NEW PROGRESS IN CONSULTING AND SHARING THE SWEDISH EXPERIENCE

Lars B. Nilsson
Swedish Nuclear Fuel and Waste Management Co.,
Stockholm, Sweden

ABSTRACT

The primary responsibility for the management of nuclear wastes in Sweden lies with the nuclear power utilities. They have delegated the R&D work as well as the construction and operation of facilities to the jointly owned Swedish Nuclear Fuel and Waste Management Co., SKB. During the last few years considerable progress has been made. After review by several international and domestic expert groups, the Swedish government has approved the KBS concepts for final disposal of HLW and spent fuel as acceptable with regard to safety and radiation protection. A transport system for spent fuel and nuclear wastes is in operation. An interim storage facility for spent fuel and a final repository for low- and medium level wastes from reactor operation will be completed in the near future.

The scientific and technological know-how and experience of SKB and associated groups are now available internationally on a consultative basis. Examples of areas of special competence are given.

GENERAL BACKGROUND

The nuclear program initiated in Sweden in the 1960's was a fairly ambitious one. The plans of that time have now been partly realized. Ten nuclear reactors are in operation and two are at a late stage of commissioning. Together these twelve reactors will cover 45-50% of the current electricity demand in Sweden. On a per-capita basis, Sweden will then have the highest production of nuclear power in the world. In spite of this fact, a political decision has been taken that nuclear power shall be completely phased out of the Swedish power system in the year 2010. This decision emanates from an intense public debate in the late 1970's ending up in a referendum on the nuclear power program in 1980. Opponents to nuclear power focused on two main issues - the unacceptable hazards associated with reactor operation and the impossibility to take care of the radioactive wastes in a safe way. Regarding waste management, the debate resulted in a new legislation of 1977 which stipulated that the owner of a new reactor had to demonstrate to the satisfaction of the Government how and where safe handling and final disposal of spent nuclear fuel could be implemented. If he failed in this mission, he would not be allowed to operate the reactor. To meet this challenge, the utilities jointly organized a task force, the KBS Project.

The efforts of the utilities have resulted in three main reports, KBS-1 published in 1977, dealing with vitrified HLW from reprocessing and KBS-2 and KBS-3, both dealing with handling and final disposal of unreprocessed spent fuel. KBS-3, issued in 1983, is an updated version of KBS-2 published in 1979.

At the request of the Swedish Government, the work presented by KBS has been reviewed and assessed by several competent groups. The latest report - KBS-3 - was scrutinized by about 20 Swedish and 8 foreign expert groups. The outcome was positive. The Government has, therefore, concluded that the knowledge and technology available today make it possible to accomplish a final disposal of spent nuclear fuel that is acceptable with regard to safety and radiation protection.

When the KBS Project was completed, the Swedish nuclear power utilities delegated to their jointly owned company, the Swedish Nuclear Fuel and Waste Management Co., SKB, all activities necessary for the accomplishment of a safe nuclear waste management system. This means that SKB carries the responsibility not only for the R&D work but also for the design, construction and operation of the waste facilities. This concentration of duties has given the staff of SKB a good overview of the entire field, which is important when priorities have to be made. It also gives an opportunity to benefit from experience and feedback in an effective way. SKB's total waste management program is illustrated in Fig. 1.

Depending on tradition and administrative structure, different types of organization for nuclear waste management have been established in different countries. In Sweden, where the primary responsibility lies with the nuclear power utilities, the following organization has been chosen and deemed to be the most effective one.

In the R&D field, a small management group within SKB is responsible for initiating, planning, coordinating and reporting of the activities. For the scientific and technological work, a great number of expert groups and individuals are contracted. The management group puts special emphasis on creating an interdisciplinary understanding and coordination, which is of utmost importance for the final results and the cost-effectiveness of the work.

For the design, construction and operation of facilities, other project management groups are established for the detailed design and construction. To a great extent the competence and capability of the owners of SKB, the nuclear power utilities, are utilized for these tasks.

The organization of work in the Swedish nuclear waste management program is illustrated in Fig. 2.

The main achievements in the Swedish program are listed in Table I. A transportation system for spent fuel and nuclear wastes started to operate in 1982. The construction of central facilities for interim storage of spent fuel (CLAB) and final disposal of low- and medium-level wastes from reactor operation (SFR) are well underway. They will be operative in the near future.

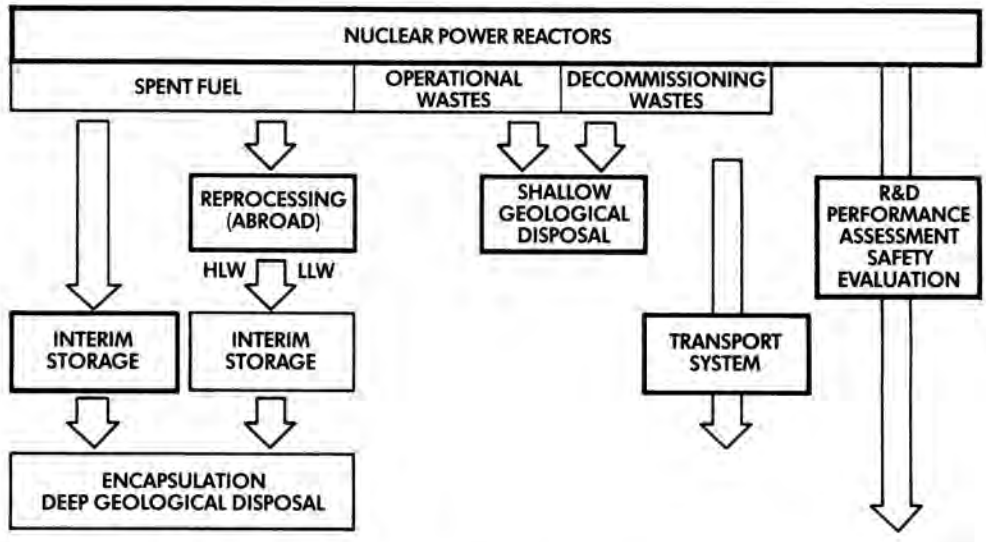

Fig. 1. The Swedish nuclear waste management system.

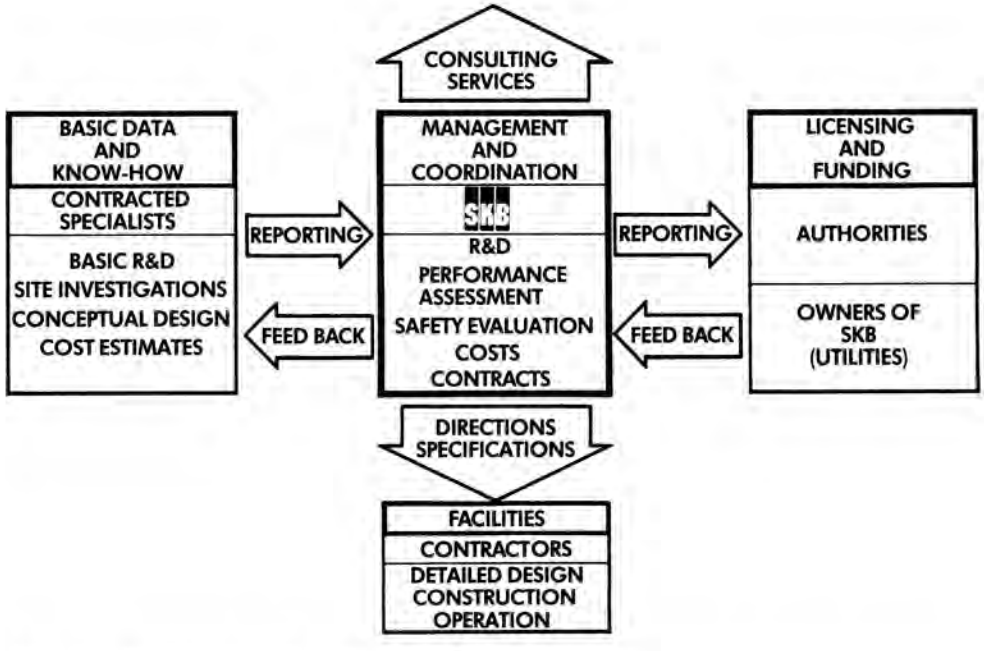

Fig. 2. Distribution of tasks in the Swedish nuclear waste management program.

TABLE I
Some milestones in the Swedish nuclear waste management program.

Historical	
1976	KBS Project organized
1977	KBS-1 report (vitrified HLW) issued
1979	KBS-2 report (spent fuel) issued
1980	KBS-1 approved by Government
1980	Construction of CLAB (AFR) starts
1982	Transport system in operation
1983	Construction of SFR starts (final repository for MLW and LLW)
1983	KBS-3 report (spent fuel) issued
1984	KBS-3 approved by Government
Future	
1985	Scheduled start of operation of CLAB
1988	Scheduled start of operation of SFR
2010	Scheduled start of construction of final repository for spent fuel

CONSULTING SERVICES

General

The work performed within the Swedish nuclear waste management program has been paid international interest and requests have been received from foreign organizations which want to make use of the Swedish know-how. SKB and associated groups have, therefore, decided to market their joint competence internationally on a consultative basis. The coordination and the contractual responsibility to the clients lies with SKB. The groups, currently participating in this cooperative undertaking, and their main areas of competence are listed in Table II.

Consulting services from SKB and associated groups can consist either of direct involvement in the clients work or of reviews of the clients program or parts thereof.

Some countries with nuclear power have not yet formulated their waste management programs or are just beginning of the process. Other countries are planning to embark on a nuclear power program and then they also have to consider waste management matters. As SKB has gone through all phases of the backend, its staff has the qualifications to give professional assistance in feasibility studies and to contribute in the planning, organization and implementation of waste management programs.

In countries with established national waste management programs, there may also be special areas where the assistance of SKB and associated groups fits in.

The assistance of SKB can be organized in different ways depending on the type and size of assignment. One way to cooperate with the client, which often may be practical and effective is illustrated in Fig. 3. For each task, SKB will select a team of individuals with the necessary competence and give one of them the leadership and responsibility for the performance of work within the contracted scope of work. Integrating the staff of SKB with the staff of the client in project teams should in most cases promote smooth and effective cooperation.

Fields where SKB and associated groups have special competence and experience are described below.

Site Characterization

Comprehensive site investigations for final disposal of spent fuel or HLW in crystalline rock have been performed by SKB in Sweden. Seven potential sites have been studied and more than 50,000 m of cored boreholes have been drilled and measured. During these investigations, a unique base of hydrological, geophysical and geochemical data has been built up.

The site investigations follow a standardized program that is successively updated as new or improved methods and instrumentation become available.

In the initial phase, a number of areas are studied by aid of literature, maps and satellite images. In a screening process, a few are then chosen for characterization.

In the second phase, geological mapping and geophysical surface measurements are performed within an area of about 5 km^2 in order to get an overview of the geological conditions and especially the existence of faults and fracture zones.

If phase two has given favorable indications, drillings are started in a third phase. Hammer and cored boreholes are drilled to a depth down to 250 m in order to verify surface indications of fracture zones and to give details about their geometry. To get information about the conditions at greater depth, a series of deep cored boreholes are drilled, normally 10-15 and to a maximum depth of 1000 m. Most of these holes are inclined.

A series of geophysical and geochemical observations are made in the boreholes and groundwater is sampled and analyzed. The hydraulic conductivity is measured in packed off sections and the groundwater level as well as the piezometric pressure at various depths is recorded.

The fourth and last phase of the program is the evaluation of the results. A descriptive model of the site is compiled from surface and borehole investigations. This model constitutes the base for numerical calculation of the groundwater flow. Finally, an assessment is made of how and at what rate different radionuclides may migrate from penetrated canisters.

For measuring of the hydraulic conductivity in boreholes, a special mobile multihose equipment has been developed. The principles are shown in Fig. 4. The operation and recordings are computerized and preliminary plots of results are available on-site immediately after measuring. One 1000 m borehole is measured in 20 m sections in one to two weeks. The measuring limit corresponds to a hydraulic conductivity of about 10^{-11} m/s.

Another equipment of interest is a specially designed mobile chemical field laboratory where most of the groundwater analyses are made onsite immediately after sampling. Thus, contamination during handling and transport can be avoided. The field laboratory is combined with a down-hole device, which measures Eh,

TABLE II

SKB and associated groups.

Organization	Area of competence
Chalmers University of Technology	- Radionuclide and groundwater chemistry - Sorption and solubility of radionuclides
FBAB	- Geoscience in general
IPA-Konsult	- Down-hole instrumentation
IVL - The Swedish Environmental Research Institute	- Control and compilation of groundwater sampling and analyses
Kemakta Consultants Co	- Groundwater transport and chemical calculations
Luleå University of Technology	- Rock mechanics
Royal Institute of Technology	- Near-field chemistry - Migration of radionuclides - Actinide chemistry and solubility - Geochemical instrumentation and calculations - Codes for groundwater flow
Studsvik Energiteknik AB	- Biosphere studies - Dose calculations - Waste characterization - Hot cell experiments
Swedish Corrosion Institute	- Corrosion of canister materials
Swedish Geological Co	- Geological, hydrological and geophysical instrumentation and investigations - Site characterization - Buffer and backfill studies
SKB - Swedish Nuclear Fuel and Waste Management Co	- Management and coordination of nuclear waste services - General programs and program reviews - Safety assessments

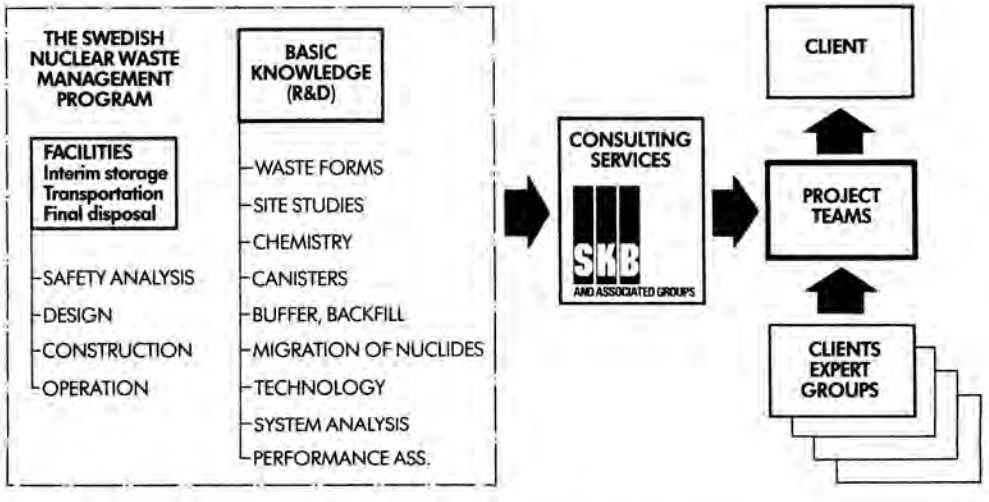

Fig. 3. Organization of "Nuclear Waste Services" from SKB.

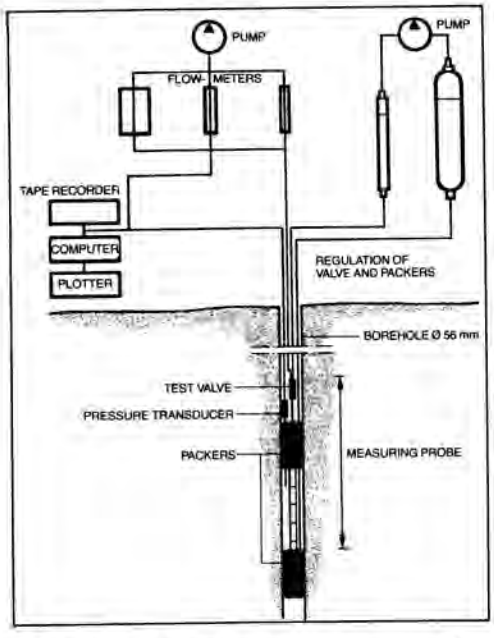

Fig. 4. Equipment for downhole measuring of hydraulic conductivity.

pH and sulfur and oxygen content of the groundwater in-situ. For checking and comparison, the same parameters are also measured in pumped-up water at the surface. The equipment is schematically shown in Fig. 5.

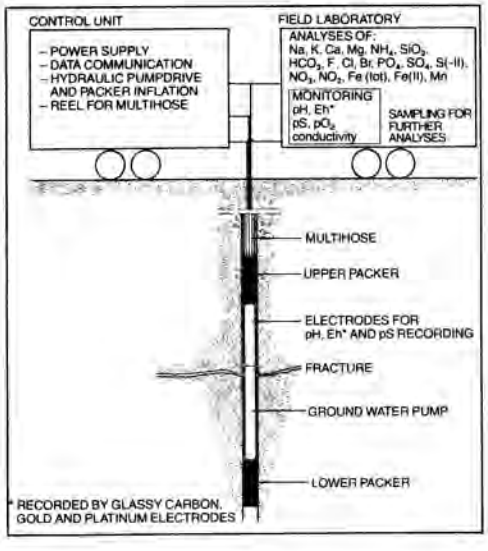

Fig. 5. Equipment for downhole measuring of pH, Eh and pS.

Special equipments for automatic recording of the groundwater level and of the piezometric pressure in various sections of boreholes have also been developed.

Most of the down-hole instruments used in the Swedish site investigation program are designed for a borehole diameter of 56 mm. The use of slim borehole techniques gives considerable budget savings.

Groundwater Flow

Strong efforts have been devoted to the understanding, modelling and calculation of groundwater flow in fissured rock. The result of the work is that advanced computer codes and a broad hydrogeological data base are now available.

Chemistry

The chemistry of and the interaction between species, which can influence the long-time performance of a repository, has been and still is an important domain for research in the Swedish program. Studies performed cover relevant radionuclides, groundwater, minerals and materials in engineered barriers as well as influence of radiolysis. A special part of the program deals with corrosion and leaching of spent fuel and various waste forms.

The work has generated a better understanding of important chemical processes and a considerable amount of basic data regarding solubility, sorption, complexing, etc., in various environments and conditions.

Migration of Radionuclides

Models and codes have been developed for the assessments of how and at what rate radionuclides will migrate from penetrated canisters in the near-field and in the geosphere. In the models, consideration is paid to physical and chemical effects such as groundwater flow rate, redox conditions, solubilities, sorption, diffusion into the rock matrix, dispersion and radioactive decay. The work is based on available knowledge and data from the hydrogeology and chemistry programs, laboratory experiments, in-situ tests and studies of natural analogues.

Engineered Barriers

Comprehensive investigations have been performed on copper as canister material. Also titanium and ceramic materials have been studied.

Studies of bentonite clay as buffer, backfill and sealing material have been important elements in the Swedish R&D program. A good knowledge of the properties and function of bentonite clay in different applications has thereby been achieved.

Performance Assessment

A system for performance assessment has been developed where possible effects and processes in the whole sequence from the release of radionuclides from the waste to dose to man are taken into account.

Facilities

Considerable theoretical and technological experience has been gained during the implementation of the transport system, the interim storage facility for spent fuel (CLAB) and the final repository for reactor wastes (SFR). Consulting services in the technological and engineering field are marketed by the cooperating company SwedPower, which is another subsidiary of the Swedish power utilities.

INTERNATIONAL COOPERATION

SKB is heavily involved in the international cooperation in the field of nuclear waste management.

Representatives of SKB frequently participate in commitees organized by IAEA and OECD/NEA. Agreements for information exchange and possible joint projects have been signed with US DOE, AECL in Canada, NAGRA in Switzerland and CEA in France. SKB has been entrusted the management of the Stripa Project where 9 OECD nations participate. The JSS-Project, where Japan, Switzerland and Sweden share the costs for hot glass studies, is also managed by SKB.

SKB regards the international cooperation and an open information exchange as an essential part of its program. It should be clearly stated that SKB's consulting activities will not be allowed to interfere with the good relations to cooperating parties. SKB's consulting services should rather be seen as a supplement to existing international cooperation.