DISPOSAL OF CANADA'S NUCLEAR FUEL WASTE

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1 Introduction

Three provincial utilities, Ontario Hydro, Hydro-Québec, and New Brunswick Power, own and operate CANDU power reactors and own the used fuel removed from them. A limited amount of used fuel, from three prototype power reactors that have been permanently shut down, is owned by AECL.

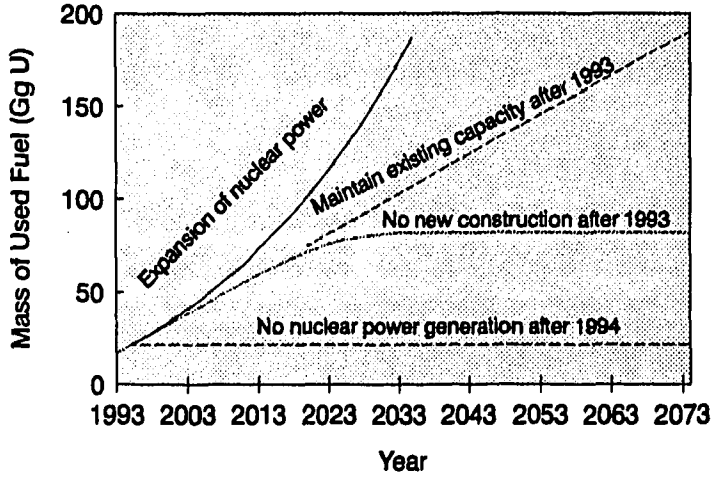

Figure 1: Projected Quantities of Used Fuel in Canada

Figure 1 shows projections for the amount of used fuel that would arise in Canada under four scenarios: expansion of nuclear power at a rate of about 3% per year, maintaining existing nuclear generating capacity, running existing reactors for their projected lifetimes with no replacement, and no nuclear power generation after 1994.

The used fuel is currently stored in water-filled pools or dry-storage concrete containers by its owners. Current storage practices have an excellent safety record. They permit easy monitoring and retrieval and could be continued for many years. They do, however, require institutional controls such as security measures, monitoring, and maintenance.

Used fuel is not necessarily waste, because it could be reprocessed to extract useful material for recycling. However, in Canada used CANDU fuel is not currently reprocessed, and there are no plans to reprocess and recycle it [1]. If it is reprocessed in the future, most of the fission products and actinides that are not recycled could be incorporated in a solid such as a borosilicate glass. When we refer to "nuclear fuel waste," we mean either the used fuel itself, if it is not to be reprocessed, or the high-activity solid formed from reprocessing waste.

According to Canada's nuclear regulatory agency, the Atomic Energy Control Board [2],

> *For the long-term management of radioactive wastes, the preferred approach is disposal, a permanent method of management in which there is no intention of*

retrieval and which, ideally, uses techniques and designs that do not rely for their success on long-term institutional control beyond a reasonable period of time. ... Where reasonable disposal alternatives clearly exist, those options which rely on monitoring, surveillance or other institutional controls as a primary safety feature for very long periods are not recommended. This is not because of concern that future generations will be technologically incompetent, but rather because methods of ensuring the continuity of controls are not considered very reliable beyond a few hundred years.

Reviews initiated by governments in Canada have concluded that disposal is necessary. For example, the study group chaired by F.K. Hare [3] recommended that waste should not be allowed to accumulate indefinitely in interim storage. Ontario's Royal Commission on Electric Power Planning [4] concluded that "There is clearly an urgent need to develop ultimate disposal facilities to ensure that these wastes are isolated from the world's ecosystems." The House of Commons Standing Committee on Environment and Forestry [5] also recognized the need for disposal, stating that, whatever the future of nuclear energy, "the waste which it produces must be disposed of."

Thus storage, while an effective interim measure, is not a permanent solution. Canada needs a method of managing nuclear fuel waste that does not depend on institutional controls to maintain safety in the long term. Society may choose to implement long-term institutional controls at a disposal facility, but the facility should be designed such that, if such controls should fail, human health and the natural environment would still be protected.

In 1978, the governments of Canada and Ontario established the Nuclear Fuel Waste Management Program "to assure the safe and permanent disposal" of nuclear fuel waste [6]. Responsibility for research and development on "disposal in a deep underground repository in intrusive igneous rock" was allocated to AECL. Responsibility for studies on interim storage and transportation of used fuel was allocated to Ontario Hydro. In 1981, the governments of Canada and Ontario further announced that "No disposal site selection will be undertaken until after the concept has been accepted" [7].

In 1974, through consultation between the Department of Energy, Mines and Resources and AECL, it was decided to direct most of the research on disposal of nuclear fuel waste toward disposal in plutonic rock, prevalent within the extensive area of the Canadian Shield in Ontario [8] (Figure 2). The decision was based on studies carried out by three branches of Energy, Mines and Resources: the Geological Survey of Canada, the Earth Physics Branch, and the Canada Centre for Mineral and Energy Technology. Subsequently, the Hare study group [3] confirmed that resources ought not to be spread too thinly, and that the primary effort should be given to the crystalline rocks of plutonic origin; but they added that careful attention should be paid to the work of scientists in other countries on different rock types.

The preference for plutonic rock was also supported by the Royal Commission on Electric Power Planning [9].

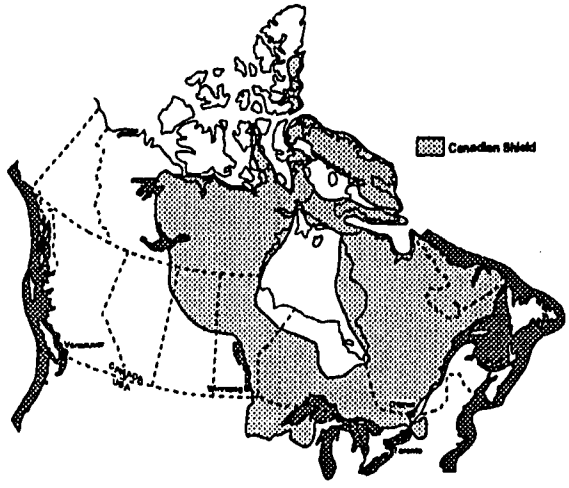

Figure 2: The Canadian Shield

The disposal concept, then, is a proposed method for geological disposal of nuclear fuel waste in which the waste form—used fuel or solidified reprocessing waste—would be placed in long-lasting containers and emplaced in a disposal vault nominally 500–1000 m below the surface in plutonic rock. The containers would be surrounded by sealing material (buffer), and eventually all excavated openings in the rock would be backfilled and sealed in such a way that the system would be passively safe.

As shown in Figure 3, the disposal vault would be a network of horizontal tunnels and disposal rooms, with vertical shafts extending from the surface to the tunnels. Rooms and tunnels might be excavated on more than one level. The vault would be designed to accommodate the rock structure, groundwater flow system, and other subsurface conditions at the disposal site. The disposal container and vault seals would also be designed to accommodate the subsurface conditions at the chosen site. Although the figure illustrates emplacement of the containers in boreholes in the room floor, other emplacement designs, such as emplacement in a clay mass in the room itself, may be preferable under particular geological conditions.

After the disposal facility was closed, multiple barriers—the container, the waste form, the buffer, backfill and other vault seals, and the geosphere—would protect humans and the natural environment from both radioactive and chemically toxic contaminants in the waste.

In the following sections, we discuss the R&D that has been conducted to develop and assess the disposal concept, the evaluation of acceptability of the concept currently under way, and the future steps that are envisaged should the concept be found acceptable.

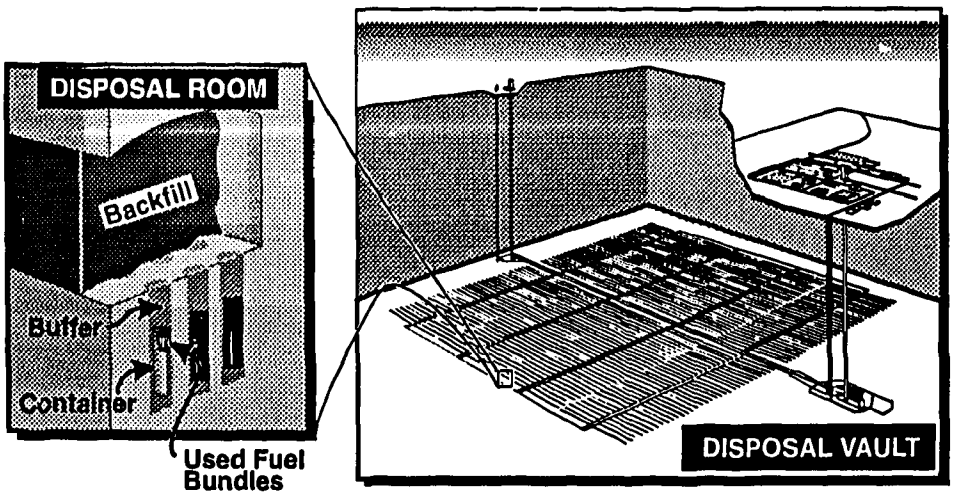

Figure 3: Illustrative Disposal Facility

2 Research and Development for Disposal

Most of AECL's research and development on disposal is currently funded by AECL and Ontario Hydro through the CANDU Owner's Group. In addition, through a Technical Assistance Program, Ontario Hydro provides expertise and advice to AECL on topics such as disposal containers and vault seals, and has assessed the potential environmental effects of nuclear fuel waste disposal during the preclosure phase. Ontario Hydro is also responsible for studies on interim storage and transportation of used fuel.

From 1978 to 1992, AECL's research and development on disposal cost about $413 million, of which $305 million was from funds provided to AECL by the federal government and $77 million was from Ontario Hydro. The remaining funding was obtained primarily through cooperative programs with other countries. These cooperative programs have also enhanced the cost-effectiveness of Canadian research and development by providing valuable information from work carried out internationally. Table 1 outlines the scope of the research and development.

In developing and assessing the disposal concept, AECL has consulted broadly with members of Canadian society to help ensure that the concept and the way in which it would be implemented are technically sound and represent a generally acceptable disposal strategy. Many groups in Canada have had opportunities to comment on the disposal concept and on the Nuclear Fuel Waste Management Program. These include government departments and agencies, scientists, engineers, sociologists, ethicists, and other members of the public. The Technical Advisory Committee to AECL on the Nuclear Fuel Waste Management Program, whose members are nominated by Canadian scientific and engineering societies, has been a major source of technical advice [10].

Long-term management of nuclear fuel waste has received much attention internationally.

Table 1: Research and Development on the Disposal Concept

Aspect	Objectives	Activities
Disposal Container	Understand the behaviour of potential disposal containers in order to design and test long-lasting containers and to develop models for estimating their performance under disposal vault conditions.	• studies of corrosion of titanium, copper, nickel alloys, and a variety of steels • manufacture and structural testing of prototypes of several container designs
Waste Form	Understand the behaviour of nuclear fuel waste in order to develop models for estimating the rate of release of contaminants from a waste form in a disposal vault.	• studies of processes for making glass and glass-ceramic reprocessing waste forms • studies of dissolution and leaching of used fuel and solidified reprocessing waste • studies of uranium ore bodies, such as that at Cigar Lake in northern Saskatchewan, as analogs of the used fuel as a waste form
Vault Seals	Understand the behaviour of potential vault seals in order to develop methods for sealing a disposal vault and to develop models for estimating the rate of transport of contaminants through the seals.	• studies of both clay-based and cement-based sealing materials for use as – buffer around the container – backfill in excavated openings – grout in fractures in the rock – bulkheads or plugs in rooms, tunnels, shafts, and boreholes
Geosphere	Understand the behaviour of plutonic rock and associated groundwater flow systems in order to assess the performance of plutonic rock as a host medium.	• studies of processes that could affect contaminant transport • development and demonstration of methods for obtaining the geoscience data needed for screening and evaluating potential disposal sites
Surface Environment	Understand the surface environment of the Canadian Shield in order to develop models for estimating the transport of contaminants through the biosphere and the potential exposure of humans and non-human biota.	• development and demonstration of the methods for characterizing and monitoring the surface environment • studies of movement of contaminants in the near-surface and surface environment
Total System	Develop and evaluate engineering conceptual designs for a disposal facility and transportation systems in order to assess feasibility, cost, and safety.	• large-scale, in situ tests and demonstrations of excavation methods, engineering activities, and selected elements of disposal vault designs in the Underground Research Laboratory • designing a cask for transportation of used fuel, obtaining a design approval certificate from the AECB, and manufacturing a full-scale demonstration cask
Assessment of Environmental Effects	Develop and demonstrate the methodology for evaluating the effects of nuclear fuel waste disposal on human health and the natural environment.	• identifying factors important to safety • developing, testing, and evaluating assessment models • estimating the environmental effects of disposal systems (including transportation systems) • analyzing the sensitivity of the estimates to changes in the disposal system

The Nuclear Fuel Waste Management Program, developed in parallel with programs in other countries, includes monitoring of the research being done internationally on disposal in plutonic rock, on disposal in geological media other than plutonic rock, and on alternative waste forms, container materials, and other engineered components of a disposal facility. Canada exchanges information on nuclear fuel waste management with the United States, Sweden, Finland, Japan, Republic of Korea, and the Commission of European Communities. We also have representatives on international working committees of the IAEA and the OECD/NEA. Canada participated in international research on seabed disposal and in the International Stripa Project, a program of underground experiments and developmental research on disposal conducted in an abandoned mine in Sweden [11,12].

We believe that the research in Canada, supported by research conducted in other countries, provides convincing evidence that Canada's nuclear fuel waste can be safely disposed of in the plutonic rock of the Canadian Shield using current technology or reasonably achievable developments.

3 Evaluating the Acceptability of the Concept

The acceptability of the disposal concept is now being reviewed under the federal Environmental Assessment and Review Process. In 1988, the Minister of Energy, Mines and Resources referred the issue of nuclear fuel waste management to the Minister of the Environment, requesting that a review be conducted of the disposal concept and of a broad range of nuclear fuel waste management issues [13]. Although many organizations have contributed to the Nuclear Fuel Waste Management Program, AECL is the sole proponent of the disposal concept in this review.

In 1989, a federal Environmental Assessment Panel was appointed to conduct the review [14], and in 1990, the Panel established a Scientific Review Group to provide a scientific evaluation of the disposal concept. The Panel conducted a number of activities to help it develop guidelines for an Environmental Impact Statement (EIS). In 1990, the Panel held open houses in Ontario, Quebec, and New Brunswick, the provinces that have nuclear generating stations; in Manitoba, where AECL conducts much of its research on nuclear fuel waste disposal; and in Saskatchewan, where there are uranium mines. The objective was to inform potential review participants about the review process and the disposal concept. Later the same year, the Panel held scoping meetings at 14 locations in the same five provinces, hearing presentations from the public and from government departments and agencies. The Panel also obtained input from written presentations, a conference for university students, and a workshop for aboriginal groups. The Panel issued draft guidelines in 1991, received extensive comments on them, and issued the final guidelines in 1992 [15].

AECL is preparing the EIS to provide information requested by the panel and to present AECL's case for the acceptability of the disposal concept. A Summary of the EIS will be issued as a separate report. Nine major reference documents, which provide detailed support

for the EIS, are also being released as separate reports. In addition, hundreds of papers in the scientific literature provide information relevant to assessing the acceptability of the concept.

After the Panel has received and reviewed the information requested in the guidelines, it will hold public hearings and consider the findings of the Scientific Review Group. According to the Panel's terms of reference [14],

> *As a result of this review the Panel will make recommendations to assist the governments of Canada and Ontario in reaching decisions on the acceptability of the disposal concept and on the steps that must be taken to ensure the safe long-term management of nuclear fuel wastes in Canada.*

4 Future Steps

We assume that those who have responsibility for the safe management of used fuel, the federal government and the owners of the used fuel, also have responsibility for implementing the disposal concept if it is found to be acceptable.

Disposal of nuclear fuel waste would proceed in sequential stages—siting, construction, operation, decommissioning, and closure—and would entail a series of decisions about whether and how to proceed [16]. The involvement of potentially affected communities would be sought and encouraged throughout all stages. Any potential host community would share in the decision making regarding whether and how to proceed with siting and subsequent stages of implementation.

All activities undertaken in connection with the implementation of the disposal concept, including the transportation of nuclear fuel waste to a disposal facility, would have to comply with applicable legislative requirements. In addition, directives, policies, or procedures of the governments or government agencies might have to be considered. Approvals, including licenses, would be required from several regulatory agencies. One of these would be the AECB, which takes a sequential approach to licensing nuclear facilities.

Potential environmental effects would be identified, and measures would be taken to avoid adverse effects, to mitigate unavoidable adverse effects, and to compensate for adverse effects that were not avoided or sufficiently mitigated. The implementing organization would be responsible for protecting public health and the natural environment and for ensuring that every reasonable precaution was taken to protect employees from occupational disease or injury.

It is estimated that, considering the need to fully involve the public in the decision making, and considering the time required to obtain information on geological conditions at potential sites, it would take about 20 years or more to complete the siting stage, and several more years to begin emplacing waste at a disposal facility.

Thus acceptance of the disposal concept at this time should be viewed as the first of many steps necessary to implement safe disposal. In particular, acceptance at this time would not imply approval of any particular site or facility design. It is important to a successful review, that representatives of the nuclear industry participate in the hearings and make their views known to the panel. We believe that a successful review will lead to concept acceptance, a vital first step in establishing Canada's ability to safely dispose of its nuclear fuel waste.

References

[1] P. Brown and R. Morrsion, "Radioactive waste management policy in Canada," in *Waste Management '92*, (Tucson, Arizona), pp. 145–151, 1992.

[2] AECB, "Regulatory objectives, requirements and guidelines for the disposal of radioactive wastes—long-term aspects," Regulatory Policy Statement R–104, Atomic Energy Control Board, Ottawa, June 1987.

[3] A. Aikin, J. Harrison, and F. Hare, "The management of Canada's nuclear wastes: report of a study prepared under contract for the Minister of Energy, Mines and Resources," Tech. Rep. EP 77-6, Department of Supply and Services, Ottawa, 1977.

[4] Royal Commission on Electric Power Planning—Arthur Porter, Chairman, "The report of the Royal Commission on Electric Power Planning," 1980.

[5] Standing Committee on Environment and Forestry— B. Brisco, Chairman, *High-level radioactive waste in Canada: The eleventh hour, Report of the Standing Committee on Environment and Forestry, Second Session of the Thirty-Third Parliament, 1986–87.* Ottawa K1A 0S9: Supply and Services Canada, 1988.

[6] "Canada/Ontario radioactive waste management program. joint statement by the Minister of Energy, Mines and Resources Canada and the Ontario Energy Minister," June 5 1978.

[7] "Canada/Ontario joint statement on the Nuclear Fuel Waste Management Program. joint statement by the minister of Energy, Mines and Resources Canada and the Ontario Energy Minister," August 4 1981.

[8] J. Scott, "EMR program for geological disposal of high-level radioactive wastes," Published for the Canadian Geoscience Council by the Geological Survey of Canada as Paper 79–10, 1979.

[9] Royal Commission on Electric Power Planning—Arthur Porter, Chairman, "A race against time, interim report from the Royal Commission on Electric Power Planning," 1978.

[10] Technical Advisory Committee on the Nuclear Fuel Waste Management Program—L.W. Shemilt, Chairman, "Thirteenth annual report," TAC-13, 1993.

[11] Swedish Nuclear Fuel and Waste Management Co. (SKB), "Executive summary of Phase 1," Tech. Rep. TR-86-04, Stripa Project, 1986.

[12] Swedish Nuclear Fuel and Waste Management Co. (SKB), "Executive summary of Phase 2," Tech. Rep. TR-89-01, Stripa Project, 1989.

[13] Minister of Energy, Mines and Resources, Canada, "Letter to the Minister of the Environment, Canada," September 23 1988.

[14] Minister of the Environment, Canada, "Terms of reference for the nuclear fuel waste management and disposal concept environmental assessment panel," 1989.

[15] Federal Environmental Assessment Review Panel, *Final guidelines for the preparation of an environmental impact statement on the nuclear fuel waste management and disposal concept.* 13th floor, Fontaine Building, 200 Sacre-Coeur Blvd., Hull, Quebec, K1A 0H3: Federal Environmental Assessment Review Office, 1992.

[16] C. Allan, "Building confidence in deep geological disposal of nuclear fuel waste: Canada's approach," Presented to the International Nuclear Congress INC93, October 1993.