigations were aimed in particular at understanding the long-term behaviour of the final disposal canisters, and the release and passage of radioactive substances, acquiring of information required in the assessment and developing reliable calculation methods. Safety assessments also examine the possibility of employees and the rest of the population to be exposed to direct radiation or to the radioactive substances released from spent fuel whilst the facility is in operation or during transportation.

Basic data about bedrock properties are required in calculatory safety assessments of the final disposal facility. Since there are major uncertainties relating to certain properties, safety assessments use general input data. The data is chosen so that the results can, with great certainty, be deemed as exaggerating the actual environmental impacts. Posiva Oy's research programme has accumulated more details than earlier about the local properties of the bedrock. The authorities intend to a greater extent to require safety assessments also based on local bedrock properties. Site-specific safety assessments would improve the understanding of regional safety issues and there is reason to describe the results available in the EIA report. Nevertheless, it is questionable as to whether such generally acceptable benchmarks could be determined with which the various localities under investigation could unequivocally be ranked in order of safety.

Under the Nuclear Energy Act, since the early 1980s issues relating to the radiation safety of the final disposal facility have been assessed under the supervision of the Ministry of Trade and Industry and the Radiation and Nuclear

Safety Authority. Intense assessment will continue until the operating licence is granted and whilst the facility is in operation. Under section 11 of the EIA Decree, the assessment report should present, to an adequate extent, an assessment of the environmental impacts of the project and its alternatives, any shortcomings and principal uncertainties in the data used including an evaluation of any environmental accidents and their consequences. On this basis, the assessment report should deal sufficiently extensively also with environmental and health risks relating to radiation. The assessment report should also pay attention to the bases for designing the canisters, choice of canister materials, the corrosion resistance of the canister in various groundwater conditions and the importance of bedrock movements on canister durability and groundwater flow pathways.

The assessment report should also deal with decommissioning of the final disposal facility and present the view of the body responsible for project of the need for supervision after decommissioning and sealing.

It is necessary to study the normal state of radiation conditions in the site to be chosen. As the ministry understands it, the normal state of radiation conditions does not affect the choice of the site for the final disposal facility, but is required as a comparison for monitoring the impacts of the facility. It is therefore sufficient for the normal state to be studied in good time before the facility begins operation as planned in 2020. The environmental impact assessment report should provide a general description of the plan to study the normal state of radiation conditions and to monitor the impacts of the final disposal facility.

Other health effects and social effects and image issues

In addition to any radiation impacts, construction and operation of the final disposal facility might result in normal environmental and health impacts attributable to industrial construction and operation in the form of dust, noise, vibration and increased traffic. Statements and opinions have dealt only relatively briefly with health effects direct linked to the project other than those related to radiation.

Statements and opinions have paid considerable attention to any indirect effects on health, which may be attributable to suspicion and fear relating to the project and changes in the social environment. In this respect the effects on health are closely linked to the social effects of the project.

Many authorities providing statements, including the Ministry of Social Affairs and Health, drew attention to the fact that whilst the EIA programme gives an extensive list of the expected social effects, the methods use and scope of assessment remain unclear. In respect of the social effects, many statements and opinions pointed out that the programme does not give the areas of impact to be examined.

Many statements provided and opinions expressed, including those of the candidate municipalities, many neighbouring municipalities and regional councils drew attention to the impact of the project on the image of the municipality and entire region among its residents and outsiders, and through this the general wellbeing of the population, and the attraction of the municipality or region for tourism, permanent domicile, a place for a holiday home and business activities. The statements considered that the impact of image might have significant economic consequences.

The statements highlighted special features of the areas concerned, such as the importance of the wilderness, the lakes or the archipelago for residents and business in the area. One view emerging was that in consequence of general recent trends, the importance of agricultural sidelines such as nature and farmhouse holidays to rural vitality has been highlighted. Image issues are of key importance to the livelihoods concerned and the uncertainty of any negative image brought to the region as a result of the project could have an impact on investment in the area.

The Ministry of Trade and Industry notes that whilst the assessment programme presents a diverse list of the estimated health and social impacts, although the methods used are not stated. Under the EIA Decree, the methods used should be described in the assessment report but it was not necessary or perhaps even possible to describe them in all respects in the assessment programme. Nevertheless, from the aspect of public information and interaction, it is hoped that the people and authorities would be aware of the methods used before assessment proper.

After completing the EIA programme, plans concerning the assessment of social effects have been specified. The body responsible for the project has submitted to the contact authority a summary of the studies planned and the methods to be used in them (Posiva Oy letter dated 9.6.1998, ledger No. 1/815/98 KTM).

In discussions about the project, the body responsible for the project noted that it intended holding a seminar in autumn 1998 on the studies to be implemented in respect of social effects, the methods used and preliminary results. Moreover, the body responsible for the project should also deal with the assessment methods of social effects in other information and interaction events relating to the EIA procedure and would strive to work together with municipal and regional social welfare and health authorities in the area of impact.

In respect of social effects, attempts should be made to pay attention also to population groups other than just the active working population. Assessment of social effects should cover not just the municipality in which the final disposal facility is to be located, but also neighbouring municipalities. Grounds should be given for the definition of impact areas.

Efforts should be made to thoroughly study the impacts of final disposal on the image of the municipality in which the final disposal facility is sited and in the region as a whole. The effect of image should also particularly take into account the views of holiday homeowners in the area of impact. As far as the effects of image are concerned, studies should be made of any indirect economic effects and the effects on the general wellbeing of residents and holiday homeowners and on the atmosphere in the locality.

Transport

Many statements and opinions paid attention to the safety of the transport of spent fuel. In particular, neighbouring municipalities of the candidate municipalities proposed that a study be made of the requirements placed on rescue operations as a result of transportation. Some statements and opinions proposed assessing the environmental impacts of transport in detail in respect of all municipalities along possible transport routes. Statements drew attention also to the inconvenience of heavy transport on other traffic especially in the centres of built-up areas.

The Ministry of Trade and Industry notes that under the environmental impact assessment programme for the final disposal facility, it is intended to include studies on transport routes and forms of transport in the assessment procedure. Examples of the routes are to be used to assess the environmental impacts. The ministry considers the method proposed adequate at this stage.

The assessment report should examine the radiation safety of the transport, the extent of the area of impact in respect of any accidents and any necessary countermeasures as well as an overview of the special requirements transportation places on the rescue services of the municipality in which the final disposal facility is sited, neighbouring municipalities and municipalities through which the spent nuclear fuel is transported.

The assessment report should deal with the impacts of transport, other than those relating to radiation safety, such as the impacts on road safety and other traffic, the townscape and the general wellbeing of the residents in the area. Besides the transportation of spent fuel, the assessment report should also look at other transport required by the project. The impacts of transport, alternative modes of transport and choice of route should also be examined, especially with regard to the centre of Loviisa.

Other aspects

An appendix to the statement by the Technical Research Centre of Finland (VTT) examines in detail the various parts of the EIA programme and makes the following comments and explanations: assessment of the impacts on social structure should take into account the indirect or direct changes brought about by the project in activities (living, public and commercial services, production, agriculture, etc.) and in their physical framework (buildings, traffic networks, technical supply network, areas of greenery, etc.). The statement notes that the EIA Decree mentions the impacts on buildings as a distinct group. The impacts on landscape should also be examined from the aspect of the natural environment and the impacts on the townscape should also be assessed, taking into account the peculiar features of each municipality. Furthermore, the assessment should examine the natural environment as an integrated part of people's living environment.

Statements and opinions also drew attention to the following aspects:

In addition to studies on the natural state of the environment around the facility, investigations into soil quality and hydraulic conductivity are also important. As far as the impacts on groundwater are concerned, studies should also be made of the impact on wells in the vicinity in respect of residents' water supply.

The Kivetty area in Central Finland is an exceptionally extensive unbroken area of old forests, with species avoiding human habitation.

Vibration of the bedrock caused by blasting could disturb permanent and holiday settlement and may also affect the behaviour of the fish stock in the area.

The impacts of the final disposal facility should also be examined from the point of view of land use planning in the areas nearby.

According to some statements, the assessment programme shows inaccuracies in the distances between the planned final disposal facility and permanent settlement and in the text concerning the limit of the area reserved for municipal engineering needs in the plan.

The presentation means should be easily understood and, for example, the quantities and units relating to radiation should be presented by illustrations. To facilitate outlining the whole, the assessment report should seek to distinguish clearly between the long-term or extensive impacts of the project on the one hand and the short-term or local impacts on the other.

The ministry considers that the aspects presented above should be taken into account when implementing the assessment and completing the report. Information especially concerning settlement and the planning situation should be checked and any errors or uncertainties should be rectified in the assessment report.

Assessment by international experts

Certain views proposed the establishment of an international group of experts to oversee the EIA procedure on the final disposal facility.

International experts are to be used in assessing the safety of the final disposal project and in particular the environmental impacts relating to radiation. Priority will be given to detailed safety assessments and investigations relating to site selection on which any application for the decision in principle of the Council of State would be based. In this respect, foreign experts would be more involved in the decision procedure than in the EIA procedure. Although no decisions have yet been made as to how assessment by international experts would be implemented, the ministry considers the most expedient thing would be for the Radiation and Nuclear Safety Authority (STUK) to arrange assessment.

Statements from neighbouring states

The Swedish authorities consider that given existing information it is impossible to say whether the project would result in significant transboundary environmental impacts in Swedish territory. Because of this uncertainty and the great importance in principle of the project, Sweden wishes to have an opportunity to take part in the EIA procedure.

According to the Swedish authorities, it would be important from Sweden's point of view to investigate also alternative final disposal concepts, the possibilities to retrieve the fuel from the final repository to the surface and the possibility of long-term interim storage in the EIA procedure. It is also important to study the environmental impacts of interim storage, transport and the encapsulation phase. It is particularly important to assess the impacts on nature in the Baltic Sea region.

The Estonian authorities do not consider the project would cause significant transboundary environmental impacts in Estonian territory. Estonia has no comments to make in respect of the final disposal project. Referring to an environmental cooperation treaty ratified by Finland and Estonia on 7 November 1991, the Estonian authorities nevertheless would appreciate an opportunity to take part in the EIA procedure for the final disposal facility so as to gain experience of radioactive waste management and the international EIA procedure.

The Russian authorities consider the project could result in transboundary environmental impacts. The Russian authorities point out that the EIA programme does not deal with the criteria used in selection of the final disposal site, the plan to investigate the geological properties of the bedrock, the plan to investigate the physical and chemical properties of the cask materials and structures, information concerning cleaning the exhaust air from the encapsulation plant and emergency plans for the handling stages.

Sweden, Russia and Estonia will be asked to provide statements on the environmental impact assessment report on the final disposal facility.

The ministry notes that the information mentioned in the Russian statements are presented in other reports concerning the final disposal project. Posiva Oy should provide a summary of these in the EIA report.

Statement by the contact authority

To summarise the above, the Ministry of Trade and Industry issues the following statement as provided for under Section 12 of the Act on Environmental Impact Assessment Procedure (468/1994).

The aim of the Act on Environmental Impact Assessment Procedure is to promote environmental impact assessment and consistent consideration in planning and decision-making and to increase the availability of information and opportunities for the public to participate. The environmental impact assessment procedure does not replace the licences required by other acts. The EIA report and the statement issued on it by the contact authority will be used when the authority considers the licence required for the project or other similar decisions.

Under the Nuclear Energy Act, the EIA report on the final disposal facility for spent fuel should be appended to the application for a decision in principle. The application should also include other studies that deal in detail with the geological aspects relating to the site of the facility and issues relating to radiation safety in various phases of the final disposal project. Besides the safety and environmental aspects, the Council of State will also base its decision on the overall interest of society.

The key bodies providing statements and experts in the decision-making process concerning the final disposal project include the candidate municipalities where facility is to be sited, the Ministry of the Environment, the Technical Research Centre of Finland (VTT) and the Geological Survey of Finland. The statements provided by these bodies mostly consider the EIA programme to be appropriate and very comprehensive. Nevertheless, the statements also contain numerous comments and views concerning covering the alternatives for nuclear waste management, the importance of various topics, the extent of coverage and certain details in the assessment.

Other statements and opinions present numerous questions and views, most of which, as the ministry understands, can be explained in the assessment procedure or have been dealt with in earlier studies.

This statement deals with the most important comments arising. The ministry considers that in the assessment procedure, the body responsible for the project should also pay attention to comments and views given in other statements and opinions, and seek in the EIA report to reply to as many of the questions arising as possible.

The EIA report should also include a clear description of the many stages in the decision-making procedure in respect of the final disposal facility for spent nuclear fuel and state the objectives, the limits and the importance of the EIA procedure in relation to the application for the decision in principle under the Nuclear Energy Act.

Project alternatives

The EIA programme briefly introduced some of the alternatives in spent fuel management. It was noted that these violate either Finnish legislation or international treaties or are not technically feasible. The programme noted that continued storage in pools is out of the question as an alternative to final disposal. This is because the Nuclear Energy Act requires the permanent disposal of spent fuel. Based on this, the body responsible for the project considers that non-implementation of the project is out of the question.

The ministry notes that the Nuclear Energy Act provides no requirements in respect of the final disposal schedule. Requirements in respect of final disposal are given in the decision in principle of the Council of State dating from 1983 and in decisions on the principles of nuclear waste management 7/815/91 KTM and 11/815/95 KTM issued by the Ministry of Trade and Industry. Requirements concerning the objectives and schedule of research and planning given in valid decisions issued by the Ministry of Trade and Industry are binding on those responsible for nuclear waste management. Nevertheless, these requirements do not bind the Council of State or Parliament when considering the decision in principle. Nor do they bind the council in the municipality where it is planned to locate the facility or any other bodies issuing statements in respect of the decision application. For the reasons above, the EIA report should, for the sake of completeness, also examine the environmental impacts of non-implementation of the project, even though we are not aware of any factors that would give reason to change the objectives of spent fuel management.

The EIA report should examine the various technical concepts of final disposal in the bedrock and their environmental impacts in general and compare these with the environmental impacts of the base alternative proposed by Posiva. These concepts include horizontal disposal, hydraulic cage and deep hole alternatives. Studies should also be made of any possibilities to retrieve the spent fuel.

The EIA procedure plays a fundamental role in communications and public debate in the project. This is why the ministry proposes that the body responsible for the project considers examining in general in the EIA report, those alternatives in principle for the management of spent fuel whose technical implementation is uncertain or which do not comply with existing legislation.

Scope of project

The ministry considers that the EIA procedure should, as presented in the EIA programme, in addition to the basic case, also study a case where Finland's existing nuclear power plants were to operate for 60 years. This would mean the amount of fuel to be finally disposed of would correspond be a maximum of around 4,000 tU.

The body responsible for the project could, at its discretion, also deal with the case presented in the EIA programme whereby the spent fuel from any future nuclear power plants to be built in Finland would also be placed in the final disposal facility now under examination. The ministry notes that the decision application in respect of the final disposal facility should not apply to a larger project than in the appended EIA report. Should the decision application nevertheless apply to a larger project, the EIA report should be completed accordingly. Under the Act on Environmental Impact Assessment, an authority may not grant a licence to implement a project or make any comparable decisions until it has obtained an EIA report and a statement by the contact authority on that report.

Radiation safety and readiness to deal with accidents

Radiation safety is of crucial importance in assessing the environmental and health effects. The EIA programme does not deal with how the radioactive substances in the spent fuel could pose health risks or how the effects in question are assessed. The EIA report should deal adequately with issues relating to radiation safety and the risk of accidents in the final disposal facility and with the principal uncertainties relating to these issues. All stages of final disposal operations should be examined: transport of spent fuel to the final disposal site, storage in the final disposal facility, encapsulation, transfer of the canisters to the repository and the long-term safety of the repository.

The report should also deal with the corrosion resistance of the canisters in various groundwater conditions and the significance of bedrock movements on canister strength and groundwater flow taking also the decay heat of the spent fuel into account.

The EIA report should examine in a popularized way the significance of the release and transport of radioactive substances in respect of radiation impacts. The report should also show any effects of radiation on health, how these effects are related to radiation dose, the basis of present opinions about the health risks from radiation and what kind of uncertainties are related to these risks.

As far as long-term safety is concerned, the report should examine in a popularized way the significance of the canister, the tunnel backfill and bedrock on radiation safety. With regard to transport, the encapsulation plant and final disposal repository, the report should examine radiation effects during normal operations and radiation risks in the event of accident or malfunction. Assessment of radiation safety should provide values of the amounts of radioactive materials released, the radiation doses arising and their possible effects on health in connection with the situations studied. The EIA report should also give illustrative information of fuel radioactivity and how this decreases with time.

As far as the accident situations examined are concerned, the report should provide information about the extent of any affected area and the countermeasures necessary.

Other health, social and image effects

The EIA programme featured a comprehensive list of the health and social effects to be assessed but did not provide the assessment methods. Under the Environmental Impact Assessment Decree, the methods used should be described in the EIA report. It was neither necessary nor possible to describe these in all respects in the EIA programme. As far as public information and interaction is concerned, it is hoped that the people and authorities are aware of the methods to be used before assessment begins. The body responsible for the project should deal with the methods used in assessing the social effects in information and interaction relating to the EIA procedure and strive for cooperation with municipal and local social welfare and health authorities in the affected area.

As regards social effects, efforts should also be made to pay attention to population groups other than the active workforce. Assessment of the social effects should also cover the neighbouring municipalities of the municipality where the final disposal facility may be located.

A thorough study should be made of the effects of the final disposal facility on the image of the municipality where may be located and of the surrounding area. The views of holiday homeowners in the affected area should especially be taken into account as regards the effect on image. Any indirect economic effects on image should be studied, as should the effects on the general well-being and atmosphere of the locality among permanent and holiday residents. The grounds for defining the affected areas should also be presented in the EIA report.

Transportation

The EIA report should examine the radiation safety of transport. As far as accidents are concerned, the report should also give information about the extent of the affected area and the countermeasures necessary.

The EIA report should also provide a general account of the special requirements resulting from the transport of spent fuel on the emergency services of the municipality where the facility may be built, neighbouring municipalities and municipalities through which the spent nuclear fuel passes on its way to the final disposal facility.

The EIA report should also include an estimate of the number of spent fuel transportations made each year, examine the effects of transport other than those relating to radiation safety including road safety and other traffic, the townscape and the general wellbeing of residents in the surroundings. The impacts of alternative forms of transport and routes should also be examined, especially in respect of the centre of Loviisa.

Aside from the transportation of spent fuel, the EIA report should also examine other transport required by the project.

Impacts on the environment and community structure

The EIA report should consider the interaction between the social effects and the effects on the community structure and natural environment. Besides structures, operations should also be examined. With regard to community structure, as well as studying the technical infrastructure, the report should examine the social structures and the effects on services. The natural environment should also be examined as an integrated part of the living environment.

The EIA programme mentions studies of culturally and historically important buildings. Under the EIA Decree, the effects on buildings should also be examined more generally.

The effects on the landscape should also be examined in respect of the natural environment. The effects on the townscape should, where necessary, be assessed taking into account the peculiar features of each candidate municipality.

The EIA report should examine limits and other effects caused by the final disposal facility on land use in the vicinity.

Any errors or vague expressions in the EIA programme in respect of population settlement and planning, particularly in the Loviisa area, should be reviewed in the EIA report.

Changes in groundwater conditions and mapping the basic state of groundwater conditions in the vicinity of the facility, also in respect of individual dwellings, should be included in the assessment. Studies of the impact of construction work should also examine the effects of blasting on population settlement, nature and particularly on the fish stand in the area.

Information and interaction

Information and interaction during the assessment procedure can essentially be dealt with in the manner proposed in the assessment programme. Nevertheless, information should adequately take into account the entire area, irrespective of municipal boundaries, and all population groups affected by the project. Arrangements and scheduling should also take into account the actual possibilities for holiday residents in the affected area to receive information and to air their views about the project. Interaction with various local, regional and central administration authorities should continue also during the assessment stage.

The EIA programme gives no plan concerning especially information about the assessment report. The body responsible for the project should provide information about EIA report in a similar way to the EIA programme.

Once the EIA report has been completed, the Ministry of Trade and Industry will publicly announce it and put on public display. The Ministry will also invite the public and authorities to comment on the report. The statement issued by the Ministry of Trade and Industry as the contact authority for the EIA report will be sent for the information of the municipalities in the affect area, the regional councils responsible for regional planning and other relevant authorities.

Compatibility with procedures in accordance with other acts

The question of compatibility largely arises in connection with the decision in principle procedure according to the Nuclear Energy Act. Dealing with the decision application includes consulting municipalities, authorities and local citizens, which involves a statutory hearing in the place where the facility is to be sited. A decision application can apply to the all the potential sites for the final disposal facility examined in the EIA report or just some of them.

The ministry aims that the statement by the contact authority on the EIA report on the final disposal facility is available to those making statements about the project, and in particular to municipalities making statements in the affected area, when they present their statement on the decision in principle application.

As the ministry currently understands it, the EIA report and the decision in principle application in respect of the final disposal facility will progress as separate procedures, but possibly partly at the same time. The final decision in respect of compatibility will be made when schedules of the assessment report and decision application are settled.

Minister of Trade and Industry
Antti Kalliomäki

Senior adviser
Jorma Sandberg

APPENDIX 2

List of the reports on the management and disposal of spent nuclear fuel

YJT-79-07 Alternatives and foreign services for spent fuel management. Veijo Ryhänen. TVO Power Company December 1979. (in Finnish)

YJT-79-08 Safety analysis for disposal of high-level repro-cessing waste or spent fuel in crystalline rock. Jari Puttonen, Jukka-Pekka Salo, Seppo Vuori, Hannu Härkönen. Technical Research Centre of Finland. December 1979

YJT-79-10 Assessment of risks involved in the transportation of spent fuel from Loviisa power station. Erkki Rämö. Technical Research Centre of Finland. December 1979

YJT-80-06 Assessment of risks involved in handling spent fuel at Loviisa nuclear power stations. Hannu Kaikkonen, Sirkka Vilkamo. Technical Research Centre of Finland. February 1980

YJT-80-07 Research methods of bedrock for studying the final disposal of nuclear wastes, Part I Contents of studies. Esko Peltonen, Pekka Rouhiainen. Technical Research Centre of Finland. February 1980 (in Finnish)

YJT-80-08 Research methods of bedrock for studying the final disposal of nuclear wastes, Part II Descriptions of research methods. Esko Peltonen, Pekka Rouhiainen. Technical Research Centre of Finland. February 1980 (in Finnish)

YJT-80-10 Assessment of risks involved in handling spent fuel at TVO nuclear power stations. Hannu Kaikkonen, Sirkka Vilkamo. Technical Research Centre of Finland. April 1980

YJT-80-12 Funding requirements for future costs and cost estimates of nuclear waste management in different countries. Heikki Raumolin. TVO Power Company. July 1980 (in Finnish)

YJT-80-14 Cost estimate of management of TVO's spent fuel. Jukka-Pekka Salo, Veijo Ryhänen. TVO Power Company. November 1980 (in Finnish)

YJT-81-01 Suitability of intermediate storage in bedrock for final disposal of reactor wastes. Krister Almark, Reijo Gardemeister, Rauno Hiekkanen, Esko Tusa. Imatra Power Company. January 1981 (in Finnish)

YJT-81-04 Spent nuclear fuel integrity and surveillance during interim storage. Esa Vitikainen, Jan-Olof Stengård. Technical Research Centre of Finland. February 1981 (in Finnish)

YJT-81-11 Transport in biosphere of radionuclides released from finally disposed nuclear waste - Background information for transport and dose model. Riitta Hulmi, Ilkka Savolainen. Technical Research Centre of Finland. July 1981 (in Finnish)

YJT-81-15 TVO's spent fuel management alternatives. Veijo Ryhänen, Jukka-Pekka Salo, Ilkka Mikkola, Heikki Raumolin. TVO Power Company. September 1981 (in Finnish)

YJT-81-16 System analytical model of TVO nuclear power plant waste management. Timo Vieno. Technical Research Centre of Finland. September 1981 (in Finnish)

YJT-81-18 Assessment of criticality safety and neutron dose of transport cask for spent fuel from Loviisa nuclear power plant. Seppo Vuori. Technical Research Centre of Finland. October 1981 (in Finnish)

YJT-81-21 Interim storage of TVO's spent fuel at power plant site. Jukka Kangas, Ilari Aro, Veijo Ryhänen, Jukka-Pekka Salo, Tapio Vähämaa. TVO Power Company. October 1981 (in Finnish)

YJT-82-02 Integrity and surveillance of spent nuclear fuel during the interim storage - final report. Esa Vitikainen, Jan-Olof Stengård. Technical Research Centre of Finland. January 1982 (in Finnish)

YJT-82-03 Risk study of the spent fuel storage extension at Loviisa nuclear power plant. Heli Talja, Timo Vieno. Technical Research Centre of Finland. January 1982

YJT-82-06 Composition, activity and decay heat of TVO's spent fuel as a function of decay time. Markku Anttila Technical Research Centre of Finland. January 1982 (in Finnish)

YJT-82-08 Further studies on risks involved in handling spent fuel at Loviisa power plants. Pertti Hyppönen, Markku Rajamäki, Risto Sairanen, Timo Vieno, Seppo Vuori, Frej Wasastjerna. Technical Research Centre of Finland. February 1982

YJT-82-09 Thermal and stress analysis of a nuclear waste repository. Olli Halonen, Heikki Noro. Technical Research Centre of Finland. February 1982 (in Finnish)

YJT-82-16 The near-field phenomena of the repository for spent fuel. Olli J. Heinonen. Technical Research Centre of Finland. April 1982 (in Finnish)

YJT-82-17 Airborne releases and radiation doses in the vicinity of the spent fuel interim storage during normal operation. Ilkka Savolainen, Timo Vieno, Seppo Vuori. Technical Research Centre of Finland. April 1982

YJT-82-20 Application of blasting and operation techniques of mines to the final disposal of high-level nuclear waste. Tuomo Tahvanainen, Raimo Matikainen. Helsinki University of Technology. Laboratory of Mining Engineering. May 1982 (in Finnish)

YJT-82-32 The deep diamond drill holes in Finland and possibility to use them for nuclear waste investigations. Tuomo Tahvanainen, Raimo Matikainen. Helsinki University of Technology. Laboratory of Mining Engineering. June 1982 (in Finnish)

YJT-82-35 Borehole, shaft and tunnel sealing. Pekka Holopainen. Technical Research Centre of Finland. July 1982 (in Finnish)

YJT-82-36 Geological factors in the final disposal of high-level nuclear waste. Heikki Niini, Veikko Hakkarainen, Pekka Patrikainen. Geological Survey of Finland. January 1982 (in Finnish)

YJT-82-37 Encapsulation materials for final disposal of spent fuel. Pertti Aaltonen, Hannu Hänninen. Technical

Research Centre of Finland. June 1982 (in Finnish)

YJT-82-40 Sorption of radionuclides from spent fuel in crystalline rocks. Anneli Nikula. Helsinki University. Department of Radiochemistry. October 1982 (in Finnish)

YJT-82-41 Safety analysis for final disposal of spent fuel. M. Anttila, O. Halonen, P. Holopainen, R. Korhonen, M. Kätkä, K. Meling, H. Noro, E. Peltonen, K. Rasilainen, I. Savolainen, S. Vuori. Technical Research Centre of Finland. October 1982 (in Finnish)

YJT-82-42 Groundwater chemistry in bedrock. Margit Snellman. Technical Research Centre of Finland. October 1982

YJT-82-43 Final repository alternatives for spent fuel. Tenho Laine. Saanio & Laine Oy. October 1982 (in Finnish)

YJT-82-44 Comparative temperature and stress analyses for repository alternatives for spent fuel. Olli Halonen, Heikki Noro. Technical Research Centre of Finland. October 1982 (in Finnish)

YJT-82-46 Final disposal of spent nuclear fuel into the Finnish bedrock. Industrial Power Company Ltd. November 1982 (in Finnish)

YJT-82-47 Final disposal of spent nuclear fuel into the Finnish bedrock. Summary. Industrial Power Company Ltd. November 1982 (in Finnish)

YJT-82-49 Risk study of the spent fuel interim storage at TVO nuclear power plant. M. Anttila, H. Melkas, I. Savolainen, T. Vieno. Technical Research Centre of Finland. November 1982

YJT-82-53 Transport and transfer of spent fuel at TVO I/II. Jukka-Pekka Salo, Ilari Aro. Industrial Power Company Ltd. December 1982 (in Finnish)

YJT-82-54 Interim storage of TVO's spent nuclear fuel at the power plant site - complementary report. Ilari Aro, Jukka Kangas, Heikki Raumolin, Jukka-Pekka Salo. Industrial Power Company Ltd. December 1982 (in Finnish)

YJT-82-55 Programme and schedules for TVO's nuclear waste management. Heikki Raumolin. Industrial Power Company Ltd. December 1982 (in Finnish)

YJT-82-56 Site investigations for final disposal of high-level nuclear waste - research programme. Timo Äikäs, Tenho Laine. Saanio & Laine Oy. December 1982 (in Finnish)

YJT-82-57 Costs of TVO's nuclear waste management. Heikki Raumolin. Industrial Power Company Ltd. December 1982 (in Finnish)

YJT-82-58 The suitability of the Finnish bedrock for final disposal of high-level radioactive waste. Paavo Vuorela, Veikko Hakkarainen. Geological Survey of Finland. December 1982 (in Finnish)

YJT-82-59 Safety analysis of the disposal of spent nuclear fuel - supporting detailed results. R. Korhonen & al. Technical Research Centre of Finland. December 1982 (in Finnish)

YJT-82-60 Sorption properties of the most common Finnish soils and some materials found in bedrock fractures. Anneli Nikula. University of Helsinki. Department of Radiochemistry. December 1982 (in Finnish)

YJT-83-02 Sorption of radionuclides in the bedrock, mineralogical factors and the autoradiographic method. Antero Lindberg. Geological Survey of Finland. Sinikka Pinnioja, Anneli Nikula. University of Helsinki. Department of Radiochemistry. February 1983 (in Finnish)

YJT-83-06 Suitability of certain borehole geophysical methods for structural and hydrogeological studies of Finnish bedrock in connection with disposal of nuclear waste. Ari Poikonen. Technical Research Centre of Finland. April 1983

YJT-83-07 Drilling of disposal holes in the repositories for spent fuel. Tuomo Tahvanainen, Raimo Matikainen. Helsinki University of Technology. Laboratory of Mining Engineering. July 1983 (in Finnish)

YJT-83-08 Economic issues involved in nuclear waste management in various countries. Heikki Raumolin. Industrial Power Company Ltd. August 1983 (in Finnish)

YJT-83-09 Conditioning and plans for final disposal of radioactive wastes in foreign countries. Hannu Härkönen, Veijo Ryhänen. Industrial Power Company Ltd. August 1983 (in Finnish)

YJT-83-10 Reprocessing of spent fuel and recycling of plutonium in light water reactors. Jukka-Pekka Salo. Industrial Power Company Ltd. August 1983 (in Finnish)

YJT-83-11 Dissolution of uranium dioxide in groundwater. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. September 1983

YJT-83-12 Release of the radionuclides of spent nuclear fuel from the canisters placed in the tunnel. Esko Peltonen, Martti Kätkä. Technical Research Centre of Finland. Nuclear engineering laboratory. June 1983 (in Finnish)

YJT-83-13 Release of radionuclides from the spent fuel repository - grounds for the release model. Esko Peltonen, Pekka Holopainen. Technical Research Centre of Finland. May 1983 (in Finnish)

YJT-83-14 Report on the possibilities of finding tin mineralizations of type Greisen in the bedrock of Hästholmen. Marianne Lehtiö. Geological Survey of Finland. August 1983 (in Finnish)

YJT-83-15 Tracer technique in groundwater hydrology. Risto Kuoppamäki, Kari Saari, Matti Valkiainen. Technical Research Centre of Finland. September 1983

YJT-83-16 Geophysical borehole methods used in determining the suitability of crystalline rock mass for final dis-posal of nuclear waste. Audrey Griffioen. September 1983

YJT-83-17 Sorption of strontium, cesium, nickel, iodine and carbon in aggregate-bentonite mixtures. Raija Hietanen, Maarit Alaluusua. University of Helsinki. Department of Radiochemistry. November 1983 (in Finnish)

YJT-83-18 Final disposal of spent fuel, Geochemical groundwater investigations. Paula Lampén. Imatran Voima Oy. December 1983 (in Finnish)

YJT-83-19 Final disposal of spent fuel, Deep borehole drilling and associated geological investigations. Pekka Anttila. Imatran Voima Oy. December 1983 (in Finnish)

YJT-83-20 Development of an autoradiographic method for measuring the sorption of radionuclides on natural fracture surfaces. Seija Muuronen. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. November 1983 (in Finnish)

YJT-84-01 Final disposal of spent fuel, Geophysical borehole measurements. Pekka Rouhiainen. Imatran Power Co. January 1984 (in Finnish)

YJT-84-02 Radiometric, electrical and acoustic borehole geo-phy-sical studies in the Loviisa power plant site in 1983. Pauli Saksa. Technical Research Centre of Finland. January 1984

YJT-84-04 Sorption of strontium, cesium, nickel, iodine and carbon in concrete. Raija Hietanen, Eeva-Liisa Kämäräinen, Maarit Alaluusua. University of Helsinki. Department of Radiochemistry. February 1984

YJT-84-06 An analysis of the calculation methods for the biospheric transfer of radionuclides by studying the naturally occurring radionuclides. Riitta Korhonen. Technical Research Centre of Finland. Nuclear Engineering Laboratory. February 1984 (in Finnish)

YJT-84-08 Chemical conditions in a repository for spent fuel. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. January 1984

YJT-84-09 Final disposal of spent fuel, Hydraulic testing of the bedrock. Timo Äikäs. Saanio & Laine Ltd. April 1984 (in Finnish)

YJT-84-10 Chemical composition of groundwater in the bedrock of Finland. Juho Hyyppä. Geological Survey of Finland. Nuclear Waste Disposal Research. April 1984 (in Finnish)

YJT-84-12 Tunnel boring, an alternative method in construction of spent fuel repositories. Jukka Christersson. Helsinki University of Technology. Laboratory of Mining Engineering. May 1984 (in Finnish)

YJT-84-14 Sorption of cesium, strontium, iodine, nickel and carbon in sand in groundwater/concrete environments. Raija Hietanen, Maarit Alaluusua. University of Helsinki. Department of Radiochemistry. June 1984

YJT-84-15 Hydraulic properties of rock mass and their measurement. Kari Saari, Pekka Holopainen, Veijo Pirhonen, Ari Poikonen. Technical Research Centre of Finland. Geotechnical Laboratory. March 1984 (in Finnish)

YJT-84-17 Corrosion of copper in nuclear waste repository conditions - a literature review. Pertti Aaltonen, Hannu Hänninen, Kari Klemetti, Erkki Muttilainen. Technical Research Centre of Finland. Metals Laboratory. April 1984 (in Finnish)

YJT-84-18 Fabrication of canisters for final disposal of spent nuclear fuel in Finland. Pertti Aaltonen, Hannu Hänninen. Technical Research Centre of Finland. Metals Laboratory. April 1984 (in Finnish)

YJT-84-19 Sorption of carbon, cobalt, nickel, strontium, iodine, cesium, americium and neptunium in rocks and minerals. Sinikka Pinnioja, Timo Jaakkola, Eeva-Liisa Kämäräinen, Annakaisa Koskinen. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. September 1984

YJT-84-20 Determination of hydraulic conductivity in Lavia borehole, Finland. Karl-Erik Almén, Ove Persson. Swedish Geological Co Uppsala. September 1984

YJT-84-21 Stress corrosion testing of pure OFHC-copper in simulated groundwater conditions. Pertti Aaltonen, Hannu Hänninen, Markku Kemppainen. Technical Research Centre of Finland. November 1984

YJT-85-01 Summary of the Lavia borehole investigations in 1984. Timo Äikäs, Antti Öhberg. Saanio & Laine Ltd. Veijo Ryhänen. Industrial Power Company Ltd. February 1985 (in Finnish)

YJT-85-02 Dissolution experiments of unirradiated uranium dioxide pellets. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. January 1985

YJT-85-03 Diffusion in compacted bentonite. Arto Muurinen, Juha Rantanen. Technical Research Centre of Finland. Reactor Laboratory. January 1985 (in Finnish)

YJT-85-04 Ore potential of Olkiluoto district. Pekka Ilveskivi, Heikki Niini. Helsinki University of Technology. Laboratory of Economic Geology. January 1985 (in Finnish)

YJT-85-06 Borehole geophysical investigations of Lavia deep testhole, Finland. Pauli Saksa. Technical Research Centre of Finland. Geotechnical Laboratory. February 1985

YJT-85-07 Geophysical borehole logging in Lavia borehole, Results and interpretation of sonic and tube wave measurements. Per Andersson, Leif Stenberg. Swedish Geological Co. Luleå. February 1985

YJT-85-08 Corrosion of titanium and titanium alloys in spent fuel repository conditions - a literature review. Irina Aho-Mantila, Hannu Hänninen, Pertti Aaltonen, Seppo Tähtinen. Technical Research Centre of Finland. Metals Laboratory. March 1985 (in Finnish)

YJT-85-10 Uranium solubility and speciation in groundwater. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. April 1985

YJT-85-11 Mean sea level and change in the hydrological regime off Loviisa power plant around the year 2050. Pentti Mälkki, Aarno Voipio. Institute of Marine Research. April 1985

YJT-85-14 Measurement of the state of stress in deep drillholes. Anne Väätäinen, Pekka Särkkä. Helsinki University of Technology. Laboratory of Mining Engineering. May 1985 (in Finnish)

YJT-85-15 The solubilities of actinides (Pu, Np, Th) and fission products (Cs, I) released from spent fuel and corrosion products of a spent fuel repository. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. May 1985 (in Finnish)

YJT-85-16 Sorption and diffusion of cobalt, strontium, cesium and americium in natural fissure surfaces and drill core cups studied by autoradiography, I. Sinikka Pinnioja, Eeva-Liisa Kämäräinen, Timo Jaakkola, Marja Siitari, Seija Muuronen. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. June 1985

YJT-85-18 General earthquake study relating to final disposal of spent fuel. Arto Koskiahde, Jari Puttonen, Jouni Saari. Imatran Voima Oy. July 1985 (in Finnish)

YJT-85-21 Future long-term environmental changes in Finland and their influence on deep-seated groundwater. Pekka Nurmi. Geological Survey of Finland. October 1985 (in Finnish)

YJT-85-22 Safety analysis of disposal of spent nuclear fuel - normal and disturbed evolution scenarios. Esko Peltonen, Seppo Vuori, Markku Anttila, Kari Hillebrand, Kurt Meling, Kari Rasilainen, Pertti Salminen, Vesa Suolanen, Mikael Winberg. Technical Research Centre of Finland. Laboratory of Nuclear Engineering. September 1985 (in Finnish)

YJT-85-23 Safety analysis of disposal of spent nuclear fuel - disruptive events. Timo Vieno, Esko Peltonen, Seppo Vuori, Markku Anttila, Kari Hillebrand, Kurt Meling, Kari Rasilainen, Pertti Salminen, Vesa Suolanen, Mikael Winberg. Technical Research Centre of Finland. Laboratory of Nuclear Engineering. September 1985 (in Finnish)

YJT-85-26 Radiolysis of groundwater and the effect of radiolysis in a repository for spent fuel. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. Markku Anttila. Technical Research Centre of Finland. Laboratory of Nuclear Engineering. September 1985 (in Finnish)

YJT-85-27 Geological site selection studies for the final disposal of spent nuclear fuel in Finland. Martti Salmi, Paavo Vuorela, Aimo Kuivamäki. Geological Survey of Finland. October 1985 (in Finnish)

YJT-85-28 The environmental factors to be considered in the site selection studies of the spent fuel final disposal. Timo Äikäs. Saanio & Laine Ltd. October 1985 (in Finnish)

YJT-85-29 Site investigations for the disposal of spent fuel - Investigation program. Timo Äikäs. Saanio & Laine Ltd. November 1985 (in Finnish)

YJT-85-30 Final disposal of spent nuclear fuel into the Finnish bedrock. Industrial Power Company Ltd. December 1985 (in Finnish)

YJT-85-36 Sorption of iodine, neptunium, technetium, thorium and uranium on rocks and minerals. Annakaisa Koskinen, Maarit Alaluusua, Sinikka Pinnioja, Timo Jaakkola. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. December 1985

YJT-85-37 Encapsulation plans for spent nuclear fuel in foreign countries. Pertti Aaltonen. Technical Research Centre of Finland. Metals Laboratory. December 1985 (in Finnish)

YJT-85-38 Sorption of cesium, strontium, iodine, nickel and carbon in mixtures of concrete, crushed rock and bitumen. Raija Hietanen, Maarit Alaluusua, Timo Jaakkola. University of Helsinki. Department of Radiochemistry. September 1985

YJT-86-01 Loviisa Power Station, Hydrological conditions of Hästholmen, Finland. Henry Ahokas. Imatran Voima Oy. January 1986 (in Finnish)

YJT-86-03 A test of the vertical seismic profiling method at the Lavia site. Calin Cosma, Keijo Hämäläinen, Reijo Korhonen. Geoseismo Oy. March 1986

YJT-86-04 The summary of the investigations in the deep test borehole. Timo Äikäs, Antti Öhberg. Saanio & Laine Ltd. Anneli Nikula. Industrial Power Company Ltd. May 1986 (in Finnish)

YJT-86-06 Interpretation of water loss tests in the Lavia test borehole. Arto Ylinen. Technical Research Centre of Finland. Geotechnical Laboratory. April 1986 (in Finnish)

YJT-86-07 Rock stress measurement at Lavia, Finland. Part I: A technical report on principles of the hydrofracturing method, instrumentation, field work, sources of error. Bjarni Bjarnason CENTEK/University of Luleå. Part II: The interpretation of rock stress measure-ments using hydraulic fracturing method in the Lavia test borehole, Finland. Erik Johansson, Anne Väätäinen, Pekka Särkkä. Helsinki University of Technology. Laboratory of Mining Engineering. April 1986

YJT-86-08 Initial data of the safety analysis of final disposal of spent fuel. Edited by Kari Hillebrand. Technical Research Centre of Finland. Nuclear Engineering Laboratory. April 1986 (in Finnish)

YJT-86-09 Hydrogen embrittlement of titanium and its alloys - a literature review. Irina Aho-Mantila, Hannu Hänninen. Technical Research Centre of Finland. Metals Laboratory. May 1986 (in Finnish)

YJT-86-11 The Lavia test borehole - summary of groundwater investigations from 1984 to 1985. Pirjo Wickström, Paula Lampén. Imatran Voima Oy. June 1986 (in Finnish)

YJT-86-13 Factors affecting actinide solubility in a repository for spent fuel, I. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. July 1986

YJT-86-14 Diffusion of cesium, strontium, carbon and nickel in concrete and mixtures of crushed rock and bentonite. Arto Muurinen, Pirkko Penttilä-Hiltunen, Juha Rantanen. Technical Research Centre of Finland. Reactor Laboratory. July 1986 (in Finnish)

YJT-86-27 Sorption and diffusion of cobalt, nickel, strontium, iodine, cesium and americium in natural fissure sur-faces and drill core cups studied by autoradiography, II. Seija Suksi, Eeva-Liisa Kämäräinen, Timo Jaakkola, Heini Ervanne. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. September 1986

YJT-86-28 Dissolution of unirradiated uranium oxide pellets at various parametric conditions. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. September 1986

YJT-86-30 The composition of the groundwater in bedrock in the precambrian shield areas of Finland and other countries. Juho Hyyppä. Geological Survey of Finland. November 1986 (in Finnish)

YJT-86-31 Processing of vertical seismic profiles from the Lavia test hole. Calin Cosma, Pekka Heikkinen, Kari Laasonen. Vibrometric Oy. November 1986

YJT-86-32 Hydrogeochemical interpretation of the groundwater at the Hästholmen site, Finland. Darrell Kirk Nordstrom.U.S. Geological Survey. November 1986

YJT-86-34 Corrosion of iron and low alloy steels in the repository environment. Pertti Aaltonen, Hannu Hänninen. Technical Research Centre of Finland. Metals Laboratory. Leena Carpen. Technical Research Centre of Finland. Metallurgy Laboratory. December 1986 (in Finnish)

YJT-87-03 Geochemical modelling and water-rock interaction of Lavia borehole. Petteri Pitkänen, Veijo Pirhonen. Technical Research Centre of Finland. Geotechnical Laboratory. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. January 1987

YJT-87-05 Dissolution mechanism of UO2 in groundwater. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. April 1987 (in Finnish)

YJT-87-06 A review on colloidal systems in general and in respect of nuclear waste disposal. Ulla Vuorinen. Technical Research Centre of Finland. Reactor Laboratory. April 1987

YJT-87-08 Utilisation of the refraction seismic method. Olli Okko. Technical Research Centre of Finland. Geotechnical Laboratory. May 1987 (in Finnish)

YJT-87-09 Effect of depth in final disposal of spent fuel. Jyri Liimatainen, Raimo Matikainen, Pekka Särkkä. Helsinki University of Technology. Laboratory of Mining Engineering. June 1987 (in Finnish)

YJT-87-10 Sorption of cesium, strontium, cobalt and technetium in mixtures of concrete, crushed rock and bitumen. Maarit Alaluusua, Martti Hakanen. University of Helsinki. Department of Radiochemistry. October 1987

YJT-87-11 Factors affecting actinide solubility in a repository for spent fuel, II. Margit Snellman, Ulla Vuorinen. Technical Research Centre of Finland. Reactor Laboratory. August 1987

YJT-87-13 Development of biosphere scenarios for safety analysis of spent nuclear fuel disposal. Vesa Suolanen, Timo Vieno. Technical Research Centre of Finland. Nuclear Engineering Laboratory. September 1987

YJT-87-14 Diffusion of uranium and chloride in compacted sodium bentonite. Arto Muurinen, Pirkko Penttilä-Hiltunen, Juha Rantanen, Kari Uusheimo. Technical Research Centre of Finland. Reactor Laboratory. September 1987

YJT-87-17 Sorption and diffusion of cobalt, nickel, strontium, iodine, cesium and americium in natural fissure surfaces and drill core cups studied by autoradiography, III. Seija Suksi, Eeva-Liisa Kämäräinen, Marja Siitari-Kauppi. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. October 1987

YJT-87-18 Status report of spent fuel management. Esko Peltonen, Veijo Ryhänen, Jukka-Pekka Salo, Ilkka Mikkola. Industrial Power Company Ltd. December 1987 (in Finnish)

YJT-87-19 Factors effecting carbonate equilibria in natural waters. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. December 1987

YJT-87-21 Effects of fuel burn-up and cooling periods on thermal responses in a repository for spent nuclear fuel. Aimo Hautojärvi, Markku Anttila, Veikko Taivassalo. Technical Research Centre of Finland. Nuclear Engineering Laboratory. December 1987

YJT-88-01 On the interpretation of hydraulic interference tests. Kim Pingoud, Terhi Jaakkola, Auli Kuusela, Arto Ylinen. Technical Research Centre of Finland. Geotechnical Laboratory. January 1988 (in Finnish)

YJT-88-02 Shallow reflection seismic soundings in bedrock at Lavia. Olli Okko. Technical Research Centre of Finland. Geotechnical Laboratory. March 1988

YJT-88-03 Hydrogen embrittlement of titanium and its alloys. Irina Aho-Mantila, Markku Kemppainen*. Technical Research Centre of Finland. Metals Laboratory. Metallurgy Laboratory*. March 1988

YJT-88-04 Dissolution mechanism of UO2 at various parametric conditions. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. April 1988

YJT-88-05 Sorption experiments at oxic and anoxic conditions. Annakaisa Koskinen, Martti Hakanen. University of Helsinki. Department of Radiochemistry. Antero Lindberg. Geological Survey of Finland. April 1988

YJT-88-06 Review on the research methods of matrix diffusion. Arto Muurinen, Matti Valkiainen. Technical

Research Centre of Finland. Reactor Laboratory. March 1988 (in Finnish)

YJT-88-07 REFREP: A near-field model for a spent fuel repository. Aimo Hautojärvi, Timo Vieno. Technical Research Centre of Finland. Nuclear Engineering Laboratory. May 1988

YJT-88-09 Corrosion of pure OFHC-copper in simulated repository conditions, Part I. Pertti Aaltonen. Technical Research Centre of Finland. Metals Laboratory. June 1988

YJT-88-10 Modelling of the biospheric transfer of radionuclides released from the geosphere into a lake. Vesa Suolanen, Timo Vieno. Technical Research Centre of Finland. Nuclear Engineering Laboratory. October 1988

YJT-88-13 Intraval Project, Test case 5: Traces tests at Finnsjön, Predictive modelling of the radially converging experiment. Aimo Hautojärvi, Veikko Taivassalo. Technical Research Centre of Finland. Nuclear Engineering Laboratory. November 1988

YJT-88-14 Long term creep strength of silver alloyed copper. Pertti Auerkari, Stefan Sandlin. Technical Research Centre of Finland. Metals Laboratory. December 1988

YJT-89-01 Geophysical borehole methods in fracture analysis of crystalline bedrock of the Loviisa site. Pekka Rouhiainen. G-Syst Oy. April 1989

YJT-89-04 Solubility and speciation calculations for Pu, Np and Th in simulated groundwaters. Margit Snellman. Technical Research Centre of Finland. Reactor Laboratory. May 1989

YJT-89-05 A literature survey on the dissolution mechanism of spent fuel under disposal conditions. Kaija Ollila. Technical Research Centre of Finland. Reactor Laboratory. June 1989 (in Finnish)

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