



**STATENS
KÄRNBRÄNSLE
NÄMND**

NATIONAL BOARD FOR SPENT NUCLEAR FUEL

SKN Report 17

Technical and

Socio-political Issues

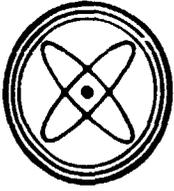
in Radioactive

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SKN -- 17 (V. 1A).

Volume I A

Safety, Siting and Interim Storage.
Appendices: Countries and International Organisations.



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NATIONAL BOARD FOR SPENT NUCLEAR FUEL

**TECHNICAL AND SOCIO-POLITICAL ISSUES
IN RADIOACTIVE WASTE DISPOSAL
1986**

**Volume IA
Safety, Siting and Interim Storage
Appendices: Countries and International Organisations**

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of
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APPENDIX A

THE COMMISSION OF THE EUROPEAN COMMUNITIES

A.1. OVERVIEW OF WASTE MANAGEMENT AND DISPOSAL STRATEGIES IN THE CEC MEMBER COUNTRIES

A presentation of the radwaste management and disposal strategies in the European Community is made in a recent paper (Orlowski, S. 1986). It is shown in that paper that amounts of low and intermediate level wastes (LLW and ILW) arising in France and in the United Kingdom will be about the same during the period 1986-90, in spite of the fact that the installed nuclear capacity in the UK is less than one third that of France. This is explained by the fact that 40% of the British capacity is gas cooled reactors, which only represent a small percentage of the capacity in France. The gas cooled reactors and the reprocessing of their spent fuel produce considerably more low level waste than do the oxide fuelled reactors. Typical figures for LLW & ILW are as follows (Flowers, R. 1982).

Magnox	8000 m ³	from reprocessing per GWeY
AGR	1300	from reprocessing per GWeY
PWR	850	from reprocessing per GWeY

The high level waste (HLW) policy of the CEC member states, with the exception of Spain, is to reprocess or at least to keep the reprocessing option open. This is in accordance with the recommendations by the CEC. Spain has the policy not to reprocess, and is therefore studying the direct disposal of spent fuel. Germany is also keeping the direct disposal option under review, even though it has a clear policy to reprocess.

The French AVM vitrification process is commercially available and is also being adapted to the Sellafield plant in the UK. The German PAMELA process is comparatively new and not yet as established as the French process.

Interim storage is needed both for HLW and for spent fuel. Pool storage facilities are already (or will soon be) available at La Hague and at Sellafield. Large dry storage facilities are ready at Gorleben and Ahaus in Germany. Italy is planning to build a large dry central interim storage facility in the 1990's. Central interim storage of vitrified waste has been used for more than ten years at Marcuole, France. New interim storage facilities for vitrified waste are planned at La Hague (around 1990) and at Sellafield (around 1995). The UK policy is to store the vitrified waste for several decades.

Regarding deep geological disposal on land, all the CEC countries which have nuclear energy programmes have studies in progress. Various media are considered (salt, clay, crystalline rocks). The time period needed to advance from the national geological survey of possible sites to the operation of a repository is expected to be 30-35 years.

A.2. The CEC Programme on Radioactive Waste Management

The mandate of the programme on radioactive waste management of the Commission of the European Communities (CEC) is to promote coordinated research activities between its Member States. The basis of the CEC's involvement is the Euratom Treaty of 1958. The general concept of environmental protection is based on principles issued by the Council of Ministers in November 1973. Since that time a European Community

radioactive waste policy has been gradually emerging. The rationale is that action taken at Community level should give added scientific value to that taken at national level, and, in addition, promote more public confidence than action by a single Member State. The Community policy emphasizes that the radioactive waste problem can only be tackled within a long-term perspective.

The Community Plan of Action (1980-1992) was initiated in order to give a policy framework for the activities of the CEC in the area of radioactive waste management. The 12 year plan is revisable every three years. Work is being coordinated in the Nuclear Fuel Cycle Division of the Directorate for Science, Research and Development of the Commission. Activities of the CEC are: to periodically evaluate and report on the state of radioactive waste management; to promote community cooperation in the management and disposal of radioactive wastes; and to promote the necessary research and development. In order to successfully carry out these tasks, the CEC has a yearly budget of approximately US\$ 20 million, which is about 10% of the total spent in the Member States themselves on R&D within this area.

Part of the CEC sponsored research is carried out by the Ispra establishment of the Joint Research Center, which is directly operated by the Commission with a four year planning base. Part of the research is carried out by various laboratories in the Member States, through a set of cost-sharing contracts under the coordination of the Commission, following a succession of five-year plans. In the years preceding the programme period, the Commission prepares proposals on well defined topics.

After approval by the CEC Council of Research Ministers, laboratories from the Member States apply for funding. The CEC provides today nearly one-half of the funds for such projects. However, when the subject of research is of great interest for the Commission itself, total funding may be provided.

A list of scientific reports and equivalent publications published by the CEC on radioactive waste management and covering the period from the start of the programme in 1975 up to November 1984 has been issued by the CEC (Hebel & Falke, 1984). This list does not include the numerous papers presented by the national laboratories at conferences, seminars, etc. within the framework of the CEC programme. A second edition of that report (Hebel & Falke, 1986) is in print and will include all reports published by the CEC on radioactive waste R&D 1975-84, as a result of both the shared-cost action programme and the JRC (Joint Research Centre, Ispra) programme.

A.2.a. The First Programme (1975-79) and the Second Programme (1980-84)

During 1979-1984, work within the CEC programme included studies on waste treatment and conditioning for all types of wastes, including the immobilization of gaseous wastes as well as geological disposal and shallow land burial.

The coordinated Community action on the evaluation of solidified high level waste has been, since 1975, an example of multinational scientific collaboration with an integrated approach spanning seven European laboratories. One topic of research has been the evaluation of

potential waste matrices. Results of the characterization of low and medium active waste forms have been compiled (Pottier & Glasser, 1986). Several reference glasses were selected (borosilicate glass and vitreous ceramics). Parametric investigations on the leaching of the glasses included the effects of leachants specific to the particular formations chosen (i.e., salt, clay, granite), thermal stability (devitrification, crystallization), radiation damage, and mechanical strength and fracture mechanics. The conditions governing the release of radionuclides from the vitrified wastes were identified and quantified in the majority of the cases. The development of physical and chemical models that describe these phenomena was initiated so that they could be used in safety studies on geological disposal. In 1983 a "Round Robin Test" was carried out by 12 laboratories to develop a standard autoclave leaching test for vitrified wastes in the Community.

More than half of the R&D expenditure during the 2nd Programme has been on waste disposal in deep geological formations, primarily for the disposal of high level wastes.

During the 1st Programme (1975-1979) an inventory of saline, crystalline and argillaceous formations possessing characteristics suitable for underground repositories was made in the Member States (CEC, 1980). The aim of subsequent R&D has been to confirm (or deny) that the formations were suitable. The research was on the feasibility and the safety of the waste containment system and the properties of its components, namely the packaged waste and its container, backfill materials, underground disposal facilities, host rock, and the

geological formation itself. Preliminary studies of deep repositories were carried out (CEC, 1982d).

Laboratory studies on the behavior of host rocks under temperature and pressure stresses were completed. Tests were carried out on granite specimens from the United Kingdom and France (from the test boreholes in Altnabreac and Auriat, respectively), on clay from the Boom formation in Belgium and from Italy, and on salt from the Asse mine in the FRG.

In particular, a joint study (Admissible Thermal Loading) was carried out between the CEC and three national laboratories to review the thermal effects induced by the geological disposal of high level wastes and to assess their consequences (CEC, 1982a). Three parallel studies dealt with the three main CEC formations. The studies used only vitrified high level waste, and the multi-barrier approach was considered. Disposal was assumed to be in a mined geological repository, under normal conditions only. The results are generic for granite, formation-specific for salt (i.e., for the Zechstein Salt type found in Northern Germany), and site-specific for the Boom clay formation in Belgium.

Realistic temperature limits were set for each rock type, taking into account the heat propagation, thermo-mechanical effects inside the rock formations, induced or modified ground water or brine movement, effects on the backfill material, the canister and on the glass, as well as on nuclide transport. Values for both waste and repository parameters resulting in an admissible heat loading of the host rocks were obtained. The goal of the exercise, however, was not to arrive at realistic working criteria, but rather at indicative values. Based on

this study, it was possible to conclude "within the current state of knowledge, that heat emission does not make the disposal of HLW into deep geological formation an impossible or unrealistic operation" (Come & Venet, 1983).

Large scale verification of the behavior of selected geological formations has started in Boom Clay at Mol, Belgium and in the Asse salt mine in the FRG. In the former, an experimental chamber was constructed at a depth of 225 m. Experiments are being made in the underground laboratory to assess waste/host rock interactions. Corrosion loops are being inserted into the clay from the underground room in order to test the interactions between clay and selected metals. In the Asse mine, some existing galleries were adapted for full scale tests, such as in-situ heating, stress and strain measurements and surveys of gases and fluids released by the salt. The heating experiments No. 5 and 6 were recently completed. The former allowed the determination of fluids released by heating of polyhalite, a secondary salt mineral. The latter aimed at inducing fractures in salt following excessively high temperatures deliberately generated (CEC, 1986a; CEC, 1986b). In addition, a 300 m deep borehole (at a depth of 750-1050 m) was dry drilled from one chamber of the mine, and its stability was monitored over almost two years.

The JRC has also done work on the feasibility of subseabed disposal. Both the drilling of disposal holes to a great depth, followed by the insertion of the waste from a semi-submersible platform, and the "penetrator" concept have been studied.

Two Community projects during the 2nd Programme are to contribute to an indirect proof of the safety of disposal of high level wastes in geological formations (Cadelli et al. 1983; Orłowski et al. 1983).

The MIRAGE (MIgration of RADionuclides in the GEosphere) project contributed to several research areas important for the safety assessment of repositories. The project addressed seven topics: radionuclide chemistry, laboratory simulation of migration, the characterization of host rock/radionuclide interactions, in-situ measurements, the search for natural geological analogues, the role of microorganisms at depths, and the development of new calculation tools. The MIRAGE project will make a major input to the far-field models. This has been found necessary because far-field chemistry is not sufficiently known.

The PAGIS (Performance Assessment of Geological Isolation Systems) project confronts the dilemma between doing general studies on the one hand, and site-specific studies on the other, for assessing the safety of geological formations. PAGIS is an attempt, between a generalized risk analysis and a site-specific study, to evaluate the efficiency of the engineered barriers (i.e., waste matrix, overpack, backfill), the impact on the environment, and the dose to man when selected parameters are varied (i.e., the depth of the repository, waste aging, etc.). This project involves most of the CEC Member States' experts in the field.

The first phase of PAGIS is finished and Phase II running (Cadelli et al 1984). The selection of the sites and the appropriate data were based on the CEC inventory. Three reference sites were selected for the PAGIS project. The Gorleben dome was selected as the reference for salt, but the range of characteristics considered covers typical domes

in the Netherlands and Denmark, as well as bedded salt in France. For clay, the Boom formation in Belgium was chosen; however other characteristics of clays in Italy and the United Kingdom are also used as variants. No particular site has yet been selected for granite. Three types of formations - outcrops, formations under sedimentary cover and coastal granite - are being considered. The data cover the range of values corresponding to the most promising CEC granite formations. In addition to these, three subseabed disposal locations were examined from a list of 15 in the North Atlantic, designated by the NEA Seabed Working Group.

Deterministic models are used to analyze the performance of the system under the normal evolution scenario. External events, largely probabilistic and time dependent, modify the conditions of the normal evolution of the repository. These altered evolution scenarios can be either short-, medium- or long-term events. The intrinsic probabilistic nature of these scenarios necessitates the use of the concept of risk. Finally, disruptive scenarios leading to large and abrupt radioactivity releases to the biosphere are also considered. The objective here is to show that these events (e.g., meteorite impacts, etc.) have such low probabilities of occurrence that they do not deserve detailed consequence analysis.

The initial goal of the model selection process is to collect the best available description of the various chemical and physical phenomena relative to waste degradation, canister corrosion and radionuclide migration. Because most existing near-field models are rather simple and existing knowledge about the near field interactions is

insufficient, the PAGIS project adopted a modular structure for the near field model with submodels for leaching, diffusion and solubility. The far-field models for PAGIS will be developed from hydrological site-specific models already available for many of the sites, as well as from geochemical models. Again, a modular structure was adopted.

The CEC has made an effort to evaluate the radiological consequences of radionuclide release into the biosphere. The work, which was carried out jointly by the National Radiological Protection Board (U.K.) and the Commissariat Energie Atomique (FR), has resulted in a comprehensive set of models and codes which allow dose estimation within the population of the CEC (CEC, 1979; CEC, 1982a).

The second phase of the PAGIS project started in 1984. This phase includes the development of detailed models for selected release scenarios, and the calculations of the consequences to the most exposed individuals and population. Sensitivity studies will be carried out on selected parameters to evaluate the uncertainty margins. The data base generated during the first phase will be updated.

In the third phase, safety assessments will be done for each formation, and the conclusions will provide guidance for future R&D programmes.

A.2.b. The Third Programme 1985-1989

The R&D programme for the period 1985-1989 was adopted by the Council on 12 March, 1985 (CEC, 1984; CEC, 1985). The main elements related to the disposal of radioactive wastes in mined geological formations are described below. The first five tasks are

generic, but the last three are site-specific and consist of the construction of experimental underground facilities on the territories of Member States, which will be open to members of the Community for cooperative research. Their purpose is to determine in-situ the numerical values of the parameters for building industrial scale disposal facilities and to develop radioactive waste emplacement techniques.

A.2.b.1. System Studies

Their objective will be to evaluate the feasibility and availability of management schemes for each waste category and to optimize their radiological and economic features. Gaseous, low, medium-level, long-lived (alpha) and high-level wastes will be studied. Though spent fuel is not regarded as waste in the Community, these studies will examine spent fuel management to obtain a comprehensive picture of the options, mainly as far as long-term interim storage is concerned. Studies may also examine the separation of heat emitting radionuclides (i.e., Sr, Cs) from the high-level waste.

A.2.b.2. Evaluation of the Multi-barrier Concept

The objectives of this task are the assessment of the long-term behavior of multi-barrier systems for the retention of radioactivity (i.e. waste conditioning, matrices, container, backfill, etc.) for predictive modeling, and the establishment of project quality control. In particular, the following studies of high-level wastes will be carried out: study of leaching mechanisms in geological media to evaluate the stability of vitrified high-level wastes; the acquisition

of data and models necessary for safety analyses; studies on containers, including degradation mechanisms and performance assessments; long-term effects of irradiation on the various barriers; studies on host rock/waste interactions to define source terms for migration studies; continuation of backfilling and other large-scale emplacement experiments; development of a standard test to evaluate radiolysis and the damage caused by irradiation; development of means and methods, including non-destructive methods, to assure the quality control of conditioned wastes; interlaboratory comparisons of testing and control equipment and methods.

A.2.b.3. Research in Support of Disposal Facilities

The objective of this task is the assessment of the long-term behavior of the geological barrier for predictive modeling and the development of disposal facilities. The realization of underground facilities will also require further work and will include the following studies: ground water transport of radionuclides and the hydrogeology of the repository environments; laboratory studies of the properties of the media where the in-situ experiments are performed; study of natural geological systems with regard to their long-term containment of certain radionuclides; resource availability; rock mechanic and other in-situ experimental studies, such as deep drilling and underground laboratories; conceptual design of repositories; and conceptual design of seabed disposal.

A.2.b.4. Safety Studies

The first phase of the PAGIS project has been completed during the 2nd Programme. In this 3rd Programme, the PAGIS methodology will be used to obtain an assessment of the isolation capacity of various waste disposal systems. Plans are under way to apply the methodology to other wastes, such as alpha and medium-level wastes.

A.2.b.5. Joint Elaboration of Waste Management Policies

The Community cooperation which has been developed at the scientific and technical stages during the first two programmes should be extended to the elaboration of criteria and recommendations for radioactive waste conditioning with respect to their handling and final disposal; for radiological limits for disposal, especially for the long periods of time involved in geological disposal; for satisfactory execution, taking into account the safety and environmental protection standards of the various operations involved in the management and disposal of radioactive wastes; for the management and disposal of radioactive wastes; for de minimis values for alpha/non-alpha and radioactive/non-radioactive wastes; and for multinational dimensions of waste management, such as regional waste disposal.

A.2.b.6. Pilot Facility in the Asse Salt Mine (FRG)

This project started in 1984, and the pilot facility was in operation by the end of 1986. The studies covered by the Community programme include: Excavation (at 800 m depth) and the installation of a gallery having the dimensions and the characteristics foreseen for a future industrial repository for high-level waste; emplacement of borosilicate glass spiked with Cs137 and Sr90 to simulate heat

production and beta and gamma radiation of a waste package; study of the combined effect of heat and radiation on salt, including measurements of the amount of water and gas liberated; the interaction of these components with the surrounding rock and containment; the rock-mechanical behavior of a salt pillar under conditions representative of an operational repository facility; and demonstration of the entire disposal system for high-level wastes in salt formations.

A.2.b.7. Pilot Facility in Clay at Mol (Belgium)

The project started in 1984 and is expected to be in full operation by 1995. The work covered by the Community programme will include the following activities: definition of the number and the features of galleries and the type of waste to be emplaced; followed by detailed studies, including mining engineering and radiation protection; excavation of one or more galleries representative of a future industrial repository from the existing access shaft at the 230 m level; depending on the results of the current R&D programme, the development and the construction of an excavation machine specially adapted to clay; and development of handling and radiation protection instruments.

A.2.b.8. Experimental Facility in France

The project should begin in 1987 and should be fully operational by 1989-1990. The geological medium will be chosen by the French government. The work covered by the Community Programme will include the following activities: detailed design of the facility; formulation of the experimental programme; construction of shafts, galleries and an experimental room; operation of the facility, including

qualitative and quantitative determination of the rock behavior (both in a disturbed and non-disturbed state); determination of parameters characterizing the migration of radionuclides and corrosion products; and in-situ testing of the components of a future industrial facility.

A.2.b.9. Natural Analogues

A Natural Analogue Working Group was established by the CEC in 1985 with the purpose of bringing modellers together with earth scientists and others, so that maximum benefit can be obtained from natural analogue studies with regard to safe disposal of radioactive waste.

A report from the first meeting of that group in November 1985 has been published (Come & Chapman ed. 1986). At the meeting attempts were made to identify the modellers' needs and the earth scientists' capacity to provide for them. Some of the most important processes, mechanisms, and properties that may be studied with the aid of natural analogues are:

	Leaching/ Mobilization	Transport	Retardation/ Retention
Solubility limitation	x		x
Groundwater accessibility	x	x	x
Radiolysis	x		
Material thermal stability	x	x	x
Colloid formation	x	x	
Dispersion		x	
Channeling		x	
Short-circuit pathways	x		
Fracture hydrology		x	
Diffusion			
matrix		x	x
intra-crystalline	x		
backfill	x	x	
Redox behavior	x		x
Sorption:			
fracture			x
mineral			x

The report also includes a list of available analogues (current as well as possible ones).

The next meeting of the Natural Analogue Working Group took place in June 1986. An international conference of analogue studies will be organized by the CEC early in 1987, to which a wider audience will be invited.

A.3. Literature on the CEC R&D Programme

The main results and discussions of all research activities during the periods 1975-1979 and 1980-1984 can be found in the proceedings of the two CEC conferences on radioactive waste management held in Luxembourg in 1980 and 1985 (Simon & Orłowski, 1980; Simon, 1985). Recent overviews of the R&D programme on radioactive waste management and storage are given in (CEC, 1982b; CEC, 1982c; CEC 1983; Orłowski, 1985).

A selection of documents published 1984-86 has been listed after the reference list in order to give the reader an impression of the detailed studies.

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THE INTERNATIONAL ATOMIC ENERGY AGENCY

The statute of the International Atomic Energy Agency (IAEA) was approved on October 23, 1956, and entered into force on July 29, 1957. The Agency is part of the United Nations family, and with 111 members it is the largest organization of this type. The objectives of the waste management programme of the Agency are "to assist its member states in the safe and effective management of information, providing guidance and technical assistance, and supporting research (Semenov, 1983).

The Agency has limited funds available for sponsoring research but encourages research in member states through the organization of coordinated research programmes. It does, however, sponsor research work directly in the laboratories of developing countries and its own laboratories.

Though the IAEA had a programme on radioactive waste since its inception, it became more active in the field after the 1972 United Nations Conference on the Human Environment requested greater international cooperation on the topic and after the emergence of nuclear power as a major contributor to the world's electricity generation capacity. At the request of its general conference, the Secretariat prepared a report on the work of the Agency in the field (Semenov, 1983).

The Agency's mandate to "seek to accelerate and to enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" necessitates that a safe method of handling and disposing of radioactive wastes be found. To that end, the Agency convenes a variety

of meetings where research results and national and international programmes can be discussed and made available to member nations, and holds technical committee and advisory group meetings to formulate guidelines and international recommendations for use by national authorities and to develop information for use in international law, if requested. In addition, the Agency provides experts, training, technical assistance, and study tours. In some areas, the recommendations of the Agency are widely adopted (e.g., suggested regulations for transport of nuclear materials).

The Agency's waste management programme is divided into three categories:

1. Waste Handling and Treatment - Includes low- and intermediate level solid and liquid wastes and effluents, gaseous wastes and effluents, high-level and alpha waste, decommissioning and decontamination and non-power plant waste.
2. Underground disposal - Includes low- and intermediate-level waste in shallow ground, low- and intermediate-level waste in rock cavities, high-level and other waste deep underground and waste from uranium mining and milling.
3. Environmental Aspects of Nuclear Energy - Includes marine environmental protection, sea disposal, IAEA's role under the London Convention, environmental paths of radionuclide releases, and environmental assessment of nuclear facilities.

The Agency has recognized that the disposal methods for high-level and transuranic wastes that are "most generally accepted are the emplacement of the conditioned wastes in mined repositories in deep, stable geological formations" (Semenov, 1983).

The results of their studies on this topic are published as recommended safety standards and guidelines. The Agency proposes to publish in 1988 a code of practice for the disposal of radioactive wastes in shallow ground rock cavities and deep geological repositories and criteria for underground disposal of high-level radioactive wastes.

The Agency has already published the following Safety Series Reports:

- Development of Regulatory Procedures for the Disposal of Solid Radioactive Wastes in Deep Continental Formations (No. 51, 1980);
- Underground Disposal of Radioactive Waste: Basic Guidance (No. 54, 1981);
- Safety Assessment Methods for the Underground Disposal of Radioactive Waste (No. 56, 1981).
- Concepts and Examples of Safety Analysis for Radioactive Waste Repositories in Deep Continental Geological Formations (No. 58, 1983); and
- Criteria for Underground Disposal of Solid Radioactive Wastes (No. 60, 1983).
- Performance Assessment for Underground Radioactive Waste Disposal Systems (No. 68, 1985)

The Agency has also published the following Technical Reports:

- Site Selection Factors for Repositories of Solid High-Level and Alpha-Bearing Waste in Geological Formations (No. 177, 1977); and
- Site Investigations for Repositories for Solid Radioactive Wastes in Deep Continental Geological Formations (No. 215, 1982).

- Deep Underground Disposal of Radioactive Wastes: Near Field Effects (No. 251, 1985)
- Techniques for Site Investigations for Underground Disposal of Radioactive Wastes (No. 256, 1985)

In Criteria for Underground Disposal (Safety Series No. 60) most recommendations are couched in general terms such as "the hydrogeological characteristics of the geologic environment should tend to restrict ground water flow within the repository".

In their Basic Guidance for Underground Disposal (Safety Series No. 54) in the table of "Tentative Relationship of Preferred Disposal Options and Radioactive Waste Categories", they show that the only recommended disposal option for high-level long lived wastes is emplacement in deep geological formations in a repository excavated especially for the disposal of radioactive wastes. If the repository is naturally isolated from moving ground water (i.e., dry), then the wastes should be solid, immobilized, packaged and spaced for heat dissipation. If the repository is in a geological environment with some movement of ground water (i.e., wet) then the comments for dry storage hold, but the comment is added that this type of repository should possibly have more engineered barriers.

In addition, the IAEA published its Basic Radiation Safety Standards and the Safety Series No. 45 on the limitation of releases of radioactive substances, jointly with the International Labour Organization (ILO), Nuclear Energy Agency (NEA), of the OECD, and the World Health Organization (WHO). Both contain basic concepts and policy choices relevant to waste disposal policy.

It should be noted that the IAEA plays an essential role in the free exchange of information on radioactive waste disposal. Through its

auspices major technical conferences on the topic have been held (we have relied heavily on the papers presented at its conferences) and scientists of many nations have worked together and exchanged information on its technical committees and review boards. Through these contacts many personal, bilateral and regional exchanges have developed.

Parallel to the work of the International Commission on Radiological Protection (ICRP) on dose determination and limitation, the IAEA's work on guidelines and standards for site selection, performance assessment and transportation provide internationally approved guidance and standards by which national programmes can be judged and evaluated. Their standard methodology enables laboratories around the world to compare results, knowing that they were obtained under uniform conditions.

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APPENDIX C

THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION AND THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

The International Commission on Radiological Protection (ICRP), founded in 1928, issues basic recommendations on radiation protection. These recommendations form the basis for regulations on radiation dose limitation in most countries as well as for the Basic Safety Standards of the international organizations IAEA, NEA/OECD and WHO.

ICRP has a close relationship with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), a standing committee under the United Nations General Assembly, issuing comprehensive reports on current knowledge of radiation effects and dose levels, including exposures from the nuclear power industry (UNSCEAR, 1982). The reports of ICRP and UNSCEAR are the most authoritative international sources of information for radiation risk estimates.

Both ICRP and UNSCEAR assume that, for low radiation doses, the probability of stochastic harm (cancer and severe hereditary damage) is proportional to the dose. On this assumption, the total radiation health detriment in an exposed population is proportional to the collective dose. This linearity assumption forms the basis of present radiation protection recommendations.

ICRP has proposed the following three basic requirements for radiation protection (ICRP, 1977):

1. No practice shall be adopted unless its introduction produces a positive net benefit (justification of practice);
2. All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account

(optimization of protection);

3. The dose to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission (dose limitation).

ICRP has adopted Radiation Protection Principles for solid radioactive waste disposal (ICRP, 1985) because of the probabilistic nature of discharges and the length of the time periods of concern. These principles fall within the guidance of ICRP 26 (1977) and 30 (1979). The Commission has recommended that its current dose limits should apply for normal releases from repositories and that risks from probabilistic events be limited by taking into account the probability of the dose as well as the probability of serious health effects from the dose so as to limit the average annual risk to a level less than about 10^{-5} .

Another Task Group studying optimization techniques other than cost-benefit analysis is expected to consider also the development of optimization techniques applicable to probabilistic exposures.

The Commission has established rules exempting individual dosages and risks "below which there would be no further need for radiation protection concern" so as not to waste limited resources on trivial problems at the cost of neglecting major problems. (ICRP, 1985). Therefore, it has concluded that annual individual doses of 0.01 mSv should be exempt from consideration provided that the collective dose commitment is lower than of the order a man Sv.

A Task Group of ICRP Committee 2 is developing a more realistic model of human metabolism of actinide elements than the one used in ICRP Publication No. 30 (ICRP, 1980). This work will also include

reassessment of the absorption of neptunium from the gut, a matter of particular interest in long-term assessments of risks from nuclear waste.

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APPENDIX D

THE NUCLEAR ENERGY AGENCY

The Nuclear Energy Agency (NEA) - a branch of the Organization for Economic Cooperation and Development (OECD) - is a multinational body that stimulates and coordinates the efforts of its member countries in several areas of radioactive waste management (Johnston, 1983; Olivier & Stadie, 1983). The NEA membership includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, the Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America. The agency sponsors and coordinates international cooperative projects between member countries, performs reviews of research programmes, issues policy guidelines and state-of-the-art reports, sponsors workshops and symposia, and seeks to enhance the exchange of information among national research teams and regulatory agencies (Olivier, 1984a; Olivier & Stadie, 1983). These activities differ from those of the CEC and the IAEA. The CEC serves primarily as a research financing institution, distributing funds to its member countries for projects that have multinational appeal. In recent years the IAEA has become more involved in developing countries, assisting the transfer of nuclear technology to these nations. In contrast, it is a basic policy of the NEA not to engage in research that is accomplished routinely by member countries (Olivier, 1984a).

The NEA is more concerned with enhancing the state-of-the-art in specific areas through information exchange and coordination of research (Olivier, 1984a). The NEA Newsletter is published twice a year, and contains informative overviews of various topics in the nuclear energy field. Articles on radioactive waste disposal appear quite frequently in that publication (Olivier, 1984b; Detilleux, 1985; NEA, 1985b). Overviews can also be issued as separate reports (NEA, 1985c).

Recent activities of the NEA have included an expansion of its data bases the International Sorption Information Retrieval System (ISIRS) and the chemical thermodynamic data base of the NEA data bank of Saclay, France, the establishment of long-term radiation protection objectives for waste disposal, and state of the art reviews on geologic disposal on land and seabed disposal (Muller, 1984). The NEA has also arranged meetings in connection with the international Stripa project and worked to clarify the meaning of a "demonstration" of the concept of safe disposal of radioactive waste. Much of the work is aiming at increasing confidence in the waste disposal techniques among technical people as well as among the public. Particular interest is therefore paid to areas such as public acceptance, institutional factors, etc.

The competent body of NEA for decisions on its radioactive waste management program is the Radioactive Waste Management Committee (RWMC). The members of RWMC are senior representatives from nuclear authorities and nuclear waste programs of the member countries. To advise the RWMC in specific areas, advisory groups have been set up in program areas of importance. There are presently three such groups:

- The Performance Assessment Advisory Group (PAAG),
- The Advisory Group on In-Situ Research and Investigations for Geological Disposal,
- The Seabed Working Group.

D.1. Data Exchange Activities

ISIRS is a computer-based data bank for geochemical information relevant to radionuclide migration in the geosphere (Muller, 1983). The data consist of K_d values for various elements under defined physical and geochemical conditions. Compilations of these values are examined statistically to determine trends and are useful in scoping calculations to assess the suitability of various geological media for disposal and the sensitivity of radionuclide transport to changes in geochemical variables. Currently emphasis is placed on actinide sorption from natural ground waters under reducing conditions (Johnston, 1983).

Four quality control systems must be passed before data are admitted to the ISIRS bank (Muller, 1984). First, ISIRS Technical Committee members from each member country screen the data and examine the validity of the research methodology that produced them. If passed, the data are transferred to the ISIRS data base management system, which then issues a printout that is examined for transcriptional errors. The third control measure involves a check by NEA personnel. In consultation with the original researchers, a confidence weighting factor is determined, reflecting the precision and accuracy of the experimental technique and the subjective confidence of the researchers and the NEA reviewers in the applicability of the results to geospheric migration. Finally an internal computer based check examines the data for

mathematical consistencies in such matters as ionic strength, charge balance, and reasonable specific surface areas for the geological media.

Though modelling groups are clamoring for K_d values, some geochemists have voiced their objections to this simplified parameter (NEA, 1983b). The K_d concept is an averaging technique, phenomenologically related to a wide variety of physical, chemical and biological processes in the geosphere. These processes include sorption, ion exchange, precipitation, diffusion into dead pore space, ultrafiltration and chemical substitution reactions (NEA, 1982a). They are confounded in turn by complexation and speciation events and the formation of colloids.

In addition to ISIRS, the NEA has begun the compilation and critical review of more fundamental parameters, such as the Gibbs energy of formation, entropy of formation, enthalpy of formation and heat capacity values, from which speciation and equilibrium constants can be forecast for ten elements of interest in nuclear waste disposal (uranium, neptunium, plutonium, americium, technetium, cesium, strontium, radium, iodine and lead). Data for surface bonding polarization models can also be stored in this system. This chemical thermodynamic data base will serve most phenomenological codes now being developed for radionuclide migration in the geosphere (Mueller, 1985). The question is whether these codes, while perhaps more satisfying from a specific point of view, will have sufficient engineering applicability to real design situations where data bases are never exhaustive and confidence in model calculations derives as much from tractability as from theoretical rigour. The K_d concept has remained popular precisely because it is easy to comprehend and apply. Originally developed by chemical

engineers, it models the geosphere as a huge ion-exchange column. Provided that the transported species is simple (say, has but one oxidation state), and the media is uniform for K_d , the concept is a useful modelling tool. For example, in principle it can accurately predict the migration of Cs or Sr in homogeneous clays. For the migration of transuranic elements in fractured media under poorly defined redox conditions, transport predictions based on K_d values are of much more questionable value (NEA, 1983b).

At NEA, developers of the geochemical data base are seeking a balance between the alluring but potentially misleading simplicity of the K_d approach and the muddled complexity of a more rigorous thermodynamic model (Muller, 1984). They suggest that complex codes be constructed with provisions to selectively cancel subroutines for all but the most dominant retardation mechanisms. With this approach the geochemical complexity of the overall model can be systematically and intelligently reduced. The hidden assumptions in the K_d approach are addressed and justified if possible, while more complex phenomena are modelled only if required for overall accuracy. If only one or two species dominate in the migration of a single radionuclide, other species will not be carried through the calculations. The calculational resolution may be decreased in either the hydrological or the geochemical routines. Finally, a provision for variable time steps may be introduced, so that slowly changing properties need not be recalculated at every time interval. For all of these choices the important factor is to know why a particular balance has been struck between practical constraints, and the attempt to model geospheric transport as

rigorously as possible. Conservative estimates for effective K_d values may be useful, however, and NEA officials generally support those of Krauskopf cited in the WISP report in the context in which they were used (Muller, 1984; US-National Research Council, 1983).

At present, complexation with large organic species is not included in the thermochemical data base. The impact of simple organic compounds is assessed on a limited basis. In response to interest expressed by several member countries, the NEA has sponsored a workshop on the effects of naturally occurring organic compounds and micro-organisms on radionuclide transport. It was generally agreed that in the post closure environment of deep geological repositories of high level waste, neither organic complexes (anthropogenic or natural) nor microbes are expected to be of significant concern in the mobilisation of radionuclides from the repositories when considered in the context of other transport mechanisms. They also found that the detrimental influence of organic compounds and microorganisms seems limited to: i) increase in radionuclide solubility, and ii) potential mobilisation by sorption to microorganisms. The degree to which these detrimental influences will occur is not yet quantifiable.

The influence of colloidal transport is perceived as a more serious problem (Muller, 1984). Uncertainties are compounded because much of the current laboratory and field data relevant to colloidal events are of questionable value due to sampling and analytic procedures. For example, oxidation of ground water samples can result in the precipitation of ferric hydroxide colloids. The colloids of most interest are probably those that will form at the redox front, where the transition

between oxidizing and reducing conditions lowers the solubility of many key radionuclides. Whether the insoluble species will precipitate entirely from solution or will be transported in colloidal form is a critical issue. Colloidal formation may actually retard radionuclide migration if transport is diffusion-limited. The diffusivity of colloids is always lower than dissolved species, and in the case of matrix diffusion, colloids trapped in tight pore spaces may be permanently removed from the flow path. The significance of colloids in an overall safety assessment is yet to be demonstrated.

A special Newsletter Series on Radionuclides Migration in the Geosphere is also issued by the NEA twice a year (NEA, 1983c, 1983d, 1984d). This publication is distributed free of charge to over 500 scientists.

In 1984 two workshops were arranged within this R&D area: The CGDD/USIRS workshop on Coupling of Hydrologic and Geochemical Models in Radioactive Waste Safety Assessments, Paris, June 12-13, 1984 and The Workshop on the Source Term for Radionuclide Migration from High-Level Waste or Spent Fuel under Realistic Repository Conditions, Albuquerque, New Mexico, USA, Nov. 13-15, 1984.

D.2. HYDROCOIN

The International Hydrocoin Project was started in May 1984. The study is set up by fourteen organisations, including the Swedish Nuclear Power Inspectorate (SKI) acting as managing participant and OECD/NEA taking part as a member of the project Secretariat.

HYDROCOIN is an international project for studying groundwater hydrology modelling strategies. This means that it is concerned with how to use the modelling tools in an appropriate way. It deals with:

- the computer codes and how accurate they are (code verification)
- the capabilities of the hydrological models to describe field measurements and real world hydrological situations (model validation)
- the impact of various parameters and physical phenomena on the results (uncertainty and sensitivity analysis).

The overall aim is to gain further understanding of and confidence in the complex field of hydrological modelling of potential repository sites.

NEA will publish the results of the HYDROCOIN study. Through its Data Bank it promotes the exchange of hydrological codes being used in the study.

D.3. Radiation Protection Objectives

The Committee on Radiation Protection and Public Health (CRPPH) and the Radioactive Waste Management Committee (RWMC) of the NEA have issued a report titled "Long Term Radiation Protection Objectives for Radioactive Waste Disposal" (NEA, 1984b). This review concludes that an individual risk upper bound is the best criterion for performance assessment. It recommends that this limit be set at 10^{-5} yr^{-1} for chronic exposures, which by ICRP standards corresponds to 1 mSv yr^{-1} for exposures and scenarios of probability one. For exposures of limited duration, the recommended risk limit is $5 \times 10^{-5} \text{ yr}^{-1}$ (5 mSv yr^{-1}). Individual countries must decide how this total risk limit should be

apportioned among various sources of radiation to establish risk limits for activities in the field of radioactive waste disposal. Standards based on collective dose were not recommended because calculations for collective doses in the far future involve significant uncertainties related to population behavior and other factors. The report suggests, however, that the optimization approach using collective doses should be useful for comparative purposes in assessing various waste management strategies. No de minimis standards were recommended. It was agreed, however, that comparative analyses of collective dose in optimization studies could be truncated at a time when further calculations would fail to distinguish among the disposal options.

D.4. Overview of Geological Disposal

The NEA has completed another review titled "Geological Disposal of Radioactive Waste: An Overview of the Current Status of Understanding and Development" (Johnston & Hamstra, 1983; NEA, 1984a). The report concludes that there is no technical reason preventing immediate safe underground disposal of HLW, but that technical advantages do accrue if the wastes are first aged to reduce their thermal output. Thermal damage to the integrity of salt formations has apparently been overestimated; recent German experimental work at Asse demonstrates that salt anneals (i.e., its microfractures self-heal) under gentle heating and cooling cycles.

Economic analyses were characterized as being difficult. Costs of regulatory compliance and detailed site characterization may constitute a large fraction of the total cost of developing a deep geological

repository (Olivier, 1984a). These costs cannot be predicted with confidence. Engineering costs, even for disposal featuring a large copper canister, are expected to be modest by comparison.

Borosilicate glass is viewed as an acceptable waste form, and no pressing need is perceived among the member countries for developing a more leach resistant matrix material (Muller, 1984). Except in high ground water flow environments, solubility limits and the outward diffusive flux are expected to control the source term.

The question of an international repository for nuclear work has been raised by some member countries of NEA. In response to this NEA recently has performed a preliminary study on "International Approaches on the Use of Waste Disposal Facilities." The aim of this study was to develop an understanding of the requirements and justification, if any, for a comprehensive study of aspects associated with this issue. As this is a highly sensitive question and as in any case an international repository would have to await the establishment of a national repository, it is probable that further studies of this approach will still have to wait for a long time.

D.5. Subseabed Disposal

Subseabed disposal is dealt with in Volume II of this report. The description of the NEA activities within that R&D area is included in that volume. Some references are included in the reference list here (NEA, 1983e, 1983f, 1984c, 1984e).

D.6. Demonstration

The NEA in 1983 published a brochure on the meaning of a demonstration for the safe disposal of radioactive wastes (NEA, 1983a). The report distinguishes between a direct demonstration, which is relevant to short term activities, and an indirect demonstration, which is the only possible kind for longer term processes such as HLW disposal in mined geological repositories.

Direct demonstrations involve the actual design and construction of experimental facilities that represent the disposal environment at an appropriate scale. Examples include underground laboratories for in-situ experimentation, pilot plants for waste treatment, and transportation units. In 1985 the NEA published a survey of projects relevant to demonstration in its member countries (NEA, 1985a).

Indirect demonstrations on the other hand rely on predictive analyses based on extrapolation from a body of scientific data and engineering experience. Such analyses will never be devoid of uncertainty, and personal judgment will always play a role in their acceptance. The NEA has therefore - under the guidance of its Radioactive Waste Management Committee - devoted a considerable amount of effort towards the further development of systems performance assessment methodologies. The first NEA workshop on this topic was held in 1982. It critically reviewed the status of performance assessment methodologies in both their generic and site-specific aspects in order to provide guidance for the further development of predictive mathematical models and also to facilitate comparison of different approaches to modelling and between safety assessments of alternative disposal options. In

October 1985 a second workshop on this subject was arranged by the NEA in Paris (NEA, 1986). This workshop was concentrated on the examination of links or interrelationships between the major components of performance assessment, in particular the following:

- the links between performance assessments and regulatory requirements;
- the links between mathematical models used in performance assessments.
- the links between model development and field/laboratory observations.

D.7. Waste Classification

The NEA is not working on a waste classification scheme (Olivier, 1984a). Such schemes have a multiplicity of objectives. Waste classification is probably most useful when site-specific disposal targets are defined.

D.8. Performance Assessment of Nuclear Waste Disposal

As indicated above, a major part of the NEA waste management programme concerns the field of long term performance assessment and the associated R&D. The current and planned programmes cover a wide range of activities in this field. It is ultimately aimed at building confidence within the technical community in the methods used and the results obtained when analysing the potential risks from nuclear waste disposal.

It is an area of great interest for both those developing assessment methodologies and making long term predictions on the behavior of disposal systems and those regulators having to critically evaluate the results from such calculations. Within NEA, a new permanent Group of

Experts on Performance Assessment has been created recently to advise the Radioactive Waste Management Committee (RWMC) in this increasingly complex field, particularly on priority topics and joint activities. Another objective of this Group is to ensure that performance assessment is approached in a way which allows the coherent integration of all the relevant physical, chemical, geochemical and biological factors which may affect the possible return of radioactivity to man. Discussion in common of the methodologies used for performance assessments and of the results obtained contributes to increased confidence and represents in itself, through the intensive and detailed reviews made, a kind of quality assurance programme. The best illustration of this practice is the success enjoyed by intercomparison exercises for mathematical models used in performance assessments, such as hydrological models verified and validated within the HYDROCOIN exercise which was initiated by Swedish Authorities with the cooperation of NEA.

The NEA's main activity geared towards helping the advancement of predictive modelling techniques is in the development of probabilistic assessment techniques via the Probabilistic Systems Assessment Codes (PSAC) User Group. This group was established in early 1985 for the purpose of exchanging information and experience on SYVAC-like codes, providing for mutual peer reviews and discussing specific technical issues such as code quality assurance and verification. The work of the User Group falls under three main headings:

- exchanging and compiling codes;
- code intercomparison, and;
- holding topical specialist meetings.

The first activity is based on work at the NEA Data Bank, in Saclay, France, and currently involves the testing of fully developed computer programs, including codes from Canada (SYVAC) the United Kingdom and the CEC. The second activity which is just beginning involves the intercomparison of codes via a series of benchmark exercises where the same cases are run by different participating organisations using different codes and the results are compared for discrepancies. The third activity involves holding informal topical meetings in conjunction with the main meetings of the User Group. Following critical discussion of each participant's experience and problem areas, a series of guidelines are prepared and a summary of presentations is made. Such meetings have been held on: input data acquisition and handling; methods and procedures for sensitivity analysis; the presentation of results; and statistical sampling procedures.

In the area of systems performance assessment, international cooperation takes many forms and is likely to expand even further in the next few years. Within NEA, in addition to a series of topical workshops to be organised shortly on uncertainty analysis, scenario identification and near-field effects, it is planned to expand the NEA Data Bank activities in the area of performance assessment in the next few years. Computer services provided jointly for the handling of data bases, the collection, testing and distribution of codes on a wide basis, and the coordination of intercomparison exercises appear as a logical development of present activities.

D.9. Decontamination and Decommissioning

NEA has performed a survey of decommissioning technology in member countries (Johnston, 1983). In 1984 a workshop was held on the comparison between storage with surveillance and immediate dismantling of nuclear reactors (NEA, 1984).

An agreement has been set up between nine OECD Member Countries on Co-operative Programme for the Exchange of Scientific and Technical Information concerning Nuclear Installations Decommissioning Projects. Twelve facilities that are to be decommissioned are included in the project, notably the Rapsodie (France), Shippingport (US) and Lingen (FRG) nuclear power plants and the West Valley Reprocessing Plant (US). A five-year program has been prepared giving time-schedules for each facility participating within the agreement.

D.10. Stripa Project

The NEA plays an important role as sponsor for the international Stripa project in Sweden. The NEA has arranged workshops and contributed to the documentation on the project (NEA, 1982b, 1983g, 1985d; Carlyle, 1985).

D.11. Public Acceptance, Institutional Factors, etc.,

During the last few years increased weight has been given to a number of non-technical aspects, which are very important in connection with waste disposal issues, such as public acceptance, institutional factors, legal aspects, etc. (NEA, 1984f; 1984g, 1984h; Shapar, 1984; Cheghikjan, 1984). A workshop on Radioactive Waste Management and Public Information is being planned by NEA and will be held in 1987.

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APPENDIX E

THE FEDERAL REPUBLIC OF GERMANY

E.1. Introduction

The term "Entsorgung" in German describes all aspects of radioactive waste management, including the handling of spent nuclear fuel, conditioning, reprocessing, fuel fabrication and final disposal. The Integrated Entsorgung Concept is progressing on a timetable that anticipates full scale operation of all components by the year 2000 (Salander 1983). These components include one reprocessing plant (including buffer storage, vitrification facility, and interim glass block storage), interim storage facilities and final repositories for all types of wastes.

By the end of 1985 nuclear power was generating more than 30% of the FRG's electricity with a combined plant capacity of about 17 GWe. (Gloss and Einfeld 1986). It is expected that 25-30 GWe of nuclear capacity will be on line by the turn of the century. Total spent fuel accumulation of 10,000 Mg by the year 2000 is expected. The planned repository at Gorleben is being designed to accommodate a nuclear electricity production of 2500 GWe-yr. Costs for the construction and operation of the repository are projected at $DM 2.6 \times 10^9$ (1984 Marks) (Schneider 1984). The reprocessing plant at Wackersdorf of 350 Mg yr^{-1} is expected to cost around $DM 5 \times 10^9$.

In February 1980, the state and federal governments issued a statement known as the Revised Principles of Entsorgung (BMI 1983). According to these principles, increasingly concrete steps must be

taken toward Entsorgung (i.e., site selection for a reprocessing facility and a repository, time table for their construction, etc.) before new plants can receive operating licenses and old ones can continue operating. Presently the Atomic Law requires the reprocessing of spent fuel because of its valuable fuel content. This has resulted in increasing pressure on the utilities to go ahead with a fuel cycle with reprocessing. Efforts to site and license a reprocessing plant and facilities for the storage and disposal of vitrified wastes are in progress. Legal challenges have delayed licensing and construction of nuclear facilities in the past and are also delaying back-end fuel cycle facilities.

The newly created Federal Ministry for Environment, Nature Protection and Reactor Safety is responsible for the regulation of nuclear activities and the establishment of regulatory requirements. This activity was previously in the Ministry of Interior. The ministry is advised by the Commission for Reactor Safety (RSK) and the Commission for Radiation Protection (SSK). The federal regulations are routinely adopted by the states, which have the actual licensing authority.

The federal government has the ultimate responsibility to plan, construct, and operate facilities for the collection and final disposal of radioactive wastes. The Federal Institute for Science and Technology (PTB) is the lead agency. The PTB is similar to a national bureau of standards and has expertise in the areas of radiation safety and engineering. Construction of the repositories will be carried out by the German Company for the Construction and Operation of Waste Repositories (DBE), while the geological and geotechnical work is done by the Federal Agency for Geosciences and Resources (BGR). Supportive

research and development are conducted by the Company for Radiation and Environmental Research (GSF), the Karlsruhe Nuclear Research Center (KfK), Julich Nuclear Research Center (KfA) and the BGR.

All other aspects of the back-end of the fuel cycle are the responsibility of the nuclear utilities. Through their jointly owned subsidiary, the German Company for the Reprocessing of Nuclear Fuels (DWK), they handle waste conditioning, treatment, reprocessing, and interim storage. The costs incurred by the PTB for work on final disposal are reimbursed mainly by the DWK (and consequently the electricity consumers) and to a smaller extent by other nuclear waste producers such as universities and hospitals.

Government sponsored research on disposal and other activities for Entsorgung is coordinated by the Federal Ministry for Research and Technology (BMFT), but most of this work is conducted by the nuclear research centers such as the KfK, and other organisations such as the GSF, PTB, The Hahn-Meitner Institute for Nuclear Research (HMI), or the BGR.

E.2. Disposal Strategy

E.2.a. Geology

More than any other nation, the Federal Republic of Germany is committed to the geological disposal of high level radioactive wastes in deep salt formations. From 1967 to 1978, the abandoned salt mine Asse - near Braunschweig in Lower Saxony - was used for the disposal of all low-level and most of the medium-level wastes produced in the FRG during that period for experimental purposes (Hirsch 1983). The

operating permit expired in 1978. Since that time no final disposal of any radioactive waste has occurred in the FRG. The Asse mine now serves as a test facility for experiments relevant to radioactive waste disposal in the salt dome at Gorleben.

Salt has several advantages as a repository medium. Its thermal conductivity is high ($5 \text{ W m}^{-1} \text{ }^{\circ}\text{C}^{-1}$), and its viscoplastic behaviour at low to moderate temperatures promotes the self-healing of fractures. The very existence of a salt formation testifies to the local absence of circulating ground water. Should water intrude, the initial permeability would be rather low. Salt is also very easy to mine. The disadvantages of salt include high solubility, instability at high temperatures and pressures, the corrosive nature of most brines, and a generally poor sorptive capacity. The salt dome at Gorleben is being explored, and an experimental programme is in progress to define the mechanical and geochemical responses of salt formations and brine inclusions to thermal and radiation stresses.

The German programme also includes work on alternative rock types, such as iron-ore (for LLW and decommissioning wastes (DCW)), and to a smaller extent on granite (for HLW). The abandoned iron-ore mine Konrad is located 1100-1200 m deep near Salzgitter in Lower Saxony. Following extensive studies, the GSF concluded in 1982 that this dry mine was suitable for the disposal of low-level and decommissioning wastes (Hermann 1984). Over $500,000 \text{ m}^3$ of emplacement volume is available. A safety analysis has been performed and indicates that the facility can be operated safely (Bergetal 1984). Start-up for LLW emplacement is scheduled for 1991. Work on granite is confined to regional surveys

and cooperation with Swiss researchers in their underground laboratory at Grimsel (Lehr 1983). Clay formations have been examined in Lower Saxony as far as they are part of the sedimentary complex of the Konrad site.

The PTB favours mined geological repositories. The Danish concept of deep boreholes is not considered suitable in the FRG, because it will have much greater volumes of wastes, which would - amongst other reasons - entail unacceptably large ground surface requirements (Scheider 1984). Prior to canister emplacement, pressurized water would be required to keep the holes open, and thus local brine-induced corrosion would be accelerated. The in-situ geology would also be less well defined.

The Gorleben salt dome is 15 km long, 5 km wide and more than 3 km deep. The repository itself is designed to occupy a 5 km by 1 km area, 800-1100 m below the surface. At least 200 m of undisturbed rock salt should border the repository on all sides. Acceptance of the Gorleben site depends on the results of an extensive underground exploration programme, which will not be completed before the early 1990s. No other site is being considered today for the disposal of HLW. In case Gorleben is not found suitable, it is claimed that it will be possible to locate and evaluate another site relatively rapidly, because the lessons from Gorleben would be applied to another salt dome.

Four deep (2000 m) boreholes have been drilled into the flanks of the Gorleben dome. Pilot holes for two central access shafts have been sunk to 1000 m, and work on the shafts themselves commenced in 1984. Shaft walls will be lined with layers of asphalt and concrete (Schneider

1984). These shafts and a connecting gallery at 800 m are scheduled for completion in 1988. Horizontal drifts up to 1000 m long will be mined from the gallery. It is anticipated that HLW canisters will be stacked in boreholes drilled 300 m deep into the floors of drifts.

The central section of the Gorleben dome consists of pure rock salt, but the older rock salt is not as large as was expected. Severe criticisms of the site has been voiced by the anti-nuclear Ecology Group (GOEK) in Hannover (Hirsch 1983; Kreuzsch and Hirsch 1984). This organization charges that the official safety analyses are too optimistic on many points and disregard existing uncertainties. The group claims that there is no unfractured rock mass at Gorleben large enough to accommodate a repository. Additional allegations include possible seismic activity during the past million years and the presence of natural gas in association with the dome. Although currently noncirculating, these fluids may be mobilized following heat induced deformation of the salt mass. One prominent critic has advocated the development of several repository sites, arguing that thermal problems will be mitigated by decentralization of the wastes (Hermann 1983).

E.2.b. Reprocessing and Spent Fuel Disposal

Spent fuel will be stored seven years before reprocessing. Storage facilities include compact racks in pools at reactor sites and nodular cast iron transport casks for AFR storage. In the latter, the fuel is kept dry in a helium atmosphere.

The utilities of the FRG have contracted with COGEMA and BNFL for their reprocessing needs; current agreements expire between 1988 and

1993 (Closs, 1986). Reprocessing technology has been studied at Karlsruhe, where WAK has operated the 35 Mg yr⁻¹ reprocessing plant for DWK since 1971. The original HLW management program called for an Integrated Entsorgung Center at Gorleben, including a single large (1400 Mg yr⁻¹) reprocessing plant, and facilities for MOX fuel fabrication, vitrification, interim storage, and final disposal. An international review of the plans for the Gorleben center was held in March and April of 1979 (Paschen et al 1982). The Gorleben Hearing, as it came to be called, focused on the issue of reprocessing. Critics emphasized the incompleteness of the safety report submitted by the DWK. In addition, they argued for the inherent safety advantages of dry storage of the entering spent fuel. While admitting the need for further work, the DWK generally was able to demonstrate that plant safety was feasible with current technology. No joint resolution was issued from the Gorleben Hearing, but subsequent political decisions by the government of Lower Saxony changed the course of Entsorgung in the FRG. Citing the doubtful economy and need for early reprocessing, State Governor Albrecht vetoed plans for the 1400 Mg yr⁻¹ facility because it was not politically attainable. Instead DWK, in February 1985, decided to build a reprocessing plant at Wackersdorf, near Schwandorf in Bavaria, with an annual maximum throughput of 500 Mg spent fuel. Site preparatory work began in 1985 in the face of strong opposition, and the cold and hot start-up of the plant has been projected for 1993 and 1995, respectively (Closs and Einfeld 1986).

One of the consequences of the Gorleben Hearing was that the federal government initiated a feasibility study for the disposal of

unreprocessed spent fuel. BMFT was in charge of this Other Entsorgung Technologies Project (PAE), but the actual work was managed by a team based in the KfK. The project which cost DM 60 million lasted from 1981-1984. The study started with a broad outlook, surveying nine methods of fuel conditioning, ten canister concepts, and three emplacement techniques. The reference concept and emplacement technique, decided by decision analysis had three intact fuel elements enclosed in a dry, gas tight storage bin. The bin is then placed into the disposal canister, most likely featuring a steel body with a corrosion resistant Hastelloy C4 casing. The spent fuel package is designed to sustain the lithostatic pressure. A canister lifetime of 500 years is assumed under accident (i.e., water inflow) conditions. Finally, the canister is enclosed in "lost shielding" of cast iron with polyethylene plates fixed to the surface to reduce radiation doses so that the packages can be contact handled. The total package will weigh 53 Mg, with a 1.4 m outside diameter and 5.9 m length. These packages would be placed horizontally on the gallery floors and covered with backfill. Two prototype canisters were made and tested in 1984.

A comparison of safety, technical and economic issues for waste disposal with and without reprocessing was completed in 1985 (Project Group Alternative Entsorgung 1985). A number of major results emerged (Papp and Closs, 1986, Papp and Loser, 1986):

- * direct disposal is technologically feasible but must be demonstrated
- * total direct disposal results in lower radiological exposures, the difference is minor relative to doses from natural radiation background

- * unresolved but not unresolvable issues of safeguards for the direct disposal repository exist
- * costs for direct disposal are advantageous (by 30 percent)
- * fuel reprocessing will be mandatory in the long run (because of an eventual shortage of uranium)
- * construction of a fuel reprocessing plant is needed to sustain and advance the technology
- * further development of direct disposal should occur

Based on these results, the Federal Cabinet stated its policy on direct disposal (Figure E-1), and a follow-on programme on direct disposal is underway which will run till 1992.

E.2.c. Performance Assessment

Performance criteria dictate a maximum permissible individual dose of 0.3 mSv yr^{-1} . This dose applies separately to inhalation and ingestion pathways in the operating phase. No decision has been made regarding the time period in the post-operating phase over which doses must be projected but a 10,000 year limit has been recommended (Merz, Kuhn, und Bloser 1986). There is no assessment of collective dose for the post-closure period of the repository. The SSK does not feel that the population dose standard can be implemented on a scientific basis at this time (Neider 1984). This belief is based not only on the difficulty of predicting the behaviour of future populations, but also on the enormous uncertainties in dose-response relationships for exposure to low levels of radiation. In many scenarios the collective dose would be dominated by the exposures of very large populations to

Figure E-1. Decision of the Cabinet of Federal Republic of
Germany of January 23, 1985

The Federal Government gives the following summary of the results of its assessment of alternative waste management and disposal techniques and the conclusions to be drawn:

1. The Federal Government adheres to its concept of a speedy realization of a German reprocessing plant. It does not see any reason for abandoning the waste management and disposal concept laid down in the Atomic Energy Act, which stipulates the reuse of residual substances and thus upholds the principle of the reprocessing of spent fuel elements.
2. The question raised by the Heads of the Federal and Lander Government in their decision of September 1979 as to whether the direct disposal of spent fuel elements from light water reactors might offer decisive safety advantages over waste management by way of reprocessing can be answered in the negative.
3. From the present point of view, direct disposal cannot serve as proof of the provision of waste management and disposal techniques for nuclear power plants with light water reactors. Although direct disposal seems technically feasible, in principle it still requires further research and development work. The Federal Government considers it expedient that, in addition to waste management by way of reprocessing, the direct disposal of fuel elements be further developed. It will contribute to this paying due regard to international development.
4. From the present point of view, direct disposal is only suitable for those fuel elements for which the development of a special reprocessing technique is economically not justifiable. By means of research and development activities the Federal Government will contribute to developing direct disposal of those fuel elements not easily reprocessed.

very low doses. The SSK may adopt a de minimis concept, wherein doses below a certain threshold would be ignored in safety assessments (Neider 1984). That threshold would most likely be set between 10^{-3} and 10^{-2} mSv yr⁻¹. Although the SSK will recommend federal standards for repository performance, ultimate licensing power resides with the individual states.

The Entsorgung Safety Studies Project (PSE) finished in 1985, was responsible for the development of the methodology for a safety analysis of the back-end of the fuel cycle in the FRG. Over 20 industrial, academic and government agencies were involved, contributing approximately 60 man-years annually. The task of the PSE was to develop methodologies by which doses could be assessed quantitatively, thereby providing the tools to compare alternative management schemes (e.g., reprocessing vs. direct disposal of spent fuel).

The PSE chose two different approaches to safety analysis [PSE, 1985]. For fuel reprocessing, spent fuel conditioning and transport PSE employed a probabilistic safety analysis, though PSE itself is not a risk study. The developed codes concern the modeling of radionuclide release and of the consequences, including collective doses. For the repository deterministic codes were used to trace the migration of radionuclides from the salt dome to the biosphere. For the operating phase of the repository an interpretation of accident statistics of conventionable mining was made.

A complete assessment of repository performance is dependent upon the availability of site-specific information from Corleben. As the

Gorleben dome is explored during the next decade, data will be incorporated in the safety analysis. This analysis has been transferred to GSF/Brunswick.

No surface markers, except the salt dump are planned following the closure of the repository. Surface monitoring will be restricted to topographical surveys and normal environmental protection measures.

E.2.d. Public Attitudes and Response

Since the early 1970s, there have been protests against nuclear energy in the Federal Republic of Germany. At first, this opposition was restricted to some scientists and conservative intellectuals. But it grew during the 1970s, attracting environmental groups, citizen action groups, and portions of the left movement (Paschen et al. 1982). Meanwhile demonstrations grew in intensity and scope, producing sometimes violent mass demonstrations at nuclear facility sites across the country. As a result, nuclear power issues have become politicized and the public polarized. Not surprisingly, radioactive waste issues have been caught up in this broader debate, as illustrated by the active public opposition to the Gorleben complex and, more recently, to Wackersdorf.

The opposition to nuclear energy has also entered different social institutions (Paschen et al. 1982):

- * The scientific community: technical and scientific critics have appeared who are actively involved in the nuclear energy and radioactive waste debate, including such technically competent groups as those at the University of Bremen, the Oko Institute in Freiburg, and the Ecology Group in Hannover

- * the courts have been confronted by both broad local challenges and the appearing of disagreeing scientific experts and called upon to rule on substantive technical matters

- * the political parties have become increasingly involved in these issues, with substantial differences in positions among them.

These conflicts had receded somewhat in the early 1980s but were reawakened and given new intensity by the Chernobyl accident. Levels of public concern following the accident may well have been higher in West Germany than in any other European country. Indeed, post-Chernobyl public opinion polls have shown substantial increases in respondents indicating opposition to nuclear power and supporting a movement out of the nuclear commitment (Störmer 1986). While public reactions need to be assessed over time to discover their long-run changes, Chernobyl may well prove to be a watershed event in the social history of nuclear power in the FRG.

Chernobyl has also reinvigorated the anti-nuclear movement in the FRG. In the months following the accident, West Germany experienced one of the largest demonstrations against nuclear power in its history. Demonstrations at Wackersdorf in June involved some 20000 persons and left over 100 police injured. Meanwhile, nuclear power (and especially reprocessing and "the plutonium economy") became for a time, one of the dominant public issues in the FRG.

This situation has far-reaching political consequences, of course. The Christian Democratic Union (CDU), the ruling party, faces a national election in January 1987. Increased concern, and debate, has emerged in the party over its commitment to nuclear power and reprocessing, especially in light of the perceived angst of the German people over Chernobyl and the escalation of demonstrations. The Lower Saxony elections of June 1986 were quite crucial for the CDU because, if it had lost these elections in this key state (it did not by a narrow margin), there would have been strong pressures within the Party to change the commitment to nuclear power and reprocessing (Gerstein 1986). Since that election both the Declaration of Chancellor Kohl and the Economy Report to the Parliament (September, 1986) have remained pro-nuclear.

The Social Democratic Party (SPD) has had an evolving position moving to greater opposition to nuclear power, especially since the mid-1970s (Störmer 1986). The major movement to greater opposition occurred from 1982-84, when the SPD left the government. Its policy at the time (1984) was an energy system without nuclear power, and particularly without the development of the breeder and associated

reprocessing. Included was a preference for direct disposal of spent fuel. No timetable was set for these changes, however. Since Chernobyl, party leaders have moved to a firmer position against the breeder and reprocessing, and are now examining how quickly a movement out of nuclear power (Ausstieg) is possible. A particular issue will be the five nuclear plants currently under construction. It is certain that the SPD and the Greens, who advocate the immediate closure of the nuclear plants, will make the nuclear issue a central question in the 1987 election.

The elections could do much to determine the course of radioactive waste management in the FRG. If the SPD wins and achieves a majority in the Bundestag, it will seek to change the Atomic Energy Act (article 9) where reprocessing is required. A decision will be needed as to the appropriate timetable for phasing out existing nuclear plants. Direct disposal of spent fuel will replace reprocessing as the key element of policy, and the Wackersdorf plant will be cancelled. If the CDU wins, there will be greater consistency, of course, with current policy but the CDU will over the coming months face considerable pressure from the opposition papers. If demonstrations continue and public concern remains high, there will be pressures to modify current policies. The position of the Free Democrats, who could form a coalition with the CDU if the CDU wins the next federal election but lacks an absolute majority, is: (1) Nuclear energy should be pursued only as long as no other energy source is available with less environmental impact, and (2) There should be a reevaluation of reprocessing versus direct disposal.

Such a coalition would add to the pressure for modification of the CDU's current policies on radioactive waste management.

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APPENDIX F

FRANCE

F.1. Introduction

France has a very ambitious programme of nuclear electricity production (CEA, 1983; de Fontreaux et al., 1983). By mid-1985, 35 GWe capacity was installed, which will grow to 44 GWe by 1986. The country plans a 58 GWe capacity by 1990, covering 28% of total energy needs. In 1985, 65% of the electricity production was of nuclear origin. This is expected to grow to over 70% by 1990. The state-owned electricity company, Electricite de France (EdF) operates 4 gas-cooled reactors and 38 PWRs, with 19 more PWRs under construction (Vendryes, 1986). An advanced fast reactor reached criticality on September 7, 1985 and was connected to the grid on January 14, 1986.

French energy policy is concentrated in the executive branch of government and has been strongly directed towards achieving national energy independence since 1945, when the Commissariat a l'Energie Atomique (CEA) was founded by President de Gaulle. Long term planning in the areas of defense, the economy, industry, and research is facilitated by centralized governmental power. The long tenure of top officials in the various segments of the electrical power industry has contributed to the development of the French nuclear programme. Overall policy recommendations to the government are prepared at monthly meetings of the CEA, chaired by the Minister

of Industry or, in his absence, the Administrateur General of the CEA. (Vendryes, 1986). France is deeply involved in all nuclear fuel cycle activities, as well as development of technology for those activities. Development of the French nuclear power programme has been pursued with zeal equivalent to that of the U.S. space programme of the 1960s. Though the French programme for the selection of sites for a high level waste repository was initially behind most of the countries surveyed, the programme is moving rapidly now and, if it meets present schedules, will be among the first to have an operational facility for disposal of high level wastes. Preliminary French studies are investigating concepts for disposal of high level wastes.

It is expected that by the year 2000 approximately 20,000 Mg of spent fuel will have accumulated. After reprocessing, this will result in the following quantities of waste (CEA, 1983):

Type A:	700,000 - 900,000	m ³
Type B:	60,000 - 80,000	m ³
Type C:		3,000 m ³

All types of wastes will be isolated from the biosphere in either surface or near-surface installations for low and medium level wastes or in deep geological formations for alpha and high level wastes. The three categories of waste considered are the following:

Category A or low level wastes will contain mainly beta and gamma sources, with weak alpha contamination (mean alpha activity less than 370 Bq g^{-1} (0.01 Ci.t^{-1})) and total alpha activity in a

container no greater than 18.5 kBq g^{-1} (0.5 Ci.t^{-1}) (Chapuis, 1986). After approximately 300 years they will have decayed sufficiently to pose little potential hazard. These wastes are destined for disposal in surface facilities, such as the Centre de la Manche, near La Hague, and 2 other land facilities. A new site has been qualified at Soulaines in the Aube district. This site is being licensed (Boucher, 1986). While sea-dumping may be the best disposal route for certain wastes, such as tritiated water, no resumption of it is presently anticipated.

Category B or alpha wastes will contain beta and gamma sources of low and medium strength, contaminated by alpha sources with half-lives greater than 30 years. These wastes will be disposed of in deep geological formations. Some alpha wastes are being stored in drywells at Centre de la Manche while awaiting development of a permanent repository.

Category C or high level wastes are the vitrified glass blocks resulting from reprocessing. They include all sources of high and very high activities and materials contaminated by alpha sources. They will also be disposed of in deep geological formations, but due to their high heat output and long-term toxicity additional barriers will be needed.

France is heavily committed to the reprocessing of spent fuel and to the vitrification of the resulting liquid wastes. Reprocessing and vitrification are the responsibility of the government owned company, COGEMA, which has been operating the UPl reprocessing plant at La Hague and the AVM vitrification facility at

Marcoule. This vitrification facility had produced 300 m³ of glass by the middle of 1983 (CEA, 1983). Production will increase considerably when the new reprocessing (UP2 and UP3) and vitrification (AVH) facilities at La Hague come into operation. These plants will not only reprocess all of France's spent fuel, but also fuel from several contracting countries, such as the Federal Republic of Germany, Belgium, Switzerland, Japan, etc. In spite of a clear policy for reprocessing, direct disposal of the spent fuel elements is supposed to be under consideration, mainly due to political pressure, but with low priority. On the other hand, the idea of "delayed" reprocessing of spent fuel is under serious scrutiny.

From a technical point of view, the most important critical group in France was the Castaing Commission, set up by ministerial order in 1981 to evaluate the back-end of fuel cycle activities. The chairman of the Commission - Professor Raymond Castaing - was appointed by the CSSN (Supreme Council for Nuclear Safety), but most of its members were not. The first report of the Commission dealt primarily with reprocessing (Castaing, 1982) and the second with the disposal of radioactive wastes (Castaing, 1983). A third report including recommendations for research was published in 1984 (Castaing, 1984). The waste management proposals of the CEA published in June 1984 had (CEA, 1983) already responded to some of the criticisms of the Castaing Commission.

The Commission criticized the CEA proposals essentially in three areas. First, it recommended that both the direct disposal of

spent nuclear fuel and the separation of actinides should be evaluated to see whether they were feasible, and if so under what conditions. The Commission recommended that if actinide separation with transmutation turns out to be feasible, it should become a priority area for research and development of the CEA.

Second, the Commission felt that France was behind in geological work compared to other countries. Consequently, it recommended an intensive geological programme in all three major potential host rock formations (i.e., granite, clay, and salt and possibly schists) in the country. It suggested that after intensive hydrogeological and laboratory investigations underground laboratories should be built in each of the formations, before any final choice is made for a repository location. Third, concerning the wastes of Category A, it recommended that a limit be fixed for their average alpha contamination, and suggested a limiting value of the order of 10^{-2} Ci/Mg (0.37 kBq g^{-1}) for the mean alpha activity of those wastes. The Castaing Commission was dissolved upon completion of its 3rd report. A 20-member administrative advisory panel known as the Groupe Permanent has been ministerially appointed to advise the safety authorities in the field of waste disposal.

F.2. Division of Responsibilities

All nuclear activities in France used to fall under the jurisdiction of the Ministry responsible for industry. Actual work is carried out by a number of different organizations, independent

of each other, but mostly under the ministerial tutelage of the ministry of industry.

The Atomic Energy Commission (CEA) has overall responsibility for the formulation and implementation of plans for radioactive waste management, research and development. The responsibility for the preparation, construction and operation of temporary and final storage facilities belongs to the National Agency for the Management of Radioactive Wastes (ANDRA) - which is a special branch of the CEA. ANDRA's costs are reimbursed on a yearly basis by the French Electricity Company (EdF) and other waste producers (primarily COGEMA).

Much of the research and development work of the CEA toward final disposal is done within the Institute for Nuclear Protection and Safety (IPSN), the Institute for Technological Research and Industrial Development (IRDI), and/or under ANDRA's contracts. These activities are coordinated by the Directorate for Radioactive Wastes and Effluents (DED). A new commission, the Scientific Commission on Radioactive Wastes (CSDR), was formed by ministerial order within the CEA in March 1984 (MRI, 1984). The members of the CSDR come from all the organizations involved in the management of radioactive wastes, as well as scientists and trade unions, and its responsibility is to review all of the CEA's activities in this area. The CEA, particularly ANDRA, relies also on other organizations for R&D, such as the Bureau of Geologic and Mining Research and the various technical and mining schools, notably the Paris School of Mines.

Regulatory responsibility also belongs to the Ministry of Industry. Dose limits are set by law. In general they follow ICRP (International Commission on Radiological Protection) recommendations. They are administered by the Central Service for Protection against Ionizing Radiation (SCPRI) of the Ministry of Health. Regulatory requirements are formulated by the Central Service for the Safety of Nuclear Installations (SCSIN) of the Ministry of Industry, in cooperation with the IPSN and other ministries.

The role of the Superior Council for Nuclear Safety (CSSN) - a broadly representative scientific body - is to oversee these activities and provide advice to the Ministry of Industry.

Disposal of nuclear wastes is not legally limited to any particular method or medium. ANDRA is simply charged with presenting a safety report that adequately shows safety objectives will be met. As no intermediate requirements for multiple barriers exist, research into each level can be coordinated so as to optimize the overall radiation protection at reasonable costs. Waste treatment streams can be tailored to produce waste packages that can be handled, transported, and emplaced safely and efficiently. Thus, many waste facilities are co-located. For example, the Centre de la Manche is located close to the La Hague reprocessing plant. At La Manche type A wastes are permanently disposed in concrete monoliths in concrete-lined trenches, while type B wastes are stored temporarily in steel-lined shafts set in concrete. LaHague will provide pool storage of spent fuel, and air-cooled vault storage of vitrified high level wastes.

F.3. High Level Waste Disposal

F.3.a. Geology

No final decision has been made for a disposal concept. The leading contender, however, is the multi-barrier concept (CEA, 1983; Sousselier & Van Kote, 1983), with the emplacement of a borosilicate waste matrix, aged about 30 years, a few hundred metres deep in a mined geological repository, in a host rock such as clay, granite, salt or shales. For example, the tertiary clays of the Aquitaine basin have been studied (le Pochat, 1984). While it is unlikely that the option of deep geological disposal will be abandoned, other alternative options are also being studied, mainly due to political pressure. These studies include work on subseabed disposal and smaller studies on actinide separation with either transmutation of the actinides in nuclear reactors or their disposal in space and the direct disposal of spent nuclear fuel.

France has been a strong proponent of research into subseabed disposal as an international option for closing the back end of the fuel cycle. Subseabed is not acknowledged as a first option for national high level waste disposal, but is considered a back-up in the event land-based repositories should fail to meet safety objectives. Actinide separation is still considered too complex to be practicable, particularly in view of the larger secondary waste streams that would be created. Since the string of American and European launch disasters, space disposal has lost what little appeal it once held.

Within the CEC site investigation programme France has studied granite media. It is perhaps due to this that crystalline rock has been the major focus of its repository research up till now. Potential underground laboratory sites are being investigated in clay, salt, and shale formations as well.

One or more laboratory sites will be selected by 1989. Operation is expected to start in 1992, and if the results of the experiments are favourable, the laboratory could be developed into a national high level waste repository at some later date. Site selection criteria and the screening process used to identify candidate sites in France are discussed in Volume 1 of this report.

F.3.b. Repository Design

Three possible options are being considered in France for the disposal of high level waste (Andre-Jehan et al., 1983):

Short-term Interim Storage is the "classical" option, where the vitrified wastes are aged a few decades in an interim storage facility, followed by emplacement in the repository and closure. A repository area of 2-4 km² will be necessary for wastes resulting from 48,000 Mg of uranium. The emplacement holes will be 1 m in diameter, each holding a stack of canisters.

Long-term Interim Storage is similar to the above, except for the much longer interim storage period (i.e., 80-100 years) to allow for more heat decay. This will allow more compact disposal. The canisters would be packed into holes of 3 m diameter, in two levels of emplacement. This considerably reduces repository area,

and also gives greater flexibility in allowing for continuous improvements in overall disposal policy. The disadvantage is the high cost of interim storage.

In-situ cooling, suggested only by France (Hoorelbeke, 1986), has the advantage that wastes that have been cooled only a short period of time can be placed in the repository. Cooling would be provided by fresh air galleries below the wastes. The ventilation system would function on a natural convection system. Examples of disposal systems, both with and without cooling, are shown in Figure 1. The emplacement configuration is critical in determining and minimizing the heat load to host rock.

The relative costs of various disposal options have been calculated. Based on "in-situ cooling", with 6000 m³ of wastes emplaced in 30 m deep holes, with a maximum canister surface temperature of 125°C, the optimal cooling time was found to be between 80-100 years.

F.3.c. Performance Assessment

Two objectives have been set by the SCSIN concerning the long-term management of radioactive wastes (de Fontreaux, et al., 1983). The primary objective is to protect workers and the public from radioactive substances and ionizing radiation, for as long as these present a radiation hazard. The second, to minimize the interim storage of radioactive wastes for which satisfactory methods for treatment, conditioning and final disposal exist.

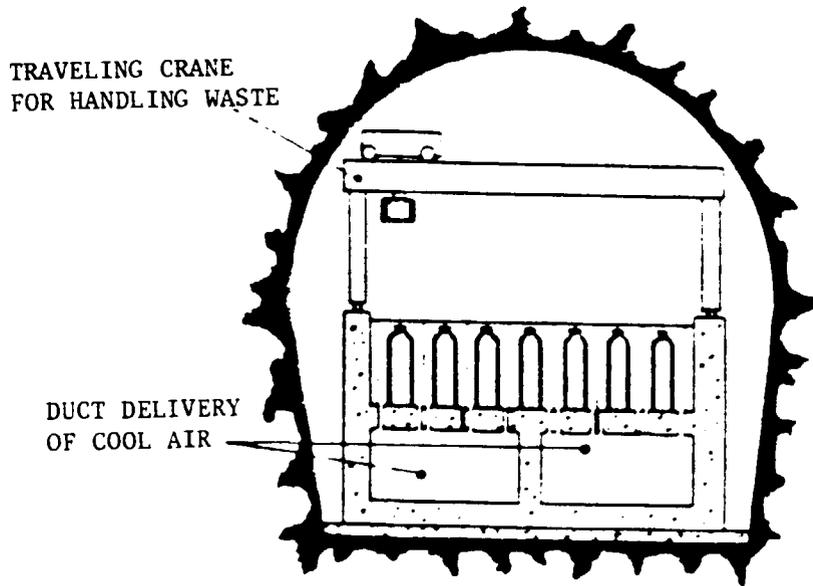


Figure F-1. Cross-Section of a Gallery for Disposal of High Level Waste (Type C) with Air Cooling.

Although no explicit, numerical requirements have been established for dose limits on repository performance for high-level wastes, the ICRP recommendations will be followed (CEA, 1983). Specifically, there are the following requirements (CEA, 1983):

1. Collective dose will be kept as low as reasonable achievable (ALARA), taking social and economic factors into account.
2. Individual doses will be kept lower than the authorized limits.
3. Consequences of future accidents should not lead to higher doses than authorized.
4. In general, it will be ensured that most of the burdens created by the disposal of the wastes will be borne by the generation benefiting from the nuclear electricity produced.

No de minimis values have been set, but the issue is under consideration by the safety authorities. Detailed regulatory requirements have been issued for low level wastes (SCSIN, 1984).

No safety or performance assessments have been published for a high level waste repository in France. Safety analysis, however, will be a central aspect of the proof for the regulatory authorities. The responsibility for producing the safety assessment of a repository lies with ANDRA. The methodology is now being done by the IPSN, IRDI/DRDD (Lewi, 1986). As site-specific data become available, the first safety assessments will also be carried out. France is a member of the

joint European Performance Assessment of Geological Isolation Systems (PAGIS), coordinated by the CEC.

A deterministic risk assessment model, MELODIE (Raimbault et al, 1985) which includes all submodels, Condiment, (near field), Metis (nuclide transport underground), and Abricot (biosphere model) has been developed (Lewi, 1986). This study is carried out within the framework of the European Community's PAGIS Project (CEC, 1985). France has the responsibility to do the performance assessment on three granite sites, Auriat, Barfleur (a coastal site) and a site in the U.K.

Model studies are integrated with field studies (Chapuis, 1986) at the laboratory for methodological instrumental studies in the Fanay uranium mine in a granitic formation (Barbreau, 1985). The evaluation of the hydraulic properties of a fractured, crystalline rock from an underground facility and the scaling factors for properties measured at a small scale can be extrapolated to a larger scale. This work includes the use of tracers to determine if the fractured medium can be treated as an equivalent porous medium. In addition, an experiment to test the coupled hydraulic, thermal and mechanical effects in granite is carried out.

Major migration studies, however, are carried out within the aegis of the CEC MIRAGE Project (CEC, 1984).

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APPENDIX G

SWEDEN

G.1. Introduction. Power Situation and Waste Arisings

The total production of electric power in Sweden in 1984 was 119 TWh. Fifty-six percent of that (67 TWh) was produced from hydropower and 41% (49 TWh) from nuclear power (SOS, 1986a).

In August 1985 the last two reactor units (of the twelve accepted by the referendum in 1980 and by the Parliament decision) were taken into commercial operation. According to preliminary statistics for 1985 (SOS 1986a) the total power production that year was 132 TWh, and of that amount 53% (70 TWh) came from hydro and 42% (56 TWh) from nuclear.

The oldest reactor unit is Oskarshamn 1 (440 MWe), built in 1972, and the newest units are Oskarshamn 3 (1050 MWe) and Forsmark 3 (1050 MWe). No additional reactors are under construction or planned. Nine of the twelve reactors are of the BWR-type, delivered by the Swedish company ASEA-ATOM AB, whereas the remaining three units (Ringhals 2, 3 and 4) are of the PWR-type, delivered by Westinghouse, USA.

The average energy availability for the nuclear power stations in Sweden was 86% in 1985, which means that the stations would have been able to produce an amount of energy corresponding to full power during 86% of the year. This figure could be compared with the world average for BWR and PWR, which is 68% (Kraftsam, 1986).

The installed nuclear capacity is 9500 MWe (net). Since no further capacity is planned, the annual energy production capacity is only expected to increase to about 60-65 TWh/year. The difference over the

56 TWh in 1985 is mainly due to the availability of units 11 and 12 through the whole year.

The Swedish energy policy is that the future need for cheap and safe energy shall be met by an energy system which as far as possible is based on non-exhaustible -- preferably renewable and indigeneous -- sources of energy. A more efficient use of energy in the various demand sectors and an intensified conservation of energy shall also be promoted. Thereby, the pre-requisite condition may be created for a settling of the nuclear energy question in Sweden in accordance with the decision by the Parliament to take the last reactor out of operation not later than the year 2010. No installations of nuclear reactors for heat production (in district heating systems) or of breeder reactors will be considered (Gov. Bill 1984/85:120).

The circumstance that the nuclear power epoch for Sweden can be well specified with regard to number, size and type of reactor as well as period of use regard to timing, makes it comparatively easy to estimate the total arisings of radioactive waste of different categories. The total accumulated amount of waste from the nuclear power plants and from the interim storage of spent fuel up to the year 2010 is estimated by SKB to be (SKB, 1986a):

Spent fuel	7,750 tonnes
Low and Intermediate Level Wastes	90,000 m3
Waste from decommissioning	
of nuclear power plants	100,000 m3
of other plants	15,000 m3

The corresponding accumulated electricity production from the nuclear power stations up to 2010 is estimated to be about 1900 TWh (SKB 1986a).

G.2. Division of Responsibilities

G.2.a. Legal Framework

The acts which are most important to issues on handling and disposal of radioactive waste are:

- The Act on Nuclear Activities
(In Swedish: Lag (1984:3) om kärnteknisk verksamhet)
- The Radiation Protection Act
(In Swedish: Stralskyddslag (1958:110))
- The Act on the Financing of Future Expenses for Spent Nuclear Fuel Etc.
(In Swedish: Lag (1984:5) om finansiering av framtida utgifter för anvant kärnbränsle m.m)

The structure on the authority side is to a large extent adopted to supervising compliance with the above acts.

SKI Statens Kärnkraftsinspektion (Swedish Nuclear Power Inspectorate) supervises the Act on Nuclear Activities.

SSI Statens Stralskyddsinstitut (National Institute for Radiation Protection) supervises the Radiation Protection Act.

SKM Statens Kärnbränslenämnd (National Board for Spent Fuel) supervises the Act on Financing Etc., and also supervises the R&D programme.

On the utility side SKB Svensk Kärnbränslehantering AB (Swedish Nuclear Fuel and Waste Management Company) is jointly owned by the four power utilities which generate electric power in nuclear power plants.

G.2.a.1. Act on Nuclear Activities (DSI 1984:18)

The content of the Act on Nuclear Activities that is germane to waste disposal issues is that:

- a special permit is required for fueling a nuclear power reactor for the first time and that such a permit is granted only if the reactor possessor has proved that there is a method for the handling and final disposal of spent nuclear fuel and radioactive waste deriving from it, which is acceptable with regard to safety and radiation protection and has presented a programme for the R&D work necessary for ensuring that spent nuclear fuel from the reactor and radioactive waste deriving from it can be handled and finally disposed of in a safe manner. Such an R&D programme shall present a survey of all measures that may be necessary and also specify the measures that are intended to be taken within a period of at least six years. The programme shall, beginning in 1986, be submitted to the Government or to the designated authority every third year for examination and evaluation.
- the holder of a license to operate a nuclear power reactor or a plant for the handling, intermediate storage or final disposal of nuclear material which is not to be recycled shall give the local safety committee, appointed by the Government, insight into the operation of safety and radiation protection procedures at the plant.

The Act on Nuclear Activities reflects two basic rules. The first is that the producer of the waste bears the primary responsibility - technically and financially - for the safe disposal of the nuclear waste products. The second is that the State bears the ultimate and long-term responsibility for the disposal of the nuclear waste in a way that is satisfactory for society.

G.2.a.2. Radiation Protection Act

A new Radiation Protection Act is presently being considered (SOU 1985:58). It will replace the 1958 act. Some of the recommendations in

the proposal, as compared to the present act, are:

- The protection of animals, plants and the environment as a whole will be included
- Non-ionizing radiation will be included
- The responsibility for the final disposal of all radioactive waste (i.e. including waste from hospitals, industries etc.) shall be taken by the users. All radioactive waste shall be handled according to the same standards as the waste from the nuclear energy sector
- The new radiation protection act will be harmonized with the act on nuclear activities

G.2.a.3. Act on the Financing of Future Expenses for Spent Nuclear Fuel etc.
(DSI 1984:18)

The main content of the Act on Financing is that:

- The holder of a license to possess or operate a nuclear power reactor (the reactor owner) shall defray, inter alia, the costs for:
 - the safe handling and final safe disposal of spent nuclear fuel from the reactor and radioactive waste deriving from it.
 - the safe decommissioning and dismantling of the reactor installation.
 - the performance of the R&D work necessary for the conditions, referred to under the two subsections above, to be met.
- The reactor possessor shall also defray the costs incurred by the State in:
 - supplementing the R&D work referred to above.
 - administering the fee system, etc.
 - the monitoring and inspection of final repositories.

- the reactor owner shall, in consultation with other reactor owners, prepare or have prepared an estimate of the costs necessary for fulfillment of what is mentioned in the first section above. The estimated costs shall include an assessment of the costs of all measures that may be necessary as well as the costs of measures intended to be taken within a period of at least three years. The cost estimate shall be reviewed annually and submitted annually to the Government or to the authority designated by the Government.

G.2.b. Authorities

One could, with some simplification, say that there are different authorities supervising the safety (SKI and SSI) and the research and development and financing of waste disposal (SKN).

G.2.b.1. SKI

SKI, the Swedish Nuclear Inspectorate, has a total staff of about 85 people. It has two technical offices, one for Regulation and Research and one for Inspection. The Nuclear Waste Department with its seven scientific collaborators belongs to the office for Regulation and Research. It also employs the assistance of many consultants, inside as well as outside Sweden. A lot of R&D is initiated by SKI and performed through contracts with Swedish and foreign universities, Studsvik, Harwell, different international organizations etc. For a country like Sweden, with a very limited number of specialists on nuclear waste, it is necessary to have an interchange of experience between the utilities and the authorities. This is beneficial to all parties as long as, at the licensing stage, the respective roles are kept very clear.

SKI has made evaluations of the KBS studies and also performed the licensing of CLAB (the interim storage facility for spent fuel) and of SFR (the final repository for LLW and ILW). Parts of this evaluation work are also documented with extensive reports in English (SKI, 1984a,b,c; DsI 1984:17).

Presently there is no major new case within the nuclear waste area to be evaluated by SKI, and the Inspectorate has therefore taken the opportunity to prepare for the important decisions that must be made in the 1990s by initiating a special study called "Project 90". Its purpose is to make it possible for SKI to perform a complete evaluation of a final repository for HLW and spent fuel. The site under consideration may not be a "real" site, but will have well specified properties with regard to geology, etc. The SKB concept will be used for the repository. The work on Project 90, which has recently started, will be finished in 1989-90 and will be followed by a small international group of experts with an advisory function.

The role of SKI in connection with a future final repository for HLW is to assure that the safety of the repository is adequate. SSI will have a similar role regarding radiation protection. To that end SKI has to approve the design of the repository and give its consent to the commissioning. Furthermore, SKI will, together with SSI, approve the waste forms to be deposited. Before commissioning SKI will make its own safety analysis of the plant.

G.2.b.2. SSI

The National Institute for Radiation Protection, SSI, is the Swedish competent authority in the field of radiation protection. It

has a total staff of about 140 people, of whom around 80 have a scientific background. The radioactive waste questions are handled within the Nuclear Power Division, by a Waste Group of 7 people (5 scientists). The Waste Group deals with all types of radioactive waste.

SSI has been involved in the licensing procedure for CLAB and SFR and has particularly considered the radiation protection aspects around the facilities (public radiation safety), and inside the facilities in connection with handling and operations (staff radiation safety). The evaluations are available (SSI, 1985; SSI, 1983). Also, the KBS 3 study has been assessed by SSI. An English translation of that review is available (Bergman C, Boge, R and Johansson, B., 1984).

Concerning the SFR repository at Forsmark, SSI has emphasized that the repository is not at all optimized from technical and economical points of view. SKB has included very large margins in order to facilitate the licensing procedure as a result of "social pressure". SSI has pointed out that large amounts of money could have been saved by using the simplest type of SFR rock caverns for all the material (Bergman, C., Johansson, G., and Boge, R., 1986). SKB is certainly well aware of this "overdesigning". A very good performance of the LLW and ILW handling and disposal is expected to be advantageous for the public acceptance of nuclear waste handling as a whole. However, it should be mentioned that "overdesigning" may also create new problems.

When considering the SFR license application, one member of the Board of SSI made a separate reservation to the decision, claiming that there must be a hidden reason for SKB to construct such an expensive facility which is so much "overdesigned" for its purpose (SSI, 1983).

Before the loading of waste into the SFR repository may start, the final design and the handling procedures will be scrutinized for final approval by SSI.

SSI has the responsibility for applied research on radiation protection in Sweden. For the fiscal year 85/86 about 3 million Swedish Krona (MSEK) was spent on R&D directly connected to the nuclear waste area. SSI closely cooperates with the other nuclear authorities (SKI and SKN), and also with the authorities with environmental protection responsibilities.

The SSI R&D on nuclear waste covers areas such as:

- physical and chemical properties of the waste
- handling and treatment of the waste
- decommissioning of nuclear plants
- declassification of very-low-level waste
- transportation and storage

Concerning the biosphere, extensive work is done on field experiments as well as on modelling. SSI has initiated an international study, BIOMOV3 (BIOSphere Model Validation Study), with 8 participating organisations and IAEA and NEA as observers. The aim is to test calculation models against independent field data.

The migration of radioactive substances in the ground and the outflow of radioactivity from a rock repository are other areas under study.

In 1986 SSI started a systematic study on risks and risk evaluations in very long time perspectives. High priority is given to the study of the circulation of radionuclei through the ecological systems (Bergman et al., 1985). A four year R&D programme has been

proposed. The work aims at acceptance criteria for very long-lived radioactive waste.

G.2.b.3. SKN

SKN, the National Board for Spent Fuel, has a total staff of eight people. Three of these handle technical and scientific issues.

As supervisor to the Financing Act SKN administers the capital collected to cover expenses for spent fuel management and for decommissioning of the nuclear power stations. This capital is built on fees levied on nuclear generated electric energy. The fee calculation done by SKN has three components

- a cost calculation provided by SKB based on detailed technical plans for decommissioning and spent fuel handling
- an estimation of future nuclear power generation based on the decisions about the Swedish nuclear programme
- assumptions about the long term real interest rate (assumed to be in the range 2-2.5%).

The calculation of the fee is updated yearly.

As of June 1986 the total future expenses were predicted to about 38 GSEK in the price level of 1986. The fee for 1986 was 0.019 SEK/kWh.

SKN is also inspectorate for the R&D carried out by SKB on behalf of the reactor owners. Starting in 1986 SKB shall every third year submit its R&D programme to SKN. This programme shall cover the whole scope of research needed up to closure of the repositories. The programme is forwarded to the Government by SKN after review and assessment.

SKN has an annual budget for studies and research of about 6 MSEK. This is used for evaluation of other concepts for disposal and to support research on such concepts which are found to have merit. SKN also supports research in areas relevant to disposal, including studies in the social and behavioural sciences.

G.2.b.4. KASAM

SKI, SSI and SKN all have their own R&D budgets, which they are free to spend on work they consider important. In order to facilitate coordination, exchange of information, etc, a special advisory committee, KASAM, was established in 1985. All three authorities are represented on that committee, which once a year issues a status report on the level of knowledge on nuclear waste handling and gives advice to the authorities.

G.2.c. Implementing Organisation

G.2.c.1. SKB

SKB, Swedish Nuclear Fuel and Waste Management Company, is owned by the four utilities which produce electrical power from nuclear reactors. SKB has been given the task to develop, plan, construct and operate plants and systems for handling and disposal of spent fuel and radioactive waste from the Swedish nuclear power reactors. SKB is also responsible for the extensive R&D within the nuclear waste area, which the Swedish State has ordered the producers of nuclear power to perform. Furthermore, SKB is handling a number of matters on the supply side of the nuclear fuel cycle. SKB has performed the KBS studies (KBS-1, 1977;

KBS-3, 1983) to meet the Stipulation Act showing that safe disposal is possible. KBS also prepared the documents necessary for licensing of the CLAB and SFR facilities (SKB, 1985d; SKB, 1982), and is/will be responsible for their operation. SKB is also responsible for taking all the necessary measures for the siting of a final repository for HLW.

SKB has a staff of about 45 people. The R&D division has about 12 persons and an annual R&D budget of about 70 MSEK (excluding international contributions to the Stripa project etc). More than 200 man-years are devoted yearly on waste management issues.

G.2.d. Constitutional Framework: State, Local

As has been mentioned already, the Swedish State, through the Government and the responsible authorities, has final responsibility for the nuclear energy programme, including the waste programme.

The reactor owner (or, in questions concerning waste handling, the jointly owned company, SKB) applies for necessary licenses, and the governmental authorities (SKI, SSI and SKN) have a very active role in evaluating these applications before decisions are taken by the Government.

In matters where siting of nuclear plants of any kind (reactors as well as waste repositories) is involved, Swedish legislation allots rather strong influence to the local community under consideration. This influence is regulated through the Construction Act (Byggnadslagen 1947:385), section 136a, in which it is stated that the siting of major industrial or similar activities, which are of considerable importance for the management of energy, wood resources or of the ground and water

resources, shall be decided by the Government, and that approval can be given only after consent by the community involved. This "local community veto-right" has been practiced for several years in Sweden. There is some discussion about the future of this local veto-right.

In 1985 the Government proposed a new law on Conservation of Natural Resources (Government Bill 1985/86:3). In the bill the responsible minister states that certain installations have such great national importance that they must be sited somewhere within the country. A repository for nuclear waste is mentioned as an example of that kind. If all communities under consideration in the siting process for such a facility would use their veto, no facility could be built. In such a case it should - according to the Bill - be possible for the Government to let national interest override local interest and approve a site without consent from the local community.

The Parliament Committee responsible for preparation of the decision, however, in its report in October 1986 unanimously proposed that the veto-right should not be changed. Even the representatives of the ruling party in that Committee do not support the Government Bill on that particular point. The Parliament is therefore, not expected to make a decision to change the veto-right for the moment. In a special statement the Committee declared that it is well aware of the problems that may arise in the siting of, for instance, a HLW repository, and proposes that the question on limitations in the local veto-right should be further prepared (by the Government Office or otherwise) with careful consideration of how to work out the procedure for the handling of such

a case on limitations in the veto-right. The Government thereafter, should come back to the Parliament with a new proposal.

The issue of limitations on the local veto may thus be postponed for some time.

G.3. Disposal Strategy

The owner of the three Oskarshamn reactors, OKG AB, has a contract with British Nuclear Fuels Limited, UK for reprocessing of 140 tonnes (U) of spent fuel. That material has been shipped to the UK.

SKB has contracts for reprocessing some of the fuel from the reactors at Barseback, Ringhals and Forsmark at COGEMA, France. There are two small, older contracts from the 1970's covering in total 57 tonnes of spent fuel, and one more recent contract (from the 1980's) which is part of a cooperative arrangement between a number of customers from Belgium, France, Japan, the Netherlands, Switzerland, Sweden and the Federal Republic of Germany. These customers have agreed in common to finance a reprocessing plant - UP3-A - at La Hague, which is owned and operated by COGEMA. During the first ten years of operation of the UP3-A, the part of its capacity that could be devoted to spent fuel from Sweden should be 672 tonnes. The UP3-A unit is scheduled for operation in 1988.

Up to November 1983, 57 tonnes of spent fuel had been sent to France from Sweden, corresponding to the old contracts mentioned above.

Because of the Swedish political decision not to have more than 12 reactors and not to allow any nuclear reactor to be operated after the year 2010, the interest in recycling is now very small, and the waste

policy is mainly directed towards placing the spent fuel in the final repository. As a consequence of this the SKB and the German utility company, RWE, have agreed to swap some spent fuel. RWE would take possession of the 57 tonnes of Swedish spent fuel already sent to COGEMA, and in return SKB would receive about 24 tonnes of old spent mixed-oxide fuel (which is not suitable for reprocessing in the available facilities). SKB has also indicated that it is trying to transfer the contract with COGEMA for reprocessing of all 672 tonnes of spent fuel to other customers. A contract has already been signed with a Japanese power company for the transfer of 178 tonnes (SKB, 1985b). If all the material from reprocessing could be swapped against spent fuel, there would be no HLW from reprocessing for final disposal in Sweden and work could then be concentrated solely on disposal of spent fuel.

The main categories of radioactive waste products to dispose of as a result of the Swedish nuclear energy programme are shown in Table G1 (SKB, 1985a).

G.3.a. Disposal Facilities

The contracts on reprocessing between Swedish utilities and foreign reprocessing companies have already been mentioned.

A central interim storage for spent nuclear fuel - called CLAB - was put into operation in 1985. It is situated near the Oskarshamn nuclear power station. The storage building is located underground in a rock cavern, the top of which is about 25-30 m below the ground level.

TABLE G1
RADIOACTIVE WASTE PRODUCTS

Product	Main origin	Units	Number in final repos.	Volume, m ³
HLW	Spent fuel Vitrif. waste from reprocess.	Capsules	5,700	12,000
Alpha-contam- inated waste	LLW and ILW from reprocess.	Barrels	5,100	4,300
Core components	Nucl. reactors	Ingot moulds	1,800	14,600
LLW+ILW	Operation of nucl. power and waste treatment plants	Barrels and Ingot- moulds	120,700	100,800
Decommissioning waste	Decommissioning of nucl. power and waste treatment	Contai- ners (10-20 m ³)	9,000	113,500

The cavern is L120 x W21 x H27m and contains four large storage pools and one smaller pool for handling. Each of the storage pools contains about 3000 m³ of water and can store 750 tonnes of spent fuel. A future expansion of the storage can be provided by excavating additional rock caverns (SKB, 1986b). The construction cost for the first stage (3000 tonnes of U) was about 1.7 GSEK.

A final repository for LLW and ILW - called SFR - is under construction close to the Forsmark nuclear power station. The entrance to the repository is on the shore at the Forsmark site, but the repository itself is excavated in the bedrock off-shore under the Baltic Sea. The LLW and ILW to be deposited in the SFR repository contain only traces of long lived radioactive substances. It is therefore, considered to be harmless to human beings and to the environment after about 500 years. The SFR repository is built as a series of rock caverns designed to hold different kinds of waste. Cylindrical silo repositories H50m x D25m will be used for the ILW, whereas the LLW will be placed in horizontal tunnel-shaped caverns (SKB 1986c). There is at least 50m of rock above the repository, and the water depth on top of that is about 5m. ILW and LLW are presently stored at nuclear reactor stations and at Studsvik, which stores the radioactive waste from industry, hospitals and nuclear research laboratories. When the first stage of the SFR repository is ready for loading (which is expected to be in 1988), the waste will be transported by the dedicated ship "Sigyn" from the reactor sites (excluding Forsmark) and from Studsvik to the SFR (SKB 1986d).

The construction of SFR stage 1 (access tunnels plus 1 silo and 4 caverns) will cost about 700 MSEK. Stage 2 construction (1995-99) will consist of another silo and 1 or 2 caverns and is estimated to cost 200-250 MSEK. The operating costs are estimated to be 240 MSEK and the costs for closing the repository 60 MSEK. In total, the costs for SFR would then be 1.25 GSEK. All figures refer to the monetary value of SEK in 1985 (SKB 1985a).

A new waste treatment and interim storage facility - called AMOS - has recently been built at Studsvik. It will be used for treatment of liquid and solid waste, mainly ILW, and for interim storage of ILW and LLW ready for transport to SFR. Interim storage there is also in underground rock (Studsvik, 1984).

G.3.b. Disposal Timetable, HLW

The present planning concept for handling of spent nuclear fuel in Sweden is based on interim storage for about 40 years in the CLAB facility before the fuel is transferred to the final repository. This means that encapsulation and disposal of the spent fuel is expected to start around the year 2020.

SKB has made a sensitivity study on how the cost for spent fuel disposal would be affected if encapsulation and disposal were to commence as early as 2005 or as late as 2080. The total cost in fixed monetary value would be about the same (19 GSEK) in all three cases, but there will be differences due to the different distribution of the costs overtime. If the removal of spent fuel from interim storage is postponed until 2080, the fee for future expenses (to be included in the

price of the electricity) could be reduced by about 0.002 SEK/kWh. If the transfer to the final repository would start in 2005, the same fee would have to be increased by about 0.004 SEK/kWh (SKB 1985c).

The interim storage of spent fuel plays an important role, because it gives some freedom in the choice of method for final disposal and provides opportunities for further development of methods for handling and final disposal for another couple of decades.

The site selection process for the final repository for HLW has started in the sense that a survey for sites that could be suitable for a deep geological repository has begun. From a study of maps and literature some 400 sites were originally listed. This number was then reduced to about 25 by restrictions such as:

- No interesting mineralizations that could make the site interesting for future mining activities should be present.
- The ownership of the land should not be too complicated. Preferably it should be owned by the State or by some of the large forest industry companies or at least have only one private owner.
- There should be no mixture of old and young rocks at the site.
- The bedrock should be well exposed at ground level.

Field investigations were made at the 25 sites and extensive drillings at eight sites of which four sites show promise. Additional drillings are planned for the period up to 1990.

During the period 1990-2000 detailed investigations (including shaft sinking) will be made at about 3 sites. These sites may be among

the already listed sites or completely new ones. One of these 3 sites will be chosen as the site for the final HLW repository. The application for a license is expected not later than the year 2000. Then, there will be ample time for the licensing procedure so that construction work can start in 2010 and the repository be ready for loading with HLW in 2020.

G.4. Public Attitudes and Response

The representation of political parties in the Swedish Parliament (Riksdagen) as of October, 1986 is as follows:

	No. of Seats	%
Conservatives	76	21.8
Center Party*	44	12.6
Liberal Party	51	14.6
Social Democrats (Labour)	159	45.6
Communist Party	<u>19</u>	<u>5.4</u>
Total	349	100.0

*Includes one representative from Christian Democrats.

The official energy policy, including the nuclear energy policy (as described briefly in Section G-1), has been written by the Social Democratic Government.

The Center Party and the Communist Party take positions more in opposition to nuclear power than do the Social Democrats. Those two parties had strong connections with the "No"-side during the campaign before the referendum in 1980. They certainly agree with the official policy that the nuclear power stations should be taken out of operation, but they claim that this process should start much sooner than the year 2000 and also should be finished much sooner than the year 2010. They

had also proposed that the last two reactor units (No. 11 and 12) should never have been put into operation.

The Conservatives, particularly, have taken a more positive attitude towards nuclear energy, emphasizing the need for cheap energy and that possible alternative energy production systems are connected with impacts on human beings and on nature that are greater than those of nuclear energy. They have also claimed that it is not necessary at this time to stipulate that all nuclear power plants in Sweden shall be closed by 2010. If some reactors still are in good shape after that time they could very well be used for a somewhat extended period.

It should, however, be mentioned that there seems to be a rather wide range of attitudes towards nuclear energy within each of the parties. For example, within the Social Democratic Party, the youth organization, the women's organization and the Christian fraction are proposing a rapid shutdown of the Barseback nuclear power station with its two reactors.

Since the Chernobyl accident the Liberal Party has emphasized that the decision to take the last reactor out of operation not later than 2010 is a firm decision, that an even faster time schedule could be considered, that a real plan for the phasing out of nuclear power should be presented as soon as possible, and that it should be considered whether the Barseback reactors should be the first ones to be closed down, because of their siting close to densely populated areas in Sweden and Denmark. Prior to the Chernobyl accident, the debate on nuclear issues in Sweden had been rather subdued as compared to the very intense debate in connection with the referendum.

No real debate is going on about waste disposal. The siting procedures for the interim storage facility for spent fuel - CLAB - as well as for the final repository for LLW and ILW - SFR - were performed without very much public discussion. One possible explanation to this is that in both cases the sites chosen already had nuclear installations (power reactor stations).

The People's Campaign Against Nuclear Power - an organization founded in Sweden in 1977 which played an important role in connection with the referendum and presently has about 5000 members - has directed some criticism against the SFR repository. The main argument is that since the rock on top of the repository is not completely tight the disposal of radioactive waste in the repository should be considered as sea-dumping, which is not allowed by Swedish law. The critics also claim that nobody knows to what extent the concrete will perform as a barrier over a 500 year period. They are also concerned about a major fracture zone which extends through the access tunnel regions of the rock. Another concern is that the effect on the environment has not been properly considered at SFR. The arguments have been put together in a publication issued by the Organization for Nature Conservation, County of Uppsala (Westerlund, 1983). The People's Campaign has the impression that their comments have caused no reaction from SKB or from the authorities. Nobody has even tried to refute their arguments, according to their spokesman.

A strong defense was presented on all the above points, when the criticisms from the People's Campaign were presented to SKB at our meeting with them. It seems clear, however, that neither SKB nor the

authorities have found it worthwhile to take part in a debate with the representatives from the People's Campaign.

Among the critics there seems to be a complete lack of confidence in the nuclear industry as well as in the authorities and the Government. The main reason for this lack of confidence - according to a critic - is that the KBS-3 report was accepted by the authorities and the Government as a safe waste disposal option, thereby allowing the fuelling of the last reactor units and a continuation of the nuclear energy programme (as described in Section G-1). According to the critics, the nuclear power programme in Sweden is proceeding without the waste disposal question being solved, and is therefore not in accordance with the Act on Nuclear Activities (c.f. Section G-2 a(1)). The nuclear waste issues - according to the critics - should not be solved by the nuclear industry, but by the Swedish society, through a Commission representing all parts of the society.

The final repository for HLW is not an issue for public debate at this stage. A conscientious R&D programme is being performed and since the KBS 3 study there has been a period of relative calm.

On the local level, however, there is considerable activity among critics on individual sites, where test drillings have been made or are planned. The drillings have been totally blocked by demonstrators at two of the sites (Almunge and Kynnefjall). The Kynnefjall site has been continuously guarded by local demonstrators for more than six years. During the last years (after the KBS 3 report) the resistance seems to be more organized. There is informal cooperation amongst critical groups at different sites, called "The Waste Chain". Local people can

get advice and support from a small volunteer central coordinating group.

The arguments for blocking even drillings for preliminary geological investigations are - according to a spokesman for the Waste Chain - distrust of the nuclear companies and of the authorities, and a fear that future generations will suffer from living close to a repository. A description of the local resistance at one of the blocked sites has been issued. (Noresson, 1985).

In principle, geological test drillings can be started without any permission other than that of the land owner. An area of about 5 square km is needed.

It is clearly understood by all involved parties that the question of public acceptance may very well be the most difficult one in connection with site selection for a final HLW repository. The Government has therefore, asked SKN to particularly discuss suitable procedures for the Government to make a decision on site selection based on experience, results from geological tests and from other parts of the R&D programme. Furthermore, suggestions shall be made on how information could be distributed in the communities under consideration, and who could be responsible for distributing information. SKN has a small group of experts working on these questions concerning the decision process.

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APPENDIX H

SWITZERLAND

H.1. Introduction

As in Sweden, the future of nuclear power in Switzerland is tied legally to a timely solution of the radioactive waste problem. Swiss law places the responsibility for radioactive waste disposal squarely on the producers, and the Federal Council requires that a waste management solution be "guaranteed" by 1985 or no new operating licences for nuclear power plants will be issued and existing ones will be revoked (Niederer, 1984a). The so-called Guarantee Project (Project Gewähr) of the national disposal company (NAGRA) was originally to provide the required guarantee by the end of 1984 - giving ample time to the authorities for review before the final deadline in 1985. However, the definition of what is meant by "guarantee" is a highly controversial issue. Irrespective of the outcome of this project, the future of nuclear energy is still clouded in Switzerland. The September, 1984 popular initiative (which, if passed, would have resulted in no further construction of nuclear plants, and no replacements for the present ones) was rejected in a nationwide referendum by a margin of 45:55. (The next referendum cannot be held for 5 years). Two new referenda are planned - an *Aussteig* referendum similar to the motion in the Federal Republic of Germany to phase out existing plants in 20

years and another moratorium referendum on the construction of new plants. Consequently, from a political standpoint, the federal government will have great difficulties in giving the go ahead for an expansion of nuclear generating capacity. However, NAGRA is basing its plans for disposal of high level waste based upon an installed nuclear power capacity of 6 GWe (NAGRA 1983a).

Five nuclear reactors are in operation in Switzerland with a total installed capacity of approximately 3 GWe. Nuclear electricity now represents about 40% of the country's production. Currently, Swiss contracts with COGEMA in France and British Nuclear Fuels Limited in the United Kingdom provide for the reprocessing of all spent fuel through 1990. It is not considered economically feasible for such a small nation to reprocess its own wastes (NAGRA, 1983a). The foreign reprocessing companies have the option to return to Switzerland the wastes from reprocessing of the fuel discharged after 1979. This return will take place after 1992. It is anticipated that this arrangement will continue, so Swiss research and development efforts focus primarily on the disposal of reprocessed wastes. Nevertheless, strategies for the management of unprocessed spent fuel also receive the necessary attention (Kowalski, 1984).

H.2. Division of Responsibilities

Major responsibility for developing a nuclear waste management plan is vested in the National Cooperative for the Storage of Radioactive Wastes (CEDRA in French; NAGRA in German).

Formed in 1972, this private consortium of six utility companies and the Swiss Confederation (represented by the Federal Department of Interior (EDI) acts in cooperation with federal research institutes and private engineering firms (NAGRA, 1983a). It is responsible for the Guarantee Project, the mandated study that must guarantee the safety of waste disposal. NAGRA was a small operation with only a few full-time employees prior to the establishment of the Guarantee Project in 1978 (Kiener, 1984); now about 60 employees work at NAGRA, beside several hundreds of engineers, geologists, hydrogeologists and other experts who work on NAGRA's programme. NAGRA contracts much of its modelling and experimental work to the Federal Institute for Reactor Research (EIR) (Flury, 1984). Costs are shared among the waste producers on the basis of plant thermal power and are borne ultimately by the consumer as a kilowatt surcharge. A fictitious thermal output and cost assessment are assigned to the Swiss Confederation, which collects radioactive wastes produced in medicine, research and industry. Funds are being reserved now for repository construction and operation.

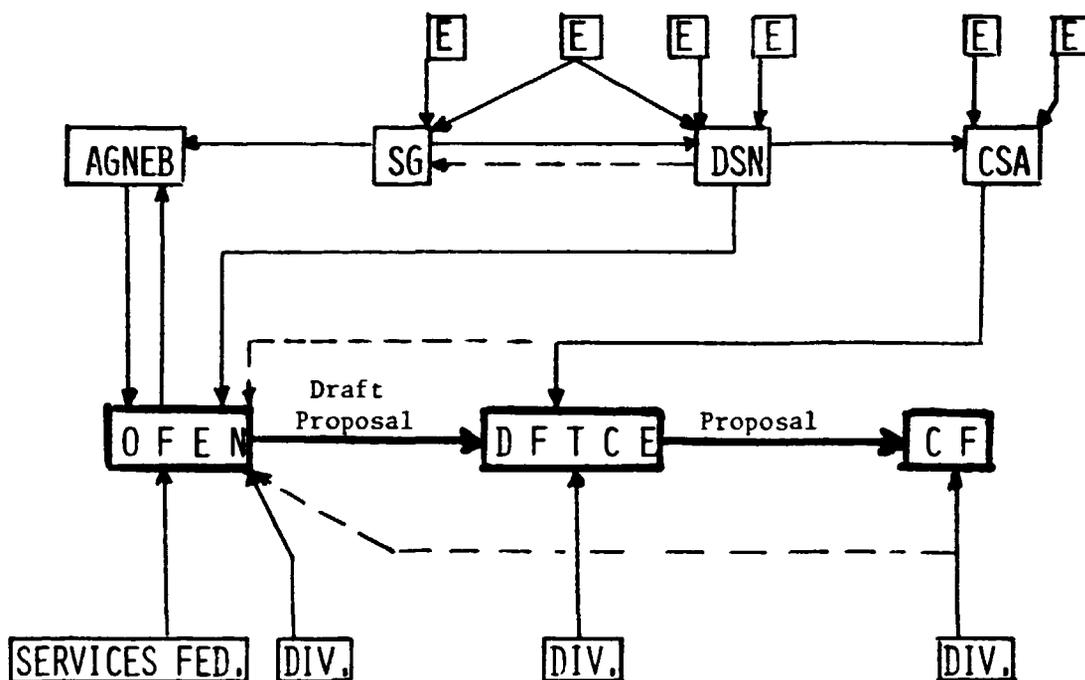
The federal government is advised by the Federal Interagency Working Group on Nuclear Waste Management (AGNEB).

This panel prepares technical material to support decisions by the Federal Council and monitors the progress of all parties in matters of waste management by publishing yearly reports (AGNEB, Kiener, 1984). Switzerland lacks a federal geological survey, but AGNEB has formed an advisory geology subgroup (UGE0), whose members represent the major geological associations in the country. Regulatory authority is vested in the Nuclear Safety Division (HSK) of the Federal Office of Energy (BEW) and the Commission for the Safety of Atomic Installations (KSA), a consultative body of the Federal Council. The Federal Administration licenses waste management facilities based on the expert opinion provided by these groups (Niederer, 1984a). The Federal Council will pass on the adequacy of Project Gewaehr with the assistance of the groups shown in Fig. H-1. However, because of the difficulty in obtaining permission to drill exploratory boreholes, the reports of the Guarantee Project were delivered in January 1985 (NAGRA 1985 a-h). Because of the complexity of the reports, the government postponed its verdict on the technical feasibility and safety of the proposed solution. Because of the divergence of key personnel performing that evaluation to the evaluation of the Chernobyl accident, the review has been further delayed.

AGNEB has the responsibility for the preparation of the necessary technical material to support the decisions of the Federal Council and the Federal Department of Transport, Communication and Energy (EVED) and with following the progress of third parties in the nuclear waste field. The Federal

Figure H-1.

The Decision Procedure of the Federal Council on "Project Gewähr" 1985.



- AGNEB: Federal Working Group on Management of Nuclear Wastes
- CF: Federal Council
- CSA: Federal Commission for the Safety of Nuclear Installations
- DFICE: Federal Department of Transport, Communications and Energy
- DSN: Division of Safety of Nuclear Installations
- E: Experts
- OFEN: Federal Office of Energy
- SG: Sub-Group on Geology
- DIV: Others

Commission for the Safety of Atomic Installations (KSA) and the Federal Office of Energy, primarily in the Nuclear Safety Division (HSK) will review the disposal projects for the federal licensing authorities.

To prepare for the review HSK and its consultants have prepared a series of studies to develop and test the methodology for the safety assessment of C type (high level) repositories for both normal and abnormal events. By including the development of analysis techniques and computer codes, independent of NAGRA, they have become familiar with the important processes and parameters involved in each safety assessment (ASK et al. 1980, HSK et al 1982, HSK et al 1985).

Radioactive waste management in Switzerland is shown in Figure H-2.

H.3. Waste Classification

Wastes are classified according to their origin and their conditioning and packaging for disposal in three types of repositories as shown in Table H-1. These divisions were derived through a sophisticated process shown in a logic diagram in Figure H-3 whereby all wastes expected to arise in Switzerland were divided into 4 major classes: reprocessing; operational; decommissioning; and wastes arising from medicine, industry and research (Tables H-2a-d). These were further subdivided according to their origin, treatment, and quantity and type of activity. Then, as shown in Figure H-3, these were

Table H-1. Total Waste Quantities for the 240 Gwa Nuclear Energy Scenario with Reprocessing in Terms of the Management Concept and Finalisation in Project Gewähr 1985.

General definition of the management concept (NTB 83-02)							Finalisation of concept in Project Gewähr 1985		
Waste sort (repository type)	Waste composition	Waste features	Waste origin	Weight of radioactive material in fresh waste	Activity of radioactive material (10 years after unloading)	Volume of conditioned waste	Additional reserve for volume-intensive conditioning, packaging, etc.	Distribution of waste types between repositories Gross volume of conditioned waste	Repository type
Low-level LLW (Type A)	Low-level short-lived radionuclides (only traces of long-lived radionuclides)	can be manipulated without shielding or cooling	mainly dismantling of NPP's, partly from medicine, research and industry	less than 1 t	less than 0.01 MCi	100,000 m ³	40,000 m ³	200,000 m ³ LLW + ILW	Type B
Low-and intermediate-level LLW + ILW (Type B)	Low-and intermediate-level short lived, limited component of long-lived radionuclides	can be manipulated without cooling but, to some extent, only with additional shielding	operation of NPP's, partly dismantling of NPP's, operation of reprocessing plants, partly from medicine, research and industry	less than 2 t	less than 150 MCi	70,000 m ³			
High-level HLW (Type C)	High-level short- and long-lived radionuclides	initially high heat output: can be manipulated only with cooling and heavy shielding	reprocessing plants	290 t	less than 4400 MCi	1000 m ³	200 m ³	10,000 m ³ ILW 1200 m ³ HLW (net volume HLW = 884 m ³)	Type C

H-7

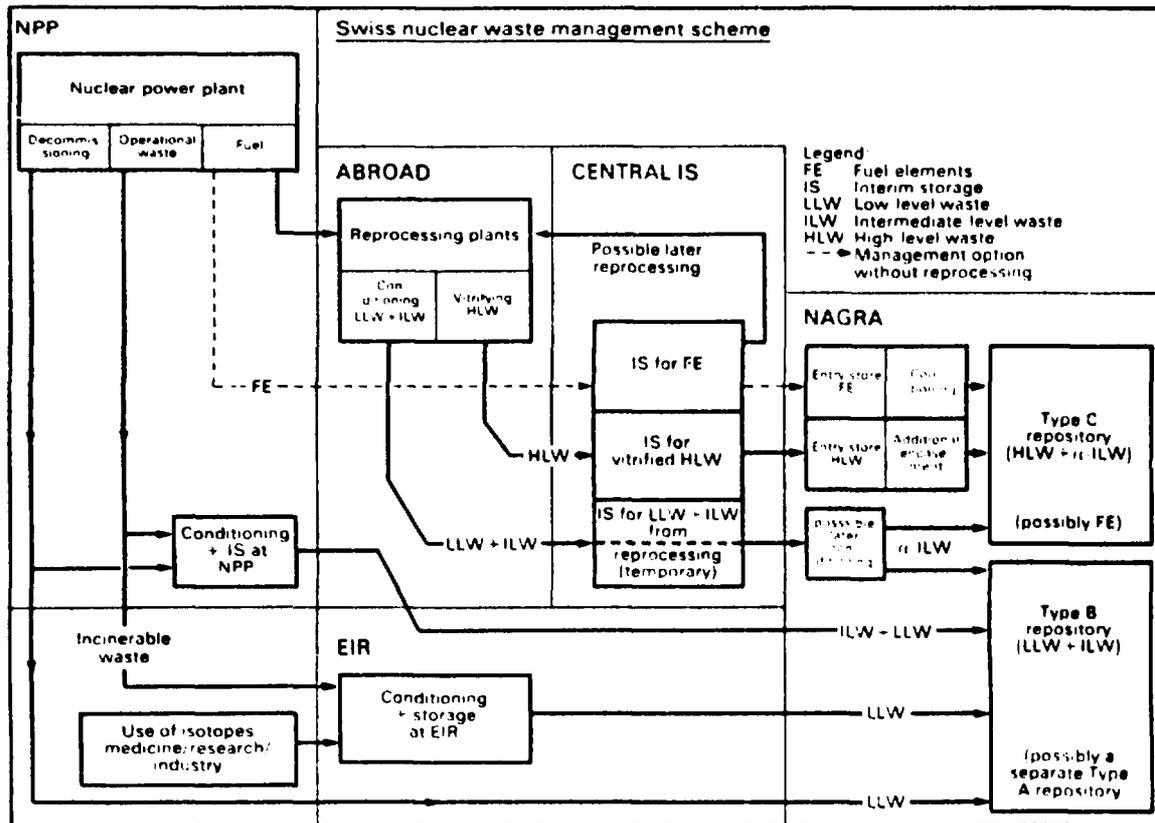


Figure H-2. Schematic Representation of Nuclear Waste Management in Switzerland According to Project Gewähr 1985.

EIR: Eidgenössisches Institut für Reaktorforschung (Swiss Federal Institute for Reactor Research)

SOURCE: NAGRA NGB 85-09

Table H-2a.

Reprocessing Waste (WA)

Waste sort	Nature of waste	Solidification matrix	Container	Gross volume (l)	Average activity per container Ci/container (reference age)	Number of containers	Total Gross volume (m ³)
WA-1	Verified high-level waste	Glass	High-grade steel canister 150 l	150	$B/v = 1.9 \times 10^6$ $\approx 1.6 \times 10^7$ (40a)	5 005	1 120
WA-2	Preprecipitates and concentrates	Bitumen	High-grade steel drum 200 l	220	$B/v = 210$ ≈ 0.62 (3a)	19 050	4 320
WA-3	Ion exchange resins from storage pools	Cement	Asbestos-cement container	1100	$B/v = 700$ $\approx 3.8 \times 10^7$ (5a)	700	660
WA-4	Fuel element hulls and end-caps	Cement	Steel container 1400 l	1430	$B/v = 2.0 \times 10^7$ ≈ 8.8 (40a)	3 930	5 600
WA-5	Technological waste (low a)	Cement	Asbestos-cement container	680	$B/v = 3.5$ ≈ 0.11 (4a)	40 872	27 000
WA-6	Technological waste (medium a)	Cement	Asbestos-cement container	1180	$B/v = 120$ ≈ 4.7 (4a)	11 780	13 900
Total sorts WA-2, WA-3, WA-5 and WA-6						73 008	47 000
Total sorts WA-2 to WA-6 (LLW + HLLW)						77 078	52 500

Table H-2c.

Distribution of waste sorts between repositories (gross volume)

Waste sort	Type C repository	Type B repository
Reprocessing waste		
WA-1 (HLW)	1 120	-
WA-2	(4,320)*	4,320
WA-3	-	660
WA-4	5,600	-
WA-5	-	27,000
WA-6	-	13,900
WA-sorts in B repository (total)		47,000
Operational waste (BA)		44,000
Decommissioning waste (SA)		97,000
Waste from medicine, industry and research (MIR)		7,500
<hr/>		
TOTAL HLW (approx)	1,120	-
LLW + ILW (approx)	5,600	185,000
	(10,000)*	(200,000)*

*) as planning assumption for construction project

Table H-2b.

Operational waste (BA)

Waste sort	Nature of waste	Solidification matrix	Container	Gross volume (l)	Average activity per container Ci/container (reference age 20 or 50 for BA 7)	Number of containers	Total Gross volume (m ³)
BA-1	Ion exchange resins	Cement, resin	Steel drum (200 l) (partly 100 l)	220 (110)	$B/v = 38$ $\approx 3.7 \times 10^6$	168 120 (incl. 8217 100 l)	35 100
BA-2	Concentrates, slurries	Cement, bitumen	Steel drum (200 l)	220	$B/v = 0.44$ $\approx 2.0 \times 10^7$	5 361	1 150
BA-3	Filters	Cement	Steel drum (200 l)	220	$B/v = 9.7$ $\approx 8.1 \times 10^6$	480	100
BA-4	Air ventilation filters	Cement	Steel drum (200 l)	220	$B/v = 2.7 \times 10^7$ $\approx 1.7 \times 10^8$	380	150
BA-5	Non-incinerable solid waste	Cement	Steel drum (200 l)	220	$B/v = 4.7 \times 10^7$ $\approx 3.1 \times 10^8$	25 352	5 470
BA-6	Incinerated waste	Cement	Steel drum (200 l)	220	$B/v = 0.81$ $\approx 1.7 \times 10^6$	2 608	540
BA-7	Fuel element casks	Cement	Steel drum (200 l)	220	$B/v = 150$ $\approx 6.9 \times 10^6$	8 180	1 750
Total operational waste						278 511 (incl. 8217 100 l)	48 000

SOURCE: NAGRA NGB 85-09

Table H-2d.

Decommissioning waste (SA)

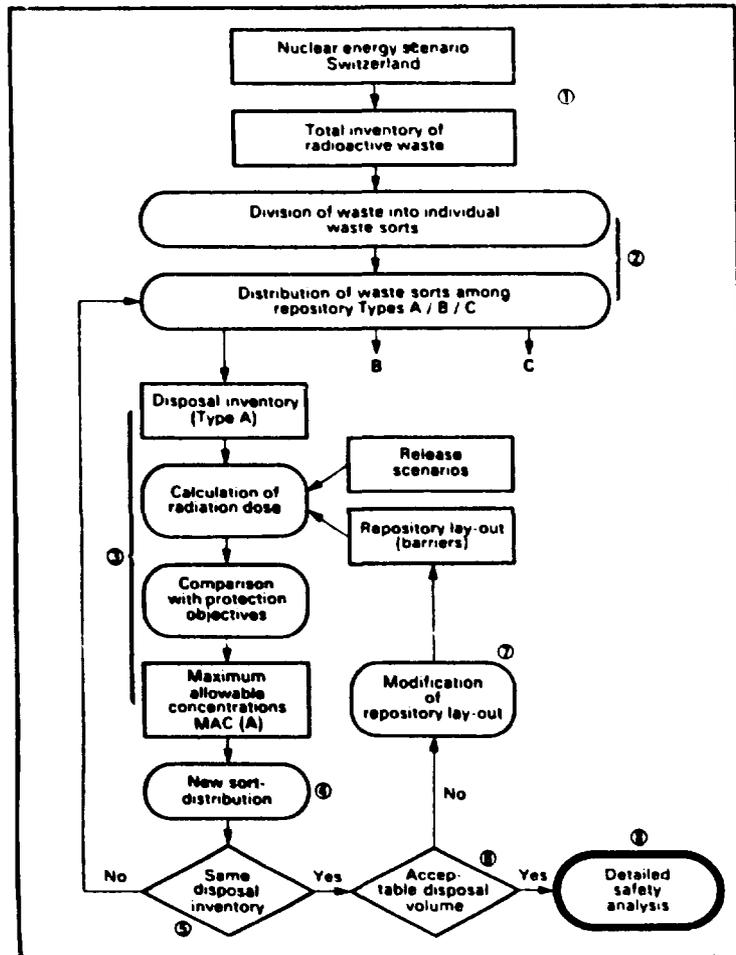
Waste sort	Nature of waste	Solidification matrix	Container	Gross volume (l)	Average activity per container Ci/container (reference age 2a)	Number of containers	Total Gross volume (m ³)
SA-1	Intermediate-level activated primary waste (steel)	Cement	Large container 2.08 m x 2.18 m x 4.78 m	217 m ³	$\beta/\gamma: 1.1 \times 10^6$ $\alpha: 3.4 \times 10^{-4}$ (1a)	437	9,480
SA-2	Intermediate-level activated primary waste (concrete)				$\beta/\gamma: 50$ $\alpha: 0$	86	1,480
SA-3	Low-level activated primary waste (steel)				$\beta/\gamma: 84$ $\alpha: 3.5 \times 10^{-4}$	272	5,910
SA-4	Low-level activated and contaminated primary waste (concrete)				$\beta/\gamma: 16$ $\alpha: 0$	461	10,010
SA-5	Intermediate-level contaminated primary waste (steel)				$\beta/\gamma: 2.2$ $\alpha: 2.3 \times 10^{-7}$	471	10,220
SA-6	Low-level contaminated primary waste (steel)				$\beta/\gamma: 5.2 \times 10^{-7}$ $\alpha: 7.5 \times 10^{-4}$	1,837	39,870
SA-7	Low-level contaminated primary and secondary waste				$\beta/\gamma: 0.22$ $\alpha: 2.2 \times 10^{-6}$	346	7,510
SA-8	Contaminated secondary waste (resins, concentrates, etc.)				$\beta/\gamma: 180$ $\alpha: 0.18$	583	12,660
Total decommissioning waste						4,473	~97,000

Table H-2e.

Waste from medicine, industry and research (MIF)

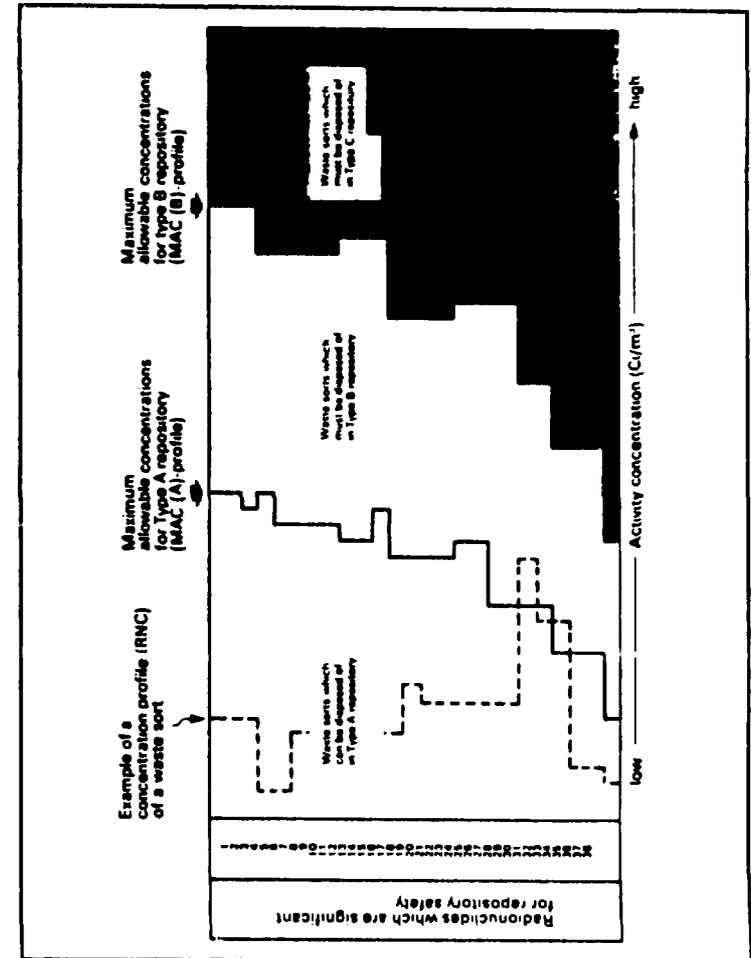
Waste sorte	Nature of waste	Solidification matrix	Container	Gross volume	Average activity per container Ci/container (reference age 1a)	Number of container	Total Gross volume (m ³)
MIF-1	Beta-/Gamma emitters (without tritium)	Cement	Steel drum 200 l	220 l	$\beta/\gamma: 0.71$ $\alpha: 0$	14,000	3,000
MIF-2	Tritium-containing waste				$\beta/\gamma: 310$ $\alpha: 0$	2,800	600
MIF-3	Alpha-emitters (without radium)				$\beta/\gamma: 2.9 \times 10^{-7}$ $\alpha: 1.5 \times 10^{-1}$	8,750	1,870
MIF-4	Radium-containing waste				$\beta/\gamma: 0$ $\alpha: 5.8 \times 10^{-7}$	1,050	230
MIF-5	Alpha and emitters				$\beta/\gamma: 1.6$ $\alpha: 5.0 \times 10^{-7}$	8,400	1,800
Total MIF-waste						35,000	7,500

sorted into groups for disposal in repository types A, B, and C. A safety analysis was prepared utilizing the quantities of the 38 nuclides most important to repository acceptability, taking into account various release scenarios and the multiple barriers of the waste package and repository to nuclide release. In the performance assessment, radioactive doses were calculated and compared with the protection objectives. The maximum allowable concentration for each of these 38 nuclides in the repository was determined by utilizing the release scenarios to arrive at a maximum dose of 10 mrem/year. If the doses fell within the protection objectives, the waste allocational storage inventories were assessed for safety and economic optimization. If the doses do not fall within the protection objectives, then the waste types may be assigned to a different type of repository and the release scenarios recalculated. The process is repeated until the calculated doses fall below the protection objectives. The end results are shown schematically in Figure H-4 and Table H-3 which shows the final allocation of wastes to the repositories. As can be seen in Table H-3, for the present, only repository types B (low and intermediate level waste) and C (high level waste) are being considered. All the remaining low level wastes, it is envisaged, will be put into the type B repository, though the option for developing a type A repository is left open.



Procedure involved in allocation of different waste sorts to the three repository types.

Figure H-3.



Representation of the concept of maximum allowable concentrations of radionuclides in a repository and of the RNC profile of a waste sort.

Figure H-4.

H.4. High Level Waste Disposal

In numerous ways Swiss research and development programmes parallel Swedish efforts in the same areas. Indeed the two countries have cooperated extensively on several studies, including the international Stripa Project. Terminal geological storage in deep stable crystalline bedrock is the favoured disposal option, although no final decision has been reached. Project studies are under way on a timetable that anticipates site selection for a high level waste repository by the year 2000, and repository operation by 2020 (NAGRA, 1983a).

H.4.a. Geology

Salt and shale are not promising as potential media for a Swiss repository due to their scarcity and lack of homogeneity. The most studied and most promising geological formation in the country is crystalline bedrock, but clay, anhydrite and Permian rocks are also under consideration. A 1200 km² area in the northern lowlands of Switzerland is the favoured location for a high level waste repository (NAGRA, 1983a). Here granitic and gneissic bedrock lies 200- 2000 m below a sedimentary cover that includes a thick (80-100 m) Mesozoic clay formation. The last major folding and metamorphosis of this basement occurred 300 million years ago. The hydrothermal phase extended until 200 million years and possibly until 100 million years ago in high water flow zones (Hadermann, 1984). The repository would be constructed at a depth of 600-1500 m.

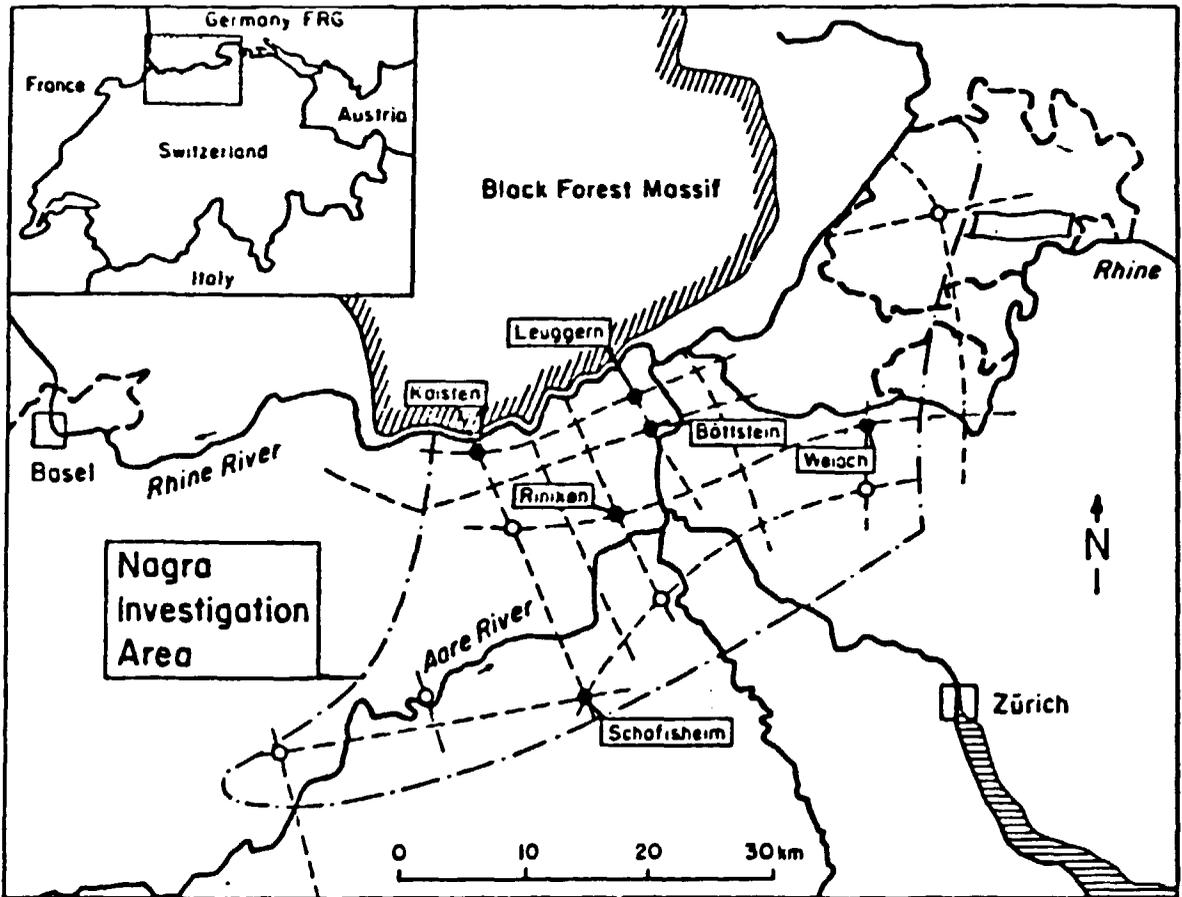
Utilizing among other methods a microseismic observation network, tectonic investigations in the region indicate relative bedrock stability between Basle and Schaffhausen. Repository locations to the south have been ruled out due to the greater depths of the bedrock (up to 5000 m) and the relative instability of the Swiss Alps. A rock laboratory has been established, however, in the alpine Grimsel Pass area where the bedrock is exposed at the surface (Pfister and Nold, 1983). Experimental methodology developed in this readily accessible formation will later be employed in site characterization studies at potential repository locations.

Hydrological investigations are under way to describe the three-dimensional flow regime in the candidate bedrock (NAGRA, 1983a; Rometsch and Issler, 1983a; Rometsch and Issler, 1983b). These studies depend also on the KRISTAL programme, a drilling campaign featuring a grid of 12 core boreholes. Borehole logs are compared with the results of surface geophysical studies, which to date have included over 450 km of vibroseis lines, aeromagnetic and gravimetric surveys, and seismic refraction studies. The boreholes penetrate the sedimentary cover and then pass approximately 1000 m into the bedrock, yielding cuttings from sections of the bedrock (NAGRA, 1983a). Geophysical logging employs amongst others, radioactive, sonic, seismic and television surveys, and various radiometric logs. Hydraulic conductivity is measured at selected depths mainly by the double packer method. Use of deionized water as drilling

fluid is expected to avoid disturbing the local chemistry and to minimize local clogging of apertures intersected by the borehole and so provide a more realistic assessment of in-situ permeabilities. An additional assessment of flow properties comes from production tests and labelled slug tests. In the latter, the movements of injected radioactive tracers are monitored by gamma logging.

The borehole programme has been plagued with difficulties from the start. No geophysical screening preceded the selection of the specific drilling sites; their selection was based largely on surface geography and desk studies (Kowalski, 1984). As a result, critics contend, several of the drilling locations are poorly placed geologically (Buser and Milnes, 1984; Buser and Wildi, 1984). Some local communities initially objected adamantly to the programme, and licensing requirements at the cantonal and communal levels have delayed the drilling at some sites.

Six core boreholes have been drilled to depths of 1501, 2482, 1801, 2006, 1689, 1306 meters (McCombie, 1985a; Kiener, 1984) in Northern Switzerland (Figure H-5). Initial results show that multiple, isolated water tables can exist, and there are some zones of extremely low hydraulic conductivity at greater depth, where fractures in granite are filled with clay minerals (Rometsch and Issler, 1983a; Rometsch and Issler, 1983b). At sites near disturbed zones, however, highly conducting zones can be found at depth in unaltered gneiss (Kowalski, 1984).



Nagra investigation area with drilled deep boreholes (black circles) and reflection seismic lines (dashed lines).

Figure H-5.

SOURCE: NAGRA NGB 85-09

There has been no evidence of selective leaching or transport of natural uranium (Rometsch and Issler, 1983b). Results from these first boreholes and seismic studies show that the crystalline bedrock surface is deeper and less regular than initially anticipated. This situation may significantly restrict candidate sites for the repository. Particular complications arise due to the presence of thermal water zones and the recently discovered Permo-Carboniferous trough. The Permo-Carboniferous trough courses in an east-west direction through the center of the northern lowlands. Some drilling sites are located immediately above it. Filled with sand, clay and coal, this trough cuts deeply into the crystalline bedrock - in places it is 3000 m deep - and it is associated laterally with fractured granite (See Figure H-6). Critics contend that deposits within the trough are too heterogeneous, porous, and permeable to accommodate a repository, and that underlying granites are simply too deep for waste emplacement (Buser and Milnes, 1984; Buser and Wildi, 1984).

The sedimentary filling of the Permo-Carboniferous trough is of relatively low permability but with some open fractures in which drilling fluids and have been lost (McCombie et al 1985). In the basement rock, flow is through the crushed zones and fracture system. From analyses of the first six boreholes the average hydraulic conductivity in the upper 500 m is

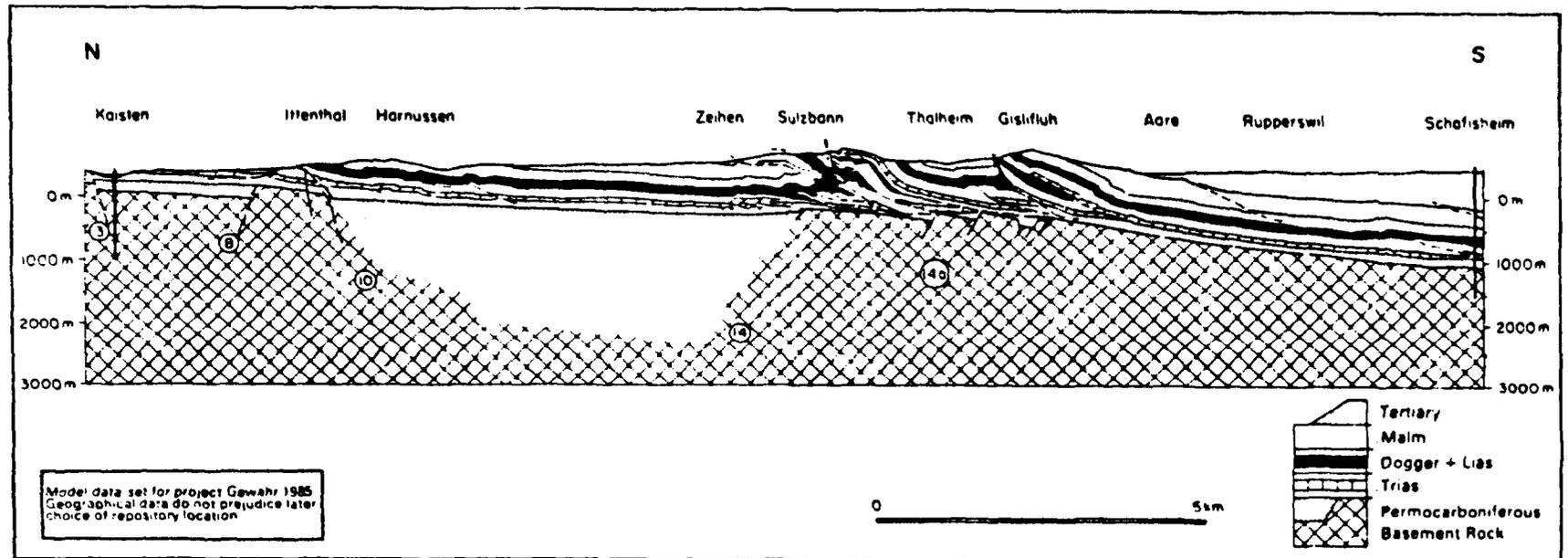


Figure H-6. Geological north-south profile along a seismic reflection line through the region of investigation in northern Switzerland.

SOURCE: NAGRA NGB 85-09

10^{-7} m/s. Below that, except in the flow zones, the average hydraulic conductivity is 10^{-11} m/s.

Thermally active areas compromise the potential of other borehole locations. Transport dynamics are less predictable in these zones, and the thermal waters themselves, like the coal of the Permo-Carboniferous trough, are potential energy sources (Rybach, 1984).

Measurements of hydraulic conductivity at the Grimsel facility have fallen in the 10^{-9} to 10^{-11} m s^{-1} range (Pfister and Nold, 1983). These values are similar to those measured in Swedish bedrock. At one of the borehole locations (Boettstein), hydraulic conductivity in solid granite has been assessed at 10^{-13} to 10^{-10} m s^{-1} , with the smaller values occurring at greater depths (Hadermann, 1984). Values for weathered granite were 10^{-6} to 10^{-8} m s^{-1} in zones where water flow was appreciable, and around 10^{-11} m s^{-1} in the Permo-Carboniferous trough (Kowalski, 1984).

Geochemical analyses are also part of the borehole programme. Ground water samples are drawn at depth in pressurized vessels and sealed before removal for surface analysis. Inclusion of organic tracers in the drilling fluid is used to reveal any accidental contamination of the sample. Early attempts to define in-situ redox conditions suffered from oxygen contamination (McKinley, 1984), but longer-term measurements and evaluations of various redox couples are yielding data that are more consistent with theoretical values,

indicating that reducing conditions prevail at depth (Hadermann, 1984).

At the University of Neuchatel, a regional flow model covering 25,000 km² has been constructed using a finite element solution of the steady state equation in three dimensions. This model has been calibrated by data from the core borehole tests, and by an analysis of chemical speciation and the age and thermal distribution of well and spring waters throughout the region. Water samples from more than 120 springs have already been analyzed. Analysis of water ages, including the use of krypton-81 isotopic dating, is a significant component of these calibration studies. Preliminary results suggest very old and saline ground waters in some formations (Kowalski, 1984), but most waters seem to be much younger (Niederer, 1984b).

A local hydrodynamic model covering 1000 km² of the most relevant area has also been constructed. Inflows into the local model are derived from the regional model. Initial validation of the two models has been carried out. They will be improved based upon increased knowledge of the geochemistry and the hydraulic heads.

H.4.b. Type C Repository Design

The Swiss programme will benefit from Stripa Project studies on the effectiveness of backfill and borehole sealing

with bentonite mixtures. No extensive studies are planned in these areas at the Grimsel facility.

A forty year aging of the immobilized wastes prior to final disposal promises to reduce thermal stresses in the repository. Interactions between temperature, geochemical conditions and hydrological variables are being studied at Grimsel (Pfister and Nold, 1983).

A single-level repository area of about 1 km^2 is expected to house up to 1000 m^3 of reprocessed waste or up to $15,000 \text{ m}^3$ of unreprocessed spent fuel (Niederer, 1983a). Some combination of the two waste forms could also be accommodated. The repository will be located at least 500 m deep into the crystalline bedrock; total depth below the surface should be 600-1500 m.

H.4.c. Far-field Transport

Modelling of radionuclide transport in the geosphere requires a description of the flow field on a regional and local scale and chemical speciation and behaviour under a range of potential conditions. A three-dimensional hydrogeological model has been developed with a flexibility to handle the more complex fracture zones in one or two dimensions only (Hadermann and Schweingruber, NAGRA, 83a; NAGRA, 83c).

Evaluation of solubility and sorption parameters is being performed within a matrix of values of pH, redox potential, ionic strength, and various complexing agents (McCombie,

et al., 1983). To track radionuclide speciation, the computer code MINEQL has been advanced beyond its original development at the Massachusetts Institute of Technology in the U.S.. The need for more data on the speciation and complexation of the actinides is acknowledged (Hadermann, 1984; McKinley, 1984). Particularly lacking are reliable sorption coefficients under low redox conditions.

Radionuclide transport is modeled in one or two dimensions by the RANCH and RANCHN codes (McCombie, 1983; NAGRA, 83c). These programmes treat fractured granite as an equivalent layered porous medium and model sorption as a linear process. Alternative codes, RANCHMD and TROUGH, model radionuclide migration along distinct fractures with diffusion to the adjacent porous matrix. TROUGH has the capacity to handle sorption kinetics. More experimental work is required on matrix diffusion. Preliminary observations suggest that such diffusion may be enhanced in a relatively narrow zone of weathered rock immediately adjacent to a fracture (Hadermann, et al, 1982). Examination of natural fractures for long-term matrix diffusion by analogue elements is considered a fruitful approach. The codes RANCH, RANCHN, RANCHMD and TROUGH have been tested in the International Nuclide Transport Code Intercomparison Study (INTRACOIN, 1984).

H.4.d. Performance Assessment

The HSK and the KSA have imposed an individual dose rate limit of 0.1 mSv yr^{-1} from projected repository releases (HSK/KSA, 1980). This limit applies to the worst case individual under realistic exposure scenarios; unusual events that result in higher doses must be proven to be not reasonably expected (HSK/KSA, 1980). Some consideration is being given to supplementing the dose rate limits with risk-based safety criteria (Niederer, 1984b). The 0.1 mSv yr^{-1} level is less than the variation in natural background dose rates, which in Switzerland range from 1 to 3 mSv yr^{-1} with a mean rate of 1.43 mSv yr^{-1} without consideration of the effects of naturally occurring radon (NAGRA, 83a). Emphasis is placed on overall system performance rather than on standards for each barrier. The repository will be designed and operated in such a way that it can be sealed at any time and no post closure surveillance will be required. Deterministic models previously described allow estimates of radionuclide releases to the biosphere. The Swedish code, BIOPATH, has been adapted for the relevant areas of Switzerland. Collectively, these codes constitute the safety analysis model for the Guarantee Project and for later repository projects (NAGRA, 83c).

Canisters are expected to remain intact for at least 1000 years, during which time the radiotoxicity and heat generated from most fission products will decay to safe levels. Primary concern then focuses on the transuranic elements.

Under the prevailing local chemistry plutonium should experience high sorption and decay during the geosphere transport. Neptunium, however, is expected to be transported by ground water in the biosphere. Preliminary safety analyses have been conducted for the base case scenario of gradual waste package failure and slow subsequent transport in ground water. Because limited geological and geochemical data are available, conservative estimates for the modelling parameters have been employed (Hadermann, 1984). Sensitivity studies featuring variations in these parameters have identified sorption coefficients, solubility limits and distance of diffusion into the rock matrix as the key variables influencing dose. Under all reasonable and conservative assumptions, however, dose rates were well below the 0.1 mSv yr^{-1} limit (Hadermann, et al. 1982; Haderman and Schweingruber 1981; NAGRA, 1985j). This limit was exceeded only when the calculations were performed assuming no sorption at all. The calculations took credit for dilution in the geosphere (by a factor of 4000) and in surface waters (by a factor of 40,000). Probabilistic analyses of accident scenarios are anticipated in the near future.

The Swiss authorities, like most of the authorities interviewed, are sensitive to the public debate on nuclear safety issues (Niederer, 1984b). Public relations activities of NAGRA include current reports to the news media and open guided tours of drilling sites and the test site at Grimsel (NAGRA, 1985). A monthly information bulletin has a circulation of over 30,000.

In addition a technical and scientific quarterly bulletin (in German and French) is published. In dealing with the public, analogies between the radioactivity in a repository and in natural geological deposits are stressed. For example, due to natural uranium there is the same level of radiotoxicity in a few hundred meters of overlying granite as in the neptunium of a high level waste repository (Rometsch and Issler, 1983b).

The Swiss, cognizant of the size of their nuclear programme, the regionally complex geology, high population density, and that their reprocessing is done in France and the U.K. would welcome an international solution to their radioactive waste disposal needs under certain conditions (Buser and Wildi, 1981, Niederer, 1984b). These conditions include guarantees that: 1) the accepting country has sufficient safety criteria; 2) the repository is available continuously into the far future; 3) the accepting country has its own nuclear energy programme and has solved the final disposal problem itself; and 4) public acceptance in the host country. An international review of the proposals submitted by NAGRA under the Guarantee Project has been proposed by critics. The authorities did not favour this, but have engaged some foreign experts to review selected topics. Future plans include regional investigations and site selection (1980/89), detailed investigation at one to three locations and selection of one site 1989 to 1995. Then, detailed exploration of the site and construction of an underground laboratory

between 1995 and 2005. The repository will be in service in 2020. (McCombie & Issler, 1986).

H.5. Site selection for low and intermediate level waste repositories

All low and intermediate level waste in Switzerland will be stored in a B-type repository, except for the alpha-containing intermediate level waste, which will go to a C-type repository.

An extensive site selection process has been performed to find a suitable site for a B-type repository. This process has been systematic and is amply documented in reports (NAGRA, 81, NAGRA, 83d). However, since the procedure is of general interest it will also be briefly described here.

H.5.a. Condensation of an 100 site-list to a 20 site short list

A start was made from a list of about 100 potential site areas representing five classes of formations, namely:

- 23 in Anhydrite
- 15 in Alpine marl and claystone
- 25 in Opalinus clay
- 23 in "screened off" formations above the water table
- 14 in Crystalline rocks

These site areas were assessed and ranked within each type of host formation.

The first part of the assessment was made with regard to spatial and geological factors, such as:

- the spatial situation of the host rock in the site area
- the water impermeability of the host rock in the site area
- the hydrogeological situation at the site area
- the properties with regard to possible tunnel construction in the host rock and of the neighbouring rocks (to be penetrated by the access tunnel).
- the predictability of the geometry
- the predictability of the geology and of the hydrogeology
- the predictability of future geological changes
- the present level of knowledge of the spatial and of the geological and hydrogeological situation for the site

The sites assessed under these criteria were designated as good, average, acceptable or unacceptable. If a site had "unacceptable" in one or more of the above criteria it was eliminated from the list. The results of the assessment are presented in detail in tables in NAGRA, 81.

Some important information, not included in the assessment, was included as additional information:

- seismic activity
- distance to mineral springs and hot springs
- risk of flooding
- conservatio of natural beauty and wildlife
- exploitation
- distance to settlements
- different interest conflicts with mountain-rights or mountain laws or with underground construction activities in the surroundings of the site area.

The influence of these -- mostly non-geological -- factors on the assessment of a site area was clarified in detail for each individual site.

As a result of this procedure a short list was obtained, containing 2-5 sites for each host material. In total, the

short list contained 20 sites which should be further investigated. The result of the assessment including a detailed presentation of the 20 site areas was published in November 1981. Table H-4 illustrates - as an example - the assessment of the 23 anhydrite sites and how the four most suitable sites were selected.

H.5.b. Condensation of the 20 site list to an 11 site list

The next step in the assessment was to reduce the number of site candidates by:

- a more intense study of the existing geological and hydrological data
- making extended design studies on the construction work
- making new systematic considerations of the impacts on area planning and environment

Five of the 20 sites were dropped from the list for geological reasons. One site was eliminated because it would interfere with the exploration programme for one of the potential high level waste sites. Two more sites were dropped for having too thick a cover on the host rock. One site was dropped due to area planning conflicts. This work is described in NAGRA, 83d.

H.5.c. Condensation of the 11 site list to a 3 site list

The 11 potential site areas which remained on the list were then further assessed in the following aspects:

TABLE H-4

LIST OF FINAL TWENTY SITES

	LOCATION	RATING
ANHYDRITE	Le Montet	II
	Val Canaria	III
	Glaubenbuelen	III
	Bois de la Glaive	I
ALPINE MARL AND CLAY	Oberbauen Stock	I
	Palfris	III
	Niderbauen	II
	Schaffens	II
	Mayens de Chamoson	III
OPALINUS CLAY OF THE JURA	Limperg	III
	Randen	III
	Les Coperies	III
	Chalhochi	III
CALCAREOUS FORMATIONS OVERLAIN WITH IMPERMEABLE ROCKS	Castilun	II
	Buis	III
	Fallenflue	III
	Mouron	III
	Mont Aubert	III
CRYSTALLINE	Piz Pian Grand	I
	Chaistenberg-Strick	II

- Landscape
 - . Environmental Protection
 - . Nature and Homeland Protection
 - . Land and Forest Economics
 - . Disturbance Potential (Landscape and Settlements)
 - . Incorporation Possibilities (Landscape and Settlements)
- Settlements
 - . Settlement District
 - . Inhabitants (industry, tourism, recreation area)
 - . Supply, Plant Management
- Traffic
 - . Plans
 - . Road Access
 - . Rail Access
 - . Narrow passages through villages, towns etc.
- Water Protection
 - . Spring water, Ground water, Surface water
- Military Installations
- Proprietary Situation
- Deposition possibilities for excavated material
- Mountain judicial licences

Furthermore, a more sophisticated assessment was made of the 11 sites with regard to:

- Ecological and Hydrogeological Aspects
 - . Remaining lack of knowledge on the site
 - . Evaluation of the exploration programmes performed
- Construction Techniques
 - . Determination of the position for the entrance zone
 - . Site specific considerations on construction work
- Area Planning
 - . New consideration with regard to exact position of repository, entrance point etc.
 - . Creation of traffic and noise
 - . More sophisticated assessment criteria on the construction phase, the deposition of excavated material and on the pre-closure period of the repository.

The potential sites were also assessed with regard to some other factors connected to the construction of the repository, such as:

- Time needed for necessary further exploratory work and associated costs
- The risk in starting the work, due to the limited knowledge of the geology
- Time needed for licensing procedures
- Time and funding needed for construction of the repository

As a final result the list shown in Table H-4 was obtained.

For the nuclear safety (corresponding to the post-closure phase) the assessments values are condensed to one value each for:

1. Geology
2. Hydrogeology
3. Biospherical situation (Dispersion)
4. Predictability of changes
5. Chemical Properties of the Geosphere
6. Prospective Use Conflicts

These six assessment values are then further condensed to a single value for "nuclear safety".

Similarly for operations (corresponding to the construction and pre-closure stages) the assessment values are condensed to one value each for:

7. Extent of necessary clarification work
8. Time needed for construction of the repository
9. Cost for construction of the repository
10. Environmental compatibility
11. Importance to political economy
12. Time needed for licensing

These six values are also further condensed to a single value for "OPERATIONS".

The final step in using the assessment values for "nuclear safety" and for "operations" to get a ranking of the sites according to the following:

- The nuclear safety has priority one whereas operations has priority two.
- The condensed assessment values are not plain averages. A weighting procedure is used, which is not described in detail in the report.
- The only "unacceptables" (i.e. value "4" in the table) are related to construction aspects (rock stability; and cost of construction).
- The nuclear safety and the operations assessment values are averaged and - if the result is not an integer - generally rounded off in the more unfavorable direction (2 and 3 will be III, 1 and 2 will be II etc.

In the bottom line of Table H-4, the 20 sites here been classified as follows:

Group I	Highest priority	3 sites
II	Reserved	5 sites
III	Deferred	12 sites

The three high priority sites were located one in each of the three main language areas of the country.

One of the five reserve sites achieved some prominence when its canton approached NAGRA and declared that it would welcome a low level waste and intermediate level waste repository, if the geology is suitable for it and the safety can be guaranteed by the federal government. The government of the Canton, which by the way has no nuclear power plants, considers that the programme of investments and activities in

connection with the construction and operation of such a repository would be beneficial for the canton. Two months after this approach all the members of the canton government were reelected (Issler, H., 1986).

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APPENDIX I

THE UNITED KINGDOM

I.1. Introduction

At the end of 1985, nuclear reactors in the United Kingdom had a net generating capacity of 5 GWe, or some 10% of the nation's public supply electricity. At the end of 1985 nuclear power accounted for some 16% of electricity generation and by the 1990s nuclear power may supply a third of the UK's electrical needs. To accommodate potential increases in nuclear capacity, the back end of the fuel cycle is being designed for up to 20 GWe by the year 2000.

Fuel reprocessing has been carried out at Sellafield (previously Windscale) since 1952 and at Dounreay since 1958. British Nuclear Fuels PLC (BNFL), a government-owned corporation, now operates the Windscale plant; 25,000 Mg of magnox (metallic uranium) fuel have been treated there. A new plant, THORP, is expected to process 6,000 Mg of oxide fuel by the year 2000. Acidic liquid wastes are stored in cooled stainless steel tanks, with secondary concrete containment, at Sellafield, pending development of vitrification facilities. Recently BNFL has decided to adopt the French AVM technology rather than further develop the FINGAL/HARVEST process of UKAEA. A vitrification plant employing the AVM process is scheduled for operation at Sellafield in the late 1980's.

During the 1970's the United Kingdom initiated a programme of geological and geophysical exploration to assess potential areas for a high-level radioactive waste repository in granite. In December 1981, however, this programme was suspended because the Government said that there were technical advantages in delaying disposal for periods in excess of 50 years in order to allow the heat output of the waste to fall thereby facilitating its disposal. In addition it was also felt that the feasibility of disposal had already been proven in principle. This strategy has been accepted by the industry and the Government's independent waste management advisors. Final decisions on HLW disposal are not expected for several decades.

The British maintain an active interest in the potential for seabed disposal. Through cooperation with the OECD/NEA, they expect to analyse the marine option as fully as land-based options before any final decision is made. Research in the UK on HLW now centres primarily on interim storage, technology for immobilizing wastes, paper studies of repository design, participation in the International Stripa Project, and assessment of the progress of other countries.

1.2. Division of Responsibilities

The Department of the Environment (DoE) develops overall policy and sponsors research programmes for radioactive waste management (Keen and Duncan 1983; Johnston 1986). Much of the research and development are placed with the British Geological

Survey (BGS) and the United Kingdom Atomic Energy Authority (UKAEA), but a large amount is contracted to other organizations, including the Institute of Oceanographic Sciences, and to private sector companies. Almost 50% of DoE's funds go to private firms. DoE is not only an environmentally oriented agency, but is responsible for a wide range of planning applications. DoE shares a regulatory role with the Ministry of Agriculture, Fisheries and Food (MAFF) and the Nuclear Installations Inspectorate (NII). DoE and MAFF act together to set discharge limits for radioactive substances, and to authorize discharges. MAFF reports releases of radioactivity from nuclear sites; the Ministry is particularly involved with radionuclides in the marine environment and has regulated past sea dumping activities.

NII, a division of the Health and Safety Executive, issues licenses for industrial nuclear operations. An HLW repository has not been officially designated as a nuclear operation, but any repository will be kept under effective regulatory control by the DoE and NII. The National Radiological Protection Board (NRPB) performs safety analyses and advises the government in relation to the protection of the community from radiation hazards. Since 1978 the Secretary of State for the Environment has been advised by an independent group of experts from industry, government, trade unions and the academic community, known as the Radioactive Waste Management Advisory Committee (RWMAC). Its

purpose is ... "to advise the Secretaries of State for the Environment, Scotland and Wales on major issues relating to the development and implementation of an overall policy for the management of civil radioactive waste, including the waste management implications of nuclear policy, of the design of nuclear systems and of research and development, and the environmental aspects of the handling and treatment of wastes" (Radioactive Waste Management Advisory Committee 1985). To date, it has published seven annual reports on waste management issues.

While DoE will continue to formulate overall programme strategy, the nuclear industry is expected to shoulder development and implementation tasks to an increasing degree. For this purpose the Nuclear Industry Radioactive Waste Executive (NIREX) has been established. It is now known as UK Nirex Ltd. NIREX draws its staff from its shareholders' organizations, particularly BNFL, CEGB and UKAEA. Its responsibility is: ... "to provide and manage new facilities for the disposal of low and intermediate level radioactive waste, whether this is into a near-surface facility on land, into a deep facility on land or under the sea, or on to or into the sea bed" (Secretaries of State for the Environment, Scotland and Wales 1986).

I.3. Disposal Strategy

A 1976 report from the Institute of Geological Sciences (IGS) (now the British Geological Survey) established criteria

for the selection of potential areas for an HLW repository. (Grey et al. 1976). This document distinguishes between area selection and site selection. The former, which applies only to broad geographical and geological zones, can be accomplished via the application of generic criteria, but site selection is a far more rigorous process requiring extensive geological exploration and a demonstration of the compatibility of site and disposal method. Uncertainties in the prediction of long-term geological and climatological events are emphasized, and to compensate a multi-barrier disposal concept is advanced as an adequate solution.

More recently the British Geological Survey has looked beyond local effects ('near field') and to the geological setting as an entirety-the overall hydrogeological environment in which the repository lies. These desirable sites are characterized by: long flow path and very slow moving ground waters with potential discharge to points of high dilution (e.g. sea or mixing with large volumes of uncontaminated ground water). They have identified five desirable environments: (1) inland basins, (2) seaward dipping and offshore sediments, (3) low permeability basement under sedimentary cover, (4) hard rocks in low-relief terrain, and (5) small islands (Chapman & McEwen, 1986).

A LLW burial ground is in use on BNFL property at Drigg but based on current projections would be filled by 2010 if no

other facility were developed. Further research into clay properties is being conducted at a UKAEA site at Harwell. NIREX is proceeding with plans to locate a second LLW burial facility in clay and obtained a special development order from Parliament in 1986. Four sites are currently under consideration. NIREX is studying alternative concepts for an underground facility for intermediate level wastes, and a short list of possible sites for such a facility is not expected until 1989-90. DoE's Assessment of Best Practical Environmental Options for Management of Low- and Intermediate-Level Solid Radioactive Wastes issued in 1986, concludes that both short-lived and long-lived ILW can be safely be disposed of in engineered trenches near the surface, but that only a small amount of short-lived intermediate-level waste would be suitable for disposal in shallow land facilities. The Government decided in May 1986 that short lived intermediate level waste would not be disposed of by shallow land burial.

The British Government remains actively interested in sea and subseabed disposal of radioactive wastes, considering sea disposal generally as ".....a safe disposal option which should remain available" (Secretaries of State for Environment, Scotland and Wales 1986). Feasibility studies of the disposal of ILW under the seabed are currently in progress.

Primary emphasis in standards will be placed on individual dose limits (DoE, 1984). This decision reflects a judgement

that it is more relevant to predict the behaviour of the worst case individual than to forecast the time dependent size, location and behaviour of a general population in the distant future. In keeping with ICRP guidelines, individual doses from all sources except medical and natural background are limited to 5 mSv yr^{-1} . If the source is potentially chronic (lasting, say, for ten years or longer), this limit is decreased to 1 mSv yr^{-1} . The NRPB acknowledges difficulties with the individual dose limit approach, recognizing that worst case scenarios are bounded only by the imagination. It may always be possible to envision an event of extremely low probability that would result in the violation of the dose limit. The long-term radiological protection approach is based on risk (i.e., the product of the probabilities of occurrence and consequence). Based on this methodology, the consequences of highly unlikely events can be considered but their contributions to the dose limit will be discounted by their low probabilities. The DoE has set a target for any single repository that the annual risk to an individual should be equivalent to a dose of 0.1 mSv , i.e. about 1 in a million. Studies of attitudes to risk indicate that such small risks are routinely ignored in daily life. In its 1986 response to the Environment Committee, the government has specifically endorsed the most recent ICRP dose limit recommendations (Secretaries of State for Environment, Scotland and Wales, 1986).

Collective doses will be assessed for comparative purposes and will be subject to the ALARA principle (DoE, 1984). Doses will be integrated over all time, regardless of their individual magnitudes. Because they will be used only to compare management options, calculation of collective doses can be truncated when the uncertainties fail to discriminate between two disposal practices. Truncation time cannot be set a priori but must emerge from the numerical assessment itself. Although no de minimis standard has been set, NRPB favours the identification of collective doses attributable to integrations over very small individual exposures. It may not be meaningful to apply the ALARA principle to such doses (NRPB 1983).

In the case of HLW, performance assessment has so far been limited to generic studies. On unrealistically pessimistic assumptions, doses to man from an inland granite repository were estimated as 5-60 mSv yr⁻¹ (NRPB, 1983). Peak doses occurred after 10,000 years. Locating the repository along a coastline promised to reduce these doses by approximately two orders of magnitude. The lowest consequences were estimated for disposal on the sea floor. From a marine repository expected doses to man were less than 0.01 mSv yr⁻¹.

I.4. Public Attributes and Response.

Since the early 1980s, as the industry has developed its technical skills, public acceptability of radioactive waste disposal has become more difficult to achieve (Kemp, O'Riordan,

and Purdue 1986). High levels of public concern are evident, and waste management issues are very visible in the public debate. These concerns are reflected in the volatile public response which has occurred to proposed waste disposal sites. Vociferous opposition by environmentalists and local residents during public inquiries contributed to the 1981 Government decision to postpone its exploratory high-level R&D drilling programme. Although it agreed there was no technical justification, in order to allay the anxiety of the public at each of the four candidate sites, in May 1986 the Government directed that only LLW would be disposed of near the surface: all ILW would be consigned to a deep repository. The four low-level waste sites under consideration each face organized opposition, which has moved into broader coordinated opposition to the disposal programme in Britain, buttressed by national environmental groups (such as Friends of the Earth). Public misgivings about radioactive wastes have stimulated two critical reviews of the Government's disposal programme -- the Sizewell Inquiry, which ventured into these issues, and the House of Commons Environment Committee Report (1986).

The environmental lobby in Britain is extensive, with a strong and widespread array of groups with the potential for opposition to radioactive waste disposal efforts. Prominent among these is the Friends of the Earth (FoE). This group does not see HLW as an urgent problem. It grants that it is not economically feasible to close existing nuclear power plants.

These plants will continue to operate into the next generation, ensuring that the next generation will have a waste disposal problem regardless of this generation's actions. FoE advocates dry, on-site storage of spent nuclear fuel without reprocessing, retention of all wastes in a retrievable mode, and a careful review of waste management options during the next fifty years (Connell 1984; Boyle 1986). They see no justification for immediate reprocessing, given the availability of virgin fuel and an existing supply of plutonium sufficient for any conceivable fast breeder reactor research programme over the next half century. The nonproliferation issue also motivates their opposition to reprocessing, as does the comingling of defense and commercial wastes. Waste discharges from the Sellafield plant have not promoted confidence in the safety of reprocessing. FOE advocates a position of zero discharge at Sellafield (Boyle 1986).

FoE indicates that it approves of the work (but presumably not all positions) of RWMAC but is strongly critical of the DoE/NIREX institutional arrangement for guiding and implementing radioactive waste disposal in the UK (Boyle 1986). It perceives the government as being reluctant to define an overall integrated strategy with well described criteria for public safety. FoE argues that the ALARA principle should be applied in optimizing all aspects of waste management, and not merely in choosing between alternative management systems.

They are suspicious of risk-based performance criteria, which may demand more predictive ability than the data base justifies. Basically, FoE sees NIREX rather privately developing programmes and making the critical choices, then weathering the inevitable public abuse before DoE finally steps in with a decision. They object to the personal and private exchanges that characterize the NIREX/CEGB relationship with DoE and advocate a more open forum.

Sea disposal of wastes elicits other sources of opposition. The Political Ecology Research Group views the models used by DoE as overly simplistic and unduly focussed on doses to humans (Taylor 1986). It sees the strong possibility that public opposition to land sites will lead to unsatisfactory sea solutions. Also, the National Seamen's Union actively opposes ocean dumping programmes and sought to stop research into seabed disposal.

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THE UNITED STATES OF AMERICA

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APPENDIX J

THE UNITED STATES OF AMERICA

J.1. Introduction

The United States of America, the birthplace of nuclear power, continues to lead the world in total energy production. In 1985 84 nuclear power plants generated about 13% of the nation's electricity. Another 30 plants were either under construction or planned. It is expected that nuclear power will supply about 20% of the nation's electricity in the 1990s. Yet the future of nuclear power in the USA is clouded due to a spectrum of technical and socio-political issues, including uncertainties surrounding the management of high-level radioactive wastes.

The U.S. has explored a wide range of alternatives for the safe disposal of nuclear wastes (U.S. Department of Energy, 1980). These alternatives have included a mined geological repository, subseabed disposal, emplacement in the very deep holes, rock melting, ice sheet disposal, island disposal, deep well injection, space disposal and partitioning and transmutation. Following an extensive study of the merits and feasibilities of each of these systems, the mined geological repository was selected as the preferred disposal approach.

The Nuclear Waste Policy Act (NWPA) of 1982, established a schedule for the completion of several intermediate tasks culminating in repository operation (U.S. Congress, 1983). Five sites were selected

by President Reagan for detailed characterization in 1986 leading to the designation of three sites Yucca Mountain (Nevada), Hanford (Washington), and Deaf Smith (Texas), in 1986 for extensive underground exploration. These three sites represent three different geologic media--tuff, basalt, and bedded salt. Generic and regional studies on granite were also conducted but a proposed second repository was indefinitely deferred in 1986 following public opposition. Following detailed characterization emphasizing underground, in-situ testing, a single site will be recommended to the President in 1988. It is highly unlikely that this schedule can be met. Final approval of site selection requires presidential consent and acceptance by the affected state, although objections by the latter can be overridden by a vote of both houses of the U.S. Congress. The Nuclear Regulatory Commission (NRC) is allowed up to four years to decide whether the Department of Energy (DOE) should receive a license for repository construction. Following construction, DOE must apply for another license to possess radioactive wastes for actual emplacement. The capacity of the first repository is limited to 70,000 Mg, which is the expected accumulation by the year 2000.

The NWPA also mandates continuing exploration of alternatives to the mined geological repository. Disposal in a subseabed has received the most attention, but founding in this area has been terminated.

The final waste form has not been determined and studies on reprocessed wastes (primarily from defense activities) and consolidated spent fuel continue. Requirements are being developed to establish acceptance criteria for receipt at the repository (U.S. Department of Energy, 1985). Only a few hundred Mg of commercial fuel have been

reprocessed in the U.S., mostly at the West Valley Nuclear Fuel Services plant in New York State. This plant operated from 1965 to 1972, when it was closed for economic and safety reasons. The HLW is being stored in liquid form in stainless steel tanks. No commercial reprocessing has occurred in the country since 1977 when President Carter suspended the practice due to its potential contribution to the proliferation of fissile materials for weapons production. The Reagan administration encourages reprocessing, but continued uncertainty concerning the long-term political and economic climate continues to discourage investors.

J.2. Division of Responsibilities

Several governmental agencies share responsibilities for nuclear waste management. The three most important organizations are the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE). The EPA is responsible for establishing generally applicable standards to protect the public from adverse health effects due to radiation exposure. EPA has set safety standards based on population risks and on individual dose for the first thousand years of undisturbed performance after disposal. Deaths from premature cancers and genetic defects statistically attributable to radiation doses are not to exceed 1000 during the first 10,000 years of repository existence. To facilitate application, this standard has been translated into release limits for fifteen radionuclides by using generic transport models based on global average parameters.

Implementation and enforcement of the EPA release limits are the task of the NRC, which regulates the nation's commercial nuclear activity and high level defense waste disposal. The NRC issues technical regulations, which have the force of law, and has licensing authority over waste disposal facilities. Regulations by the NRC include a 300-1000 year lifetime for the waste container; radionuclides are to be substantially contained during this period of greatest fission product activity and thermal stress. When releases do begin, they are not to exceed 10^{-5} yr^{-1} of the 1000 year inventory for all radionuclides constituting more than 0.1% of the total activity. Finally, water travel times at any undisturbed repository site must exceed 1000 years. The NRC expects that these requirements for the performance of individual barriers will ensure adequate isolation of radioactivity from the biosphere during the first 10,000 years, as prescribed by EPA.

Actual siting, design, construction and operation of the repository and associated facilities are the responsibility of DOE. Through its Nuclear Waste Terminal Storage (NWTS) programme and numerous sub-contractors, including the national laboratory network, DOE pursues a wide range of laboratory and field activities directed toward the establishment of a mined geological repository by the year 1998, all coordinated by the Office of Civilian Radioactive Waste Management.

J.3. Disposal Strategy

The U.S. is considering nuclear waste disposal in salt, basalt, tuff and granite. Site-specific activities are well advanced in all media except granite.

No rock type has been studied as extensively over such a long period of time as salt. Salt was recommended as a disposal medium for high-level radioactive wastes by the first National Academy of Sciences Committee on Waste Disposal in 1955, and it has continued to compare favourably with other rock formations in recent analyses. The properties that make rock salt so attractive for waste isolation include its extremely low water content and hydraulic conductivity, its great abundance in homogeneous deposits, high thermal conductivity, self-healing properties and low mining costs. These traits must be balanced against less favourable attributes such as high solubility, poor sorptive capacity for most radionuclides, and the corrosive nature of brine solutions. These factors are not important, however, if the probability of significant water inflow to a salt repository is negligible, or if reasonable flooding scenarios produce insignificant releases to the biosphere. Waste packages in a salt repository below the water table will eventually be exposed to some moisture whether by the thermally motivated migration of brine inclusions, resumption of saturated conditions or the failure of shaft seals (Cranwell et al, 1983). Subsequent transport to the biosphere may occur along flow paths through more permeable strata, such as fractures in polyhalite or anhydrite impurities, associated clay seams, or breccia pipes. No salt mass consists of pure halite. Other minerals (anhydrite in particular but

clays as well) are less plastic on heating and could fracture due to the thermal stresses imposed by the waste packages. These fracture channels might provide a short circuit to the biosphere. The formation of breccia pipes, vertical formations extending through salt beds and associated formations, is not well understood. These structures could be routes for the premature escape of radioactivity and should be avoided during repository siting.

A programme to dispose of transuranic wastes from defense programmes is well advanced at the Waste Isolation Pilot Plant (WIPP) site in southeastern New Mexico. The facility is almost complete and will begin receiving wastes on a trial basis in 1988. If tests are successful, the facility will become a permanent disposal site five years later.

A series of basaltic lava flows in the Pasco Basin of south central Washington are candidate media for a nuclear waste repository. The area around Hanford, Washington, has been reserved for federal activities related to nuclear energy and weapons production since the 1940s. Considerable volumes of defense wastes are stored on the grounds, making Hanford an attractive repository site on logistic as well as administrative grounds. Investigations are organized by the Basalt Waste Isolation Project (BWIP).

Basalt is relatively impermeable and exhibits a high sorptive capacity for most radionuclides (National Research Council, 1983). Hydraulic conductivities at the Hanford site have been measured at $10^{-13} \text{ m s}^{-1}$ within the centers of the flows; flow tops are more permeable at 10^{-7} m s^{-1} . Retardation coefficients in the range of 10^2

to 10^5 have been calculated for the actinides. A reducing ground water promises to maintain most radionuclides in their least soluble form. Basalt suffers, however, from a relatively high ambient temperature (57°C at proposed repository depths) and serious boundary discontinuities, particularly along flow tops and fractured colonnades. High horizontal stresses are evidenced by the discing of borehole cores, leading some experts to fear rock bursting and other problems of medium stability during repository construction.

Perhaps the most serious obstacle to a basalt repository is the complexity of the local flow regime. Numerous wells have been drilled at the Hanford site in an attempt to map the distribution of piezometric head. However, the hydrological complexity of the medium is extreme due to the variable permeability of the basalt flows in both vertical and horizontal dimensions. This complexity and the tendency of water to follow the less resistant paths along flow boundaries, interbeds, and internal fractures decrease confidence in hydrological modeling. The US Geological Survey (1983) released a report that was sharply critical of the hydrological studies at Hanford. Attempts to define flow paths at Hanford by carbon-14 dating of ground waters have encountered similar frustration and criticism. Nevertheless, the general indication is that waste residence times in the Umtanum and Cohasset flows are on the order of 10,000 years. Flow path lengths to the Columbia River may range from 10 to 35 km.

A Near Surface Test Facility has been established at a depth of 100 m in the Hanford basalts. Although more shallow than any anticipated repository, local rock features are similar to those existing at greater

depth. The facility consists of three tunnels, each 200 m long connected by the 100 m long test rooms. Here electric heater experiments were conducted at rock temperatures up to 500°C. Extensometers situated in boreholes measure rock deformation and acoustic methods have been developed to assess changes in rock integrity during thermal loading.

Studies on tuff are in progress at Yucca Mountain, which straddles the western boundary of DOE's Nevada Test Site. Here tuffs, lavas, and associated sedimentary rocks form a 2000 m thick, complex geological structure that offers a unique combination of advantages and disadvantages for a nuclear waste repository.

Tuff consists of compacted volcanic ash. If deposited at high temperatures, tuff may be dense and welded, resembling basalt in its physical properties. An alternative form is zeolitic tuff, which is more porous with a considerable water content and high sorptive capacity. The strength of welded tuff makes it the logical candidate for the repository horizon. Zeolitic tuff is unstable under thermal stress and should be avoided in the near-field, but its presence along far-field flow paths would provide an excellent sorptive barrier.

The formation receiving the most attention at Yucca Mountain has been the Topopon Spring Member of Paintbrush tuff. This welded deposit occupies a 30 m interval beginning 375 m below the surface. An underlying layer of zeolitic tuff is 130 m thick and extends to the ground water table. The rock exhibits an unconfined uniaxial compressive strength of 100 MPa. The formation is fractured and unsaturated, two factors that confound attempts to model its hydrology. Rainfall is

limited in this arid region, and net infiltration probably does not exceed 5 mm yr^{-1} . Even during glacial periods precipitation patterns were not markedly different, and there is evidence that the maximum ground water table did not rise more than 50 m.

Ground water travel time from the surface to the saturated zone has been estimated crudely at 21,000 years. Within the saturated zone most of the permeability is concentrated along fractures in devitrified welded tuff. Assuming a ground water velocity of $2 \times 10^{-7} \text{ m s}^{-1}$, travel time to a well located 6.4 km from the site is only 1200 years. There is considerable uncertainty in this measurement; however, water travel times to Forty Mile Wash, a distance of 10 km, have been variously estimated at 10^2 to 10^5 years.

J.4. Performance Assessment

The U.S. programme has included numerous systems performance assessments in various geological media. These assessments and those of other nations have been reviewed (Koplick, et al. 1982). The Waste Isolation Systems Panel (WISP) of the National Research Council (1983) has conducted an independent analysis of the expected performance of potential repositories under the various projects. Recently, Brookhaven National Laboratory (1986) has complete a literature review of risk assessment throughout the entire waste disposal system (Hamilton et al 1986).

Mathematical exercises all suffer from a certain immaturity. In no medium is the data base sufficient to predict with confidence the ultimate distribution of radioactivity in time and space. Total

confidence is, of course, impossible, as performance assessment will never evolve beyond a wise and well documented estimate. But a continuing refinement of input parameters, including a quantification of their uncertainty, will increase the reliability of model output. Optimism is currently warranted by the fact that most predictions of human dose rates from repository releases do not exceed a small fraction of the natural dose from background radiation.

Any particular estimation of dose depends on the choice of models and the selection of their input parameters. The acceptability of any calculated dose is in turn determined by the dose criterion, itself a matter of considerable controversy. The WISP study, for example, selected an individual dose limit of 0.1 mSv yr^{-1} , and its model of radionuclide concentration reaching the human environment placed a premium on dilution in surface waters (National Research Council, 1983). The logical outcome favoured a basalt repository near Hanford, where flows in the Columbia River exceed $10^{11} \text{ m}^3 \text{ yr}^{-1}$. Conversely, the tuff site in Nevada performed poorly in large part because there is no flowing surface water in this area. By these criteria ocean disposal would likely be the favoured option for nuclear waste disposal.

The EPA has adopted performance standards in terms of limits on the total releases of specific radionuclides during the first 10,000 years after the closure of a 100 Gg repository. For each element the specified release reflects the amount of radioactivity that will cause 1000 premature deaths during this period. When more than one radionuclide is released, the sum of the ratios of the released amounts to their respective release limits must not exceed unity.

The 10,000 year limit addresses both reasonable, long-term safety goals and the inevitable erosion in predictive confidence with increasing time scales. It is long enough to encourage careful site selection based on a thorough assessment of ground water transport properties, (though time periods of 100,000 years are to be taken into account in site selection) but short enough to assume relatively constant geological conditions. Justification for the 1000 statistical deaths derives from assessments of the radiological danger of unmined ore bodies. To generate the fuel represented in a 100 Gg repository, 620 Gg of uranium dioxide must be mined. EPA has estimated that through natural ground water transport a generic deposit of this size would result in significantly more than 1000 cancer deaths during the same 10,000 year period.

EPA has also adopted several qualitative standards that all waste disposal facilities must meet. Each of these standards must be addressed in the environmental impact statement required for a repository. The standards require the prompt disposal of high-level wastes in a manner that results in releases as low as reasonably achievable. Isolation must be assured via multiple independent barriers including both man-made and natural components. No active institutional controls should be required to promote long-term safety, but the most practical permanent markers and records should be provided. The repository should not be located in an area containing commercially exploitable resources. Finally, retrievability of the wastes should be possible for a reasonable period of time. EPA contends that a carefully sited and well-designed mined geological repository will meet its release standards and

qualitative goals. Other waste disposal options are not precluded, but they would be expected to meet these same criteria.

Despite criticism of the EPA proposed standards a 1984 review has voiced general approval of the EPA approach, while advocating needed improvements in performance assessment models (U.S. Environmental Protection Agency, 1984). Especially recommended was research to improve estimates for dose-response relationships, geochemical retardation, and rock mass mechanics. This same review group also suggested relaxing EPA's release limits by a factor of ten. In justifying this recommendation, the group stressed that few other industrial activities were held to such stringent public health standards as the 10^{-1} deaths per year embodied in the EPA standard.

J.5. Public Attitudes and Response

The repository siting programme in the United States has encountered substantial public concern and opposition. Despite apparent support in the local candidate repository host regions at Yucca Mountain and Hanford, all three host states--Washington, Nevada, and Texas--have indicated that they are likely to disapprove the repository (thereby necessitating Congressional review) and have initiated litigation against the U.S. Department of Energy. In the summer of 1986, an effort by the three states to pass legislation delaying further work on site characterization narrowly failed in the Congress. A highly critical Congressional committee staff investigation into the DOE's use of multiple attribute utility analysis and its eventual ranking of sites is likely to precipitate further state litigation and perhaps congressional

amendment of the Nuclear Waste Policy Act in 1987. Meanwhile, the intense public uproar in the northern and eastern states which had candidate areas for the second repository led to a DOE decision to defer further work on such a repository. This action appears to have exacerbated public concerns in the three candidate states for the first repository, where equity issues (most U.S. nuclear plants are located in the eastern half of the country) have been forcefully raised.

Underlying these federal-state conflicts is apparent public concern over nuclear wastes and other hazardous wastes more generally. Since the mid-1970s, waste disposal has stood at or near the top of public concerns about nuclear power (National Research Council, 1984). Over the same period, opposition to nuclear power has grown, to the point where majority opposition is now clear (Figure J-1). This opposition is even more apparent when the context of the issue is the respondent's local community. The emergence of hazardous wastes as a major social issue during the late 1970s and 1980s has likely added to public anxiety over nuclear waste disposal facility siting. The Chernobyl accident has almost certainly heightened public worries over accidents involving radiation. The degree of public concern, for example, over the transport of radioactive waste appears much greater than would be suggested by expert risk assessments.

States and local communities in the United States possess considerable authority over facility siting. While the Nuclear Waste Policy Act allocates the final decision over any controversy involving repository siting to the Congress, it is widely recognized that determined state opposition would be difficult to overcome. At minimum, it would appear

that states and localities may be able, through both political and legal recourse, to introduce lengthy delays in the siting programme. The Act assumes that a well-designed and regulated facility, a sizeable compensation arrangement, and eventual federal authority will suffice to overcome local concerns. This will be tested in the years to come.

Several bright spots do exist. The Waste Isolation Pilot Plant, a facility for the disposal of transuranic defense wastes, in New Mexico is moving forward, despite early controversy over the site. Continued local support and an effective independent state review mechanism have contributed to relatively smooth progress at that site. And while the proposed monitored retrievable storage facility (MRS) suggested for Tennessee has elicited both support and opposition, prospects exist for the eventual successful siting of this facility.

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VANDERBILT UNIVERSITY



NASHVILLE, TENNESSEE 37235

TELEPHONE (615) 322-7311

Civil and Environmental Engineering • Direct phone 322-2697

June 1, 1986

Thank you very much for offering to help with the followup to our Review on Comparative Practices of High Level Wastes in Selected Countries that the Beijer Institute of the Swedish Royal Academy of Sciences did in 1984 for the National Swedish Board for Spent Nuclear Fuel (Namnden for Anvant Karnbransle). This new study will focus on:

- (1) high level waste site selection rules and regulations, technical requirements, political realities, etc.,
- (2) subseabed disposal research, both scientific and legal, official support or lack thereof of such disposal,
- (3) interim storage laws mandating it, de facto or de jure, at reactor, away from reactor, at repository, in transportable casks, rationale for interim storage, public support for or opposition to interim storage, and
- (4) determination of "safe disposal." What constitutes safe disposal? Who determines safe disposal? Who are the principal participants in the discussion? What are their positions? Etc.

The Beijer Institute team for this study will consist of Roger Kasper-son, Professor, at the Center for Technology, Environment and Development at Clark University in Worcester, Massachusetts 01610, USA (617-793-7283; Telex: 951829 and Cable: CENTED); Senior Research Fellow of the Beijer Institute, author of Equity Issues in Radioactive Waste Management; Dr. Tor Leif Anders-son, Head, Tellus Energi AB, Vitriskestigen No. 5, S-61163, Nykoping, Sweden (155-15440); and myself, Professor of Environmental and Water Resources Engineering at Vanderbilt University, Nashville, Tennessee 37235, USA (615-322-2697; Telex 554323; FAX - 615-322-2697), Senior Research Fellow of the Beijer Institute and Chairman of the Board of Radioactive Waste Management of the USA National Academy of Sciences, and Stephan Parker, our Research Assistant.

The questions of interest are attached. I will be in touch when I return to the office in July. Again, many thanks.

Sincerely yours,

Frank L. Parker

FLP:bi

Enclosure

List of Questions

High Level Waste Repository Site Selection Processes

1. How is this carried out in _____?
2. Who does this?
3. What are the requirements?
4. What are the deadlines?
5. Who approves (licenses) the site?
6. What is the capacity of the site?
7. Is there literature available on these topics? Could you please send it to us c/o the Beijer Institute?

Interim Storage Prior to Final Disposal

1. Is this practiced?
2. Where are the spent fuel and/or the reprocessed wastes stored?
3. How are they stored?
4. Whose responsibility are they during storage?
5. What are the requirements during storage?
 - a. temperature
 - b. radiation dose
6. What limitations are there during storage?
7. Can we visit an interim storage facility?
8. Is there literature on interim storage? Can you send it to us c/o the Beijer Institute?

Subseabed Disposal (SSBD)

1. Does your country participate in SSBD research?
2. Is your country against SSBD?
3. What research on SSBD is underway?
4. What is the rationale, legal, philosophical, administrative, for your position on SSBD?
5. What is your country's position on the London Convention?
6. If the United States withdraws from the NEA working group, will you continue to participate?
7. Is there literature on the topic? Can you send it to us c/o the Beijer Institute?

Safe Disposal

1. What constitutes safe disposal in your country?
2. By whom and how was this determined?
3. How is this to be determined? In the Draconian sense or liberally?
4. Is this a legal requirement?
5. Is there literature on the topic? Can you send copies to us c/o the Beijer Institute?

List of Questions

High Level Waste Repository Site Selection Processes

1. How is this carried out in _____?
2. Who does this?
3. What are the requirements?
4. What are the deadlines?
5. Who approves (licenses) the site?
6. What is the capacity of the site?
7. Is there controversy over the siting criteria? If so, who is involved?
8. Is local acceptance necessary for siting? How will it be gained?
9. Is there an arrangement for local compensation?
10. Is there literature available on this topics? Could you please send it to us c/o the Beijer Institute?

Interim Storage Prior to Final Disposal

1. Is this practiced?
2. Where are the spent fuel and/or the reprocessed wastes stored?
3. How are they stored?
4. Whose responsibility are they during storage?
5. What are the requirements during storage?
 - a. temperature
 - b. radiation dose
6. What limitations are there during storage?
7. Is interim storage an issue for critics or the public?
8. How important is retrievability in public response?
9. Will the siting of interim storage facilities be controversial?
10. Can we visit an interim storage facility?
11. Is there literature on interim storage? Can you send it to us c/o the Beijer Institute?

Subseabed Disposal (SSBD)

1. Does your country participate in SSBD research?
2. Is your country against SSBD?
3. What research on SSBD is underway?
4. What is the rationale, legal, philosophical, administrative, for your position on SSBD?
5. What is your country's position on the London Convention?
6. If the United States withdraws from the NEA working group, will you continue to participate?
7. Is subseabed disposal a matter of public controversy? If so, who is involved?
8. Is there literature on the topic? Can you send it to us c/o the Beijer Institute?

Safe Disposal

1. **What constitutes safe disposal in your country?**
2. **By whom and how was this determined?**
3. **How is this to be determined? In the Draconian sense or liberally?**
4. **Is this a legal requirement?**
5. **Is there debate over the appropriate requirement or test to be used? Have alternatives been proposed?**
6. **How important is the future generations issue in public discussion?**

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APPENDIX L

PERSONS AND ORGANIZATIONS VISITED
AND/OR FROM WHOM COMMENTS WERE RECEIVED

Commission of the European Communities

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