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The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System

Le stockage permanent des déchets de combustible nucléaire du Canada : Évaluation de pré-fermeture d'un système conceptuel

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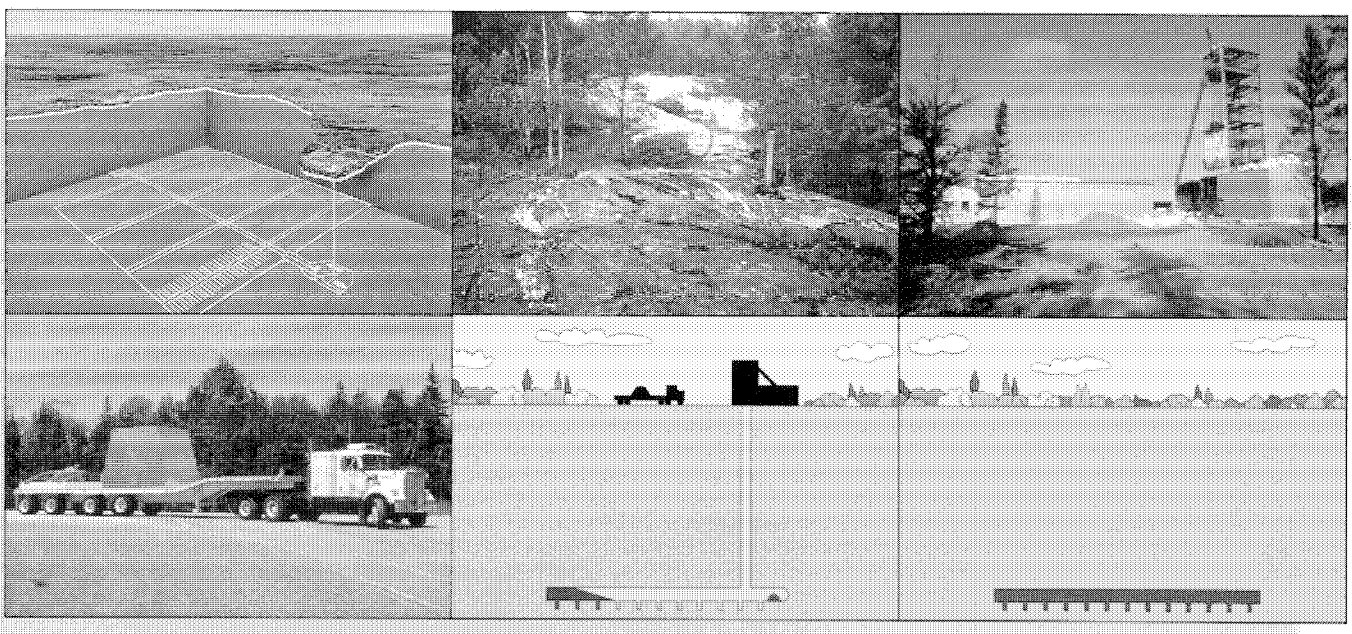

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ONTARIO HYDRO NUCLEAR

THE DISPOSAL OF CANADA'S NUCLEAR FUEL WASTE: PRECLOSURE ASSESSMENT OF A CONCEPTUAL SYSTEM

by

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Report prepared by Ontario Hydro Nuclear
for AECL Research

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Nuclear Waste and Environment Services Division
Toronto, Ontario M5G 1X6
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LE STOCKAGE PERMANENT DES DÉCHETS DE COMBUSTIBLE NUCLÉAIRE DU CANADA : ÉVALUATION AVANT FERMETURE D'UN SYSTEME CONCEPTUEL

par

L. Grondin, K. Johansen, W.C. Cheng, M. Fearn-Duffy, C.R. Frost, T.F. Kempe, J. Lockhart-Grace, M. Paez-Victor, H.E. Reid, S.B. Russell, C.H. Ulster, J.E. Villagran et M. Zeya

RÉSUMÉ

Le concept canadien de stockage permanent des déchets de combustible nucléaire consiste à stocker le combustible nucléaire dans des conteneurs de longue durée de vie placés dans une installation souterraine ouvragée excavée à grande profondeur dans la roche plutonique du Bouclier canadien. On documente la sûreté et la possibilité de réalisation technique du concept et ses effets possibles sur la santé humaine et l'environnement dans une Étude d'impact sur l'environnement (EIE) effectuée par Énergie atomique du Canada limitée (EACL), le proposeur du concept. Ontario Hydro a préparé le présent rapport pour EACL; ce rapport est l'un d'une série de neuf documents de référence principaux de l'EIE. Le rapport documente l'évaluation de la sûreté et des effets sur l'environnement et de leur atténuation, lesquels peuvent être associés à la réalisation du stockage permanent «avant fermeture», d'après une conception de système de stockage permanent conceptuel («de référence»). Le cadre de l'évaluation avant fermeture couvre la sélection éventuelle d'un site pour une installation conceptuelle de stockage permanent, la construction et l'exploitation de celle-ci, le transport du combustible usé des centrales nucléaires à celle-ci ainsi que le déclassement et la fermeture finale de celle-ci. Les facteurs examinés comprennent la santé humaine, le milieu naturel, le milieu socio-économique, la sécurité de la main-d'oeuvre et du public, la sécurité et les garanties.

Aux fins de l'évaluation avant fermeture, on a supposé que l'installation de stockage permanent serait située quelque part dans la partie ontarienne du Bouclier canadien du fait qu'on envisage que c'est Ontario Hydro qui produira la plus grande partie du combustible nucléaire usé du Canada. Toutefois, on n'a supposé aucune situation géographique particulière pour un site éventuel et on ne sélectionnera aucun site avant que le concept n'ait été accepté. Donc, l'évaluation avant fermeture est basée sur une combinaison de renseignements de référence généraux sur l'environnement et de modeles tirés des conditions réelles existant dans tout l'Ontario; elle est également basée sur l'expérience d'Ontario Hydro et son examen de cas de projets pertinents documentés dans la bibliographie. On a mis au point un certain nombre de programmes de calcul pour analyser les doses radiologiques possibles aux êtres humains et autres êtres vivants de l'écosystème ainsi que les effets toxiques connexes possibles sur ceux-ci, doses et effets pouvant provenir de l'exploitation normale et peut-être anormale du système de stockage permanent (PREAC, PSAC, CEMTOX et TADS). On a mis au point ces programmes d'évaluation à partir de modèles qui existent, là où ils existent. À ce stade, l'évaluation socio-économique, sans avoir de site particulier ou de collectivité locale particulière receveuse de site comme base, s'est appuyée généralement sur la théorie et l'étude de l'impact socio-économique, dont l'étude de projets semblables. En plus de l'évaluation principale, on a exécuté une analyse de sensibilité pour indiquer l'influence possible des variations possibles des paramètres prévus à la conception et des paramètres environnementaux. On a inclus l'analyse générale de divers cas futurs possibles (milieu naturel et milieux socio-économiques différents et cas supposés de production d'énergie nucléaire). Enfin, on a indiqué quelques stratégies d'évaluation particulière à un site et de gestion de l'impact.

La conclusion principale qu'on tire de l'évaluation est qu'on peut développer et mettre en oeuvre un système de stockage permanent basé sur le concept proposé, de telle sorte qu'aucun employé ou qu'aucune personne du public ne soit exposé(e) à une dose de rayonnement supérieure aux limites réglementaires. On peut minimiser les effets sur le milieu naturel en sélectionnant un site et en appliquant minutieusement les mesures d'atténuation établies. On souligne que pour gérer avec succès les impacts socio-économiques, il faut planifier conjointement avec la collectivité locale recevant l'installation.

Le Programme canadien de gestion des déchets de combustible nucléaire est financé en commun par EACL et Ontario Hydro sous les auspices du Groupe des propriétaires de réacteurs CANDU.

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THE DISPOSAL OF CANADA'S NUCLEAR FUEL WASTE: PRECLOSURE ASSESSMENT OF A CONCEPTUAL SYSTEM

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ABSTRACT

The Canadian concept for disposal of nuclear fuel waste involves emplacing the fuel waste in long-lasting containers in an engineered vault, deep underground in plutonic rock of the Canadian Shield. The safety and technical feasibility of this concept, and its potential effects on human health and the environment, are being documented in an Environmental Impact Statement (EIS) by Atomic Energy of Canada Limited (AECL), the proponent of the concept. The present report is prepared by Ontario Hydro for AECL and is one of nine EIS primary references. The report documents the assessment of safety and environmental effects and mitigation which could be associated with "preclosure" disposal implementation, based on a conceptual ("reference") disposal system design. The scope of the preclosure assessment covers the siting, construction and operation of a conceptual disposal facility, transportation of used fuel from nuclear generating stations to the disposal facility, and eventual decommissioning and closure of the facility. The factors addressed include human health, natural environment, socio-economic environment, worker and public safety, and security and safeguards.

For purposes of this preclosure assessment, it was assumed that the disposal facility would be located somewhere within the Ontario portion of the Canadian Shield, since Ontario Hydro is expected to produce the majority of used nuclear fuel in Canada. However, no specific site location was assumed, and no site will be selected until after the concept has been accepted. Thus, the preclosure assessment is based on a combination of general ("reference") environmental baseline information and models, derived from actual conditions across Ontario, plus Ontario Hydro's experience and review of relevant project cases documented in the literature. A number of computer codes were developed to analyze potential radiological doses and related toxic effects to humans and other life in the ecosystem from both normal and possible abnormal disposal system operations (PREAC, PSAC, CEMTOX and TADS). These assessment codes were developed from existing models, where available. Socio-economic assessment at this stage, without a specific site or community basis, was generally based on socio-economic impact theory and research, including studies of comparable projects. In addition to the main assessment, a sensitivity analysis was carried out to indicate the potential influence, on the assessment results, of possible variations in design and environmental parameters. General analysis of a range of possible future scenarios (different natural environment and socio-economic settings plus assumed nuclear energy production scenarios) was included. Finally, some strategies for site-specific assessment and impact management are indicated.

The key conclusion of the assessment is that a disposal system, based on the proposed concept, can be developed and implemented such that no worker or member of the public would be exposed to radiation in excess of the regulatory limits. Effects on the natural environment could be minimized through careful siting and application of established mitigation measures. It is emphasized that successful management of socio-economic impacts would require joint planning with the host community.

The Canadian Nuclear Fuel Waste Management Program is funded jointly by AECL and Ontario Hydro under the auspices of the CANDU Owners Group.

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PREFACE

In 1992, 15% of the electricity generated in Canada was produced using CANDU nuclear reactors. A by-product of the nuclear power is used CANDU fuel, which consists of ceramic uranium dioxide pellets and metal structural components. Used fuel is highly radioactive. The used fuel from Canada's power reactors is currently stored in water-filled pools or dry storage concrete containers. Humans and other living organisms are protected by isolating the used fuel from the natural environment and by surrounding it with shielding material. Current storage practices have an excellent safety record.

At present, used CANDU fuel is not reprocessed. It could, however, be reprocessed to extract useful material for recycling, and the highly radioactive material that remained could be incorporated into a solid. The term "nuclear fuel waste," as used by AECL, refers to either

- the used fuel, if it is not reprocessed, or

- a solid incorporating the highly radioactive waste from reprocessing.

Current storage practices, while safe, require continuing institutional controls such as security measures, monitoring, and maintenance. Thus storage is an effective interim measure for protection of human health and the natural environment but not a permanent solution. A permanent solution is disposal, a method "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" (AECB 1987).

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. AECL was made responsible for research and development on "... disposal in a deep underground repository in intrusive igneous rock" (Joint Statement 1978). Ontario Hydro was made responsible for studies on interim storage and transportation of used fuel and has contributed to the research and development on disposal. Over the years a number of other organizations have also contributed to the Program, including Energy, Mines and Resources Canada; Environment Canada; universities; and companies in the private sector.

The disposal concept is to place the waste in long-lived containers; emplace the containers, enveloped by sealing materials, in a disposal vault excavated at a nominal depth of 500 to 1000 m in intrusive igneous (plutonic) rock of the Canadian Shield; and (eventually) seal all excavated openings and exploration boreholes to form a passively safe system. Thus there would be multiple barriers to protect humans and the natural environment from contaminants in the waste: the container, the very low-solubility waste form, the vault seals, and the geosphere. The disposal technology includes options for the design of the engineered components, including the disposal container, disposal vault, and vault seals, so that it is adaptable to a wide range of regulatory standards, physical conditions, and social requirements. Potentially suitable bodies of plutonic rock occur in a large number of locations across the Canadian Shield.

In developing and assessing this 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 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.

In 1981, the governments of Canada and Ontario announced that "... no disposal site selection will be undertaken until after the concept has been accepted. This decision also means that the responsibility for disposal site selection and subsequent operation need not be allocated until after concept acceptance" (Joint Statement 1981).

The acceptability of the disposal concept is now being reviewed by a federal Environmental Assessment Panel, which is also responsible for examining a broad range of issues related to nuclear fuel waste management (Minister of the Environment, Canada 1989). After consulting the public, the Panel issued guidelines to identify the information that should be provided by AECL, the proponent of the disposal concept (Federal Environmental Assessment Review Panel 1992).

AECL is preparing an Environmental Impact Statement to provide information requested by the Panel and to present AECL's case for the acceptability of the disposal concept. A Summary will be issued separately. This report is one of nine primary references that summarize major aspects of the disposal concept and supplement the information in the Environmental Impact Statement. A guide to the contents of the Environmental Impact Statement, the Summary, and the primary references follows this Preface.

In accordance with the 1981 Joint Statement of the governments of Canada and Ontario, no site for disposal of nuclear fuel waste is proposed at this time. Thus in developing and assessing the disposal concept, AECL could not design a facility for a proposed site and assess the environmental effects to determine the suitability of the design and the site, as would normally be done for an Environmental Impact Statement. Instead, AECL and Ontario Hydro have specified illustrative "reference" disposal systems and assessed those.

A "reference" disposal system illustrates what a disposal system, including the geosphere and biosphere, might be like. Although it is hypothetical, it is based on information derived from extensive laboratory and field research. Many of the assumptions made are conservative, that is, they would tend to overestimate adverse effects. The technology specified is either available or judged to be readily achievable. A reference disposal system includes one possible choice among the options for such things as the waste form, the disposal container, the vault layout, the vault seals, and the system for transporting nuclear fuel waste to a disposal facility.

The components and designs chosen are not presented as ones that are being recommended but rather as ones that illustrate a technically feasible way of implementing the disposal concept.

After the Panel has received the requested information, it will hold public hearings. It will also consider the findings of the Scientific Review Group, which it established to provide a scientific evaluation of the disposal concept. According to the Panel's terms of reference "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" (Minister of the Environment, Canada 1989).

Acceptance of the disposal concept at this time would not imply approval of any particular site or facility. If the disposal concept is accepted and implemented, a disposal site would be sought, a disposal facility would be designed specifically for the site that was proposed, and the potential environmental effects of the facility at the proposed site would be assessed. Approvals would be sought in incremental stages, so concept implementation would entail a series of decisions to proceed. Decision-making would be shared by a variety of participants, including the public. In all such decisions, however, safety would be the paramount consideration.

The EIS, Summary, and Primary References

Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste (AECL 1994a)
Summary of the Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste (AECL 1994b)
The Disposal of Canada's Nuclear Fuel Waste: Public Involvement and Social Aspects (Greber et al. 1994)
The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology (Davison et al. 1994a)
The Disposal of Canada's Nuclear Fuel Waste: Engineered Barriers Alternatives (Johnson et al. 1994a)
The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility (Simmons and Baumgartner 1994)
The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System (Grondin et al. this volume)
The Disposal of Canada's Nuclear Fuel Waste: Postclosure Assessment of a Reference System (Goodwin et al. 1994)
The Disposal of Canada's Nuclear Fuel Waste: The Vault Model for Postclosure Assessment (Johnson et al. 1994b)
The Disposal of Canada's Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment (Davison et al. 1994b)
The Disposal of Canada's Nuclear Fuel Waste: The Biosphere Model, BIOTRAC, for Postclosure Assessment (Davis et al. 1993)

GUIDE TO THE CONTENTS OF THE ENVIRONMENTAL IMPACT STATEMENT, THE SUMMARY, AND THE PRIMARY REFERENCES

ENVIRONMENTAL IMPACT STATEMENT AND SUMMARY

Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste (AECL 1994a)

- provides an overview of AECL's case for the acceptability of the disposal concept
- provides information about the following topics:
  - the characteristics of nuclear fuel waste
  - storage and the rationale for disposal
  - major issues in nuclear fuel waste management
  - the disposal concept and implementation activities
  - alternatives to the disposal concept
  - methods and results of the environmental assessments
  - principles and potential measures for managing environmental effects
  - AECL's overall evaluation of the disposal concept

Summary of the Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste (AECL 1994b)

- summarizes the contents of the Environmental Impact Statement

PRIMARY REFERENCES

The Disposal of Canada's Nuclear Fuel Waste: Public Involvement and Social Aspects (Greber et al. 1994)

- describes the activities undertaken to provide information to the public about the Nuclear Fuel Waste Management Program and to obtain public input into the development of the disposal concept
- presents the issues raised by the public and how the issues have been addressed during the development of the disposal concept or how they could be addressed during the implementation of the disposal concept
- discusses social aspects of public perspectives on risk, ethical issues associated with nuclear fuel waste management, and principles for the development of a publicly acceptable site selection process

The Disposal of Canada's Nuclear Fuel Waste: Site Screening and Site Evaluation Technology (Davison et al. 1994a)

- discusses geoscience, environmental, and engineering factors that would need to be considered during siting

- describes the methodology for characterization, that is, for obtaining the data about regions, areas, and sites that would be needed for facility design, monitoring, and environmental assessment

The Disposal of Canada's Nuclear Fuel Waste: Engineered Barriers Alternatives (Johnson et al. 1994)

- describes the characteristics of nuclear fuel waste
- describes the materials that were evaluated for use in engineered barriers, such as containers and vault seals
- describes potential designs for containers and vault seals
- describes procedures and processes that could be used in the production of containers and the emplacement of vault-sealing materials

The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility (Simmons and Baumgartner 1994)

- discusses alternative vault designs and general considerations for engineering a nuclear fuel waste disposal facility
- describes a disposal facility design that was used to assess the technical feasibility, costs, and potential effects of disposal (Different disposal facility designs are possible and might be favoured during concept implementation.)
- presents cost and labour estimates for implementing the design

The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System (this volume)

- describes a methodology for estimating effects on human health, the natural environment, and the socio-economic environment that could be associated with siting, constructing, operating (includes transporting used fuel), decommissioning, and closing a disposal facility
- describes an application of this assessment methodology to a reference disposal system (We use the term "reference" to designate the disposal systems, including the facility designs, specified for the assessment studies. Different disposal facility designs are possible and might be favoured during concept implementation.)
- discusses technical and social factors that would need to be considered during siting
- discusses possible measures and approaches for managing environmental effects

The Disposal of Canada's Nuclear Fuel Waste: Postclosure Assessment of a Reference System (Goodwin et al. 1994)

- describes a methodology for
  - estimating the long-term effects of a disposal facility on human health and the natural environment,
  - determining how sensitive the estimated effects are to variations in site characteristics, design parameters, and other factors, and
  - evaluating design constraints

- describes an application of this assessment methodology to a reference disposal system (We use the term "reference" to designate the disposal systems, including the facility designs, specified for the assessment studies. Different disposal facility designs are possible and might be favoured during concept implementation.)

The Disposal of Canada's Nuclear Fuel Waste: The Vault Model for Postclosure Assessment (Johnson et al. 1994)

- describes the assumptions, data, and model used in the postclosure assessment to analyze processes within and near the buried containers of waste

- discusses the reliability of the data and model

The Disposal of Canada's Nuclear Fuel Waste: The Geosphere Model for Postclosure Assessment (Davison et al. 1994b)

- describes the assumptions, data, and models used in the postclosure assessment to analyze processes within the rock in which a disposal vault is excavated

- discusses the reliability of the data and model

The Disposal of Canada's Nuclear Fuel Waste: The Biosphere Model, BIOTRAC, for Postclosure Assessment (Davis et al. 1993)

- describes the assumptions, data, and model used in the postclosure assessment to analyze processes in the near-surface and surface environment

- discusses the reliability of the data and model

ONTARIO HYDRO
PRECLOSURE ENVIRONMENTAL AND SAFETY ASSESSMENT TEAM

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Disposal Concept Assessment		Transportation Assessment	
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Natural Environment Analysis	M. Fearn-Duffy L. Grondin	Public Radiological Safety Analysis	T.F. Kempe
Socio-Economic Impact Analysis	M. Paez-Victor	Natural Environment Analysis	L. Grondin
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				P.K.M. Rao

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

ES1. INTRODUCTION

ES1.1 BACKGROUND

The Canadian Nuclear Fuel Waste Management Program (NFWMP) was established in 1978 to develop the concept of deep underground disposal of nuclear fuel waste in the plutonic rock of the Canadian Shield. The proponent for the concept is Atomic Energy of Canada Limited (AECL). The NFWMP has focused on developing a disposal concept that demonstrates the technology to safely site, construct, operate, decommission and close a disposal facility in plutonic rock. A further technical objective is that the technology should be currently available or readily achievable. In addition to the technical requirements of the NFWMP, AECL believes that continuing public involvement is important to ensure social acceptability of the concept. In accordance with the 1981 Joint Statement of the governments of Canada and Ontario, no site selection will be undertaken until after the concept has been reviewed and accepted by the relevant governments.

The concept is being reviewed under the federal Environmental Assessment and Review Process (EARP). The Panel appointed for this review conducted public scoping meetings in 1990 and issued the final guidelines for the preparation of the Environmental Impact Statement (EIS) in March 1992. The EIS is currently being prepared by AECL for submission to the Panel. The Preclosure Assessment, presented in this report, is one of nine Primary References being prepared in support of the EIS.

ES1.2 SCOPE AND OBJECTIVES

The Preclosure Assessment is a non site-specific analysis of the potential safety and environmental effects associated with the preclosure phase of a conceptual disposal facility. This assessment considered the effects of all stages of the disposal facility (i.e. siting, construction, operation, decommissioning and closure of the facility, as well as transportation of the used fuel to the facility) on the natural environment, the public and the workers, and on their community. For purposes of this assessment, "closure" is defined as including the shutdown and removal of monitoring systems and the sealing of boreholes; completion of this stage defines the end of the preclosure phase. The assessment was based on a conceptual disposal centre design developed by AECL (AECL CANDU et al. 1992; Simmons and Baumgartner 1994).

This assessment had four objectives:

1) to identify the potential environmental effects and safety implications of the preclosure phase activities associated with the conceptual disposal system;

2) to identify practical measures that could be used to prevent, minimize and/or mitigate and manage environmental effects and safety hazards;

3) as much as possible in a non site-specific assessment, to assess the significance of residual environmental effects and safety hazards; and

4) to suggest guidelines and analytical methods that could be used in the assessment of disposal and transportation activities at the site-specific stage.

In this assessment the environment is defined as including the natural environment, and the social, cultural and economic environments.

The assessment assumed that the disposal facility would be located somewhere within the Ontario portion of the Canadian Shield (since the majority of used fuel is in Ontario) and used fuel would remain in storage at the reactor sites until a disposal facility becomes available.

The assessment of used fuel transportation was based on a transportation system developed by Ontario Hydro. Incremental impacts associated with transporting used fuel from reactor sites in Quebec and New Brunswick to Ontario were also addressed.

ES1.3 APPLICABLE REGULATIONS AND QUALITY ASSURANCE

Government has not yet decided on an organization to implement the disposal concept ("implementing organization"). This assessment assumed that the implementing organization would comply with all applicable federal, provincial and regional regulations and requirements, develop appropriate standards where necessary, and apply impact management measures to minimize adverse impacts.

Current applicable regulations identified in the assessment include the Atomic Energy Control Board (AECB) regulations for fixed nuclear facilities, the AECB Transport Packaging of Radioactive Materials (TPRM) regulations, regulations under the Canadian Environmental Protection Act (CEPA), regulations under the Ontario Environmental Protection Act, regulations under the federal Transportation of Dangerous Goods (TDG) Act, regulations under the Canada Labour Code, and regulations under the Ontario Occupational Health and Safety Act. Although these are the major applicable regulations, many other regulations and guidelines apply.

A quality assurance (QA) program was established to determine and monitor the assessment quality requirements as well as the application of QA to computer modelling. The task team preparing this assessment was made responsible for assuring its quality and that of the supporting documentation to this assessment (there are 16 support documents: A-1 to A-8 and B-1 to B-8).

ES2. DESCRIPTION OF THE CONCEPTUAL SYSTEM FOR USED FUEL TRANSPORTATION AND DISPOSAL

ES2.1 REFERENCE DESIGN FOR A USED FUEL DISPOSAL CENTRE

The disposal concept would combine a series of engineered and natural barriers to prevent or retard the release of radioactivity from the used fuel. This series of barriers begins with the used fuel itself, which is composed of solid uranium oxide encased in sealed tubes made of zirconium alloy. Both components resist corrosion, dissolution and radionuclide release. As a third barrier during disposal, used fuel would be sealed in corrosion-resistant titanium containers. The contained used fuel would be placed in the underground vault and surrounded by a clay-bearing buffer material. Finally, the underground vault and all of its entrances would be backfilled and sealed to isolate the used fuel from the surface environment and to prevent unintentional intrusion by humans. The conceptual engineering design for a disposal facility (referred to as the Used Fuel Disposal Centre or UFDC in this report), developed by AECL and used as the reference in this assessment, is a feasible but non-optimized (non-refined) design. The reference design specifies a self-contained complex including facilities such as a basket and container fabrication plant, the used-fuel packaging plant, a disposal vault 1000 m deep in the plutonic rock of the Ontario portion of the Canadian Shield, and all the necessary surface facilities associated with the underground operations (i.e. a concrete batching plant, a backfill preparation plant and a rock crushing plant). In addition, the reference design specified all the required operational and personnel services such as a service building, administration building, powerhouse, warehouse, fire hall and security building, and waste management (active and inactive) facilities, including quality control laboratories. The size of the site for the UFDC was specified in the conceptual engineering study to be 5.2 km x 3 km.

The reference vault, approximately 2 km x 2 km in area, was designed to dispose of about 191 000 Mg of uranium, contained in 10.1 million used fuel bundles. The average annual used fuel packaging rate, over an operation stage of about 41 years, would be approximately 250 000 bundles. The used fuel would be packaged in containers that would hold 72 fuel bundles each.

The reference design divides the preclosure phase into the following stages:

- siting (site screening and site evaluation) (23 years in duration);
- construction (7 years in duration);
- operation (41 years in duration);
- extended monitoring (two periods of undefined duration);
- decommissioning (16 years in duration); and
- closure (2 years in duration).

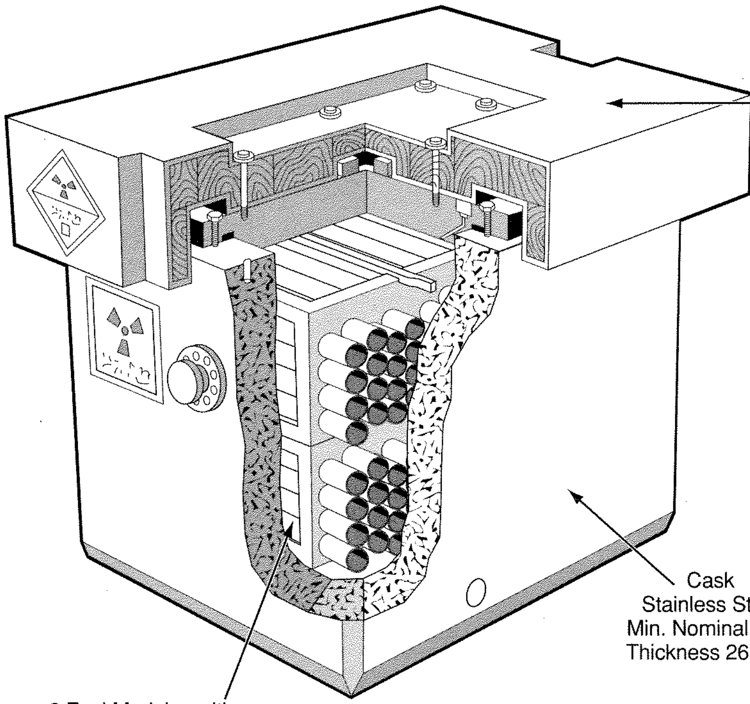
On this basis, the total duration of the preclosure phase would be approximately 90 years plus the undefined duration of the extended monitoring periods.

ES2.2 REFERENCE DESIGN FOR A USED FUEL TRANSPORTATION SYSTEM

The assessment of the impacts of transporting used fuel was based on the reference transportation system design developed by Ontario Hydro for road, rail and water transportation (Ulster 1993a). Transportation by air was not considered feasible at this time. The transportation system designs were not optimized (refined) at this conceptual assessment stage but they formed a realistic basis for the assessment.

The reference used fuel accepted for transportation would be 10-year-cooled CANDU used fuel. The used fuel would be transported dry in casks tested, approved and regulated by the AECB through the Transport Packaging of Radioactive Materials (TPRM) regulations (AECB 1991b). The TPRM regulations cover external radiation levels, allowable external surface contamination, allowable leakage of radioactivity in normal conditions, and retention of shielding capacity and containment of radioactive material in severe impact and fire accident conditions. These regulations are intended to reduce the hazards to transport workers and the general public to a safe level.

The road transportation system consists of an engineered tractor/trailer/cask system. The tractor/trailer would transport one cask per trip. The used fuel transportation casks (see Figure ES-1) for the road mode are designed to transport 192 bundles (2 modules of 96 bundles each). The main cask body is a rectangular, monolithic, stainless steel construction, forming a hollow rectangular shape with solid walls and base. A lid containing an O-ring-type double seal is bolted to the tops of the four walls to form a sealed enclosure. An impact limiter is fitted onto the upper end of the cask when it is ready for shipment. It is held in place by 8 bolts attached to the cask lid. This device, constructed of blocks of redwood encased in a steel sheath, provides impact protection and serves as thermal insulation to protect the seals between the cask lid and the body under accident conditions. The redwood itself is protected from exposure to the fire accident conditions by the sheathing which has been shown to survive the regulatory impact



Notes:
1. Empty Package Mass .... 29 700 kg
2. Mass of Fuel Bundles in Two Fuel Modules .... 5 000 kg
   Total Loaded Weight .... 34 700 kg
3. Minimum Cooling Time for Fuel .... 10 Years
4. Size with Impact Limiter Approx. 1.9m x 1.6m x 2.2m high

FIGURE ES-1: CANDU Used Fuel Road Cask

conditions. In the event of severe heating, the redwood chars but does not burn. The reference design specifies a cask life of 20 years.

The rail transportation system consists of a dedicated train with 10 railcars (each with one rail cask), 4 buffer cars, a caboose and a locomotive. Each rail cask is designed to transport 576 bundles (6 modules of 96 bundles each). The rail cask design has the same basic configuration as the road cask, but the impact limiter configuration is different. The rail cask has two impact limiters, one at each end. The reference design specifies a cask life of 20 years.

The water transportation reference design consists of an integrated tug/barge unit. The tug could transport either road or rail casks. The reference barge can be loaded to accommodate a cargo equivalent of 36 road casks or 12 rail casks on average (up to a maximum of 48 road casks and 20 rail casks). Transfer of the cask from the irradiated fuel bay to the dock at the nuclear generating station site would be achieved by a dedicated vehicle. A transfer facility would be built to transfer the casks from the water transporter to the land transporter, to complete the journey to the disposal facility, assumed to be in land.

An emergency response plan has been specified for each mode of transportation.

ES3. DESCRIPTION OF THE REFERENCE ENVIRONMENTS

ES3.1 REFERENCE DISPOSAL ENVIRONMENTS

For purposes of this assessment, the Ontario portion of the Canadian Shield was divided into three regions - Southern, Central and Northern (see Figure 1-3 in main document). In a project setting, baseline environmental conditions are normally established to give some context to the assessment of possible changes arising from the project. In this non site-specific assessment, the establishment of true baseline environmental conditions could not be done for the study area. Instead, available region-wide environmental data (e.g. air, water, geology, land use/capabilities, flora and fauna, and non-renewable resources) in the three regions were compiled into a database which was used to give context to the assessment.

ES3.2 REFERENCE TRANSPORTATION ENVIRONMENTS

For each of the three regions in the Ontario Shield, reference transportation environment data was compiled based on data from real routes originating from the existing nuclear generating station sites in Ontario and leading to the geometric centre (sometimes referred to as the centroid) of the region. The data included population densities along the transportation corridor, route distance, traffic, weather and accident data. This data was used to give context to the assessment of effects from used fuel transportation.

ES4. POTENTIAL EFFECTS FROM SITING

ES4.1 APPROACH TO THE SITING PROCESS

This assessment assumed that the objective of the siting process would be to identify a site for the Used Fuel Disposal Centre that is:

- technically suitable, based on the fundamental directives of protecting human health and safety and the natural and social environment; and

- socially acceptable to the local communities.

It was also assumed, for the purposes of this assessment and without intending to pre-empt the public consultation process, that the following general principles would be applied to the siting process:

1) commitment to safety and environmental protection;

2) commitment to voluntarism;

3) commitment to shared decision-making;

4) commitment to fairness; and

5) commitment to openness.

The "voluntarism" principle is described more fully in the main document and all five principles are discussed in detail in Greber et al. (1994).

ES4.2 POTENTIAL EFFECTS ON THE PUBLIC

Considering the kinds of activities likely to occur during the siting stage, no significant adverse physical effects on public health and safety are expected. This does not take into account the possibility of stress which some members of a local community might feel. Depending on proximity to a community or individual residence, the most likely potential physical effects would be some noise, traffic and other nuisance effects associated with access road construction, drilling and blasting. However, assuming that a cooperative siting process and reasonable mitigation measures are used, it is considered unlikely that any public health and safety effects would be significant.

ES4.3 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT AND WORKERS

The technical site characterization activities performed during siting would include activities similar to those performed during the geological exploration phase of standard mining projects. They can also be compared to the geotechnical investigations performed prior to the development of large civil structures such as hydro-electric dams, tunnels, and underground powerhouses. The analysis was based on a review of the effects of these types of activities on the natural environment and workers. Since the significance of the potential impacts depends on the specific characteristics of the site and on the characterization techniques used, the analysis was necessarily qualitative.

Characterization activities during site screening would be at a regional level and would use a combination of existing data and reconnaissance surveys. These activities would be non-disruptive and are not expected to affect the natural environment and worker safety. During site evaluation, characterization would start with reconnaissance work, and be followed by detailed surface and subsurface investigations. Some of these investigations would be disruptive to the natural environment and could result in some hazards to the workers.

A review of the practices used in mining exploration and hydraulic dam site investigations showed that methods and technologies exist that could be used to mitigate identified effects. Based on this non site-specific analysis, residual effects on the natural environment and on workers are expected to be minimal during siting, provided that adequate environmental protection and worker safety measures are taken.

ES4.4 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

The socio-economic impact assessment was based on a review of experience in siting industrial and hazardous material facilities, a review of available public opinions and concerns, and on a framework for assessing the interactions between a community and project characteristics (Paez-Victor 1993). This analysis framework used the community as the analysis unit, more specifically, the following three main community characteristics: social and cultural vitality, economic viability and political efficacy. The interaction with, and response of people and their communities, to the project's characteristics and to changes imposed by the project on the natural environment would determine the occurrence of socio-economic impacts. The significance of identified impacts could not, therefore, be determined in the absence of a site-specific community. This approach was used for all stages of the preclosure phase.

During the siting stage, socio-economic impacts are expected to result from the interaction between the implementing organization's siting activities (the project) and the socio-psychological processes, public opinion and community dynamics (community characteristics). The dynamics of the socio-economic impacts would be determined by the site selection process. Assuming that the site selection process will be guided by the principles of openness, fairness, voluntarism, shared decision-making, and safety and environmental protection, negative impacts would be greatly reduced in comparison with the impacts that might result from a more traditional siting process (not proposed).

Since the extent and significance of socio-economic impacts are site-specific, any approach designed to avoid or manage these impacts must be planned and implemented jointly with the community. The implementation of a program that gives the community a recognized and appropriate role in the decision-making process is one of the most important factors in the successful implementation of the project.

The principles on which an impact management program is based should include the following:

- protecting the environment, the health and safety of the people and their communities should be the primary objective;

- the people and communities that host the project and/or those potentially affected by it have a right to participate fully in decisions regarding the prevention, mitigation, or compensation of negative impacts and the enhancement of positive effects;

- where possible, efforts to avoid or reduce the severity of adverse socio-economic impacts should take precedence over attempts to offset such impacts;

- affected people and communities are entitled to receive compensation to offset unpredicted, unmanageable and residual impacts; and

- efforts should be made to maximize community benefits and to promote equity.

Because of the generic nature of this assessment, a range of potential measures have been identified that may be considered for a comprehensive, joint project/community impact management program. The aims of the impact management program would be to avoid impacts where possible, to minimize any adverse impacts of the project, to compensate for unavoidable impacts, and to provide benefits and enhancements where possible.

The residual effects from siting could only be fully assessed when the site-specific community and natural environment settings, which provide the social and ecological contexts, are known.

ES5. POTENTIAL EFFECTS FROM THE CONSTRUCTION OF A DISPOSAL CENTRE

ES5.1 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT

The impacts of construction of a disposal centre on the following environmental factors were considered: air quality, surface water quality, groundwater quality, soil, land use, forest fires, flora and fauna, ambient noise, non-renewable resources and traffic. Most of the analysis was qualitative in the absence of site-specific characteristics, as it relied upon the conceptual design and generic environmental data. The analysis was based on a review of the construction activities specified in the conceptual engineering study (Simmons and Baumgartner 1994) and a review of the effects of related activities carried out during surface and underground construction projects. It is expected that the construction stage would be the most disruptive for the natural environment. A review of conventional practices in surface and underground construction projects showed that methods and technologies exist that could be used to mitigate negative effects. The effect of underground excavation on the water table around the site would need to be investigated further based on site-specific data and mitigated if necessary. The effect of transporting construction material would also be dependent on the state of the local transportation network.

ES5.2 POTENTIAL EFFECTS ON THE PUBLIC AND WORKERS

Occupational hazards from disposal centre construction would include physical injuries, noise, and exposure to dust and fumes from the operation of equipment and blasting. The total risk to workers during the seven-year construction stage was estimated to be about 0.4 fatalities and 77 lost time injuries for a total workforce of about 1000 persons per year.

The impact of the construction of a disposal centre on the public health and safety would be minimal. The transportation of construction material could result in some impact. The release of naturally occurring radon and radon progeny to the atmosphere by excavation on-site was estimated to be a small fraction of the natural radon emissions to the atmosphere from surface soils.

ES5.3 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

The socio-economic impact assessment was based on a review of experience in construction projects, a review of available public views and concerns, and on a framework for assessing the interactions between a community and project characteristics (Paez-Victor 1993). Three main types of potential socio-economic impacts would occur during the seven-year construction stage:

- impacts related to the influx of workers;
- impacts related to surface and subsurface construction activities; and
- impacts related to material and services procurement, resource use and waste production.

The procurement of materials and services, and workforce requirements would create the potential for increased business activity, employment opportunities and personal income. This stage represents an opportunity for local residents and businesses to share the economic benefits of the project. A fundamental premise for the prevention and mitigation of impacts of construction is the successful completion of the siting stage. The impact management program followed during the construction stage would be a continuation of the program during the siting stage, and would follow the principles outlined in the previous section.

Concern about radiological risk, which will exist during siting, may remain to some degree throughout the construction stage. Other possible residual impacts could be those related to demographic and community infrastructure, and service changes.

The possible residual effects of construction would need to be validated with the site-specific community and natural environment settings, which would provide the social and ecological contexts.

ES6. POTENTIAL EFFECTS FROM THE OPERATION OF A DISPOSAL CENTRE

ES6.1 POTENTIAL RADIOLOGICAL EFFECTS ON THE PUBLIC AND NON-HUMAN BIOTA - NORMAL CONDITIONS

Even with filtering equipment, routine airborne and waterborne emissions would result from normal operation of the UFDC. Radionuclides released from the UFDC may lead to a radiation dose to humans via a number of internal and external pathways. These pathways are shown in Figure ES-2. Using the code PREAC (Russell 1993b), radiological doses were estimated for members of the critical group, which represents the individuals in the population that are expected to receive the highest dose. Specific exposure scenarios, such as exposure of Aboriginal people are also considered. For this assessment, the critical group was represented by the "reference man" defined by the International Commission on Radiological Protection (ICRP 1975): a male/female combination between 20 to 30 years of age, 70 kg in weight and 170 cm tall. This person was assumed to be living on a farm at the UFDC boundary located 1.5 km from the UFDC emission stack. The location of the farm was assumed to be in the wind direction that gave the largest radionuclide concentrations from airborne emissions.

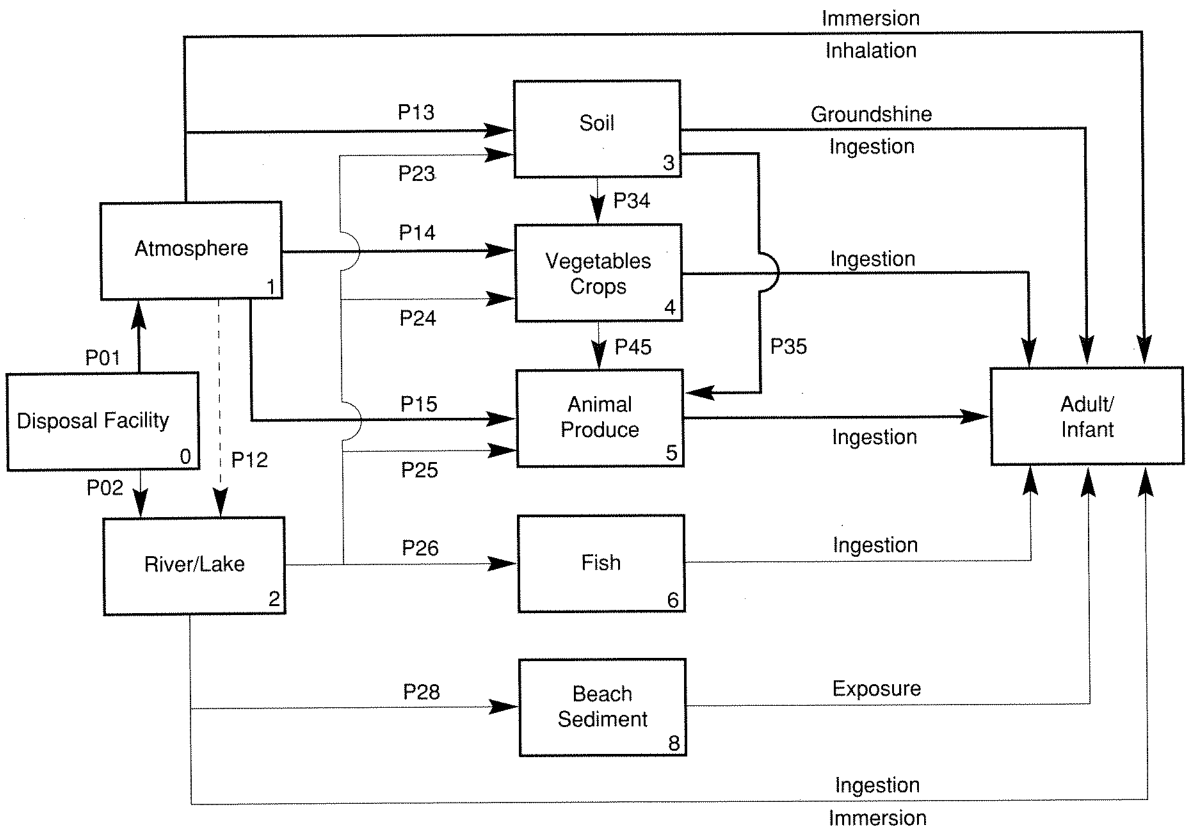
a) Individual Doses

The maximum doses to an adult and an infant living on a farm at the disposal facility boundary were estimated to be (Russell 1993a):

	Maximum Dose ($mSv \cdot a^{-1}$)		
	Northern Region	Central Region	Southern Region
Adult Dose	3×10^{-4}	2×10^{-4}	2×10^{-4}
Infant Dose	5×10^{-4}	3×10^{-4}	3×10^{-4}

These dose estimates are at least three orders of magnitude less than either average natural background radiation (3.0 $mSv \cdot a^{-1}$) or the current and proposed AECB dose limit for a member of the public (5 $mSv \cdot a^{-1}$ and 1 $mSv \cdot a^{-1}$ respectively).

Since the individual doses for the three reference environments are similar, the results for the Northern region were chosen to provide further information on the key radionuclides and exposure pathways.



The environment is assumed to be composed of a number of biological compartments with uniform radionuclide concentration. The movement of radionuclides in the biosphere has been modelled using transfer parameters. For example, the transfer of radionuclides from compartment i to compartment j is characterized by transfer parameter Pij.

FIGURE ES-2: Radiological Pathways Analysis Compartment Model

The radionuclide estimated to give the largest individual dose rate was ^{90}Sr at 1.7×10^{-4} $mSv \cdot a^{-1}$, which is about 49% of the total dose. The next largest dose contributors were ^{137}Cs at 1.0×10^{-4} $mSv \cdot a^{-1}$, which is approximately 29% of the total, and ^{134}Cs at 5.9×10^{-5} $mSv \cdot a^{-1}$, which is approximately 17% of the total. Together, these three radionuclides account for 95% of the annual dose from UFDC emissions.

The exposure pathway calculated to give the largest individual dose rate was emission to water, followed by bioaccumulation in fish and ingestion of fish at 1.4×10^{-4} $mSv \cdot a^{-1}$. This pathway accounted for about 41% of the total dose. The next most important pathway was emission to water, followed by irrigation of backyard vegetables and soil, and ingestion of vegetables at 1.1×10^{-4} $mSv \cdot a^{-1}$, which accounted for about 32% of the total dose.

b) <u>Collective Dose</u>

The annual collective dose to the population around the disposal facility was calculated using the sector-averaged atmospheric dispersion out to 100 km, and the contribution from the water pathways near the facility. The total annual collective dose from all radionuclides and pathways was estimated to be about 1.9×10^{-4} person-$Sv \cdot a^{-1}$, 1.7×10^{-4} person-$Sv \cdot a^{-1}$ and 2.4×10^{-4} person-$Sv \cdot a^{-1}$ in the Northern, Central and Southern regions, respectively.

These values were compared to the expected collective dose from natural background radiation in Ontario using the average individual dose rate of 3 $mSv \cdot a^{-1}$ and the population data from the reference environments on the Shield. The collective dose from background exposure becomes 6.0×10^{2} person-$Sv \cdot a^{-1}$, 1.7×10^{3} person-$Sv \cdot a^{-1}$ and 1.9×10^{3} person-$Sv \cdot a^{-1}$ in the Northern, Central and Southern regions, respectively. Thus, the incremental dose from routine operation of the UFDC is negligible.

c) <u>Risk to Humans</u>

Using the risk coefficient of 5×10^{-2} fatal cancers per Sv for members of the public (ICRP 1991), the number of fatal cancers resulting from 41 years of routine emissions at the UFDC were estimated to be about 3.9×10^{-4}, 3.5×10^{-4} and 4.9×10^{-4} in the Northern, Central and Southern regions, respectively. Because these risk estimates are so much less than one, no fatal cancer would be expected.

<u>Radiological Impacts to Non-Human Biota from Routine Operations</u>

The annual doses to four representative species of non-human biota were calculated using steady-state radionuclide concentrations in the environment near the UFDC and a conservative dose assessment methodology (Russell 1993a). The dose to humans is usually expressed as effective dose equivalent which accounts for the biological effectiveness of the various types of radiation and the importance of the dose to the various target organs (ICRP 1991). However, similar calculations cannot be made for biota because this information is not available. Therefore, the dose to non-humans was calculated as the total energy deposited per unit mass of tissue (Gy).

The doses to non-human biota in the three reference environments were similar because the radionuclide concentrations in the three environments were similar. Thus, the detailed dose analysis was restricted to the Northern region.

The estimated annual dose rate to a fish, plant, mammal and bird in the environment near the UFDC was 8.6×10^{-6}, 6.5×10^{-6}, 6.4×10^{-6} and 6.4×10^{-6} $Gy \cdot a^{-1}$, respectively. For fish, the critical radionuclides were ^{134}Cs and ^{137}Cs, and the critical pathway was internal exposure. For plants, mammals and birds, the critical radionuclide was ^{90}Sr and the critical pathway was groundshine.

The background dose from natural and fallout sources to non-human aquatic and terrestrial organisms has been estimated to be 2.5×10^{-4} to 5×10^{-3} $Gy \cdot a^{-1}$ (Laratta 1983). Since the estimated annual dose rate to non-human organisms from routine operations was several orders of magnitude less than background levels, the impact is expected to be very small.

Prematurely Failed Container

Johnson and LeNeveu (1993) studied the probability and radiological consequences of defective disposal containers, containing failed fuel, and sealed within an emplacement borehole in the underground vault. Two different release scenarios were modelled: dry conditions and saturated conditions.

Given the high degree of quality control in the container inspection and emplacement operation, it was conservatively estimated that a maximum of two defective containers carrying defective fuel could be emplaced in the vault during the operating life of the facility.

Under both dry and saturated conditions, the maximum release of radionuclides to air and water from emplaced fuel during the preclosure phase was estimated to be about an order of magnitude less than the estimated annual emissions to the environment from the routine operation of the facility.

ES6.2 POTENTIAL RADIOLOGICAL EFFECTS ON THE PUBLIC - ACCIDENT CONDITIONS

Definition of Accident Scenarios

The selection of scenarios that could result in accidental release of radioactivity from the UFDC was based on a systematic review of the used-fuel handling procedures for the UFDC, consideration of accident conditions postulated at existing nuclear facilities, and a review of an accident safety assessment for high level radioactive waste repositories during the conceptual design stage (Jackson et al. 1985; Harris et al. 1990; Ma and Jardine 1990). When the consequences of an accident scenario were bounded by another accident scenario, the scenario was not fully analyzed.

The accident scenarios that are examined in detail in this assessment include the scissors lift failure where either a road or rail cask is dropped before transfer to the Module Handling Cell (MHC), the overhead carriage failure where a loaded fuel module is dropped on top of another module by the MHC emptying robot, and a failure in the shaft and hoisting facilities where a fuel container (inside a steel transfer cask) is dropped down the shaft (Russell and Villagran 1993). Each of these three events is used to generate two reference accident scenarios, a first set (S1, S3, V1) where correct operation of the ventilation system is assumed and a second set (S2, S4, V2) where loss of filtration of the ventilation exhaust is added to the event sequence.

The reference accident scenarios are summarized in the following table:

Scenario	Description[*]
S1	**Scissors lift failure:** The open road/rail transportation cask is dropped before transfer of the fuel modules to the Module Handling Cell (MHC).
S2	**Scissors lift and ventilation failure:** Same as S1 but adding a failure in the ventilation system so that the airborne effluent by-passes the High Efficiency Particulate Air (HEPA) filters.
S3	**Overhead carriage failure:** A loaded fuel module is dropped on top of another loaded fuel module in the MHC.
S4	**Overhead carriage and ventilation failure:** Same as S3 but adding a failure in the ventilation system so that the airborne effluent by-passes the HEPA filters.
V1	**Failure in the shaft and hoisting facilities:** A fuel container is dropped down the shaft.
V2	**Failure in the shaft and hoisting facilities with ventilation failure:** Same as V1 but adding a failure in the ventilation system so that the airborne effluent by-passes the HEPA filters.
	[*] Facilities and equipment are described in detail in Simmons and Baumgartner (1994).

Protection against the set of external events normally considered in the design of nuclear facilities was also assessed. In general terms, the UFDC would be designed to withstand the most severe natural phenomena expected to occur once in a 100-year period, in a manner that will not result in an unacceptable risk to the public. Two other scenarios initiated by external events, with potentially serious consequences, were also analyzed: criticality due to flooding and vault cave-in.

An assessment of the potential criticality conditions (McCamis 1992) occurring as a result of flooding in the vault concluded that criticality was not possible. Based on the near-field and far-field stability studies (Tsui and Tsai 1994; Golder Associates 1993, respectively), no cave-ins serious enough to result in fuel container damage can reasonably be expected.

Analysis Results

The analysis was performed using the same public safety assessment methodology as that used for accident analysis for licensing nuclear generating stations. The short-term radiological assessment model PSAC (Russell 1993e) was developed to calculate the radiological impact on the public from accidents during operation of the UFDC. Radionuclides released from the UFDC may lead to a radiation dose via a number of routes or pathways. These are illustrated in Figure ES-2.

a) Individual Dose

The maximum individual doses from the identified accident scenarios occurring during operation of the disposal centre are presented below (Russell and Villagran 1993). The dose results indicate that inhalation is the critical pathway during an accidental release of radionuclides from the UFDC. For accident scenario S1, the critical radionuclide was found to be ^{3}H, which accounted for 62% of the total dose. For accident scenario S2, the critical radionuclides were ^{241}Am, ^{241}Pu and ^{239}Pu, which accounted for 89% of the total dose.

The thyroid dose was relatively insensitive to the presence or absence of particulate filtration since most of the thyroid dose was due to exposure to ^{3}H.

Accident Scenario	Maximum Individual Doses (mSv)			
	Total Whole Body Dose		Total Thyroid Dose	
	Adult	Infant	Adult	Infant
S1	2.3×10^{-4}	2.0×10^{-4}	1.7×10^{-4}	61.0×10^{-4}
S2	1.3×10^{-1}	2.0×10^{-1}	3.1×10^{-4}	1.5×10^{-4}
S3	7.7×10^{-5}	6.7×10^{-5}	5.6×10^{-5}	3.4×10^{-5}
S4	4.4×10^{-2}	6.5×10^{-2}	1.0×10^{-4}	5.0×10^{-5}
V1	2.9×10^{-4}	2.5×10^{-4}	2.1×10^{-4}	1.3×10^{-4}
V2	1.6×10^{-1}	2.5×10^{-1}	3.9×10^{-4}	1.9×10^{-4}

b) Collective Dose

The maximum collective doses from the identified accident scenarios occurring during operation of the disposal centre were as follows:

Accident Scenario	Maximum Collective Dose (person-Sv)
S1	6.4×10^{-5}
S2	3.6×10^{-2}
S3	2.1×10^{-5}
S4	1.2×10^{-2}
V1	8.0×10^{-5}
V2	4.5×10^{-2}

The highest population density of the three regions (namely, the Southern region) was used in the calculation of the collective dose from accidents because it would give more conservative results. The collective dose within 100 km of the UFDC for the accident scenarios under consideration varied from about 10^{-5} to 10^{-1} person-Sv. The largest collective dose to the population was estimated to be 4.5×10^{-2} person-Sv from accident scenario V2, the dropped fuel container in the vault and ventilation system failure. Also the collective dose from accident scenario S2 was similar in value to scenario V2.

c) Risk to Humans

Using the risk coefficient of 5×10^{-2} fatal cancers per Sv for members of the public (ICRP 1991), the number of fatal cancers resulting from an accident at the UFDC, assuming that an accident has occurred and that the population was there to be exposed, varied from 1.0×10^{-6} to 2.2×10^{-3}. Because these fatality risks are much less than one, no fatal cancers would be expected.

Comparison of Doses to Regulatory Criteria

Based on current safety analysis practices, the consequences and probabilities of accidents could be compared to the following regulatory compliance limits currently used for licensing nuclear generating stations (Ontario Hydro 1990a):

Class of Accident	Dose Limit (mSv)	
	Whole Body Dose	Thyroid Dose
Class 1: Accidents with a probability $f \geq 10^{-2}$	0.5	5
Class 2: Accidents with a probability $10^{-2} > f \geq 10^{-3}$	5	50
Class 3: Accidents with a probability $10^{-3} > f \geq 10^{-4}$	30	300
Class 4: Accidents with a probability $10^{-4} > f \geq 10^{-5}$	100	1 000
Class 5: Accidents with a probability $f < 10^{-5}$	250	2 500

The estimated annual frequency and the associated accident event class of the six postulated accident scenarios at the UFDC are shown in the following table. All doses to the critical group (either adults or infants) were found to be a small fraction of the dose limits.

Accident Scenario	Accident Frequency (a^{-1})	Accident Class	Maximum Individual Dose to the Critical Group (mSv)	Fraction of Dose Limit
S1	2.1×10^{-3}	2	2.3×10^{-4}	4.6×10^{-5}
S2	1.6×10^{-4}	3	2.0×10^{-1}	6.7×10^{-3}
S3	2.6×10^{-2}	1	7.7×10^{-5}	1.5×10^{-4}
S4	2.0×10^{-3}	2	6.5×10^{-2}	1.3×10^{-2}
V1	4.0×10^{-3}	2	2.9×10^{-4}	5.8×10^{-5}
V2	3.0×10^{-4}	3	2.5×10^{-1}	8.3×10^{-3}

The estimated doses for each accident scenario, can also be compared with the Protective Action Levels (PALs) (Government of Ontario 1986) (see table below) to determine which, if any, protective measures would be required.

The worst possible scenario (V2) has a maximum possible infant whole body dose of 0.25 mSv. The lowest action level, corresponding to a ban on food and water consumption, would be triggered at a dose level above 0.5 mSv. Thus, by comparison with the PALs, none of the protective measures would be required.

Protective Action Levels (PALs) (Government of Ontario (1986)				
Measure	Lower Level		Upper Level	
	Effective (mSv)	Thyroid (mSv)	Effective (mSv)	Thyroid (mSv)
Sheltering	1	3	10	30
Evacuation	10	30	100	300
Thyroid Blocking	-----	30	----	300
Banning Food/Water Consumption	0.5	1.5	5	15

ES6.3 POTENTIAL EFFECTS ON WORKERS - NORMAL CONDITIONS

Radiological and non-radiological hazards to workers were identified and quantified using labour estimates for the UFDC. It should be noted that at the implementation stage, a formal occupational radiation management program would be established to minimize radiation doses. The radiological risks for workers would be kept low by means of optimizing system designs and procedural developments.

Radiological Hazards

The estimated collective doses to workers from operation of the disposal centre were as follows:

Activity	Collective Dose to Workers (person-Sv·a^{-1})
Operation	1.4
Service and Maintenance	0.021
Repairs	0.036

The maximum individual doses for various job categories were estimated to be as follows:

Job Category	Maximum Individual Worker Dose ($mSv \cdot a^{-1}$)	Percentage of Atomic Radiation Worker Limit[1]
Management and Professional	10	20 %
Engineer/Technical (Operators)	17	34 %
Trades (Mechanics)	17	34 %
Support Staff	6	12 %

1 Currently 50 $mSv \cdot a^{-1}$, the AECB has proposed to lower it to 20 $mSv \cdot a^{-1}$.

Non-radiological Hazards

The chronic non-radiological hazards from the disposal centre operation were reviewed. They included exposure to dust, noise and emissions from equipment. At this conceptual design stage, it was not possible to quantify these hazards: the extent of airborne pollution would depend largely upon the efficiency of the ventilation system; dust in the rock crushing plant would be inherent, but quantities and concentrations have not been estimated at this stage of assessment; typical levels of noise and vibration from metal stamping machines in the basket and container fabrication area are unknown. In all cases, workers would be required to wear suitable eye, hearing and breathing protection (Simmons and Baumgartner 1994). It is expected that the implementing organization would have a better occupational health and safety record than the industry average because of the establishment of stringent working procedures, the implementation of health and safety programs and less emphasis on production targets.

ES6.4 POTENTIAL EFFECTS ON WORKERS - ACCIDENT CONDITIONS

Radiological Hazards

The worst-case scenario for a radiological accident associated with operation at the surface facilities resulted in an estimated individual dose of 16.5 mSv whole body and 7.5×10^{-6} mSv to the thyroid. The worst-case scenario for an accident occurring underground resulted in an estimated individual dose of 20.5 mSv whole body and 9.3×10^{-6} mSv to the thyroid. There is no AECB dose limit for workers under accident conditions. Ontario Hydro has established a limit of 30 mSv for possible accidental conditions at the nuclear station. The calculated dose to workers from accident conditions at the UFDC would be below this limit.

Using the risk coefficient of 4×10^{-2} fatal cancer per Sv for workers (ICRP 1991), the maximum risk of a fatal cancer resulting from an accident at the UFDC, assuming that an accident has occurred and that the worker was there to be exposed, would be 8.2×10^{-4}. Because this is much less than one, no fatal cancer would be expected.

Non-radiological Hazards

The total non-radiological effect on workers from accidents at the disposal centre over the 41 years of operation is 10 fatalities and 2433 lost-time injuries based on average industrial statistics (Zeya 1993a). These numbers are representative of average conditions in the industry, including the mining sector. It is expected that the implementing organization would have a better occupational safety record than the industry average because of the establishment of stringent working procedures, and the implementation of health and safety programs.

ES6.5 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT

Air Quality

Storage of the sand, gravel and bentonite clay, and the mined rock crushing and transfer operations would be done in enclosed spaces, thus reducing the potential for dust emissions during operations. The only source of dust would be the waste rock area. The application of dust suppression measures would likely be necessary to minimize dust emissions from the waste rock pile. Toxic chemical releases from the fuel were estimated to result in extremely small concentration in the air, of the order of 10^{-15} to 10^{-17} $mg \cdot m^{-3}$.

Water Quality

Any effect on the water quality would be associated with operation of the water supply system, site runoff and waste waters discharge. The water treatment provisions and run-off control would prevent degradation of existing water quality. The toxic chemical releases from the fuel were estimated to result in very low concentrations that are insignificant fractions of regulatory and background concentrations. The exception is technetium, which is very rare in the environment. However, concentrations of technetium resulting from releases are not expected to lead to any significant impacts on the environment.

Land Use

Provided that lands cleared during construction are landscaped and planted with new vegetation to minimize any erosion potential, future land use would be mostly affected by the presence of the waste rock pile. Toxic chemical releases from the fuel were shown to result in soil concentrations that are an insignificant fraction of the regulatory or background concentrations.

Ecosystem/Flora and Fauna

Effects during the operation stage of the facility would be similar to those in the construction stage, but much smaller in magnitude.

Ambient Noise

Noise from vehicles travelling to and from the site was expected to cause the greatest impact. Controls, such as muffling devices, would be employed as necessary to minimize excessive noise from these operations. Noise from the operation of the vault ventilation system would also need to be mitigated. Standard methods are available.

Non-Renewable Resources

Non-renewable resources, such as titanium, carbon steel, bentonite clay, glacial lake clay, silica sand, propane and glass would be used during operation of the facility. Except for bentonite clay, none of the required materials are currently in short supply in Canada, and there are substantial reserves for future use. Although there are known reserves of bentonite clay in Canada, extraction is not economical at this time and currently around 80% of the Canadian consumption of bentonite is imported from the United States. It is expected that the facility's requirements could also be fulfilled in that manner.

Traffic

A small increase in traffic would result from transportation of material during the operating stage. The effect on the local area would depend on the level of use of the existing road and rail networks.

Aesthetics, Natural and Historical Features

Aesthetic effects can be mitigated with appropriate landscaping provisions. Much of the effect of a disposal centre on surrounding natural and historical features would have occurred during the construction stage. Additional protective measures could be used during the operating stage to minimize additional effects.

ES6.6 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL, AND ECONOMIC ENVIRONMENT

The socio-economic impact assessment was based on a review of experience in the operation of large-scale, nuclear and non-nuclear projects, a review of public opinions and concerns, and on a framework for assessing the interactions between a community and project characteristics (Paez-Victor 1993). Possible impacts were identified, and possible mitigation measures that could be part of an impact management program (based on the principles outlined in Section ES.4.1) were reviewed. A list of the major case studies and industrial experiences used in this assessment is presented in Appendix D of the main Preclosure Assessment document.

Analysis elsewhere in the Preclosure Assessment shows that health and safety impacts are expected to be very small. Nevertheless, community concerns about potential health and safety impacts could constitute an important source of residual impact. It is important, therefore, to have an impact management program that is responsive to such concerns. In addition to routine monitoring and reporting of disposal facility emissions, impact management measures could include:

- continuing public and occupational health and safety monitoring, possibly linked to regulatory or academic health establishments; and

- encouragement of scientific research at the disposal facility, especially radiological research by national or international scientific institutions.

During the operation stage, the most positive impacts of a disposal facility operation would likely be those typically associated with large projects; namely, increased employment, stimulation of the local economy and associated improvements to the local infrastructure (health, recreation, education, etc.).

The in-migration of disposal facility operating staff and their families could also impact on the community by changing its demographic composition. Changes to the natural environment could also give rise to socio-economic impacts.

Impacts related to demographic changes and other types of impact could be managed within the framework of the impact management program that would have been instituted at the beginning of the siting stage, continued and adapted through the construction stage and which should be re-evaluated to manage the impacts of the operation stage. The successful management of expected and unexpected social, economic, cultural, health and/or environmental impact is contingent on a system of vigorous and creative joint impact management with the community throughout the life of the project.

Such a joint impact management program, in a site-specific social and ecological context, would be essential for full evaluation of any residual effects of disposal facility operation.

ES6.7 POTENTIAL IMPACTS ON THE PROVINCIAL AND NATIONAL ECONOMY

The economic impacts on Ontario and on the rest of Canada were estimated in terms of Gross Domestic Product (GDP) and employment, using Ontario Hydro's interprovincial input-output model.

The analysis showed that the economic impacts associated with the various stages of the disposal facility over the period 1991-2079, in Ontario as well as in the rest of Canada, would peak during the construction period (2014-2020). For Ontario, the disposal centre is expected to contribute about $4 789 millions (net present value) to the GDP and 329 000 person-years of employment. On average, these impacts represent less than 0.01% of the annual provincial GDP and labour force.

For the Canadian economy as a whole (including Ontario), the expenditures on the disposal facility are expected to contribute some 420 500 person-years of employment and $5 791 million (net present value) to the GDP.

The employment impact estimates assumed that productivity would remain at the 1991 level. The employment impacts would be smaller if they were adjusted for potential future productivity gains. Furthermore, these impacts should not be treated as benefits, because some of the jobs created may be drawn from other sectors of the economy. Consequently, the net benefits from the UFDC could be some fraction of the economy-wide estimates.

ES6.8 SECURITY AND SAFEGUARDS

Security in the context of used fuel disposal consists of physical protection measures developed to protect against wilful acts which could result in the theft of nuclear material, or sabotage of the disposal centre facilities or of the contained used fuel, so as to endanger the public and UFDC staff health and safety. Physical protection of nuclear material is the responsibility of each state. The potential hazards from used fuel are radioactive contamination and the radiation fields arising from the decay of used fuel isotopes.

With the concern that the public has for nuclear power and radioactive materials (Greber and Anderson 1989), it was recognized that the security procedures for the UFDC must be comprehensive and effective enough to protect the public, and must inspire public confidence.

Canada has among the most stringent safeguards policies in the world to minimize the risk that exported uranium and/or CANDU technology may be used to acquire nuclear weapons (DEA 1985). The Federal government safeguards commitment under the Nuclear Non-proliferation Treaty (NPT) is implemented via the Atomic Energy Control Act which authorizes its agency, the AECB, to regulate the acquisition, use, storage and transport of nuclear materials in Canada.

The design requirements for disposal centre security and safeguards were reviewed, based on current practices, AECB regulations (AECB 1988b), and International Atomic Energy Agency (IAEA) recommendations (IAEA 1972a, 1972b, 1985, 1991a, 1991b). The design provisions were found to meet all the requirements.

ES7. ANALYSIS OF POTENTIAL EFFECTS FROM USED FUEL TRANSPORTATION

The disposal centre engineering study assumed that the centre would receive used fuel from Ontario, Quebec and New Brunswick, at a rate of 250 000 bundles per year, for a total of 10.1 million bundles over the disposal facility operating lifetime. This is equivalent to 1 300 truck shipments each year, 44 train shipments, or 36 barge shipments. The transportation system design is summarized in Section ES 2.2.

Shipment of used fuel is routine practice in Europe, by rail, road and sea; between Europe and Japan, by sea; and in the US, mainly by road. No transportation accidents involving used fuel have resulted in injury or property damage attributable to the radioactive nature of the fuel. In nearly thirty years of experience, including many thousands of shipments of radioactive materials (although mostly materials other than used fuel), Ontario Hydro has never had an accident that resulted in any release of radioactive contents.

Ontario Hydro performed an environmental and safety assessment of the transportation of used fuel from the sites of its nuclear generating stations to a conceptual disposal centre located somewhere in the Ontario portion of the Canadian Shield (Grondin et al. 1993). The Ontario Hydro study examined the effects of transporting 180 000 bundles per year, which is the maximum number of bundles per year that could be taken out of used fuel storage pools based on their current design. This study was used as the basis for the transportation analysis. The potential additional effects of transporting 250 000 bundles were analyzed by sensitivity analysis.

The scope of the transportation assessment included the following activities: loading of used fuel modules at the nuclear generating stations, and off-site transportation by road, rail and water, including inter-modal transfer for water transportation. Potential effects on public and worker safety, the natural environment, the socio-economic environment, and direct, indirect and induced economic (economy-wide) impacts were examined.

ES7.1 REGULATORY FRAMEWORK

The road and rail cask were designed in accordance with the AECB Transport Packaging of Radioactive Materials regulations (AECB 1991b). These regulations specify the external dose rate around the cask and allowable leakage under normal and accident conditions. The transportation casks would provide a high standard of safety and would ensure that only insignificant quantities of radioactive material could escape from the cask, even in severe accident conditions.

The used fuel transportation program also met the requirements of the Transportation of Dangerous Goods regulations and all other standard transportation regulations and legislations.

ES7.2 POTENTIAL RADIOLOGICAL EFFECTS ON THE PUBLIC AND ENVIRONMENT - NORMAL CONDITIONS

Under normal conditions of transport, radiological impact on members of the public would be limited to exposure to the low radiation fields around the cask.

a) Individual Doses

Individual doses under normal transportation conditions were calculated (Kempe 1993a) using the models in the code INTERTRAN, sponsored by the International Atomic Energy Agency (IAEA). Doses were calculated for the following potentially exposed groups:

- the general population residing near the transportation route and pedestrians;
- the population near shipments during stops; and
- the population in other vehicles using the same transportation route.

The maximum doses estimated from transporting 250 000 used fuel bundles per year using the three modes were as follows:

Mode	Destination	Dose ($mSv \cdot a^{-1}$)	Percentage of AECB Dose Limit[d]
Road	All	0.09[a]	2 %
Rail	All	0.0004[b]	0.008 %
Water	All	0.05[c]	1 %

a Dose to persons present at a truck stop used by the shipments
b Dose to persons living beside the rail link
c Dose to persons following a shipment through a canal (Kempe 1993a)
d Current dose limit is 5 $mSv \cdot a^{-1}$, the AECB has proposed a reduction to 1 $mSv \cdot a^{-1}$

All individual doses in normal transportation were well below the AECB limit for members of the public and also well below the dose from natural background radiation, which is 3 $mSv \cdot a^{-1}$ (Neil 1988).

b) Collective Dose

The code INTERTRAN (Yamaguchi and Sartori 1986) was used to perform the collective dose calculations for normal transportation. Collective doses were calculated for the same potentially exposed groups as those listed for the individual dose calculations.

All the collective doses were small, the largest being 0.131 person-$Sv \cdot a^{-1}$ for the shipment of 250 000 used fuel bundles to the Northern region centroid by the water-road mode. Because of the low speed of the barge during travel and the relatively long stop times at the locks, doses were the highest via the water mode.

Although wide variations were seen among the cases, the absolute doses are not high enough to justify drawing a distinction between the modes and destinations, based on this measure.

Using the risk coefficient of 5 x 10^{-2} fatal cancer per Sv (ICRP 1991), the maximum number of fatal cancers in the entire exposed population would be 0.006 per year, and 0.3 over the 41 years of operation. Because this is less than one, no fatal cancer would be expected.

c) Doses to Non-human Biota

The individual doses to humans were calculated assuming high or 100% occupancy. In addition, since the assessed doses were due entirely to external radiation from the cask, absorbed dose from external radiation from the cask, absorbed dose and dose equivalent were assumed to be, for practical purposes, the same. A maximum dose of 0.09×10^{-3} Gy·a^{-1}, or about 1×10^{-8} Gy·h^{-1}, was estimated for non-human biota. This is well below the level of ~10^{-4} Gy·h^{-1}, at or below which no radiological effects have been observed in natural systems (Rose 1992).

ES7.3 POTENTIAL RADIOLOGICAL EFFECTS ON THE PUBLIC AND ENVIRONMENT - ACCIDENT CONDITIONS

The used fuel is not flammable, and only conventional fire hazards would be associated with an accident to the shipment. However, a severe transport accident involving a used fuel shipment could potentially cause radiation doses to members of the public in two ways:

- loss of shielding leading to increased exposure to direct radiation from the used fuel; and
- seal failure and fuel damage leading to escape of airborne radioactive material from the cask.

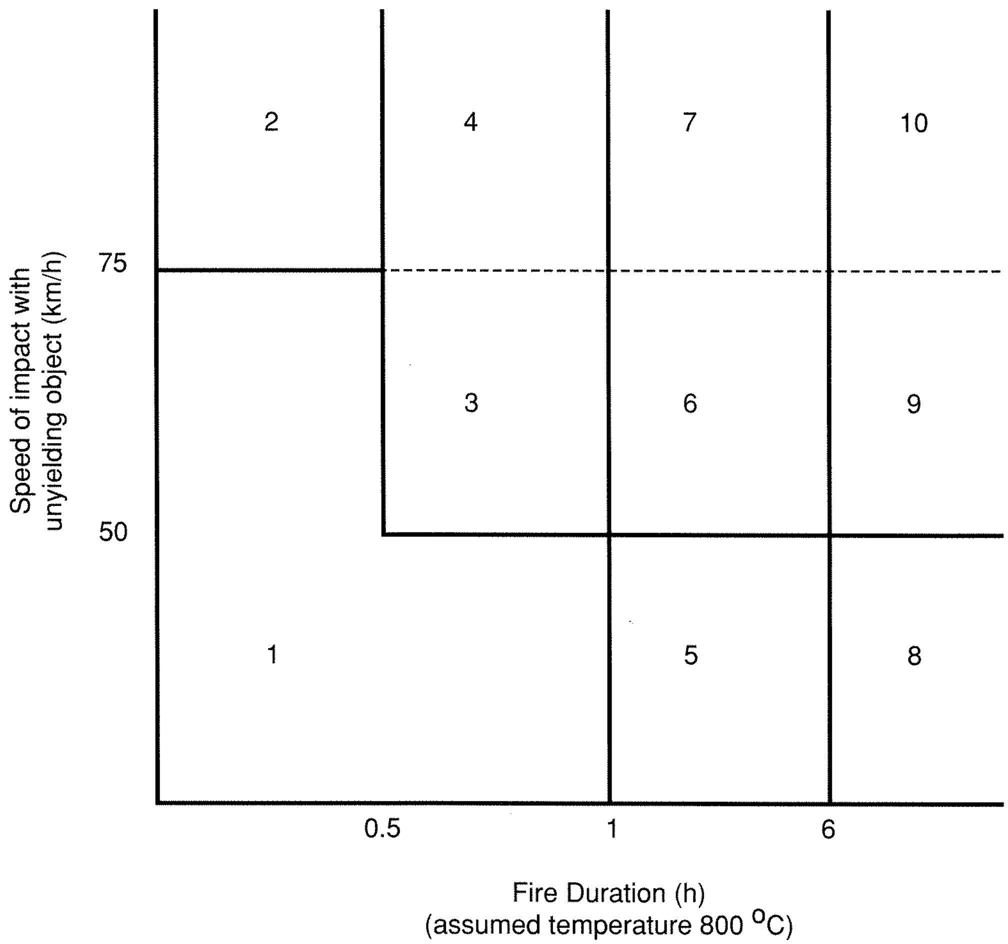
a) Accident Severity Categories

To examine the radiological impact of hypothetical accidents severe enough to cause a breach of the cask integrity, the range of postulated accident conditions was divided into a number of accident severity categories. These accident categories are shown in Figure ES-3. The first category consisted of those accidents that were not severe enough to affect the integrity of the cask, and for which the radiological consequences were bounded by the allowable leakage limits imposed by the AECB for the cask. The other categories were chosen to represent a spectrum of accident conditions for which the release from the used fuel transportation cask would vary from minimal up to the most severe credible . The spectrum of possible accidents was broken down into ten categories. The radioactive release in each severity category was characterized in terms of the following:

- the occurrence of seal failure (which might permit escape of gases and fine particulates from the cask);
- the fuel temperature reached (which would affect the release of volatiles from failed fuel, might cause additional fuel failure, and might result in oxidation of failed fuel);
- the fraction of fuel subject to impact rupture; and
- the fraction of fuel subject to creep rupture.

These parameters were in turn related to the impact and thermal environment experienced by the cask. The accident severity categories were, therefore, characterized by the impact and thermal environment experienced by the cask, as shown in Figure ES-3. Possible impacts were divided into three ranges: 0 - 50 km·h^{-1}, 50 - 75 km·h^{-1}, and over 75 km·h^{-1}. Note that these speeds represent impact with an unyielding surface although, in reality, objects involved in a collision are not unyielding. This was taken into account in deriving the impact speed with a real target needed to obtain an impact equivalent to a 50 km·h^{-1} or 75 km·h^{-1} speed of impact with an unyielding target. The thermal environment was characterized by the fire duration, assuming an engulfing fire of 800°C. The possible durations were 0 - 0.5 h, 0.5 - 1 h, 1 - 6 h, and greater than 6 h.

The ten categories were used in the calculation of radioactive releases from the cask and in the estimation of probability of accidents. In the final calculations, the release in Categories 3 and 4, Categories 6 and 7, and in Categories 9 and 10 were found to be the same. In the subsequent calculation of doses due to radioactive releases from the cask, the ten categories were condensed into seven, as indicated on Figure ES-3.



Note: Ten categories are used in the calculation of radioactive releases and in estimation of accident severity probabilities. For the dose calculations, the ten categories are condensed into seven, as indicated by the solid lines.

FIGURE ES-3: Severity Category Scheme for Transportation Accidents

b) Accident Probability

A simplified form of fault tree analysis was used to estimate the probability of each severity category, for each mode. This methodology has been commonly used to estimate the probability of rare scenarios where little or no historical data were available for those specific scenarios. The event probabilities (e.g. probability of a collision occurring in a particular speed range) were taken from the literature. Conservative simplifying assumptions were made (e.g. as to orientation of the cask at the time of impact).

The conditional probability of an accident in each severity category (i.e. the probability that an accident occurs in that severity category, given an accident has occurred) was summarized as follows:

FRACTION OF ACCIDENTS IN SEVERITY CATEGORY

Severity Category	Given an accident, probability of this accident being of a given severity		
	Road	Rail	Water
1	0.99998	0.99988	0.99999
2	10^{-5}	10^{-4}	0
3/4	10^{-7}	10^{-6}	10^{-8}
5	10^{-5}	10^{-5}	10^{-6}
6/7	10^{-8}	10^{-7}	10^{-7}
8	0	10^{-5}	10^{-5}
9/10	0	10^{-7}	10^{-6}

c) Maximum Short-Term Individual Dose

The maximum individual dose calculated for severe accident conditions was 10-40 mSv, for an accident frequency of 10^{-6} per year or less. The same radiation dose limits that applied to the safety analysis for disposal centre operation were assumed to apply to transportation accidents (see Section ES6.2.2). The worst case transportation accident, with a frequency of approximately 10^{-6}, would fall in class 5, bounded by a limit of 250 mSv. The maximum doses, 10 - 40 mSv for infants, would only be a fraction of this limit.

d) Collective Dose

The collective dose due to a severe transport accident with a frequency of about 10^{-6} per year would be of the order of 1 person-Sv for an estimated exposed population of 10^5 persons. This may be regarded as an upper bound. Using the ICRP risk coefficient of 5×10^{-2} fatal cancers per Sv (ICRP 1991), the number of fatal cancers resulting from exposure of this population to a severe transportation accident would be 0.05. Because this is much less than one, no fatal cancer would be expected.

e) Long-Term Doses

Adult doses from long-term groundshine and re-suspension were compared with the short-term doses. With cleanup, the individual dose would increase by about 60% if long-term pathways were included, but if no cleanup actions were undertaken, the dose could increase by a factor of ten, due to re-suspension. The collective dose would be affected most by inclusion of the long-term pathways, because of the effect of cesium deposition from the air during elevated releases.

Exposure via the foodchain was not included in the main calculations, because control of food supplies would be exercised, and would be the main factor affecting exposure. Calculations (Kempe 1993a) indicated that, for an accident in Severity Category 2, the foodchain dose at 100 m, without intervention (i.e. cleanup), might be a factor of 10 or so more than that for inhalation, or about twice the dose for inhalation and groundshine together. This dose is in the range (>0.5 mSv; Government of Ontario 1984) at which intervention might be considered, but, given the conservatism in the calculation, it is unlikely the intervention would be required.

ES7.4 POTENTIAL RADIOLOGICAL EFFECTS ON WORKERS - NORMAL CONDITIONS

Specific routine radiological hazards were identified through a systematic analysis of the reference transportation systems, using Ontario Hydro's experience in handling used fuel and experience in the transportation industry. The design of the reference system assessed is not yet refined to minimize worker doses. At the implementation stage, the ALARA (As Low As Reasonably Achievable) design process would be used. Various measures can be identified which would reduce both individual and collective worker doses.

a) Radiation Dose Estimates

During cask movement, the cab dose was calculated to be 0.00153 $mSv \cdot h^{-1}$. The IAEA guideline (IAEA 1985) of 0.02 $mSv \cdot h^{-1}$ maximum is, therefore, met with a comfortable safety margin. Although no specific limits exist for rail and ship crews, dose rate estimates in the rail caboose and in the occupied portions of the tug/barge were well below the 0.02 $mSv \cdot h^{-1}$ maximum specified for truck drivers.

The maximum annual individual doses received by members of the transport crews were estimated to be 2.4 $mSv \cdot a^{-1}$, 0.44 $mSv \cdot a^{-1}$ and 10 $mSv \cdot a^{-1}$ for road, rail and water, respectively. Therefore, radiation doses received by workers during transportation of used fuel were within the current and proposed Atomic Radiation Workers (ARW) dose limits (50 and 20 $mSv \cdot a^{-1}$ respectively).

For cask handling at the nuclear generating stations, assuming road transport, 3 shifts of 4 workers per shift, and 292 casks shipped from each station per year, the maximum annual individual dose would be approximately 10.6 $mSv \cdot a^{-1}$. This dose is also well below the ARW dose limits (currently 50 $mSv \cdot a^{-1}$, proposed 20 $mSv \cdot a^{-1}$).

b) Collective Dose and Risk

The annual average collective doses to workers vary from about 0.2 person-Sv to almost 1 person-Sv per year.

The radiological risk to workers were estimated as follows:

Mode	Fatal cancers per year from normal transportation using a risk factor of 4 x 10^2 fatal cancers per Sv		
	to Southern Region Centroid	to Central Region Centroid	to Northern Region Centroid
Road	1.7 x 10^2	1.9 x 10^2	2.0 x 10^2
Rail	6.3 x 10^3	6.0 x 10^3	6.2 x 10^3
Water-Road	-	2.7 x 10^2	2.8 x 10^2
Water-Rail	-	1.1 x 10^2	1.1 x 10^2

Since the numbers in this table are all well below one, no fatal cancer is expected from normal used fuel transportation.

ES7.5 POTENTIAL NON-RADIOLOGICAL EFFECTS ON WORKERS - NORMAL CONDITIONS

For normal transportation, estimates of non-radiological hazards were derived based on experience with similar industries, using equipment of the same size and type. Where quantification was not possible, a qualitative analysis was performed.

The analysis assumed that worker protection measures in accordance to the Ontario Occupational Health and Safety Act (Government of Ontario 1990c) would be implemented to ensure adequate control of noise and exhaust emissions in the working area.

ES7.6 POTENTIAL RADIOLOGICAL EFFECTS ON WORKERS - ACCIDENT CONDITIONS

The analysis used the same accident severity categories as those in the public radiological safety analysis presented above.

The potential pathways to worker exposure were:

1. inhalation of radioactive material in the plume;
2. inhalation of re-suspended radioactive materials;
3. external radiation from ground deposits (groundshine); and
4. direct external radiation from radioactive material remaining in the cask.

For the transportation crew, pathways 2, 3 and 4 were insignificant compared to 1 due to the short length of time over which the crew would be exposed and the small amount of ground deposits anticipated within 50 m of the accident site. In addition, no loss of cask shielding is expected, therefore, the contribution from 4 was equal to the chronic dose rate.

The following assumptions were used to estimate the frequency-weighted annual dose for all accidents:

- the transport crew survives all accident severities and remains within 50 m of the release point;
- in the event of a fire, the plume rise prevents a dose accumulation in the vicinity of the accident, hence the source term to workers is only the short-term release; and
- clean-up after the accident is not included in the doses.

The frequency-weighted individual doses using the above assumptions were as follows:

Mode	Individual Frequency Weighted Dose ($mSv \cdot a^{-1}$)		
	Southern Centroid	Central Centroid	Northern Centroid
Road	2.7×10^{-4}	1.1×10^{-3}	2.3×10^{-3}
Rail	1.5×10^{-3}	4.6×10^{-4}	6.9×10^{-4}
Water/Road	-	3.5×10^{-4}	3.0×10^{-4}
Water/Rail	-	4.4×10^{-4}	3.2×10^{-3}

The collective frequency-weighted doses were as follows:

Mode	Collective Frequency Weighted Dose (person-Sv·a^{-1})		
	Southern Centroid	Central Centroid	Northern Centroid
Road	3.8×10^{-7}	1.5×10^{-6}	3.2×10^{-6}
Rail	2.1×10^{-6}	6.4×10^{-7}	9.6×10^{-7}
Water/Road	-	4.9×10^{-7}	4.2×10^{-7}
Water/Rail	-	6.1×10^{-7}	4.4×10^{-6}

The risk of a fatal cancer, using the risk coefficient of 4×10^{-2} fatal cancers per Sv (ICRP 1991), were as follows:

Mode	Fatal cancers per year associated with accident conditions using a risk factor of 4×10^{-2} fatal cancers per Sv		
	to Southern Region Centroid	to Central Region Centroid	to Northern Region Centroid
Road	1.5×10^{-8}	6.0×10^{-8}	1.3×10^{-7}
Rail	8.4×10^{-8}	2.6×10^{-8}	3.8×10^{-8}
Water-Road	-	2.0×10^{-8}	1.7×10^{-8}
Water-Rail	-	2.4×10^{-8}	1.8×10^{-7}

All of these estimates are many orders of magnitude below one, so no fatal cancer is expected.

ES7.7 POTENTIAL NON-RADIOLOGICAL IMPACTS ON WORKERS - ACCIDENT CONDITIONS

It is assumed that cask handling procedures would comply with the requirements of the Occupational Health and Safety Act Regulations 213/91 and 854 on the safe operation of cranes, and would follow the guidelines of the Construction Safety Association (1975). It was also assumed that working conditions for the driving crew would comply with the Ministry of Labour regulations.

Estimates of the non-radiological risks were based on adjusted fatality data obtained from the Workers Compensation Board (Social Data Research 1986) and on labour requirements for each activity. It was anticipated that the fatality rates in the used fuel transportation activities would be lower than the industrial rates because of the extensive training, safety procedures and standards that would be applied to the system operation. The potential non-radiological hazards would be associated with cask handling (i.e. dropping of cask, cask maintenance), and cask transport (i.e. normal traffic accidents, floundering, capsizing, explosions, fires and cargo-related accidents), and would also include miscellaneous hazards such as falling, machine and tool injuries, and on-site vehicle/personnel collisions. Over the 41 years of disposal operation, the maximum number of worker fatalities resulting from used fuel transportation is estimated as less than 2 (associated with transportation by road to the Northern region.

ES7.8 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT - NORMAL CONDITIONS

The analysis showed that:

- atmospheric emissions from used fuel transportation should have minimal effects on air quality along the transportation corridors;
- noise and traffic increases would be small enough to be within the normal day-to-day variations of existing transportation traffic; and
- commitment of natural resources to used fuel transportation would be small.

ES7.9 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT - ACCIDENT CONDITIONS

Non-radiological accident consequences, such as material damage to vehicles, personal injury and, in extreme cases, loss of life were examined.

Traffic Accidents

The expected number of accidents per year on the reference routes was calculated based on reported accident rates for general traffic. The number of these accidents that could statistically involve a used fuel transportation vehicle and their consequences were also estimated.

The consequences of a used fuel transportation accident for all three modes of transport are as follows:

Consequences of UFT accidents	Location	Number of consequences per year		
		Southern	Central	Northern
ROAD				
- material damage only	Rural	0.53	1.13	2.38
	Suburban	0.02	0.03	0.07
	Urban	0.01	0.01	0.01
- personal injury	Rural	0.27	0.56	1.20
	Suburban	0.01	0.02	0.04
	Urban	0.01	0.01	0.01
- loss of life (including drivers)	Rural	0.005	0.01	0.02
	Suburban	0.0002	0.0003	0.0007
	Urban	0.0001	0.0001	0.0001
RAIL				
- personal injury	Rural	0.35	0.14	0.2
	Suburban	0.014	0.007	0.007
	Urban	0.02	0.014	0.007
- loss of life	Rural	0.11	0.04	0.06
	Suburban	0.004	0.002	0.002
	Urban	0.006	0.004	0.002

continued...

concluded...

Consequences of UFT accidents	Location	Number of consequences per year		
		Southern	Central	Northern
WATER-ROAD				
- personal injury	Open Water	-	0.0002	0.0002
	Channel/River	-	0.0004	0.0004
	Road-Rural	-	0.32	0.24
	Road-Suburban	-	-	0.03
- loss of life	Open Water	-	0.0004	0.0004
	Channel/River	-	0.0008	0.0008
	Road-Rural	-	0.006	0.004
	Road-Suburban	-	-	0.0005
WATER-RAIL				
- personal injury	Open Water	-	0.0002	0.0002
	Channel/River	-	0.0004	0.0004
	Rail-Rural	-	0.05	0.6
- loss of life	Open Water	-	0.0004	0.0004
	Channel/River	-	0.0008	0.0008
	Rail-Rural	-	0.015	0.18

Traffic Disruption

Traffic accidents could interrupt the normal road, rail and water flow of traffic and disrupt the surrounding land and water uses. The establishment of an emergency response plan, required under the Transportation of Dangerous Goods Act, should minimize impacts.

Effects on the Natural Environment

Contents of diesel tanks or radiator water could be spilled as a result of impact. The diesel tank could also catch fire. Given that these hazards would be of the same nature as for standard transportation activities, and the small amount of hazardous material available for release, there should be minimal impacts on the environment. The operation of an emergency response plan should also minimize the adverse impacts of used fuel traffic accidents on the environment.

ES7.10 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT

The analysis was based on the transportation system design, studies of the concerns and perceptions of the general public, community characteristics and the social processes which determine the nature and significance of socio-economic changes at any location. Socio-economic impact assessment research and case studies were used extensively.

The assessment had an impact management focus, in that it identified as full a range of socio-economic impacts as possible and demonstrated that they can be addressed through a number of impact management measures. It should not be assumed that potentially-affected communities would experience the full range of impacts, the same kinds of impacts, or impacts to the same degree. However, the types of impacts identified have been encountered before, and substantial experience (as outlined in Hardy Stevenson and Associates 1992a; Lockart-Grace 1993; and Paez-Victor 1993) exists in managing them.

Normal Conditions

Social, cultural and economic impacts could be associated with all aspects of the used fuel transportation, for any of the three modes under consideration: transportation along the route; transfer facility and access road/rail construction; and siting/routing.

Potential impacts to social and cultural vitality related mostly to the transfer facility and access road/railway construction could be: resident displacement, family impacts, demographic changes, changes in housing, nuisance impacts, community satisfaction, community integration, changes in recreational facilities, and impacts on Aboriginal communities. Potential impacts to the economic viability of communities could be: workforce impacts, changes in business activity, changes in environmental quality, impacts on local income and structure, changes in housing and property values, impacts to local taxes, and impacts on Aboriginal business and economy. Potential impacts to political efficacy could be: impacts to municipal facilities and services, municipal finance and administration impacts, changes in political activity, impacts on labour unions, and impacts to the political activity of Aboriginal people.

A wide variety of impact management measures could be implemented in order to avoid, mitigate and redress negative impacts and enhance positive ones. The significance of the potential impacts could not be determined in the absence of a site-specific community, and neither could the results of impact management measures be estimated with certainty. However, impacts associated with used fuel transportation have been encountered before in different types of projects, and substantial experience exists in managing these impacts. An impact management program developed jointly between the proponent and affected communities would assure compatibility with community values and interests, and would allow for communities themselves to take part in the protection and enhancement of their natural and social environment. As a result, negative impacts could be minimized and positive ones enhanced.

Accident Conditions

The key impact assessment variables, with respect to the analysis of impacts associated with an accident, were: health and safety concerns; and safety, security and administrative requirements. Public concerns over the risk of radiological contamination are sources of potential impacts. Such concerns would be intensified in the event of an evacuation, although the safety analysis shows that the likelihood of a transportation accident severe enough to require an evacuation is extremely low.

The identified impacts also include standard and conventional impacts that could be associated with any transportation accidents.

The implementation of an emergency response plan would be part of the impact management program.

ES7.11 POTENTIAL IMPACTS ON THE PROVINCIAL AND NATIONAL ECONOMY

Using the same methodology as that used for the economy-wide evaluation of the disposal facility life-cycle costs, the impact on the Gross Domestic Product and employment in Ontario from used fuel transportation activities were calculated to be as follows:

Transportation Scenario	GDP Impact ($1990 M)	Employment Impact (person-years)
Rail 1400 km	331	35 700
Water-Rail - 1600 km	257	25 200
Water-Rail - 1300 km	238	23 600
Rail- 400 km	206	21 500
Road- 1900 km	104	11 400
Water-Road - 1700 km	103	9 900
Water-Road - 1300 km	69	7 200
Road- 400 km	44	4 700

ES7.12 SECURITY AND SAFEGUARDS

Security

Since the AECB Physical Security Regulations (AECB 1983) specify security procedures according to the radiation field of the material, they were considered to be applicable to used fuel transportation. As long as the out-of-reactor years of the used fuel did not exceed 90 years, the used fuel can be transported as a self-protecting cargo (i.e. without special security measures). The security measures specified in the reference transportation system design were found to be adequate (Frost 1993b).

Safeguards

The safeguards provisions for used fuel transportation were based on existing safeguards procedures in Canada for filling, transporting and emptying the used fuel cask, and IAEA guidelines (IAEA 1985). The most important measures considered were material accountancy, use of safeguards seals and in-situ surveillance. The proposed measures were found to be adequate (Frost 1993b).

ES8. POTENTIAL IMPACTS OF FACILITY DECOMMISSIONING, EXTENDED MONITORING AND CLOSURE

ES8.1 PRE-DECOMMISSIONING MONITORING

At the end of the disposal facility operation, performance and environmental monitoring of undefined duration may take place to provide sufficient assurance of the disposal vault's performance and continued environmental protection to be able to proceed to vault closure. No new effects from the extended monitoring activities would be expected.

ES8.2 CONTAINER RETRIEVAL

During the extended monitoring period or during operation, container retrieval may be required (e.g. to demonstrate performance or for safeguards verification). Retrieval procedures were developed as part of the reference design. If retrieval is necessary, environmental protection would be ensured through proper waste water and solid waste management procedures during the buffer cutting and retrieval operations. Occupational safety would be ensured through the use of shielding rings, skirts, decks and housings necessary to minimize radiation exposure to equipment operators. The air in the room would also be filtered to remove particulates that might be present in quantities large enough to be a risk to the operators.

ES8.3 DECOMMISSIONING

The decommissioning stage of the UFDC life-cycle would begin after the waste emplacement operations have been completed, sufficient performance monitoring data have been collected to support the application for approval to decommission and seal, and the decommissioning plans have been approved by the appropriate regulatory authorities. The decommissioning plans would outline the specific decontamination, vault sealing, dismantling, demolition, waste removal, and site restoration and marking activities, their durations and their likely effects. Decommissioning would end when the vault has been sealed, and all surface facilities have been decontaminated and removed.

Public Safety

The reference design assumed that the criteria used in the decommissioning of the Gentilly I reactor would apply to decommissioning of the UFDC. These criteria should make the site surface suitable for unrestricted public access after decommissioning. The emissions of radionuclides from the facility during decommissioning are expected to be small compared to emissions during the operating stage, since the primary source of radioactivity (the used fuel) would have been completely disposed of. Dismantling activities, which could expose activated product sources, would not create sources of the same order of magnitude as those from the operating UFDC. The radiological exposure of members of the public during the operating stage is expected to be a small fraction of the regulatory limit or exposure from natural background radiation, and the exposure resulting from decommissioning is expected to be even smaller.

Occupational Safety

Non-radiological occupational hazards during decommissioning would be similar to hazards encountered in any large demolition project, such as airborne pollutants (dust and exhaust emissions from engines), noise and vibration. Provided that procedures were in accordance with regulatory requirements on conventional hazards in the Occupational Health and Safety Act of Ontario (Government of Ontario 1990c), non-radiological effects would be minimized.

The decommissioning risk from non-radiological sources would be less than 1 fatality and about 81 lost time injuries over the decommissioning period.

The estimated collective dose to workers from decontamination work was 1.3×10^{-2} person-Sv. The average dose per worker was calculated to be 0.1 to 0.2 mSv over a 2-year decontamination period, which is well below the AECB criteria for Atomic Radiation Workers (50 $mSv \cdot a^{-1}$ currently, 20 $mSv \cdot a^{-1}$ proposed).

Natural Environment

Although no experience in the decommissioning of a used fuel disposal facility exists, considerable experience has been gained within the nuclear industry in all aspects of nuclear facility decommissioning. In the U.S., highly radioactive fuel reprocessing facilities have been decontaminated and a few have been partially converted to other uses.

Potential effects of decommissioning activities include the following:

- fugitive dust emissions could arise during the demolition of site buildings, and the use of heavy equipment;
- demolition activities could change the site topography and, if not properly managed, could increase site run-off leading to sedimentation of nearby water bodies;

- demolition of the water intake and discharge structures could disturb aquatic life near the shore by increasing water turbidity and sediment concentrations;
- waste water from decontamination activities could affect water quality; and
- local wildlife could be disturbed by the increased traffic and noise from blasting and other demolition activities.

Possible mitigation measures were identified which would minimize effects of decommissioning activities on the natural environment.

In general, the potential effects of decommissioning would likely be less than those during construction or operation. According to the reference UFDC design, radioactive waste from decommissioning of the used fuel disposal facility would be shipped off site to an existing licensed disposal facility for low and intermediate level radioactive wastes (Simmons and Baumgartner 1994). It is inappropriate at this stage to speculate about possible uses of the used fuel disposal site after decommissioning and closure.

Social, Cultural and Economic Environment

During decommissioning, the main sources of socio-economic impacts would be: the reduction of the workforce after many years of steady employment (construction and operation); the reduction in materials and services purchased; concern about possible impacts on the environment and on health and safety. Although the social dynamics during decommissioning are opposite to those during the other project stages, the potential impacts could be similar. These impacts would be lessened if, throughout the years, the disposal facility management has contributed successfully to the economic viability of communities by fostering:

- policies of regional economic diversification; and
- economic activities aimed at resource sustainability.

The relatively long time span from siting through construction and operation of the disposal facility would provide ample opportunities for joint planning to minimize adverse impacts.

ES8.4 VAULT CLOSURE

Closure would involve the removal of instruments from surface boreholes used for extended monitoring and the sealing of these boreholes. The objective of closure would be to return the site to a state such that safety does not depend on institutional controls. The closure stage could begin either immediately after the decommissioning stage or after a further monitoring stage. The closure stage would end when all monitoring boreholes, that could compromise long-term safety if left unsealed, were sealed. Effects of closure on public safety and the natural environment are expected to be much less than those during the construction, operation, and decommissioning stages.

ES9. SENSITIVITY AND SCENARIO ANALYSIS

ES9.1 SENSITIVITY ANALYSIS

A sensitivity analysis was undertaken for three main reasons. First, because the assessment used average regional parameter values to represent the affected environment, a sensitivity analysis of the effects of variations in environmental parameter values on the assessment results was needed. Second, in areas where design details were lacking, analysis assumptions were made.

Finally, since an approved disposal concept would only be implemented some time after the year 2000, the effects of time on the analysis results were examined.

The sensitivity analysis showed that for normal operating conditions of the disposal centre, the estimated dose to members of the critical group was most sensitive to changes in the parameters that affect the radionuclide emissions to the environment, the concentration of radionuclides in lake water, the bioaccumulation of radionuclides in fish, and the human ingestion rate of fish and vegetables.

Under accident conditions, the estimated dose received by the critical group was most sensitive to changes in the parameters that affected the radionuclide concentrations in the environment and the total exposure.

As expected, radiation dose rates at working locations and exposure times are the dominant parameters for occupational dose during normal conditions. Accident frequency and accident severity were the most important factors for occupational dose during accident conditions. The non-radiological effects on the workers were found to be dependent on the types of industries used to represent activities at the UFDC.

When estimating the collective dose from used fuel transportation during normal conditions, the two most important parameters (assuming no modifications were made to the design of the cask) were the number of shipments per year and the distance travelled. Cooling time of the used fuel was an important parameter for both collective and individual doses estimates. Under accident conditions, the fraction of the inventory assumed to be retained in the cask and the degree of fuel oxidation were important in determining the radionuclide releases. The number of casks assumed to be affected by an accident and the distance of the receptor from the accident were also important for individual dose. The population density was an important parameter for the collective dose estimate.

The occupational dose during transportation, on a per bundle basis, was found to be most sensitive to the distance travelled. The collective dose was found to be sensitive to the number of bundles transported.

In view of the non site-specific nature of the assessment, the natural environment analysis examined a wide range of environmental parameters and was for most part only qualitative. The analysis conclusions would, therefore, not be affected by small changes in reference environment parameters. The design features and assumptions used in the analysis were found to have more effects on the analysis results.

The effects on the natural environment from used fuel transportation depended most on distance travelled, system capacity, and on existing noise and traffic.

Because the socio-economic analysis of the UFDC life-cycle activities, including used fuel transportation, identified as wide a range of impacts as possible, changes in either the reference environment or design parameters would not invalidate the results of the analysis.

Conclusion of Sensitivity Analysis

The conclusions of the base-case analysis (based on the reference design, the reference environment conditions and some basic analysis assumptions) were found to be relatively insensitive to variations in the design parameters, environmental parameters and analysis assumptions.

Because of their non-site specific nature and impact management focus, the base-case analysis of environmental effects and the socio-economic impact assessment covered a wide range of potential impacts.

ES9.2 POSSIBLE NATURAL AND SOCIAL ENVIRONMENT SCENARIOS

The implications of certain natural environment and socio-economic scenarios were assessed. The natural environment scenarios considered were: an urban location scenario, a wilderness area scenario and a sensitive environment scenario. With the kind of siting approach outlined in Section ES4.1, however, it is not expected that a disposal facility would be located in a sensitive environment. These scenarios were considered to provide a broader context for the results of the main (reference) analysis.

The socio-economic scenario analysis summarized the results of a study of reference communities done early in the concept assessment (see Stevenson 1983, a support document to the second interim concept assessment). This study assumed that the disposal facility was placed in four reference communities modelled after unidentified, real communities: a county, a town, a township and an area of unorganized territory within which a new town would be located. The analysis was based on social and economic data gathered from each community type. Limitations of the reference communities analysis were also assessed.

ES9.3 NUCLEAR ENERGY PRODUCTION SCENARIOS

Nuclear energy production in the future and, hence, the amount of used fuel produced would depend on socio-economic factors such as the demand for electricity, the cost of producing electricity by various methods, and attitudes toward nuclear energy. It would also depend on technical factors such as environmental impacts of producing electricity by other methods and the performance of the existing nuclear generating stations. Thus, any projection about the accumulation of used fuel over time must be based on assumptions regarding these factors. Three projections on future nuclear energy and used fuel bundles production were made for purposes of the present analysis:

(1) The existing capacity is maintained to the end of the assumed 40-year operating life of each nuclear generating station, but there is no expansion;
(2) There is a nuclear moratorium leading to the shutdown of all existing reactors by January 1st 1995; and
(3) There is an expansion in nuclear energy production by which all existing nuclear generating capacity is maintained, one CANDU 600 is built in Canada outside of Ontario, and there is a 3% growth in nuclear-generated electricity production in Ontario after 1995.

The third scenario corresponds to the base-case: a facility with a capacity of 10.1 million used fuel bundles. Since the base-case has the largest capacity it is expected that the impacts of the preclosure phase for the first two scenarios would be smaller in terms of releases to the environment and total occupational impacts, and similar in terms of some of the socio-economic impacts.

ES10. FUTURE STUDY STRATEGIES FOR CONCEPT IMPLEMENTATION

ES10.1 ASSESSMENT METHODOLOGY

The main differences between the assessment strategy used in the present assessment and the strategy that would be used at the concept implementation stage are:

- The assessment at concept implementation would not be generic. Environmental effects would be assessed based on the site-specific project design, and data from monitoring and sampling of the specific environment;

- The assessment at concept implementation would be done in cooperation with the local community/public, government agencies and scientist groups, and an ecological framework would be used for the environmental assessment; and

- The assessment of the social and natural components of the environment would be integrated.

The primary purpose of an environmental assessment is to present relevant ecological and socio-economic information for consideration in project planning. From an ecological perspective, a significant effect, within specific time and space boundaries, is a an estimated or measured change in an environmental attribute which should be considered in project decisions, depending on the reliability and the accuracy of the prediction and the magnitude of the change. From a social perspective, the significance of effects needs to be established with the affected public. The environmental assessment strategy has to blend these two perspectives into an integrated environmental assessment process.

As part of the future assessment strategy, cumulative effects assessment methods are reviewed.

ES10.2 CUMULATIVE EFFECTS CONSIDERATIONS

The cumulative effects of the UFDC activities in the preclosure phase were reviewed based on the methodology outlined by FEARO for application of the new Canadian Environmental Assessment Act (FEARO 1993). Application of this methodology to a future site-specific assessment was also examined.

Three possible types of cumulative effects were reviewed:

1. the cumulative effects of existing projects at or near the site of the UFDC which should be added to the estimated effects of activities during the preclosure phase - given the non site-specific nature of this assessment, the cumulative effects could only be determined in very general terms when looking at possible existing land uses;

2. the cumulative effects within the UFDC, such as the cumulative impact of transporting the used fuel and the buffer/backfill material to the facility. The cumulative effects of traffic during the operation stage were calculated and the cumulative nature of the pathways analysis and socio-economic impact assessment were discussed; and

3. the cumulative effects of future projects at or near the site of the UFDC which should be added to the estimated effects of activities during the preclosure phase. Given the long time-frame of the UFDC implementation and the uncertain implementation date, this type of effects could not be determined explicitly.

The establishment of geographic and temporal boundaries for the assessment of cumulative effects was also placed in the context of this non site-specific assessment with an uncertain time frame for implementation.

ES11. OVERALL ASSESSMENT CONCLUSIONS

The objective of this study was to assess the safety and potential environmental effects, including socio-economic impacts, of activities in the preclosure phase of the disposal concept. Limited by the conceptual and no-site nature of the project, the assessment used the experiences of the nuclear industry and other industries, and reasonable assumptions where necessary.

The conclusions are based on the results of the analyses presented in earlier sections and on the assumption that the implementing organization, when finalizing the design and work procedures, and setting up the management structure for the UFDC and disposal system, would adopt and be committed to:

- a defence-in-depth safety philosophy;
- an ALARA (As Low As Reasonably Achievable) approach regarding emissions and exposure of the public and workers;
- an environmental protection policy;
- a health and safety policy and program;
- a public involvement policy; and
- a thorough quality assurance program.

The following conclusions are selected and summarized from a longer list of conclusions presented in the main document:

1. The reference design would allow a nuclear fuel waste disposal facility to be normally operated such that no worker or member of the public would receive a radiation dose that exceeds the limits specified by the Atomic Energy Control Board. Individual doses to the public during normal operation of the disposal facility would be small fractions of natural background dose.

2. Large-scale used fuel transportation based on the used fuel transportation system developed by Ontario Hydro would meet all the requirements of the Atomic Energy Control Board (AECB), the International Atomic Energy Agency (IAEA) and Transport Canada. The analysis showed that the radiological dose from normal transportation is a small fraction of the natural background dose.

3. Non-radiological effects of the preclosure phase on the natural environment were found to be typical of large construction, underground mining and civil engineering projects. Mitigation measures exist that could reduce these effects to acceptable levels. Sensitive environmental areas would normally be avoided through careful siting of the facility.

4. The socio-economic impact assessment has been limited by the absence of a site, and, consequently, the absence of actual people and communities in which to carry out a socio-economic impact assessment. It is, therefore, not possible to be precise as to the occurrence of socio-economic impacts. Neither is it possible to evaluate the significance of the identified socio-economic impacts without knowledge of the values, opinions and concerns of the people who would be subject to these impacts.

5. The socio-economic assessment showed that the adverse impacts of the UFDC life-cycle activities can be managed based on extensive Canadian and international experiences with similar-sized projects. The assessment also concluded that the public's concerns over risk must be addressed as an integral part of the impact assessment and management process.

6. Northern communities and Aboriginal communities have particular characteristics that make them more susceptible to negative impacts from the disposal system and should be given special attention during implementation.

7. The successful management of social, economic, cultural, health and environmental impacts is contingent on a system of creative impact management jointly planned and implemented with the community.

8. Overall, the kinds of effects identified in the present document are not unique. They are similar to those encountered at large civil engineering structures, mining developments, nuclear generating stations, waste management facilities and other large scale projects. There is a considerable body of experience in the industry for assessing and managing these types of effects.

CHAPTER 1