CHAPTER 7

7. ANALYSIS OF USED FUEL TRANSPORTATION

This chapter presents an analysis of potential effects of transportation of used fuel on public and worker safety, the natural environment, the socio-economic environment, and of direct, indirect and induced economic (economy-wide) impacts.

The reference system for transportation of used fuel is described in Section 2.2. Three reference transportation systems were designed for transportation of used fuel by road, rail and water. If water transportation is used, the used fuel must be transferred to the rail or road mode to complete the journey to the UFDC. The reference transportation systems were designed to transport 180 000 used fuel bundles per year from Ontario nuclear generating stations. This yearly capacity was selected because it is the projected amount that could be handled annually at Ontario Hydro's used fuel storage pools (present and planned) with the current pool design. The difference between the design capacity of the reference transportation system (180 000 bundles/a) and the design capacity of the disposal facility (250 000 bundles/a) is discussed in Section 2.2. Transportation of used fuel from Québec and New Brunswick is discussed in Section 7.8. The effect of increasing the transportation system capacity to 250 000 bundles, and the corresponding estimates of the public and occupational risks, are given in Section 7.9.

The design of packaging to be used for transportation of radioactive materials is governed in Canada by the Atomic Energy Control Board Transport Packaging of Radioactive Materials Regulations (TPRMR) (AECB 1991b). These are based on model regulations prepared by the IAEA (IAEA 1990), and cover:

- i) radioactive contents limits for different types of packages;
- ii) approval by AECB of packages for large quantities of radioactive material and packages containing fissile material;
- iii) external radiation levels;
- iv) allowable external surface contamination;
- v) leakage of radioactivity in normal conditions; and
- vi) retention of shielding and containment of radioactive material in accident conditions.

The radioactive content of used fuel requires that it be transported in a Type B package. The requirements for Type B packages are set out in the TPRMR, and provide a high standard of safety, ensuring that only insignificant quantities of radioactive material can escape from the cask, except in extremely severe accident conditions.

The TPRMR limit the external dose rate around the package due to radiation penetrating the walls of the package. Packages are categorized and labelled, according to their external dose rate, into three categories: I - White, II - Yellow, and III - Yellow. The maximum dose rate allowed is 10 $mSv \cdot h^{-1}$ on the surface of the package, for a Category III - Yellow package, transported "exclusive use". Exclusive use is the transport of the package in or on a vehicle of which a single person has sole use, and control of all loading and unloading. The external dose rate is also limited by mode-specific regulations. These are universally based on the requirements of the IAEA Regulations (IAEA 1990 and earlier versions). In future, the AECB Transport Packaging of Radioactive Materials Regulations will also incorporate these requirements, possibly by direct reference to the IAEA Regulations. The IAEA Regulations set out limits of 2 $mSv \cdot h^{-1}$ on the surface of the vehicle, and 0.1 $mSv \cdot h^{-1}$ at 2 m from the surface of the vehicle. In addition, for road, the dose rate in any normally occupied position (i.e. the tractor cab) is limited to 0.02 $mSv \cdot h^{-1}$, unless the persons occupying such positions are provided with personal monitoring devices.

The reference transportation systems used as a basis for the analysis (see Chapter 2) are based on the demonstration cask developed by Ontario Hydro. The demonstration cask was designed for a dose rate of less than 0.1 $mSv \cdot h^{-1}$ at one metre. This corresponds with the general criterion for all packages, and results in dose rates well below the exclusive use criterion.

Changes in the annual limits recommended by the International Commission on Radiological Protection (ICRP 1991) may eventually lead to a reduction in the allowable dose rate. The effect on used fuel transportation operations is expected to be minimal, since designs exceed the present requirements.

For all packages, the maximum activity of non-fixed (removable) contamination on the external surface must be as low as practicable, and must not exceed levels specified in the regulations.

7.1 POTENTIAL RADIOLOGICAL IMPACTS ON THE PUBLIC AND THE ENVIRONMENT

7.1.1 Normal Conditions

In normal conditions, radiological impact on members of the public would be limited to exposure to the low radiation fields around the cask. The magnitude of these fields falls off quickly with distance. The maximum dose to members of the public who might be exposed to a number of shipments, and the sum of all doses to the entire population from these low fields, were calculated as described below. Full details of the assessment are given in Kempe (1993a).

7.1.1.1 Analysis Methodology

The methodology used in this assessment was developed from models originated by the U.S. Atomic Energy Commission (USAEC 1972) and later used in the U.S. Nuclear Regulatory Commission's Final Environmental Statement (FES) on the Transportation of Radioactive Material by Air and other Modes (USNRC 1977). The models used in the FES were incorporated into the U.S. computer code RADTRAN (Madsen et al. 1986) and into the IAEA sponsored code INTERTRAN (Ericsson and Elert 1983), which was based on RADTRANII. Development of INTERTRAN was reviewed and guided by an "Oversight Committee" consisting of representatives from eight IAEA member states. Research groups from various member states have carried out trial analyses using the code (De Marco et al. 1983; Petersson 1985). An IAEA Coordinated Research Programme, due to conclude in 1994, has overseen further development of INTERTRAN.

i) Collective Dose in Normal Transportation

The microcomputer version of the code INTERTRAN-1, issued by the Nuclear Energy Agency in March 1986 (Yamaguchi and Sartori 1986), was used to perform the collective dose calculations for normal transportation.

The dose to the public in each population zone was calculated for three population groups:

i) dose to general population residing near the transportation route and to pedestrians;

ii) dose to public near the shipment during stops; and

iii) dose to public in other vehicles, using the same transportation route.

The data required on the transportation environment, such as population densities and traffic counts, were mainly derived from the reference environment data base (Grondin 1993a). However, a number of assumptions and data were embedded in the INTERTRAN code. These are summarized in Table 7-1.

The INTERTRAN model represents the shipment as a point source of radiation, characterized by the transport index and the cask dimension (see below). The transport index is a number defined in the regulations, equal to the radiation level at 1 m from the package surface in units of microsieverts per hour, divided by ten (equivalent to millirem per hour). The point source representation is valid for distances from the cask about 2 m or more, and is conservative for smaller distances.

The transport index for the ten-year-cooled fuel of average burnup 685 $GJ \cdot kg^{-1}U$ was calculated to be 4.4 (Kempe 1993a). This value was derived from that given in the Safety Analysis Report for the Irradiated Fuel Transportation Cask (Ontario Hydro 1986), which is designed for ten-year-cooled fuel with a burnup of 1 008 $GJ \cdot kg^{-1}U$. This is almost the peak burnup expected, and is used as a conservative licensing criterion. The 192 bundles represent 24-48 reactor refuelling operations, which are generally random in burnup distribution. On average, the fuel to be transported would have an outer element burnup of only 685 $GJ \cdot kg^{-1}U$. Because using radionuclide data for 10-year-cooled fuel in the assessment is already conservative (10 years is the minimum out-of-reactor cooling), the average burnup was used to estimate the dose rates.

Rail cask dose rates were assumed to be the same as road cask dose rates. This is a reasonable assumption since shielding thicknesses and module orientation are similar for both cask designs.

The cask dimension used in the model was conservatively taken as the largest dimension of the cask, i.e. 1.9 m for the road cask and 4.3 m for the rail cask.

ii) Individual Dose in Normal Transportation

Individual dose under normal transportation conditions were calculated by hand (Kempe 1993a) using the same models as in INTERTRAN, for the following critical groups of most exposed individuals (these are a sub-group of the groups used for the collective dose):

i) persons living beside the route;

ii) persons at stops; and

iii) persons following a shipment.

Individual doses at stops were only calculated for the road mode, since the rail model assumes no stops (shipment is by dedicated trains with no marshalling); for the water mode, the stop time was included as part of the canal transit time used in calculating the dose to persons in a following vessel.

Note that the external doses calculated apply to all age groups. In addition, doses due to emissions from the cask in normal conditions were calculated. In normal and regulatory accident conditions (i.e. conditions which the cask would be designed to withstand), the only release of radioactivity from the cask would be by permeation through the elastomer seals. The only nuclides of interest are, therefore, those which are gaseous at normal temperatures, i.e. tritium and krypton-85. The expected releases of radioactivity in tested (normal transportation) and accident conditions are calculated in the Safety

TABLE 7-1
Assumptions Embedded in the INTERTRAN 1 Code

collective dose calculated for each transport mode	Status of shipment	Dose to		**Dose calculated for**
	- shipment stopped	Persons at stops		**all modes[1]**
	- shipment moving	Persons around the transport route		**all modes**
		Persons sharing the transport route	Moving in opposite direction	**road and rail only**
			Moving in the same direction	**road only**
zone characteristics for road mode:	Population zone	Types of road	Shielding	
	rural	2-lane highway freeway no city streets	. no shielding for pedestrians . no shielding for surrounding population	
	suburban	2-lane highway freeway no city streets	. no shielding for pedestrians . shielding factor[2] for surrounding population to account for shielding effects of buildings	
	urban	freeway city streets no 2-lane highway	. no shielding for pedestrians . various shielding scenarios for surrounding population (no shielding, shielding factor[2], total shielding[2])	
	distance	between passing vehicles:	city street 3 m 2-lane highway 3 m freeway 15 m	
		from centre of road to pedestrians	city street 5-8 m 2-lane highway 27-30 m freeway 27-30 m for rural zone 27-30 m for suburban zone none for urban zone	
		from centre of road to surrounding population	city street 8-800 m 2-lane highway 30-800 m freeway 30-800 m	
zone characteristics for rail:	distance	from centre of rail track to population	30-800 m for all zones	
		between passing trains	3 m for all zones	
	shielding	rural: none suburban: various shielding factors[2] urban: various shielding factors[2]		
zone characteristics for water:	distance	from centre of water path to population	200-800 m for rural and suburban zones no urban zone in water mode	
	shielding	none for rural zone shielding factor[2] for suburban zone no urban zone in water mode		

[1] The present analysis is based on the use of dedicated trains, with no stops.
[2] The present analysis assumed no shielding for any group.

Analysis Report (SAR) for the Irradiated Fuel Transportation Cask (Ontario Hydro 1986). The calculations conservatively assume 1% fuel failure in tested conditions and 100% fuel failure in the regulatory accident conditions.

The doses calculated for emissions (see below) were shown to be very small compared with those due to direct external radiation. This pathway was, therefore, not included in the calculation of collective doses in normal transportation conditions.

7.1.1.2 Analysis Results

1. Collective Doses

The collective doses calculated are summarized in Table 7-2. All the collective doses are small, the largest being 0.094 person-Sv per year for shipments 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, the water mode doses are the highest. The estimated exposed population for this case is 10^5 persons (an upper bound number based on the population density in each zone along the reference transportation routes and a transportation corridor width of 800 m on each side of the route), although a significant portion of the collective dose arises from exposure of smaller groups (20-30) at stops. Although there were wide variations among the cases, the absolute numbers were not high enough to justify selecting a mode or destination based on this measure.

2. Dose to Members of the Critical Groups

The maximum doses for each mode are summarized in Table 7-3. The largest calculated dose was to a person present at a truck stop used by the shipments and was 0.07 $mSv \cdot a^{-1}$. This maximum individual dose is well below the regulatory limit for members of the public of 5 $mSv \cdot a^{-1}$ (AECB 1978), and the proposed limit of 1 $mSv \cdot a^{-1}$ (AECB 1991a). It is also well below the dose due to natural background, 3 $mSv \cdot a^{-1}$ (Neil 1988). For this calculation, it was assumed that individual members of the public would be present, at 25 m from the shipment parking location, for 50% of the time, and that one-third of the shipments would stop, for one hour, at any particular truck stop.

The maximum individual doses calculated for those members of the public living beside the transportation route are given in Table 7-4. It was assumed that members of this critical group would be present continuously and be exposed to every shipment. The maximum individual doses to members of the public in vehicles following a shipment during transport are given in Table 7-5.

3. Dose from Leakage during Normal Transportation

The dose from estimated leakage from the Ontario Hydro demonstration cask during "tested conditions" (normal transportation) was calculated to be 3×10^{-6} $mSv \cdot a^{-1}$. This dose is about a factor of 10^3 less than that calculated for exposure to external radiation from the cask (Table 7-4). This pathway was, therefore, not included in the calculation of individual and collective doses for normal transportation.

TABLE 7-2
Summary of Collective Doses to the Public During Normal Transport

Mode	Destination	Collective Dose person-Sv·a^{-1}			
		Off-link[1]	On-link[2]	Stops	Total
Road	Southern Central Northern	0.0036 0.0023 0.0034	0.0070 0.0061 0.0092	0.015 0.030 0.066	0.026 0.038 0.079
Rail	Southern Central Northern	0.0033 0.0044 0.0044	0.00055 0.00033 0.00040	- - -	0.0039 0.0047 0.0048
Water-road Road Water Total	Central	 0.00029 0.021 0.021	 0.00013 - 0.00013	 0.012 0.030 0.042	 0.013 0.051 0.064
Water-road Road Water Total	 Northern	 0.0015 0.020 0.022	 0.0020 - 0.0020	 0.023 0.047 0.070	 0.027 0.067 0.094
Water-rail Rail Water Total	 Central	 0.00013 0.018 0.018	 0.00004 - 0.00004	 - 0.036 0.036	 0.00017 0.054 0.054
Water-rail Rail Water Total	 Northern	 0.00039 0.018 0.018	 0.00084 - 0.00084	 - 0.042 0.042	 0.0012 0.060 0.061

(Kempe 1993a)

1 off-link: on the side of the road, rail line or shipping lane, i.e., the surrounding population.
2 on the transportation link, i.e., in vessels using the road, rail line or shipping lane.

TABLE 7-3
Summary of Maximum Individual Dose in Normal Transportation Conditions

Mode	Destination	Dose (mSv·a^{-1})
Road	All	0.07[1]
Rail	All	0.0003[2]
Water	All	0.05[3]

1 Dose to persons present at a truck stop used by the shipments
2 Dose to persons living beside the rail link
3 Dose to persons following a shipment through a canal

(Kempe 1993a)

TABLE 7-4
Maximum Individual Dose during Normal Transport
to Members of the Public Living beside the Transport Route

Destination	Individual Dose ($mSv \cdot a^{-1}$)	
	2-Lane Road	City Street
Road		
Southern	0.0011	0.0041
Central	0.0007	0.0025
Northern	0.0006	0.0023
Rail		
Southern	0.0003	
Central	0.0003	
Northern	0.0003	
Water-Road		
Road Portion		
Central	0.0002	
Northern	0.0003	
Water Portion		
Central	0.0006	
Northern	0.0006	
Water-Rail		
Rail Portion		
Central	0.0003	
Northern	0.0003	
Water Portion		
Central	0.0005	
Northern	0.0005	

(Kempe 1993a)

TABLE 7-5
Maximum Individual Dose to Members of the Public
in Vehicles following a Shipment during Normal Transport[1]

Mode	Destination	Individual Dose ($mSv \cdot a^{-1}$)
Road	Southern	0.0020
	Central	0.0014
	Northern	0.0029
Water	All	0.050

(Kempe 1993a)

1 This exposure scenario is not applicable to rail

4. Doses to Non-human Biota

It was assumed that any non-human biota in the vicinity of the cask would be exposed to the same annual dose as humans. While assessment of doses to non-human biota is limited to absorbed dose (see discussion in Section 6.1.1.1), for external radiation from the cask, absorbed dose and dose equivalent are, for practical purposes, the same.

The annual absorbed dose of 0.07 mGy, or approximately 8×10^{-9} $Gy \cdot h^{-1}$, is well below the level of $\sim 10^{-4}$ $Gy \cdot h^{-1}$ at which no radiological effects have been observed in natural systems (see Section 6.1.1.2).

7.1.1.3 Mitigation Measures

The highest calculated dose is for persons exposed to the shipments at a truck stop, and could be controlled in practice by monitoring, use of alternative truck stops, and choice of parking location. Even with the non-optimized system analysed, the dose estimated is only 1.4% of the current public dose limit, and 7% of the proposed limit. For rail, where the maximum individual dose is dependent on the shipment speed and the distance from the track, the dose could vary significantly from that calculated, for example, if dwellings were situated close to a section of track with a low speed limit. Route surveys could be used to identify such locations. Similarly, shipment configuration at locks could be surveyed to identify any need for mitigation measures.

In summary, the routes chosen should be surveyed to identify critical groups, and, in the early stages of the program, limited health physics surveillance would be useful in ensuring doses were as low as reasonably achievable (ALARA). Doses to non-human biota exposed along the routes would not exceed those for the human critical groups, and no mitigative measures would be required.

7.1.2 Accident Conditions

The analysis presented here is based on the Ontario Hydro demonstration cask (or IFTC), as described in Section 2.2.2.2. During the certification process, a demonstration cask was built and tested. Data on the transportation system and on behaviour of used fuel transportation cask are based on Ulster (1993a) (summarized in Chapter 2), and on the Safety Analysis Report for the demonstration cask (Ontario Hydro 1986). It is assumed that a larger cask for rail transportation would meet the same requirements and respond in the same manner to accidents. The transportation environment data - population densities, shipment distances, fraction of travel in different population zones and overall accident rates, are summarized in Tables 3-8 to 3-12.

A severe transport accident involving a used fuel shipment may cause radiation doses to members of the public in two ways:

i) loss of shielding leading to increased exposure to direct radiation from the used fuel; and

ii) seal failure and fuel damage leading to escape of airborne radioactive material from the cask.

Full details of the analysis may be found in Kempe (1993a). The calculations of dose and risk were carried out using a Turbo Pascal code, TADS, written specifically for the assessment. The models used in TADS are similar to those used in INTERTRAN and RADTRAN4, which are currently the subject of an IAEA Coordinated Research Programme, as described in Section 7.1.1.1. Further information on TADS can be found in Kempe 1993a, Kempe 1993c, Kempe and Beck 1993, and Beck 1993.

7.1.2.1 Analysis Methodology

1) Accident Probabilities

a) Accident Severity Categories

The demonstration cask was designed to withstand accident conditions at least as severe as those specified in the IAEA Regulations (IAEA 1990) and the AECB's TPRMR (AECB 1991b). These conditions have been variously estimated to encompass more than 99.4% of road and rail accidents (Fischer et al. 1987), or 99.9% of impacts and 99.8 to 99.9% of fires occurring during transportation (Wilmot (1981), using data from McClure (1981)). Extended testing and analysis on the Ontario Hydro IFTC has shown that the cask would maintain containment in accident conditions more severe than the regulatory conditions. The probability of any release occurring would, therefore, be small.

To examine the radiological impact of hypothetical accidents severe enough to cause a breach of the cask integrity, the range of accident conditions which can be postulated was divided into a number of accident severity categories. The first category consists of those accidents which are not severe enough to affect the integrity of the cask, and for which the radiological consequences are, therefore, bounded by the doses corresponding to the regulatory leakage limits (AECB 1991a) (see Appendix B). 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 can be completely characterized in terms of the following:

i) the integrity of the cask seal;

ii) the maximum fuel temperature;

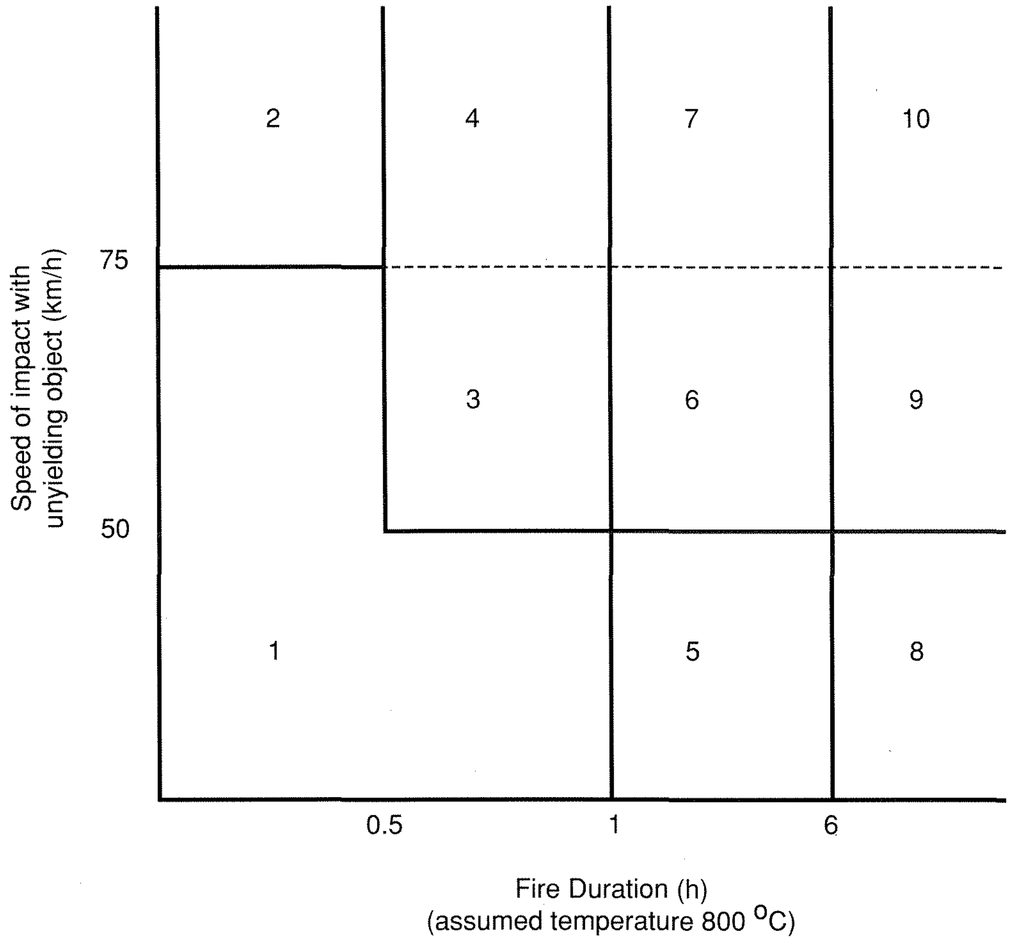
iii) the fraction of fuel subject to impact rupture; and

iv) the fraction of fuel subject to creep rupture.

These parameters are in turn related to the impact and thermal environment experienced by the cask. The accident severity categories are, therefore, characterized by the force of the impact, proportional to the speed of impact on an unyielding target, and the thermal environment experienced by the cask, proportional to the duration of the fire, as shown in Figure 7-1. Impact speeds are divided into three ranges, from 0 - 50 $km \cdot h^{-1}$, 50 - 75 $km \cdot h^{-1}$, and over 75 $km \cdot h^{-1}$. Note that these speeds represent equivalent speed of impact with an unyielding surface. In "real life", 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 equivalent impact to the 50 $km \cdot h^{-1}$ or 75 $km \cdot h^{-1}$ speed of impact with the unyielding target. The thermal environment was characterized by the fire duration, assuming an engulfing fire of 800°C. The possible durations were divided into ranges of 0 - 0.5 h, 0.5 - 1 h, 1 - 6 h, and greater than 6 h.

The ten categories shown in Figure 7-1 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 in Figure 7-1.

The accident scenarios included in each category, together with the characteristics of the release of radionuclides, are summarized in Table 7-5a.



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 7-1: Severity Category Scheme for Transportation Accidents

TABLE 7-5a
Accident Scenarios Included in Fault Tree Analysis of Each Severity Category

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
1	Impact at greater than 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration less than 0.5 h, or impact at less than 50 km•h^{-1} together with fire duration less than 1 h.	All accidents other than those in categories 2-10 are assumed to be in Category 1.			Fuel damage possible but no release from cask.
2	Impact at greater than 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration less than 0.5 h.	• The used fuel truck travelling at 75 km•h^{-1} or more collides with a rock face or concrete bridge abutment in a sideways orientation such that the cask is subject to the full impact, or • the truck and/or cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact. • If a fire occurs, it does not envelope the cask, or its duration is less than 0.5 h.	• A used fuel railcar and/or a cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at 104 km•h^{-1} or more collides with it in an orientation such that the cask is subject to the full impact. • If a fire occurs, it does not envelope the cask, or its duration is less than 0.5 h.	No scenarios involve an impact at greater than 75 km•h^{-1} (equivalent).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. The lid bolts stretch due to the impact, resulting in loss of seal compression. Seal bypass leakage occurs, releasing gases and airborne particulates. The release is assumed to take place over a short period of time, and to be at ground level.

continued...

TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
3	Impact at between 50 km•h^{-1} and 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 0.5 and 1 h.	• The used fuel truck travelling at between 50 and 75 km•h^{-1} collides with a rock face or concrete bridge abutment in a sideways orientation such that the cask is subject to the full impact, or • the truck and/or cask falls between 9 and 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the used fuel truck is in head-on collision with another truck with a combined speed of between 280 and 420 km•h^{-1}, or • another truck or a locomotive, travelling at between 140 and 210 km•h^{-1}, hits the cask sideways (e.g. at a crossroads or rail crossing) and • a fire of duration between 0.5 and 1 h occurs and envelopes the cask (this means another vehicle, carrying sufficient fuel to sustain the fire, is involved in the accident).	• The used fuel railcar and/or the cask falls between 9 and 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at between 70 and 104 km•h^{-1} or more collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration between 0.5 and 1 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• Another vessel collides with the used fuel barge at between 50 and 75 km•h^{-1} (equivalent speed of impact with unyielding surface), such that the colliding vessel's bow penetrates side of the barge and impacts a cask such that the cask is subject to the full impact and • a fire of duration between 0.5 and 1 h occurs and envelopes the cask (this means another vessel, carrying sufficient flammable material to sustain the fire, is involved in the accident).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. A combination of bolt stretch due to impact and thermal stress from the fire results in loss of seal compression. Seal bypass leakage occurs, releasing gases and airborne particulates. The release is assumed to take place over a short period of time, and to be at ground level.

continued...

TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
4	Impact at greater than 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 0.5 and 1 h.	• The used fuel truck travelling at 75 km•h^{-1} or more collides with a rock face or concrete bridge abutment in a sideways orientation such that the cask is subject to the full impact, or • the truck and/or cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact and • a fire of duration between 0.5 and 1 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• A used fuel railcar and/or a cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at 104 km•h^{-1} or more collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration between 0.5 and 1 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	No scenarios involve an impact at greater than 75 km•h^{-1} (equivalent).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. The lid bolts stretch due to the impact, resulting in loss of seal compression. Seal bypass leakage occurs, releasing gases and airborne particulates. The release is assumed to take place over a short period of time, and to be at ground level.

continued...

TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
5	Impact at less than 50 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 1 and 6 h.	• The used fuel truck is involved in an accident in which a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• The used fuel train is involved in an accident in which a fire of duration between 1 and 6 h occurs and envelopes a cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• The used fuel barge is involved in an accident in which a fire of duration between 1 and 6 h occurs and envelopes a cask (this means another vessel, carrying sufficient flammable material to sustain the fire, is involved in the accident).	10% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. The lid seals degrade due to increased temperature, releasing gases and airborne particulates. The release is assumed to take place over a prolonged period of time and to be at an effective height of 100 m due to the updraft from the fire.

continued...

TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
6	Impact at between 50 km•h^{-1} and 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 1 and 6 h.	• The used fuel truck travelling at between 50 and 75 km•h^{-1} collides with a rock face or concrete bridge abutment in a sideways orientation such that the cask is subject to the full impact, or • the truck and/or cask falls between 9 and 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the used fuel truck is in head-on collision with another truck with a combined speed of between 280 and 420 km•h^{-1}, or • another truck or a locomotive, travelling at between 140 and 210 km•h^{-1}, hits the cask sideways (e.g. at a crossroads or rail crossing) and • a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• A used fuel railcar and/or a cask falls between 9 and 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at between 70 and 104 km•h^{-1} collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• Another vessel collides with the used fuel barge at between 50 and 75 km•h^{-1} (equivalent speed of impact with unyielding surface) such that the colliding vessel's bow penetrates the side of the barge and impacts a cask such that the cask is subject to the full impact and • a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vessel, carrying sufficient flammable material to sustain the fire, is involved in the accident).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. A combination of bolt stretch due to impact and thermal stress from the fire results in loss of seal compression, or the lid seals degrade due to increased temperature, releasing gases and airborne particulates. The release is assumed to take place over a short period of time and to be at ground level.

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TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
7	Impact at greater than 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 1 and 6 h.	• The used fuel truck travelling at 75 km•h^{-1} or more collides with a rock face or concrete bridge abutment in a sideways orientation such that the cask is subject to the full impact, or • the truck and/or cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact and • a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• A used fuel railcar and/or a cask falls 22 m or more onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at 104 km•h^{-1} or more collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration between 1 and 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	No scenarios involve an impact at greater than 75 km•h^{-1} (equivalent).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. The lid bolts stretch due to the impact, resulting in loss of seal compression. Seal bypass leakage occurs, releasing gases and airborne particulates. The release is assumed to take place over a short period of time and to be at ground level.

continued...

TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
8	Impact at less than 50 km•h^{-1} together with fire duration of more than 6 h.	No scenarios involve an enveloping fire longer than 6 h.	• The used fuel train is involved in an accident in which a fire of duration longer than 6 h occurs and envelopes two casks (this means another train, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• The used fuel barge is involved in an accident in which a fire of duration longer than 6 h occurs and envelopes al the casks (this means another vessel, carrying sufficient flammable material to sustain the fire, is involved in the accident).	10% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. 10% of the remaining fuel ruptures as the temperature increases. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. The lid seals degrade due to increased temperature, releasing gases and airborne particulates. The release is assumed to take place over a prolonged period of time and to be at an effective height of 100 m due to the updraft from the fire.

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TABLE 7-5a (continued)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
9	Impact at between 50 km•h^{-1} and 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration of more than 6 h.	No scenarios involve an enveloping fire longer than 6 h.	• A used fuel railcar and/or a cask falls between 9 and 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at between 70 and 104 km•h^{-1} collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration longer than 6 h occurs and envelopes the cask (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	• Another vessel collides with the used fuel barge at between 50 and 75 km•h^{-1} (equivalent speed of impact with unyielding surface) such that the colliding vessel's bow penetrates the side of the barge and impacts a cask such that the cask is subject to the full impact and • a fire of duration longer than 6 h occurs and envelopes all the casks (this means another vessel, carrying sufficient flammable material to sustain the fire, is involved in the accident).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. A combination of bolt stretch due to impact and thermal stress from the fire results in loss of seal compression, or the lid seals degrade due to increased temperature, releasing gases and airborne particulates. The release is conservatively modelled as an initial release, assumed to take place over a short period of time at ground level, followed by a release assumed to take place over a prolonged period of time at an effective height of 100 m, due to the updraft from the fire.

continued...

TABLE 7-5a (concluded)

Severity category	Accident characteristics (as seen by cask)	Hypothetical scenarios used in fault tree analysis of probabilities			Release characteristics
		Road	Rail	Water	
10	Impact at greater than 75 km•h^{-1} (equivalent speed of impact with unyielding surface) together with fire duration between 1 and 6 h.	No scenarios involve an enveloping fire longer than 6 h.	• A used fuel railcar and/or a cask falls more than 22 m onto rock in an orientation such that the cask is subject to the full impact, or • the railcar is derailed, and a subsequent train travelling at 104 km•h^{-1} or more collides with it in an orientation such that the cask is subject to the full impact and • a fire of duration longer than 6 h occurs and envelopes two casks (this means another vehicle, carrying sufficient flammable material to sustain the fire, is involved in the accident).	No scenarios involve an impact at greater than 75 km•h^{-1} (equivalent).	100% of fuel cladding breaks due to impact, releasing gases and particulates into the cask cavity. Additional release of semi-volatiles from the fuel takes place by diffusion as the temperature increases. Oxidation of fuel takes place (consuming oxygen present in the cask and drawn in during the cooldown period) resulting in additional releases of gases, semi-volatiles, ruthenium and particulate fission products. The lid bolts stretch due to the impact, resulting in loss of seal compression. Seal bypass leakage occurs, releasing gases and airborne particulates. The release is modelled as an initial release, assumed to take place over a short period of time at ground level, followed by a release assumed to take place over a prolonged period of time at an effective height of 100 m, due to the updraft from the fire.

This type of categorization of severe accidents was used in the USNRC FES (USNRC 1977), and was recommended by a Sandia workshop on Transportation Accident Scenarios (Wilmot et al. 1980). Severity categorization is the basis of the US code RADTRAN which has been used for the US assessment of transportation of used fuel and high level wastes to future potential repository sites (Cashwell et al. 1986).

b) Fault Tree Analysis and Results

As noted above, the hypothetical accidents which could affect the sealing integrity of the cask used for the used fuel shipments are very severe. The probability of these severe events is also very small. For this reason, it was difficult to obtain an estimate of the frequency of occurrence of the severity categories of Figure 7-1 and Table 7-5a from statistical data (see Kempe (1993a)).

A simplified form of fault tree analysis was, therefore, used to estimate the probability of each severity category, for each mode. This methodology is commonly used to estimate the probability of rare scenarios where little or no historical data are 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. Details of this analysis are given in Kempe (1993a).

The conditional probability of an accident in each severity category, i.e., the probability that an accident would be in a particular severity category, given an accident had occurred, is summarized in Table 7-6. Accident rates are given in Chapter 3. The annual expected frequencies of release accidents, are given in Table 7-7. It may be noted that these are based on all-vehicle rates for the reference routes, which are likely to be conservative, since the safety standards and driver training for the used-fuel transportation operations would be higher than average. All reportable accidents are included; for example, for road, all accidents resulting in damage in excess of $400. The non-radiological consequences of these accidents, in terms of fatalities and injuries, are discussed in Section 7.4.2.

c) Number of Casks Involved

All of the transport modes, except road, involve multiple casks per shipment. The INTERTRAN and RADTRAN models assume that all the packages of a shipment experience the same accident environment, i.e. the fractional release is applied to the total radioactive inventory of the shipment.

While this may be appropriate (although conservative) for some cases, e.g. a tanker fire following a barge collision, it is not correct for other cases, e.g. release due to combined impact and thermal damage, following impact of a colliding ship's bow with a cask, where the ship's bow would impact only one cask.

In reality, the probability of a cask being subject to a severe impact or high temperatures, given an accident involving a shipment, would increase as the number of casks in the shipment increased because the casks would represent a larger 'target', and the probability of all the casks being thrown clear of a fire, or of avoiding a hard impact surface if one was present, would be smaller. The severity distribution would, therefore, vary according to the number of casks per shipment. It would be possible to derive different severity distributions for each shipment size; however, the accuracy involved in the derivation of the severity distribution does not justify this complication.

TABLE 7-6
Fraction of Accidents in Severity Category

Severity Category	Fractional Occurrence, Given an Accident		
	Road	Rail	Water
1	0.99998	0.99988	0.99999
2	10^{-5}	10^{-4}	0
3/4	10^{-7}	10^{-6}	10^{-8}
6/7	10^{-8}	10^{-7}	10^{-7}
5	10^{-5}	10^{-5}	10^{-6}
8	0	10^{-5}	10^{-5}
9/10	0	10^{-7}	10^{-6}

TABLE 7-7
Annual Frequencies of a Release Accident

Mode	Destination	Frequency of Release Accident Per Year
Road	Southern Central Northern	8.4×10^{-6} 1.7×10^{-5} 3.6×10^{-5}
Rail	Southern Central Northern	2.4×10^{-6} 7.6×10^{-7} 1.1×10^{-6}
Water-Road	Central Northern	[1]9.5×10^{-6}/[2]8.9×10^{-7} $7.9 \times 10^{-6}/8.4 \times 10^{-7}$
Water-Rail	Central Northern	[3]$4.8 \times 10^{-7}/8.7 \times 10^{-7}$ $5.5 \times 10^{-6}/8.6 \times 10^{-7}$

1 Road
2 Water
3 Rail

To avoid both the extreme conservatism inherent in the INTERTRAN-1 assumption, and an artificial 'flock' effect that would result if the number of packages damaged was restricted to one per accident, it was assumed that one cask was involved in Severity Categories 2 - 7, and in Categories 8 - 10, two casks were involved in the rail case, and all casks were involved in the water case. This covers the range of possible consequences, i.e. no accident could involve more than 36 road casks or 12 rail casks.

The involvement of all the casks in a water shipment in the more severe accident categories reflects the possibility of an all-engulfing fire following collision with an oil or gas tanker, while in the lower accident severities, where effects are due to shorter fires and to impact, only one cask would be involved. For rail, the amount of fuel involved in a fire would be less, and hence the physical extent of the fire would be smaller. However, two casks (out of 10 casks in the train) are assumed to be involved for fires longer than 6 hours. For road, only single shipments are made.

2) Inventory of Radionuclides

The amount of each nuclide present in unit mass of the fuel was taken from Tait et al. (1989). A list of potentially-significant nuclides (Table 7-8) was prepared by examination of each of the nuclides given Tait et al., taking account of the abundance in the used fuel, and of the dose conversion factors for external and internal exposure. Note that short-lived radioactive progeny of included radionuclides are not given, as the dose conversion factors include the contribution from progeny. The list of radionuclides may differ from that used in the postclosure assessment, where only the nuclides having the longest half-lives are generally of importance, and retention in the geosphere is a major factor.

The nuclides may be considered in five groups as follows:

i) Gases - tritium and krypton;

ii) Semi-volatiles - cesium and iodine;

iii) Ruthenium, here considered as a semi-volatile at fuel temperatures above 700°C;

iv) Particulate fission products, including strontium; and

v) Actinide and lanthanide particulates, including plutonium, americium, curium, cerium and europium. These are expected to be approximately uniformly distributed in the fuel (Garisto et al. 1989).

3) Release Pathway

To reach the environment, the radionuclides in the fuel must escape three barriers:

i) the cask;

ii) the fuel cladding; and

iii) the fuel matrix.

TABLE 7-8
Radionuclide Inventory for the Two-Module
Road Cask, 10-year Cooled CANDU Fuel

Nuclide	Half-Life[1]	Bq[2] in Cask
^{3}H	12.35 years	1.08×10^{13}
^{85}Kr	10.72 years	1.65×10^{14}
^{90}Sr	29.12 years	1.87×10^{15}
^{106}Ru	368.2 days	3.04×10^{13}
^{125m}Te	58 days	7.92×10^{12}
^{129}I	1.57×10^{7} years	1.06×10^{9}
^{134}Cs	2.06 years	7.05×10^{13}
^{137}Cs	30.0 years	2.78×10^{15}
^{144}Ce	284.3 days	1.04×10^{13}
^{147}Pm	2.62 years	7.34×10^{14}
^{154}Eu	8.8 years	6.76×10^{13}
^{238}Pu	87.74 years	1.10×10^{13}
^{239}Pu	24065 years	2.31×10^{13}
^{240}Pu	6537 years	3.16×10^{13}
^{241}Pu	14.4 years	1.95×10^{15}
^{241}Am	432.2 years	4.03×10^{13}
^{243}Am	7380 years	7.05×10^{10}
^{242}Cm	162.8 days	2.42×10^{10}
^{243}Cm	28.5 years	1.90×10^{10}
^{244}Cm	18.11 years	1.63×10^{12}

1 ICRP (1983)

2 From Tait et al. (1989). This gives activities per kg of uranium, for a burnup of 685 $GJ \bullet kgU^{1}$. This was converted to activity per cask using 18.93 kgU per bundle (Tait et al. 1989) and 192 bundles per cask.

a) Escape from the Cask

Potential causes of cask failure leading to leakage of radioactivity above the AECB leakage limit (AECB 1991a) were as follows:

i) loss of integrity of the elastomeric lid, vent or drain seals due to thermal degradation in severe thermal conditions; and

ii) loss of lid bolt tension (preload), leading to seal by-pass leakage, following a severe impact.

The Safety Analysis Report for the demonstration cask also considers thermal gradients in the cask walls leading to bowing and loss of lid seal compression. Although a longer fire than the regulatory thermal condition would lead to higher overall temperatures, the thermal gradient would not increase accordingly, as the inner surface of the cask wall would begin to heat up. This failure mode was not, therefore, considered explicitly, although it was taken into account in deriving the failure criterion for combined impact and thermal failure.

Puncture of the 270 mm stainless steel cask body or lid was not considered credible. This is supported by the rail coupler impact test carried out by Ontario Hydro (see Section 2.2.2.2), in which the cask survived impact at 104 $km \cdot h^{-1}$ with a locomotive coupler with only superficial scratches. An impact test with a similar, but full-scale, cask carried out in the UK (Hart et al. 1985b) showed the cask remained intact after impact at 150 $Km \cdot h^{-1}$, even though the cask was not equipped with an impact limiter, as the Ontario Hydro cask is. Similarly, loss of all lid bolts was not considered credible. There is no orientation in which prying of the lid could take place. The most severe impacts would occur via a flat-bottom drop, and would result only in slight bolt stretching, well below the ultimate strength of the extremely ductile Nitronic-60 lid bolts.

For perspective, the estimated dose rates from two unshielded fuel modules (i.e. 192 used fuel bundles, the quantity carried in the demonstration cask) are 2.7 $Sv \cdot h^{-1}$ at 3 m, and 20 $mSv \cdot h^{-1}$ at 50 m. A stay of approximately 10 min at 3 m, or 25 h at 50 m would be required to reach the threshold for acute radiation effects of 500 mSv (ICRP 1984).

There is not expected to be any significant increase in direct external radiation from the cask in accident conditions. In the regulatory drop tests, there was no loss of shielding integrity other than deformation of the corner of the cask in a drop onto a bottom corner (Ontario Hydro 1986). This would not increase the radiation field from the cask significantly, since there is a large margin of safety in shielding thickness at this point.

No leakage was observed in the one-hour thermal tests on the IFTC, mentioned in Section 2.2.2.2 (Taralis and Morandin 1988). The main (lid) seal temperature in these tests reached 180°C, below the maximum recommended continuous operating temperature, for low-temperature Viton, of 205°C. Although the drain plug seal reached 308°C, the seal was still elastic. The drain cover plate seal reached over 400°C. This seal was intact and in the seal groove, but broke when it was lifted.

For this analysis, complete seal failure was assumed to occur in fire accidents exceeding one hour duration, i.e. in Severity Categories 5 - 10.

The test discussed above was carried out with the impact limiter in place. If this was not the case, then the lid seal temperature would rise more quickly. However, in the present analysis, an impact great enough to remove the impact limiter is also assumed to fail the seal.

Complete loss of seal compression implies that the bolts would have been stretched plastically by an amount at least equal to the seal compression of 1.9 mm. In the most severe impact orientation (flat bottom drop) the bolt strength for the regulatory impact was only equivalent to 0.2 mm (Ontario Hydro 1986). To conservatively cover the possibility that some seal by-pass leakage could occur before complete loss of compression, it was assumed that seal failure would occur for impacts at speeds exceeding 1.5 times the regulatory impact speed (i.e. $1.5 \times 50\ km \cdot h^{-1} = 75\ km \cdot h^{-1}$). This occurs in Severity Categories 2, 4, 7 and 10. The bolt stretch might then be of the order of $1.5^2 \times 0.2$ mm = 0.45 mm. Tests by Ontario Hydro Research (Ontario Hydro 1986) have shown that the IFTC seals can withstand a loss of compression of at least 0.65 mm before any leakage occurs.

To conservatively cover the possibility of stress induced by thermal bowing (see above) adding to impact damage, the cask was also assumed to fail in Severity Category 3 due to a combination of an impact greater than the regulatory impact speed and thermal stress.

The same criteria were applied to the rail cask. Although the rail cask is heavier (and, therefore, has correspondingly more kinetic energy to dissipate for an impact at a given speed), the design is equipped with an impact limiter at both ends. The 'worst case' flat end impact does not, therefore, exist for this cask, and the assumptions, above, are likely to be conservative. It should be noted that the main seal of the rail cask is around the smallest cross-section, and is, therefore, of similar dimensions to that of the road cask.

The main driving force for the release of radioactivity from the cask is air movement out of the cask during relief of overpressure through the failed seal. The overpressure is due to heating of the cask cavity, by radioactive decay heat or external fire.

Based on Wilmot et al. (1980), it was assumed that particulates (including ^{90}Sr, the actinides; also Ru, Cs and I at temperatures below their volatilization temperatures) were retained within the cask with an efficiency of 0.95 due to settling and adsorption within the cask cavity, and due to trapping in the narrow metal-to-metal release path, or by the remains of the degraded seal. Other nuclides were all assumed to be released without any retention by the cask. Volatilization temperatures for Ru, Cs and I were taken from Table 6A-1 of Ontario Hydro (1986). The chemical form giving the lowest volatilization temperature was used in each case.

The effect of human error in design, manufacture or operation and maintenance, was not explicitly included in the assessment. Design and construction of used fuel casks would be to the high standards of quality assurance. For example, design procedures for the IFTC were in accordance with Ontario Hydro Design and Construction Branch Quality Engineering Procedures and Standards. The design was subject to ongoing peer review and formal technical review. A Quality Engineering Programme and Quality Engineering Plan, specific to the IFTC, define organizational controls, interfaces, and major quality engineering tasks, and ensure that design function control is exercised over design changes at all phases. Quality Assurance for manufacturing followed CAN3-Z299.2-85 (Canadian Standards Association 1985). The prototype IFTC was inspected by Ontario Hydro and AECB representatives at all stages of manufacture, leaving little probability of unchecked manufacturing error. In addition, the design of the cask in monolithic stainless steel leaves little scope for manufacturing error to significantly increase the probability of cask failure above that found with the stated conservative failure criteria.

The failure criteria outlined are believed to be sufficiently conservative to cover small defects in operation and maintenance, e.g. improper torquing of lid bolts would not increase the failure probability above that used in the assessment. The operating procedures are set out in the Safety Analysis Report (Ontario Hydro 1986) and have been reviewed by the Atomic Energy Control Board. The procedures are also subject to Quality Assurance Control. These procedures require all three cask seals (i.e. lid, vent and drain) to be tested prior to each shipment. This would ensure that the seals have been properly assembled. Other faults, such as improper tie down to the transportation vehicle, would not result in any increase in the estimated probability of occurrence of releases given in the assessment, since no credit was taken for absorption of energy by the tie downs.
The impact limiter plays an important role in the safety design of the package. The bolts are custom-made, and it would not be possible to fit lower quality 'off-the shelf' bolts. However, seal failure is conservatively included in the analysis for impacts greater than the regulatory impact combined with a fire longer than 30 minutes.

Driver error and errors in maintenance of the transportation vehicles leading to increased probability of an accident, are implicitly included by use of historical accident rates.

b) Escape from the Cladding

The fuel cladding may rupture due to impact or due to severe thermal conditions. The basic assumptions on impact rupture were that 10% of fuel would rupture in any accident conditions (up to the regulatory accident condition), and 100% would rupture in impacts at the regulatory impact speed or greater.

In an impact, the fuel within the module tubes could impact sideways against the module tube, end-on against the side wall of the cask, or in some combination. In all orientations, movement and deformation following impact is limited by the presence of the module tube. Factors to be considered when estimating the fraction of fuel failures upon impact include the orientation of the bundles, the effect of the support structure on the movement of the bundles and the manner in which energy is dissipated following impact. Very few experiments have been conducted on the CANDU fuel of interest: irradiated fuel at low (80-100°C) temperatures. Most of the fuel cladding failure experiments have used unirradiated fuel at ambient temperatures. The experiments using irradiated fuel have mainly considered drop heights less than 2 m, although it has been shown that, at high impact velocities, room temperature unirradiated bundles behave in a similar manner to hot, irradiated bundles. Analysis of the behaviour of irradiated zircaloy at 80 to 100°C indicates that its impact strength may be about 2 to 3 times less than unirradiated zircaloy at 20°C, depending on the hydrogen concentration in the zircaloy (Sawatzky 1964). A conservative approach was therefore taken, as follows, when the experimental data on unirradiated fuel was applied.

The assumption of 100% rupture at speeds greater than the regulatory impact speed was based mainly on observations during 9 m drop tests at Chalk River Nuclear Laboratories (Taylor 1976). During these tests, a package designed for used fuel transport, and containing unirradiated fuel bundles, was dropped 9 m onto an edge, followed by a one metre punch drop and a 9 m side drop. Pinhole leaks were found in nine out of 102 fuel elements, or approximately 9%. The damage appeared to have been caused by the spacer pads on adjacent elements. No damage occurred in 11 simulated elements unconstrained in a bundle. It is noted that, even with the pinhole leaks, release from the elements was less than the allowable leakage for a Type B package (i.e. not crediting the cask itself with providing containment). In this analysis, it was assumed, in contrast, that any cladding failure exposed the entire radioactive content of the element for potential release.

Other information on fuel behaviour in impact conditions has been reviewed and summarized by Pon and Archinoff (1983). The review concluded that for unconstrained speeds of impact between 15-20 $m \cdot s^{-1}$, there would be few if any cladding failures in hot irradiated fuel, although there would be extensive end plate/element separation leading to bundle disassembly. This compares with an impact speed for the regulatory accident conditions of 13.3 $m \cdot s^{-1}$. One of the references used (Jackson et al. 1981) describes tests carried out in a similar geometry to that which would be experienced in the regulatory accident conditions. These tests were carried out with unirradiated Bruce bundles. Test 1 consisted of impact of two bundles at 13.7 $m \cdot s^{-1}$ into a 'punch'-shaped shield plug. Some leakage of radioactivity from the cladding occurred, but the amount of damage was small. In Test 2, the same configuration was used, and breaks were found in about 6 fuel elements, (or 6/37 x 2 = 8% of the total number of fuel elements). In a later test of the series, with impact of 13 bundles on top of each other, there were many sheath ruptures in the first bundle, and none or one in subsequent bundles. The damage appears, therefore, to have been caused by interaction between bundles.

Other evidence on fuel behaviour comes from the Ontario Hydro research program on shock and vibration, carried out during design of the IFTC (Ribbans 1988). It was shown that the bundles would not disassemble during normal transport conditions.

Assumptions on creep rupture were based on criteria derived for the Bruce B Safety Analysis (Ontario Hydro 1984a). Creep rupture occurs when internal pressure combines with cladding creep (slipping of grain boundaries) to burst the sheath. The failure temperature depends upon the gas pressure inside the element. The Bruce B criteria range from 800°C to 1200°C, depending upon the position of the element in the bundle. These values are conservative for the ten-year cooled reference fuel, as some of the fission gases have decayed to non-gaseous products, reducing the pressure inside the sheath.

The lower failure limit of 800°C corresponds with the temperature derived for the hottest bundle in fires of duration > 6 h (see discussion below). Ten percent of remaining intact fuel cladding was, therefore, assumed to fail for fire durations greater than 6 h.

Fuel temperatures in severe thermal environments (fire durations 0-6 h) have been calculated as part of Ontario Hydro's cask design program (Ontario Hydro 1986). Average fuel temperatures would remain low in normal and regulatory accident conditions: 86°C in normal conditions, and 141°C in the accident condition, with a maximum fuel sheath temperature of 166°C (Ontario Hydro 1986). For fires longer than 6 h, the temperature of the fuel was assumed to rise up to the fire temperature, 800°C.

In this analysis, we assumed that any cladding failure exposed all radionuclides released from the fuel (see (c) below) for potential release, except in the case of a release occurring immediately as a result of impact rupture. In this case, following Wilmot (1981), the cladding was assumed to retain particulates and semi-volatiles with an efficiency of 0.9. Other nuclides were assumed to be released without any retention by the cladding. This attenuation by the cladding was only applied in the case of impact rupture, i.e. before any temperature excursion. The rationale is as follows: the data on which the release of particulates due to mechanical disruption is based (i.e. the release on impact rupture of the fuel) came from experiments in which fuel elements were intentionally pressurized by heating, until the cladding burst. For the 10-year-cooled fuel, at low temperature, the internal pressure is low, and there is less driving force to create openings and force material out. In addition, the path taken to the impact-induced crack by escaping radionuclides would be so narrow and convoluted that some trapping could be expected.

c) Escape from the Fuel Matrix and Fuel-Clad Gap

For nuclides present as gases and semi-volatiles, release from the fuel is dependent, for some mechanisms of release, upon the fraction of the nuclide which is effectively free within the cladding, i.e. not contained by the fuel matrix. The effective free inventory is defined for this assessment as the free inventory calculated by the CURIES-II code (Archinoff 1983) plus a fraction 0.1 of the grain boundary inventory (Ontario Hydro 1986). The inclusion of part of the grain boundary inventory is conservative for most of the cases considered in the assessment, particularly when no impact is involved.

The effective free inventory of gases escapes freely when the fuel cladding ruptures due to impact or thermal conditions. A part of the effective free inventory of the semi-volatile nuclides may escape with the gases released when the fuel cladding ruptures at elevated temperatures. At high temperatures, a process of vaporization and diffusion from the exposed surfaces within the cladding takes place, leading to additional release of part of the effective free inventory of the semi-volatiles. Further releases of the gases and semi-volatiles, and any release of the other nuclides, are dependent on disruption of the fuel matrix, occurring via mechanical disruption, due to impact or creep rupture, or due to oxidation following exposure of the fuel matrix to oxygen at elevated temperatures.

Details of the radionuclide release calculations are given in Kempe (1993a).

4) Exposure Pathways

Calculations of dose to the public are carried out using the Ontario Hydro code TADS, discussed above, together with separate calculations for pathways not included in TADS, as discussed below.

The flowsheet for calculation of the consequences of an accident is shown in Figure 7-2. First, the seal damage and damage to the used fuel bundles are quantified for each severity category. The amount of radioactive material released for the cask is then calculated for each category. The plume of released radioactivity disperses downwind, with exposure of the public taking place via inhalation and exposure of radioactivity deposited from the plume. In the long term, after the airborne radioactivity is dispersed, exposure takes place via inhalation of material re-suspended from ground deposits, and from exposure to the ground deposits. Direct external exposure to the radioactive plume (cloudshine) is small, compared with exposure via other pathways, for the nuclides of interest in transport of used fuel (Kempe 1993c). The pathways included in the TADS code are as follows:

i) internal exposure following inhalation of airborne radioactivity;

ii) external exposure to radiation from radioactivity deposited on the ground (groundshine):

a) immediately following deposition, and
b) over subsequent days, weeks and years, when weathering and cleanup mechanisms influence the doses received; and

iii) internal exposure following inhalation of radioactivity re-suspended from ground deposits.

Action such as monitoring and control of potentially-contaminated food supplies would be the main factor influencing the dose received via the food chain. Addition to the doses from inhalation and groundshine would be meaningless, since the calculated food chain doses would not actually be incurred. Similarly, release to a water body could result in doses via drinking water. These pathways were, therefore, examined separately; results are given below.

Results for the short-term pathways (i) and (ii)(a) are discussed separately from those for the long-term pathways (ii)(b) and (iii). As for the foodchain, doses from the long-term pathways can be mitigated.

The TADS calculations take account of the following factors:

i) severity of the accident;

ii) quantity of used fuel involved in the accident;

iii) presence or absence of a major fire, which may result in elevation of the released material;

iv) atmospheric stability during the release; and

v) location of the accident with respect to population.

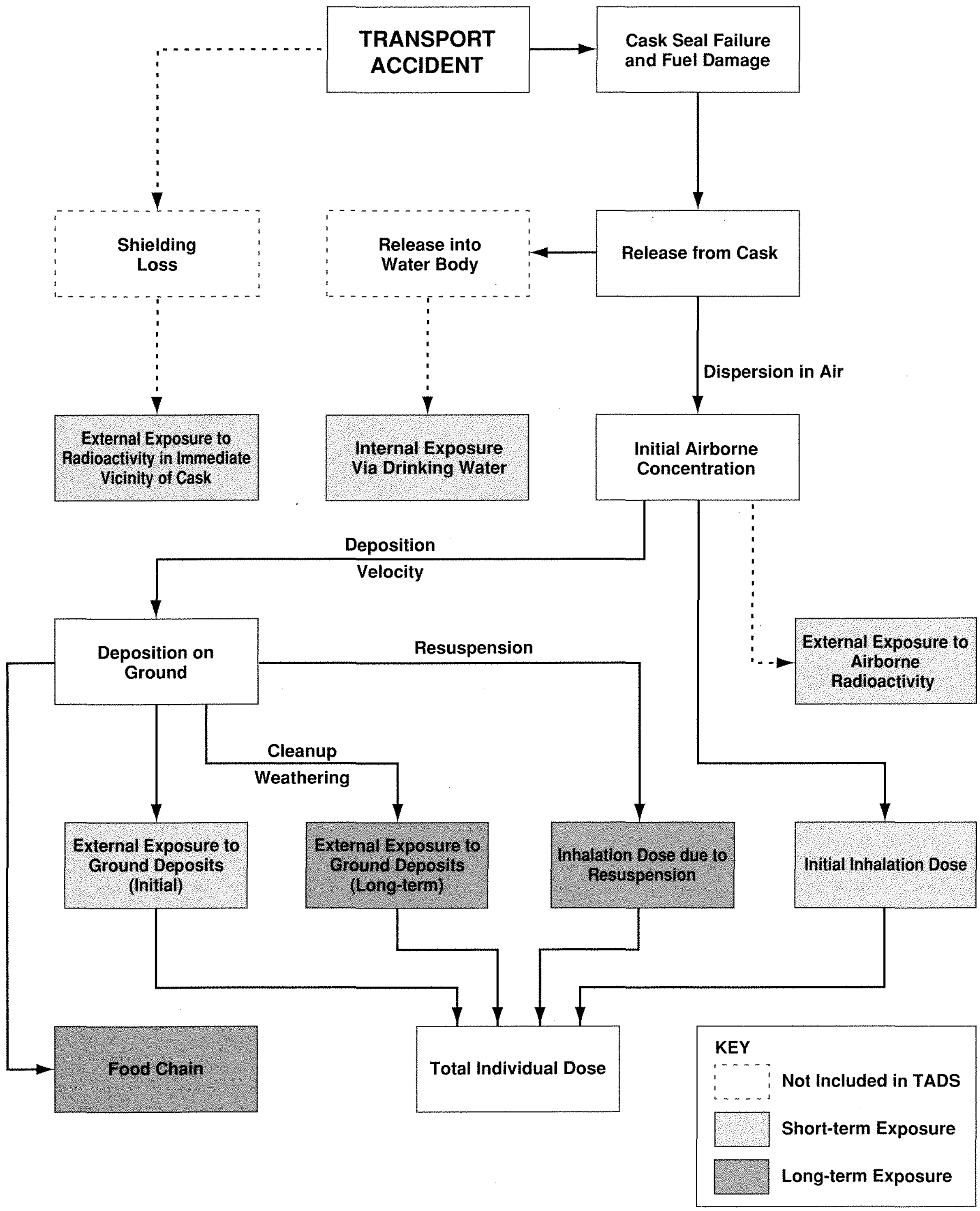


FIGURE 7-2: Exposure Pathways Following a Release in a Transport Accident

With the exception of cleanup of ground deposits, the results of mitigative actions are not included. In reality, detailed emergency response plans are in place which could be used to limit exposure of the public in the medium and long term (Government of Ontario 1986; Ontario Hydro 1991b). In the short term, actions taken by the trained drivers and by emergency personnel would limit exposure of the public at the scene (Ontario Hydro 1991b).

The models and formulations used for each pathway, together with the models for atmospheric dispersion, are described in detail in Kempe (1993c). Dosimetric factors were consistent with those used in the disposal facility assessment, Chapter 6. For the calculation of collective dose, doses were summed to a distance of 20 km. The population densities used for the urban, suburban, and rural zones were those applicable to the vicinity of transportation routes. In general the population would fall off at greater distances. It would therefore be unrealistic to continue the integration indefinitely. However, the assessment aimed to include the worst case for collective dose. Twenty kilometres was therefore chosen as an approximation to the size of the largest community.

The dispersion parameters used in the calculations are dependent upon the Pasquill atmospheric stability class. There are six Pasquill Classes (A, B, C, D, E, and F), each with an associated typical wind speed. The Pasquill stability classes provide a means of classifying weather conditions in terms of the degree of atmospheric turbulence, and hence the degree to which airborne materials would be dispersed and diluted. Class A represents unstable (highly dispersive) conditions, while D is neutral, and F and E are stable (not very dispersive) conditions. Consequence calculations were carried out for each Pasquill category in turn. For creating probability-consequence curves, and for risk calculations, the typical frequency of each Pasquill class was taken from Canadian Standards Association (1987). Since a transportation accident involving a used fuel shipment could occur at any location along the reference routes, it was not possible to use actual climate data.

7.1.2.2 Analysis of Potential Impacts

1) Dose to the Critical Group in Design Basis Accident Conditions

The individual dose calculated based on the leakage during regulatory design accident conditions (discussed together with normal conditions in Section 7.1.1.1, under part (ii)) is 0.001 mSv. This is comparable to the doses calculated for exposure to external radiation in normal transportation conditions (Table 7-4). However, the probability of this dose being received would be very much less than one.

2) Collective Doses

The results are presented in the form of a downward cumulative probability curve for each case. This gives the annual frequency of a particular dose being reached or exceeded, and shows how the frequency falls off for higher doses. The curves for road, rail and water transportation are given in Figures 7-4 to 7-6, respectively. An annotated curve is given in Figure 7-3 to assist in interpretation.

The shape of the curve is dependent on the details of the results. Since the probabilities of accident severity, Pasquill stability class, and the population density zone used are not continuous functions, but discrete values, the curves contain discontinuities.

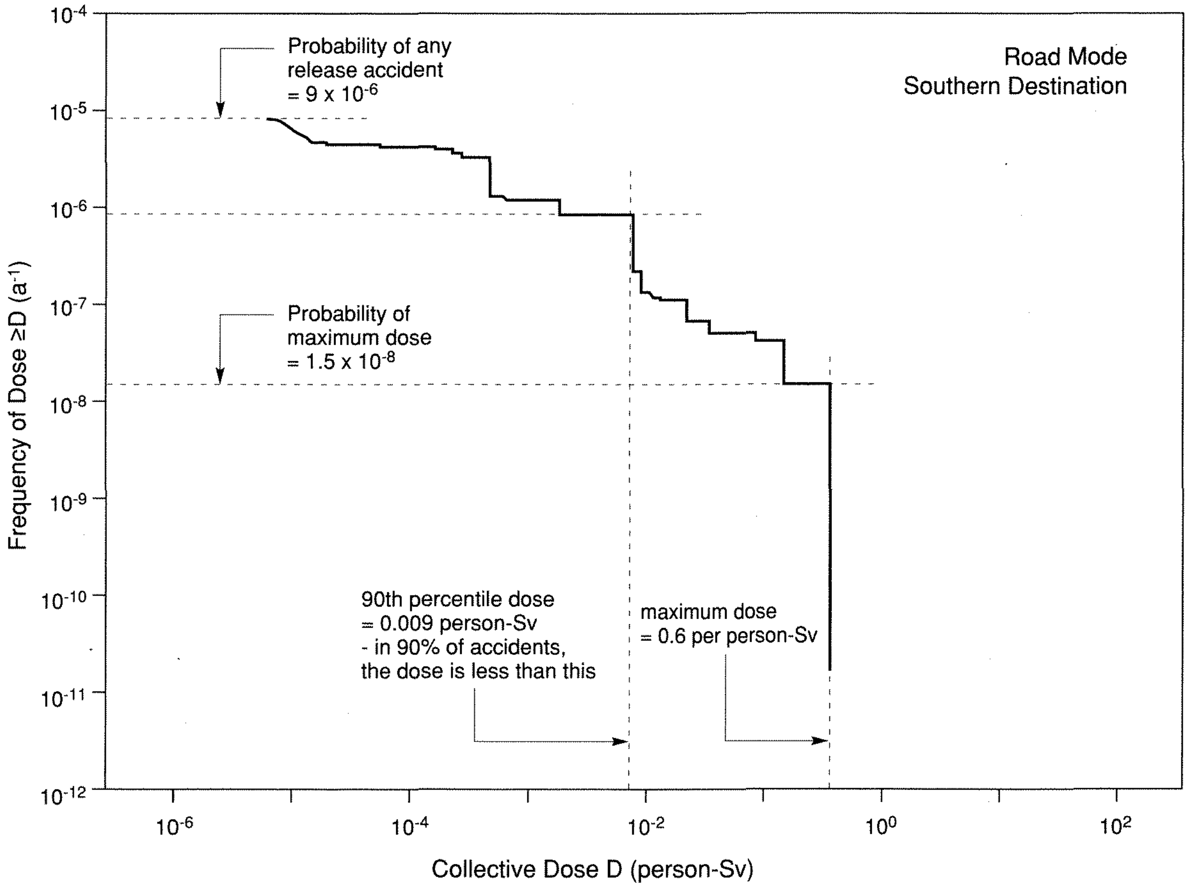


FIGURE 7-3: Annotated Dose-Frequency Curve

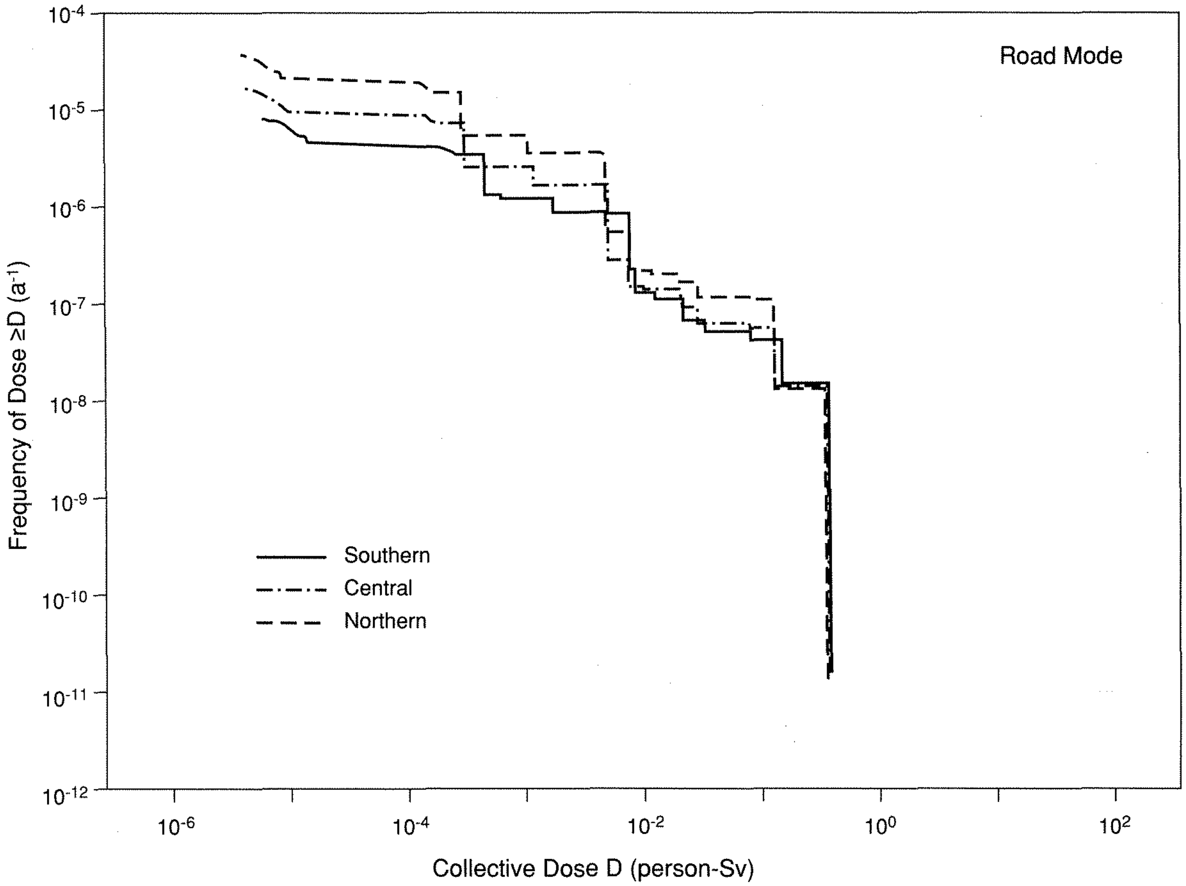


FIGURE 7-4: Collective Dose-Frequency Curve for Road Transport

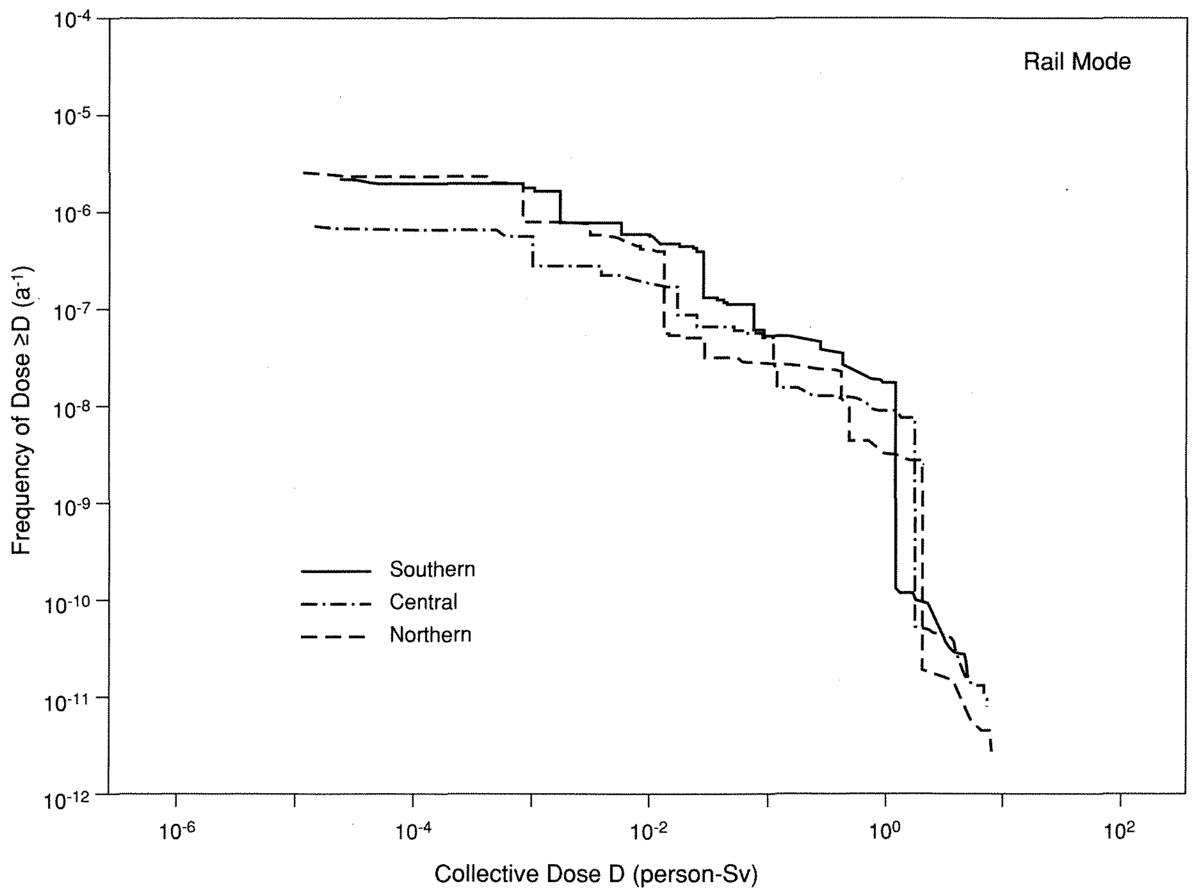


FIGURE 7-5: Collective Dose-Frequency Curve for Rail Transport

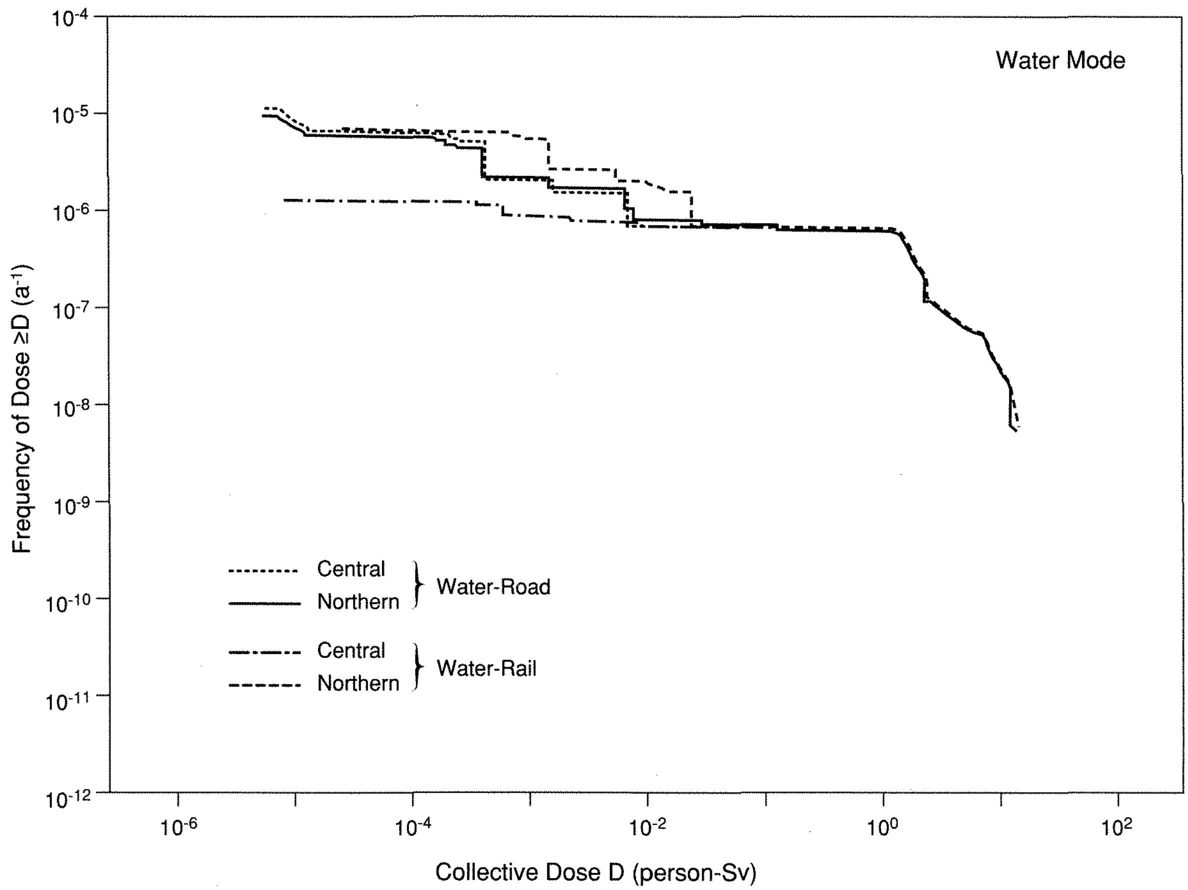


FIGURE 7-6: Collective Dose-Frequency Curve for Water Transport

The maximum collective dose would be about 10 person-Sv for the rail and water cases. This dose could be for accidents in Severity Category 9/10 (see description of accident severity categories in Section 7.1.2.1), with poor dispersion weather (Pasquill Category E weather in this case), in the most highly populated zone. For road transportation, because of the limited loads of flammable material that would be involved (Kempe 1993a), there are no accidents in Categories 8 or 9/10, and the maximum collective dose is less than 1 person-Sv, occurring in Categories 2, 3/4 or 6/7, in Pasquill Class F weather (Figure 7-4). The frequency of the mode-specific 'worst case' varies widely, from 10^{-12} per year for the rail mode to 10^{-8} per year for the road and water modes. These probabilities are very small. For more 'credible' probabilities of around 10^{-6} per year, the collective dose ranges from 0.01 to 1 person-Sv for the road mode, 0.01 to 10 for the rail mode, and 1 to 10 person-Sv for the water mode. To give some meaning to these figures, the potentially exposed population in the model ranges from about 10^3 to 10^5, depending on the population density zone in which the accident occurs. Average natural background radiation of 3 mSv per year would contribute a collective dose to these populations of 3 person-Sv to 300 person-Sv per year. In comparison, the maximum collective dose of 10 person-Sv for the road or water cases has a probability of occurring once in a hundred million years.

The dose calculated for each scenario (i.e. each combination of accident severity category, Pasquill stability class and population zone) may be multiplied by the corresponding frequency to give the frequency-weighted dose from that scenario. Summing over all scenarios gives the total annual frequency-weighted dose. This is summarized in Table 7-9.

TABLE 7-9
Annual Frequency Weighted Dose to Public Due to Accidents

Mode	Destination	Person-Sv·a^{-1}
Road	Southern Central Northern	2.1×10^{-8} 2.4×10^{-8} 4.3×10^{-8}
Rail	Southern Central Northern	6.2×10^{-8} 3.4×10^{-8} 3.3×10^{-8}
Water-Road	Central Northern	[1]8.4×10^{-9}/ [2]1.5×10^{-6} 1.9×10^{-8} / 1.5×10^{-6}
Water-Rail	Central Northern	[3]1.1×10^{-9}/ 1.5×10^{-6} 3.3×10^{-8} / 1.5×10^{-6}

[1] Road
[2] Water
[3] Rail

3) Maximum Short-Term Individual Dose

The downward cumulative frequency distribution curve for each case is presented in Figures 7-7 to 7-9. Examining the curves in the same way as for the collective dose, the maximum individual dose (to an adult) ranges from 9 mSv for the road mode to 30 mSv for the rail and water-rail modes.

Individual doses associated with a frequency of 10^{-6} per year range from 0 to 30 mSv. The individual dose which is not exceeded in 90% of release accidents ranges from 3 mSv to 30 mSv.

The maximum individual doses are summarized in Table 7-10 for each mode. If we assume that the same radiation dose limits as used for the UFDC safety analysis also apply to the used fuel transportation analysis, the limits of Table 6-17 can be used. This table specifies dose limits as a function of accident frequency. The worst case transportation accident, with a frequency of approximately 10^{-6}, would fall in accident class 5. The maximum doses, 10 - 40 mSv for infants, would only be a fraction of the 250 mSv limit for that event class.

The results may be compared with the Protective Action Levels given in the Ontario Nuclear Emergency Plan, although it should be noted that this does not apply to transport accidents. The maximum frequency of an accident resulting in a dose to the critical group greater than 10 mSv, which is the projected dose at which evacuation should be undertaken, is 4×10^{-6} a^{-1}. This is for a dose of 10 mSv to an infant, for the road mode (Kempe 1993a).

4) Long Term Doses

Adult doses from long-term groundshine and resuspension were compared with the short-term, or acute, doses. With cleanup, the individual dose would increase by about 60% if long-term pathways were included, but if no cleanup is undertaken, the dose could increase by a factor of ten, due to resuspension. The collective dose in the most severe accidents is affected more by inclusion of the long-term pathways, since in the most severe accidents the cesium deposition from elevated releases leads to higher groundshine doses over a wide area.

Exposure via the foodchain was not included in the main calculations, because control of food supplies would be exercised if necessary, and would be the main factor affecting exposure. Comparison of the dose from the various pathways (Kempe 1993a) indicated that in an accident in Severity Category 2, the foodchain dose, 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 long-term groundshine together (also without intervention). Note that these comparisons are for long-term exposure to the effects of the entire release. For locations close to the accident, this dose is in the range (>0.5 mSv; Government of Ontario 1984) at which, for locations close to the accident, bans on food consumption might be considered. However, given the conservatism in the calculation, it is judged unlikely the intervention would in fact be required. It was assumed all food is produced where the individual lives, and equilibrium transfer parameters, representing an average over the growing season, were used. In practice, further dilution of the activity would take place both in the environment and by diversity in the production location of the individual's diet.

For a Severity Category 9/10 accident, the foodchain dose without intervention might be several hundred times the dose from inhalation, or about 30% of the dose from inhalation and long-term groundshine (without cleanup) combined, reflecting the proportionally greater release of ^{137}Cs in Severity

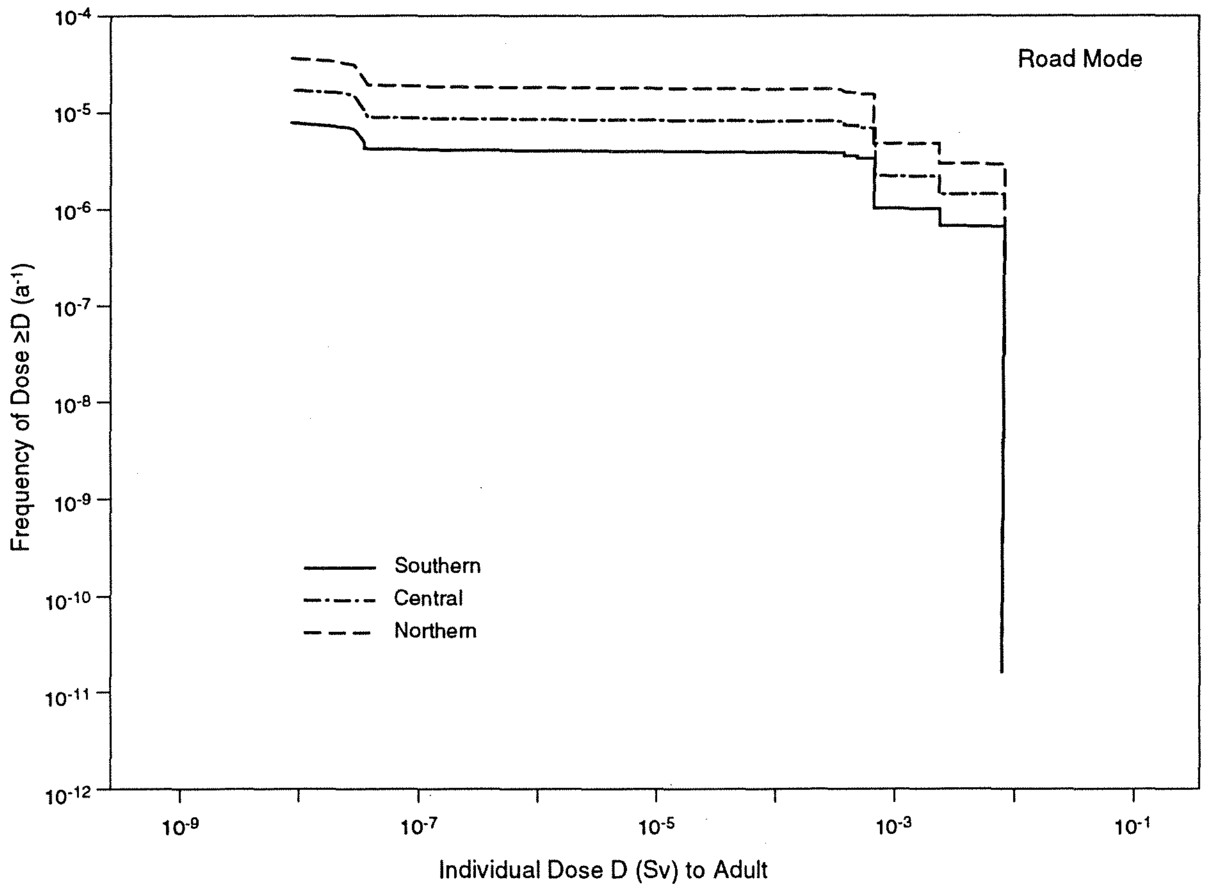


FIGURE 7-7: Individual Dose-Frequency Curve for Road Transport

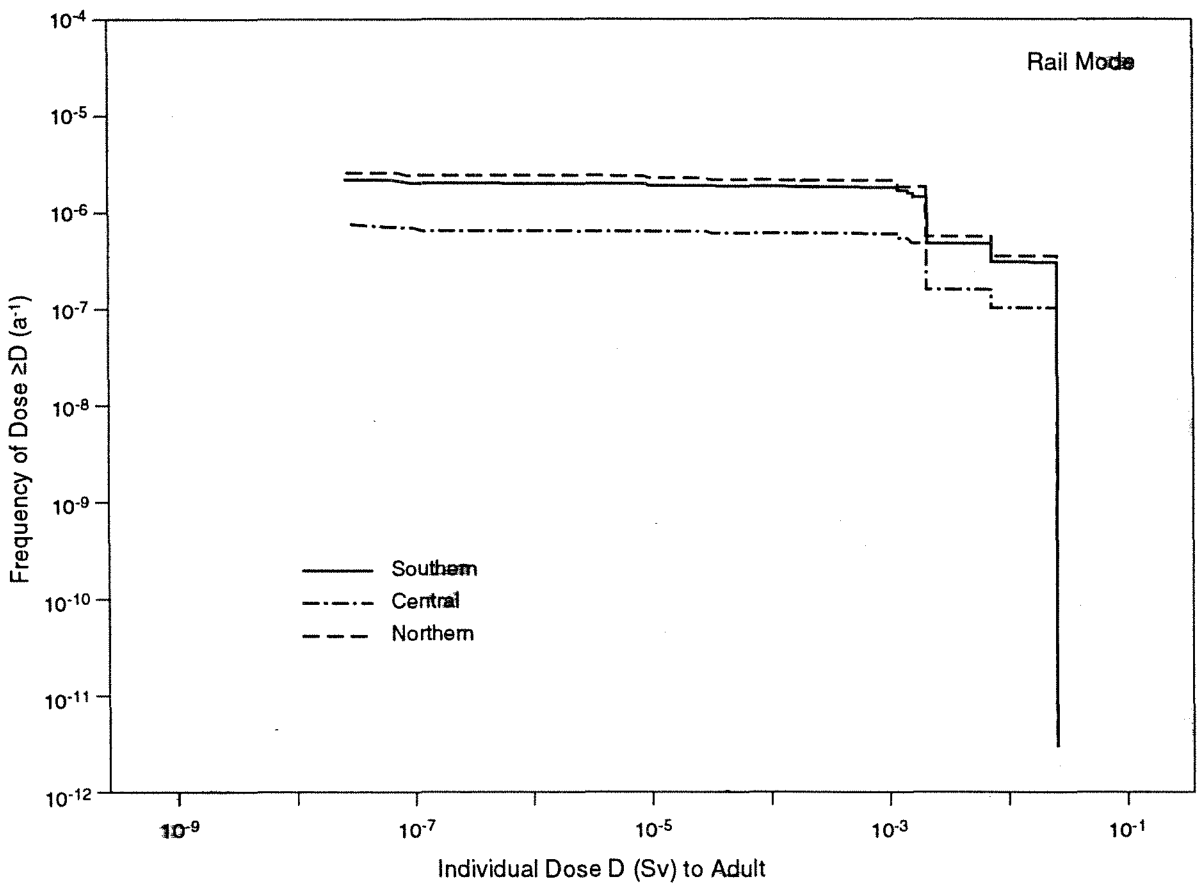


FIGURE 7-8: Individual Dose-Frequency Curve for Rail Transport

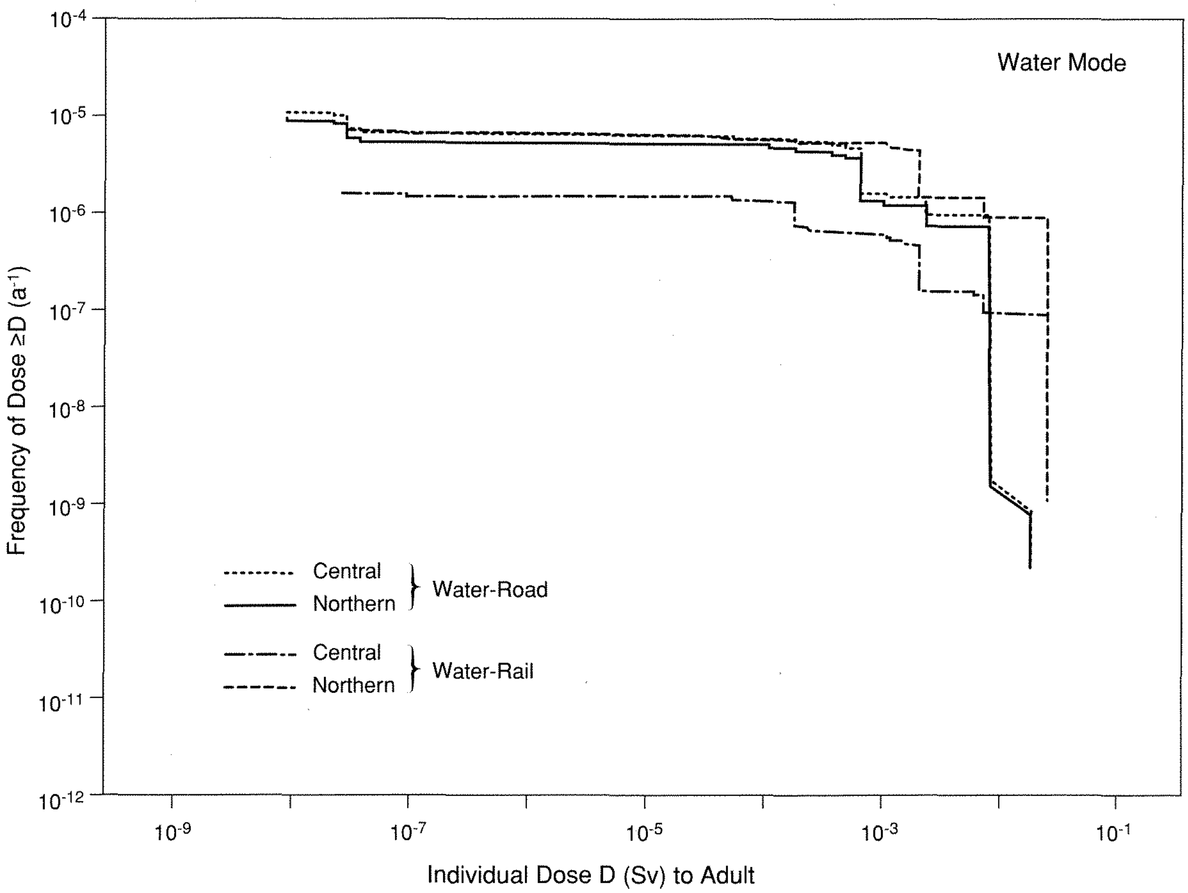


FIGURE 7-9: Individual Dose-Frequency for Water Transport

TABLE 7-10
Summary of Maximum Individual Doses
Due to Transportation Accidents

Mode	Maximum Individual Dose (mSv)			Annual Frequency of worst case
	90th percentile	Worst Case Adult	Worst Case Infant	
Road	3	9	13	3×10^{-6}
Rail	30	28	40	4×10^{-7}
Water[1]	30	28	40	8×10^{-7}

[1] The maximum individual dose is given for the water portion of the route. The maximum individual dose for the road or rail portion would be the same as for road or rail transport alone.

Category 9/10. Intervention would almost certainly be required if food crops were grown in the vicinity of the accident. Radioactivity levels would be confirmed by monitoring.

Potential doses due to release into a water body were examined by assuming a Category 9/10 accident occurred in the water mode, followed by sinking of the cask near a drinking water intake (Kempe 1993a). The individual dose calculated was about the same as that due to an airborne release. However, this dose would be subject to control by monitoring.

7.2 POTENTIAL RADIOLOGICAL IMPACTS ON THE WORKERS

This section presents the radiological impacts on workers from used fuel transportation during both normal and accident conditions. Details of the analysis are contained in Zeya (1993b).

7.2.1 Normal Conditions

7.2.1.1 Analysis Methodology

1. Hazard Identification and Exposure Time

The first step, to identify the routine radiological hazards associated with the occupational activities performed in the reference road, rail and water systems, was accomplished mainly through detailed analysis of the reference transportation system (Ulster 1993a). For the activities not included in the reference transportation system description, analysis assumptions based on experience in the industry were used. For each identified hazard, exposure time (person-hours) was determined. Most of the labour estimates were based on comparable industrial experience, since large-scale used fuel transportation has not yet been performed in Canada.

2. Hazard Quantification

An estimate of the anticipated routine doses to workers in all areas of the transportation system during normal operation was obtained by multiplying the estimated dose rate by the person-hours spent working while exposed to the particular dose rate.

Radiation doses were compared to the AECB regulatory limits and guidelines.

7.2.1.2 Analysis Results

In this sub-section, radiological hazards to workers from handling and transporting used fuel are first identified for normal transportation. The impacts of these hazards on workers are then analyzed.

The transportation activities under investigation included: unloading empty transportation casks from vehicles at the nuclear generating station (NGS), filling the casks with used fuel storage modules in the irradiated fuel bay (IFB), loading the casks onto vehicles, transporting the casks to the disposal facility by road, rail or water, and returning empty casks to the NGS. For the purpose of this assessment, the dividing line between transportation and disposal is the entrance gates to the disposal centre.

1. Routine Radiological Hazards

The radiation hazards and exposure times were determined during normal transportation activities for the three modes being analyzed (road, rail and water).

i) Nature of the Hazards

a) Hazards from cask handling activities (at the NGS):
   - direct radiation fields near the full cask;
   - ambient radiation dose rates in the IFB area; and
   - airborne radioactivity generated during decontamination of full fuel casks;
b) hazards from cask movement to station docks (water mode only);
c) hazards from cask handling at station docks (water mode only);
d) hazards from cask transportation;
e) hazards from cask and vehicle inspections;
f) hazards from emergency repairs of transportation vehicles (breakdown en route); and
g) hazards from cask handling at the Transfer Facility (water mode only):
   - direct radiation fields emanating from the casks.

ii) Exposure Time

Exposure times for road, rail and water transportation activities are shown in Tables 7-11, 7-12 and 7-13, respectively.

2. Routine Radiation Dose Rates

The dose rates were used in conjunction with the exposure times to calculate the annual effective collective dose equivalent. The dose rates used were estimated based mainly on cask-to-crew geometry and on the number of casks present. Details on the cask-to-crew geometry and other assumptions used in the dose calculations can be found in Zeya (1993b). Average distances from the cask for road, rail and water activities are shown in Tables 7-11 to 7-13, respectively.

TABLE 7-11
Occupational Radiation Hazards and Exposure Times
for Normal Road Transportation Activities

Transportation Activity/Location	Average Distance from Source (m)	Time of Exposure (person-hours·a^{-1})
Cask Handling at Station	0.5	5 000
	1.0	2 860
	2.0	6 500
	3.0	400
	4.0	0
	5.0	4 400
	10.0	6 800
	General IFB[1] Area	6 900
Driving to Southern Centroid	10.0	7 500
" " Central "	10.0	34 000
" " Northern "	10.0	61 000
Cask and Vehicle Inspection		
Southern Centroid	2.0	156
Central Centroid	2.0	310
Northern Centroid	2.0	700
Emergency Repairs		
Southern Centroid	2.0	24
Central Centroid	2.0	54
Northern Centroid	2.0	112

[1] Irradiated Fuel Bay

TABLE 7-12
Occupational Radiation Hazards and Exposure Times for Normal Rail Transportation Activities

Transportation Activity/Location	Average Distance from Source (m)	Time of Exposure (person-hours·a^{-1})
Cask Handling at Station	0.5	1 770
	1.0	1 060
	2.0	2 200
	3.0	135
	4.0	0
	5.0	1 780
	10.0	2 320
	General IFB Area	3 600
Transport to Southern Centroid	various	1 020
" " Central "	various	1 980
" " Northern "	various	3 280
Cask and Vehicle Inspection[1]		
Southern Centroid	2.0	7
Central Centroid	2.0	14
Northern Centroid	2.0	21
Emergency Repairs		
Southern Centroid	2.0	6
Central Centroid	2.0	12
Northern Centroid	2.0	18

[1] An inspection is assumed to occur prior to leaving the station and every 500 km thereafter.

TABLE 7-13
Occupational Radiation Hazards and Exposure Times
for Normal Water Transportation Activities

Transportation Activity/Location	Average Distance from Source (m)	Time of Exposure (person-hours·a^{-1})	
Cask Handling at Station		**Water-road**	**Water-rail**
	0.5	4 700	1 560
	1.0	2 550	850
	2.0	5 800	1 970
	3.0	400	135
	4.0	0	0
	5.0	3 300	1 310
	10.0	6 800	2 320
	IFB Area	2 310	3 600
Cask Movement to Station Dock		3 800	1 250
Cask Handling at Station Dock	1.0	2 500	1 250
	5.0	1 250	420
Transport			
to Central Centroid	on tug - various	14 300	14 300
	on barge - 2 m	10	10
	on barge - various	620	620
to Northern Centroid	on tug - various	16 800	16 800
	on barge - 2 m	10	10
	on barge - various	620	620
Cask Handling at TF	1.0	2 810	1 250
	5.0	940	310
Cask Transport from TF to Disposal			
to Central Centroid		3 800	2 600
to Northern Centroid		6 600	3 300
Road/Rail Inspection and Repairs			
to Central Centroid			
-repairs	2.0	20	12
-inspections	2.0	78	26
to Northern Centroid			
-repairs	2.0	32	26
-inspections	2.0	156	12
Tug/Barge Inspections/Repairs	2.0	52	52

i) Cask Handling Dose Rates

Average road and rail cask dose rates at varying distances from the surface are presented in Table 7-14. These were derived for casks containing ten-year-cooled fuel with an average burnup of 685 $GJ \cdot kg^{-1}U$, as described in Section 7.1.1.1.

ii) Dose Rates En Route

For road transportation, the dose rate in the tractor cab, calculated without crediting shielding by the cab enclosure or steel cask weather cover, was estimated to be 0.0015 $mSv \cdot h^{-1}$.

For the rail mode, it was assumed that the dose rate in an occupied area was the sum of the contribution from each cask on the train, neglecting shielding by other casks and railcar steel. The shielding provided by the train engine and locomotive housing was, however, credited. The resulting dose rates were zero in the locomotive and 0.00039 $mSv \cdot h^{-1}$ in the caboose. The dose estimates are expected to be sufficiently conservative that any additional radiation dose received by the crew when the train goes around curves can be neglected (detailed information on the route would be necessary to include this component of the dose).

For the water mode, the dose rates calculated for the two occupied locations (tug bridge and front of the barge) were 0.00086 and 0.023 $mSv \cdot h^{-1}$ for the road cask configuration, and 0.0029 and 0.011 $mSv \cdot h^{-1}$ for the rail casks. Cask movement from the NGS to the station dock via transporter would also result in occupational dose. Two workers would be required to perform this movement. It was conservatively assumed that the workers would be located only 4 metres away from the surface of the cask during the movement. The dose rate at this location was calculated to be 0.0083 $mSv \cdot h^{-1}$ due to cumulative dose from many casks.

iii) Cask Inspection Dose Rates

Inspection activities for all three modes were assumed to take place at an average distance of 2 m from the casks. The dose rate at that location was calculated to be 0.014 $mSv \cdot h^{-1}$.

iv) Emergency Repair Dose Rates

While recognizing that, whenever possible, breakdowns en route would not be repaired while full casks were on board, the 2 m cask handling dose of 0.014 $mSv \cdot h^{-1}$ was used to represent emergency repair doses for all three modes.

TABLE 7-14
Cask Handling Dose Rates

Distance from cask (m)	Average Dose Rate ($mSv \cdot h^{-1}$)
0.5	0.034
1.0	0.027
2.0	0.014
3.0	0.008
4.0	0.0052
5.0	0.0035
10.0	0.0015

7.2.1.3 Impact Analysis

1. Radiation Dose Estimates

Table 7-15 presents a summary of the annual collective dose for normal activities carried out in the road, rail and water transportation systems.

TABLE 7-15
Summary of Estimated Total Annual Effective Collective Dose Equivalents for Road, Rail and Water Systems

Mode	**Total Annual Effective Collective Dose Equivalent (person-mSv·a^{-1})**		
	to Southern Region	**to Central Region**	**to Northern Region**
Road	420	470	580
Rail	153	154	154
Water-Road	-	680	700
Water-rail	-	266	274

The maximum annual individual doses received by members of the transport crews were estimated to be 2.4 mSv·a^{-1}, 1.2 mSv·a^{-1} and 10 mSv·a^{-1} for road, rail and water, respectively.

2. Comparison with Regulatory Guidelines and Limits

For road transportation, the cab dose was calculated to be 0.00153 mSv·h^{-1}. The IAEA guideline (IAEA 1990 and Appendix C) of 0.02 mSv·h^{-1} 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 are well below the 0.02 mSv·h^{-1} specified for truck drivers.

The Atomic Radiation Worker (ARW) dose limit is set at 50 mSv per year. Therefore, radiation doses received by workers during transportation of used fuel (varying between 1.2 and 10 mSv·a^{-1}) would be within the ARW dose limit.

The AECB occupational dose limit will likely be reduced to 20 mSv·a^{-1} (ICRP 1991, AECB 1991a). The calculated doses are also within the new limit.

For cask handling at the NGS, assuming road transport, 3 shifts of 4 workers per shift, 292 casks shipped from a station per year, the maximum annual individual dose would be approximately 10.6 mSv·a^{-1}. This dose is also well below the 50 mSv·a^{-1} ARW dose limit, and the reduced limit from ICRP 60 (ICRP 1991, AECB 1991a).

7.2.1.4 Mitigation Measures

The system assessed was not refined to reduce doses. At the implementation stage, optimization of radiation dose and ALARA (As Low As Reasonably Achievable) in the design process would be used.

The work activity that would contribute most to occupational radiation dose would be cask handling at the nuclear stations. Reduction of worker exposure times to used fuel casks would, in turn, reduce radiation doses. This would be assisted by providing adequate cask handling training to workers. Work procedures could also be established so that a minimum number of workers were present in the work area. Further measures which would be considered include the use of hydraulic or pneumatic bolting equipment for the lid and impact limiter. The use of remote tooling for activities such as decontamination, contamination monitoring and lid bolting would also reduce occupational dose.

Although moving of the casks is not a major contributor to occupational dose for any mode, several ways to reduce radiation exposure during shipment can be identified (e.g. the use of shielding walls, particularly for the barge, and direct shipping routes, to reduce the travel time).

7.2.2 Accident Conditions

7.2.2.1 Analysis Methodology

Acute radiation hazards were calculated for a range of transportation accidents of varying severity and frequency. All radiation doses were expressed as annual effective dose equivalents, i.e. the frequency-weighted dose summed over all exposure scenarios. To assess safety, radiation doses are compared to the AECB regulation limits and guidelines (AECB 1978).

1) Nature of the Hazard

Accidents during cask handling at the station, prior to cask sealing would have low frequency and consequences, provided strict cask handling procedures were followed. Impact pads would be provided to eliminate any consequences from a cask or a lid drop into the IFB. Because of the low speeds within the generating station sites, and the control of flammable materials, no accident during cask handling at the station, transfer facility or station docks, would result in a drop, crush or fire exceeding the severity of the cask certification tests. Therefore, once the full casks are ready for shipment (i.e. lid bolted down and impact limiter(s) in place), no accident which could breach the cask would occur and no acute radiation dose could be received by the workers until the cask was en route.

The nature of the hazards are: (a) direct radiation from the cask contents, enhanced by a potential loss of cask shielding, and (b) radioactive materials released from the cask. The potential for these hazards only exists for severe transportation accidents, with large impact forces and/or accompanied by a fire.

2) Accident Severity Considerations

a) Road Transportation

Because of the inherent safety of the cask design, an accident severe enough to result in a significant release of radioactive material would most likely kill the driver(s). However, for conservatism in the estimation of dose, it is assumed that an accident severe enough to have radiological consequences can occur during transit and that all drivers would survive the accident and receive an acute radiation dose.

b) Rail Transportation

Based on results from an experimental crash done in the U.K. (Cook et al. 1985; Hart et al. 1985a; Holt 1985), it is anticipated that, as for the road, a rail accident potentially severe enough to damage the cask would kill the crew. For conservatism, it is assumed that a cask breach accident can occur in the rail system and that all crew members would survive and receive an acute radiation dose.

c) Water Transportation

Due to the low speeds involved, and absorption of energy by the intervening barge structure (the casks are located below decks), failure of the cask by impact alone is not considered possible. Radioactive release would only take place in a lengthy, enveloping fire, in which case it is likely that the surviving crew would withdraw from the vicinity. It is assumed that a severe marine accident could result in fire on a loaded tug/barge which does not kill the crew, but does result in the release of radioactive material from a cask.

In the event of a collision which penetrates into the barge, bulkheads can be isolated such that the barge remains stable (not sink) and the crew would be protected. The emergency response measures outlined in Appendix J would also protect the crew.

7.2.2.2 Analysis of Potential Impacts

The probability and severity of postulated accidents (road, rail and water) used for occupational safety analysis is the same as used for the public safety analysis. The potential accident dose to crew members resulting from acute radiation releases were obtained from Kempe (1993a).
The pathways leading to an acute occupational dose are:

i) inhalation of radioactive material in the plume;

ii) inhalation of re-suspended activity;

iii) external radiation from ground deposits (groundshine); and

iv) direct external radiation from radioactive material remaining in the cask.

For the transport crew, pathways ii, iii and iv are assumed to be insignificant compared with i, due to the small amount of ground deposits anticipated within 50 m of the accident site and because the crew would be evacuated allowing for a reasonable response time. In addition, no loss of cask shielding is expected, therefore, the exposure rate from pathway iv is equal to the chronic dose rate.

1) Estimate of Frequency-Weighted Individual and Collective Dose

To estimate the frequency-weighted annual dose for all accidents, the following assumptions are made:

i) transport crew survives all accident severities and remains within 50 m of the release point (on average at 25 m);

ii) all accidents take place in Pasquill weather stability class F (poor dispersion);

iii) plume rise associated with the fire in the later part of the accident prevents dose accumulation in the vicinity of the accident scene;

iv) the dose is calculated assuming that the crew would be present for the entire duration of the release; and

v) clean-up after the accident is not included in the occupational doses, since the clean-up exercise would be conducted under suitable radiological control, by trained workers other than transport crew.

The maximum acute dose to an individual worker resulting from a cask release accident based on the accident severity scheme developed for the public safety analysis is presented in Table 7-16. Taking into account the crew size, the total crew dose can be calculated for each severity category. The crew dose for each scenario (i.e. each accident severity category, since Pasquill class F weather is assumed in all cases) may be multiplied by the corresponding frequency to give the frequency-weighted dose from that scenario. Summing over all scenarios, the results are as presented in Table 7-17 (frequencies were calculated as shown in Table 7-7).

2) Comparison with Regulatory Guidelines and Limits

The worst credible accident could result in a dose of about 190 mSv. This dose would not result in any acute (or non-stochastic) effects. The probability of such an accident is extremely low.

TABLE 7-16
Maximum Acute Radiation Dose to a Worker for each Mode and Accident Severity Category (in mSv)

Accident Severity Category[1]	Mode	
	Road and Water-Road	Rail and Water-Rail
1	0	0
2	64	190
3/4	64	190
5	0	0
6/7	65	190
8	0	0
9/10	64	190

[1] See Table 7-6 for fraction of accidents in each severity category and Table 7-7 for the annual probability of a release accident.

TABLE 7-17
Frequency-weighted, Expected Annual Dose to Crew[1]
from Acute Radiation Releases during Transportation Accidents
(in person-mSv per year)

MODE	DESTINATIONS[2]		
	Southern Region	Central Region	Northern Region
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}

[1]Crew size: road: 1, 2 and 2 drivers for Southern, Central and Northern destinations
rail: 4
water: 8
[2]To the geometric centre of each region.

7.3 POTENTIAL NON-RADIOLOGICAL IMPACTS ON WORKERS

7.3.1 Normal Conditions

7.3.1.1 Analysis Methodology

The first step is to identify the specific routine and acute non-radiological hazards to workers from the operation of the reference road, rail and water systems. Hazard identification is accomplished mainly through detailed analysis of the reference transportation system (Ulster 1993a). For the activities which have not been included in the reference transportation system description, assumptions were used based on experience in the industry.

For each identified hazard, exposure time (person-hours) is determined. Most of the labour estimates were based on comparable industry experience, since large-scale used fuel transportation has not yet been performed in Canada.

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

7.3.1.2 Impact Analysis

1. Hazard Identification

i) Emissions

Atmospheric pollutants released from the tractor, locomotive and tug diesel engines could affect the cask-handling personnel and crew.

ii) Noise

Noise from the tractor/trailer and tug diesel engines could be a concern for cask-handling personnel, maintenance crews and drivers. Locomotive and railcar noise would be significantly higher than for the road, but since maintenance would be effected by the railway company, only the train crew is considered to be exposed in the present analysis.

iii) Vibration

Vibration from the operation of the tractor, locomotive and tug diesel engines can also pose an occupational health risk for driving and maintenance crews (mostly annoyance and possible loss of concentration).

iv) Transfer Facility Construction and Decommissioning

The non-radiological hazards associated with transfer facility construction and decommissioning would be similar to construction hazards encountered in small building projects.

2. Exposure Time

Because it is anticipated that chronic non-radiological hazards would not contribute to conventional fatality risk, the identified hazards were only treated qualitatively and no exposure time was determined.

7.3.1.3 Analysis Results

Routine exhaust emissions from the tractor, locomotive and tug would have a minimal impact on the crew provided adequate ventilation was provided. It was assumed that ventilation would be provided in working areas for all fuel handling personnel in accordance with standards established in Ontario Hydro (1979).

The noise environment within the tractor cab under standardized conditions should typically be within the regulations limit of 90 dB(A) (Hessel et al. 1982). Noise levels in the caboose and the locomotive depend on train speed, engine size and age, vehicle age and construction, wheel wear etc. Typical noise levels in the occupied areas and around the train, and on the tug and barge, are not available but would be within occupational health and safety limits (see Appendix B).

7.3.1.4 Mitigation Measures

Effects on workers would be mitigated by training, the use of protective equipment, and by control and surveillance of working conditions.

7.3.2 <u>Accident Conditions</u>

7.3.2.1 Analysis Methodology

1. General

For accident conditions, acute hazards were quantified as risk factors (expected number of fatalities per 100 million person-hours associated with workers' activities). To assess safety, the quantified non-radiological hazards were compared to the regulatory limits and guidelines.

An estimate was made of the statistically-expected number of fatalities from exposure to non-radiological hazards. The risk factors were multiplied by the hours of labour required for an activity to yield an estimate of the non-radiological risk for that activity.

2. Hazard Identification

a) Cask Handling

The following hazards were identified for cask handling activities:

i) dropping of casks, cask lid or lifting beam;

ii) crushing of individuals between casks or cask components while being handled; and

iii) injuries from working on casks with hand tools (e.g. wrenches) for bolting down lid, venting, pressure testing, etc.

Cask handling hazards at the transfer facility would be of a similar nature. There would be an additional falling hazard associated with dock work.

b) Cask Transportation

Normal traffic accidents would constitute a hazard for the driving crew.

For the water mode, accidents include: collisions, groundings, capsizings, explosions, fires, founderings, falling overboard and cargo/machinery-related accidents.

c) Miscellaneous Hazards

Accidents such as falling, machine and tool injuries during maintenance or cask tiedown, and on-site vehicle/personnel collisions could also occur.

3. Exposure Time

Exposure to the identified hazards are expressed in terms of person-hours per year, as shown in Table 7-18.

4. Hazard Quantification

It is expected that most of the cask-handling accidents would result in only minor injuries because of the strict safety precautions applied to cask handling, and Ontario Hydro's experience in this area. The severity of traffic accidents depends on many factors, such as speed, accident situation, and the other vehicles or obstacles involved.

No data are available on cask-handling accidents. The cask movement accident hazards have been quantified in terms of death and injury, based on data from Social Data Research Ltd. (1986).

7.3.2.2 Analysis of Potential Impacts

The non-radiological risks results presented in Table 7-19 are based on adjusted fatality data obtained from the Workers Compensation Board (Social Data Research Ltd. 1986). It is 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 fatal accident history of Ontario Hydro operations versus the general Ontario industry rate (64%) was used to adjust the industry average fatality rates for activities where Ontario Hydro has full control, such as cask handling at the station. Fatality rates for occupations such as truck driver and train crew were not subject to the reduction since they are affected by many external factors.

TABLE 7-18
Workers Exposure Time for Identified Non-radiological Hazards

Total Annual Person-hours[1] for Activity			
	Southern Region	Central Region	Northern Region
Road System Activities			
Cask Handling	45 500	45 500	45 500
Cask Movement (full & empty)	15 000	67 500	122 000
Maintenance	3 900	6 200	10 100
Support	64 700	119 900	270 900
Rail System Activities			
Cask Handling	18 200	18 200	18 200
Cask Movement (full & empty)	4 100	7 900	13 100
Maintenance	2 800	3 600	5 100
Support	56 200	57 100	58 400
Water System Activities			
Road Cask Handling			
Stations	-	43 200	43 200
Station Docks	-	7 500	7 500
TF	-	7 500	7 500
Rail Cask Handling			
Stations	-	17 100	17 100
Station Docks	-	3 300	3 300
TF	-	3 100	3 100
Road Cask Movement			
Station to Dock Return	-	7 500	7 500
Station Dock to TF	-	30 000	34 900
TF to UFDC	-	7 500	7 500
Maintenance	-	6 400	7 300
Support	-	109 900	121 500
Rail Cask Movement			
Station to Dock Return	-	2 500	2 500
Station Dock to TF Return	-	30 000	34 900
TF to UFDC Return	-	10 400	13 300
Maintenance	-	4 000	4 000
Support	-	70 600	78 500

[1]Rounded.

TABLE 7-19
Estimated Non-radiological Risk from Accident Conditions during Transportation Activities

Mode and Activity	Estimated Person-hours per year	Risk Factor		Risk Estimate	
		Injuries/ 10^8 person-hours	Fatalities/ 10^8 person-hours	Injuries/ year	Fatalities/ year
ROAD					
Cask Handling					
Southern	45 500	3 273	4.4	1.5	2.0×10^{-3}
Central	45 500	3 273	4.4	1.5	2.0×10^{-3}
Northern	45 500	3 273	4.4	1.5	2.0×10^{-3}
Cask Movement					
Southern	15 000	6 832	13.5	1.0	2.0×10^{-3}
Central	67 500	6 832	13.5	4.6	9.1×10^{-3}
Northern	214 000	6 832	13.5	14.6	33.1×10^{-3}
Maintenance					
Southern	3 900	5 590	8.4	0.2	3.3×10^{-4}
Central	6 200	5 590	8.4	0.4	5.2×10^{-4}
Northern	10 100	5 590	8.4	0.6	8.5×10^{-4}
Support					
Southern	64 700	300	0.4	0.2	2.6×10^{-4}
Central	119 900	300	0.4	0.4	4.8×10^{-4}
Northern	270 900	300	0.4	0.8	1.0×10^{-3}
Total Estimated Annual Injuries and Fatalities					
Southern				2.9	4.6×10^{-3}
Central				6.8	12.1×10^{-3}
Northern				17.5	37.0×10^{-3}

continued ...

TABLE 7-19 (continued)

Mode and Activity	Estimated Person-hours per year	Risk Factor		Risk Estimate	
		Injuries/ 10^8 person-hours	Fatalities/ 10^8 person-hours	Injuries/ year	Fatalities/ year
RAIL					
Cask Handling					
Southern	18 154	3 273	4.4	0.6	0.8×10^{-3}
Central	18 154	3 273	4.4	0.6	0.8×10^{-3}
Northern	18 154	3 273	4.4	0.6	0.8×10^{-3}
Cask Movement					
Southern	4 096	1 967	14.7	0.1	0.6×10^{-3}
Central	7 936	1 967	14.7	0.2	1.2×10^{-3}
Northern	13 132	1 967	14.7	0.3	1.9×10^{-3}
Maintenance					
Southern	2 800	5 590	8.4	0.2	2.4×10^{-4}
Central	3 600	5 590	8.4	0.2	3.0×10^{-4}
Northern	5 100	5 590	8.4	0.3	4.3×10^{-4}
Support					
Southern	56 174	300	0.4	0.2	2.2×10^{-4}
Central	57 138	300	0.4	0.2	2.3×10^{-4}
Northern	58 438	300	0.4	0.2	2.3×10^{-4}
Total Estimated Annual Injuries and Fatalities					
Southern				1.0	1.9×10^{-3}
Central				1.1	2.5×10^{-3}
Northern				1.3	3.4×10^{-3}

continued ...

TABLE 7-19 (continued)

Mode and Activity	Estimated Person-hours per year	Risk Factor		Risk Estimate	
		Injuries/ 10^8 person-hours	Fatalities/ 10^8 person-hours	Injuries/ year	Fatalities/ year
WATER-ROAD					
Cask Handling (Central and Northern)					
NGS[a]	43 200	3 273	4.4	1.4	1.9×10^{-3}
NGS Docks	7 500	3 273	4.4	0.25	0.3×10^{-3}
Transfer Facility (TF)	7 500	3 273	4.4	0.25	0.3×10^{-3}
Cask Movement					
Central:					
NGS to Docks	7 500	3 273	4.4	0.25	0.3×10^{-3}
Docks to TF	30 000	3 690	18.9	1.1	5.7×10^{-3}
TF to UFDC	7 500	6 832	14.5	0.5	1.0×10^{-3}
Northern:					
NGS to Docks	7 500	3 273	4.4	0.25	0.3×10^{-3}
Docks to TF	34 900	3 690	18.9	1.3	6.6×10^{-3}
TF to UFDC	13 100	6 832	13.5	0.9	1.8×10^{-3}
Maintenance					
Central	6 400	5 590	8.4	0.4	5.4×10^{-4}
Northern	7 300	5 590	8.4	0.4	6.1×10^{-4}
Support					
Central	109 850	300	0.4	0.3	4.4×10^{-4}
Northern	121 506	300	0.4	0.3	4.9×10^{-4}
Total Estimated Annual Injuries and Fatalities					
Central				4.5	10.6×10^{-3}
Northern				5.1	12.4×10^{-3}

continued ...

TABLE 7-19 (concluded)

Mode and Activity	Estimated Person-hours per year	Risk Factor		Risk Estimate	
		Injuries/ 10^8 person-hours	Fatalities/ 10^8 person-hours	Injuries/ year	Fatalities/ year
WATER-RAIL					
Cask Handling (Central and Northern)					
NGS[a]					
NGS Docks	17 100	3 273	4.4	0.6	$7.5x10^{4}$
Transfer Facility (TF)	3 300	3 273	4.4	0.1	$1.5x10^{4}$
	3 100	3 273	4.4	0.1	$1.4x10^{4}$
Cask Movement					
Central:					
NGS to Docks	2 500	3 273	4.4	0.1	$1.1x10^{4}$
Docks to TF	30 000	3 690	18.9	1.1	$5.7x10^{3}$
TF to UFDC	10 400	1 967	14.5	0.2	$1.5x10^{3}$
Northern:					
NGS to Docks	2 500	3 273	4.4	0.1	$1.1x10^{4}$
Docks to TF	34 900	3 690	18.9	1.3	$6.6x10^{3}$
TF to UFDC	13 100	1 967	14.7	0.3	$2.0x10^{3}$
Maintenance					
Central	4 000	5 590	8.4	0.2	$3.4x10^{4}$
Northern	4 000	5 590	8.4	0.2	$3.4x10^{4}$
Support					
Central	70 600	300	0.4	0.2	$2.8x10^{4}$
Northern	78 500	300	0.4	0.2	$3.1x10^{4}$
Total Estimated Annual Injuries and Fatalities					
Central				2.6	$9.0x10^{3}$
Northern				2.9	$10.4x10^{-3}$

1 Nuclear Generating Station

Table 7-19 shows that the conventional risks of transporting used fuel generally increase as the transport distance increases. This is specially true for the road mode due to the large risk associated with truck driver labour. The majority of conventional risk in the rail system (80%) results from the actual movement of rail casks by train and not from cask handling, maintenance or support labour. This is also true to a smaller extent for the water mode.

7.3.2.3 Suggested Mitigation

Strict adherence to safety precautions during cask handling should minimize the probability of cask handling accidents.

The use of direct, short transport routes and dedicated vehicles with well-trained drivers would help reduce the probability of accidents, driver injury and fatality risk. Limiting driving hours according to the Ontario Ministry of Labour regulations and avoiding inclement weather should also reduce the cask movement hazard.

Accidents such as falling, machine and tool injuries, could be prevented to a large extent by the provision of safety features and guards, and by a strict adherence to the health and safety regulations.

7.4 IMPACTS ON THE NATURAL ENVIRONMENT

7.4.1 Normal Operation

7.4.1.1 Analysis Methodology

For the analysis of impacts on the natural environment, potential interactions between used fuel transportation activities and existing or future land uses, availability of non-renewable resources, air quality, and the environment are first identified. The identification matrix is shown in Figure 7-10.

The incremental impacts of used fuel transport, in terms of the resulting increase in atmospheric emissions, noise, traffic and commitment of natural resources, are then determined for the identified interactions.

Finally, the significance of the identified potential impacts is assessed. The magnitudes of the quantifiable impacts are compared to applicable regulations where appropriate, and mitigative measures proposed to avoid or reduce potentially significant impacts. For areas where only a qualitative analysis could be done, due to the generic nature of the study, the significance of impacts is discussed in relation to similar projects and mitigative measures are also proposed.

7.4.1.2 Analysis of Potential Impacts

1. On Land and Water Uses

a) Magnitude of Potential Impacts

The magnitude of the predicted traffic density and noise increase along the reference routes are presented in Tables 7-20 (traffic density), 7-21 (road noise) and 7-22 (rail noise). The increase in traffic noise is also calculated for the road and rail segments with the lowest existing traffic counts in order to indicate the highest potential impact of used fuel transport (see Table 7-23). The estimated equivalent noise level from used fuel water transportation is only 27 dB, because most of the noise sources in a ship are under water.

CATEGORIES	NORMAL TRANSPORTATION ACTIVITIES			ACCIDENT COND.	RTF CONSTRUCTION & OPERATION	ACCESS ROAD/ RAIL
	Road	Rail	Water			
LAND AND WATER USES						
• Residential Land	✓	✓	✓	✓	✓	✓
• Commercial/Industrial Land and Water	✓	✓	✓	✓	✓	✓
• Recreational /Outdoor Land and Water	✓	✓	✓	✓	✓	✓
• Agricultural Land	✓			✓	✓	✓
• Historical/Arch. Site and Specific Land Uses				✓	✓	✓
NATURAL RESOURCES						
• Fuel Commitment (Diesel Fuel)	✓	✓	✓			
• Stainless and Carbon Steel						
• Chromium	✓	✓	✓		✓	
• Nickel	✓	✓	✓		✓	
• Iron and Metallurgical Coal	✓	✓	✓		✓	
• Sand and Gravel					✓	
AIR QUALITY						
• Particulates	✓		✓	✓	✓	✓
• Sulfur Oxides	✓	✓	✓	✓	✓	
• Carbon Monoxide	✓	✓	✓	✓	✓	
• Hydrocarbons	✓	✓	✓	✓	✓	
• Nitrogen Oxides	✓	✓	✓	✓	✓	
• Others		✓		✓	✓	
BIOPHYSICAL						
• Vegetation				✓		✓
• Water Quality			✓	✓	✓	✓
• Wildlife	✓	✓		✓	✓	✓
• Sensitive Natural Areas	✓	✓			✓	✓

FIGURE 7-10: Interactions of Transportation Activities with the Natural Environment

TABLE 7-20
Fractional Increase in Traffic Density due to Used Fuel Transportation to the Regional Centroid

	Average two-way traffic[1]	Fractional Increase in Traffic (%)
ROAD		
TO SOUTHERN REGION CENTROID		
Rural Zone	3 600	0.19
Suburban Zone	10 300	0.07
Urban Zone	7 400	0.10
TO CENTRAL REGION CENTROID		
Rural Zone	4 200	0.17
Suburban Zone	4 300	0.16
Urban Zone	5 100	0.14
TO NORTHERN REGION CENTROID		
Rural Zone	3 200	0.22
Suburban Zone	3 100	0.23
Urban Zone	5 100	0.14
RAIL		
TO SOUTHERN REGION CENTROID		
Rural Zone	12	1.90
Suburban Zone	27	0.80
Urban Zone	24	1.00
TO CENTRAL REGION CENTROID		
Rural Zone	12	1.90
Suburban Zone	9	2.60
Urban Zone	7	3.20
TO NORTHERN REGION CENTROID		
Rural Zone	12	1.90
Suburban Zone	4	5.70
Urban Zone	5	4.60
WATER-ROAD		
TO CENTRAL REGION CENTROID		
Open Water	12 200	0.40
Channel/River	10 800	0.50
Road-Rural	780	1.00
TO NORTHERN REGION CENTROID		
Open Water	12 000	0.40
Channel/River	10 800	0.50
Road-Rural	1 405	0.60
Road-Suburban	3 770	0.20
WATER-RAIL		
TO CENTRAL REGION CENTROID		
Open Water	12 200	0.40
Channel/River	10 800	0.50
Rail-Rural	11	2.60
TO NORTHERN REGION CENTROID		
Open Water	12 000	0.40
Channel/River	10 800	0.50
Rail-Rural	7	4.00

1 Road traffic in vehicles/24 h
Rail traffic in trains/24 h
Water traffic in vessels/a

TABLE 7-21
Estimated Values of Equivalent Noise Level Increase at 15 m from the Road Centerline for the "Reference Route" to the Regional Centroid

Population Used Zone	Noise Level Increase (dB)
TO SOUTHERN CENTROID	
Rural	0.04 to 0.52
Suburban	0.01 to 0.18
Urban	0.01 to 0.24
TO CENTRAL CENTROID	
Rural	0.03 to 0.49
Suburban	0.03 to 0.48
Urban	0.01 to 0.23
TO NORTHERN CENTROID	
Rural	0.03 to 0.49
Suburban	0.03 to 0.49
Urban	0.01 to 0.23

TABLE 7-22
Estimated Values of Equivalent Noise Level Increase at 15 m from the Railway for the "Reference Route" to the Region Centroid, due to Used Fuel Rail Transportation

Population Zone	Noise Level Increase (dB)
TO SOUTHERN CENTROID	
Rural	0.05 to 0.06
Suburban	0.02 to 0.07
Urban	0.03 to 0.07
TO CENTRAL CENTROID	
Rural	0.03
Suburban	0.07 to 0.08
Urban	0.04 to 0.06
TO NORTHERN CENTROID	
Rural	0.01 to 0.02
Suburban	0.06 to 0.07
Urban	0.06 to 0.07

TABLE 7-23
Estimated Values of Noise Level Increase due to Used Fuel Road/Rail Transportation on the Road/Rail Segment with Lowest Traffic

Mode	Noise Level Increase (dB)
Road	0.3 to 4.1
Rail	1.8 to 2.1

Non-radiological wastes which would be produced by used fuel transportation include used tires, waste oil and other routine materials. While not estimated at this stage, the quantities would be large enough to require that procedures be in place, prior to the start of large-scale used fuel transportation, to ensure proper disposal (including possible reuse/recycle) of these wastes.

Because of the generic nature of the transfer facility design, the magnitude of impacts cannot be calculated precisely but rather, correlated to the small size of the facility. The magnitude of potential impacts of road/railway construction and maintenance would be directly proportional to the length of the road/railway to be constructed.

b) Analysis of Potential Impacts

The increase in traffic is not large enough to be distinguishable from normal daily fluctuations and should, therefore, have little impact on residential, industrial and recreational land uses. As can be seen from Table 7-20, the used fuel traffic constitutes a small increase with respect to the existing road, rail and water traffic along the reference route. As an example, Table 7-24 shows that the additional road traffic would be a fraction of the traffic from the opening of a new mine or lumber mill in isolated areas. However, for roads or railways operating at or near full capacity, the used fuel transportation traffic might be significant. The increase in water traffic might be significant through the locks at the beginning and end of the shipping season. Impacts on recreational water use should be minimal. The increase in traffic from used fuel transportation can also be shown to constitute a small fraction of the dangerous goods shipments in Ontario, as illustrated in Table 7-25.

Based on the MTC Noise Policy and Acoustic Standards for provincial highways (Ministry of Transportation and Communications 1987), the impact of an increase in noise level is considered insignificant if it does not exceed 5 dB. The increases in noise level, shown in Tables 7-21, 7-22 and 7-23, vary between 0.01 and 4.1 dB, and should, therefore, not affect existing land uses (Ministry of the Environment 1978). None of the noise levels calculated are expected to lead to an exceedance of the Ministry of the Environment noise criteria (Ministry of Transportation and Communications 1987) for receptors located typical distances from the road and railway.

TABLE 7-24
Comparison of Road Used Fuel Transportation (UFT) Traffic to Typical Mining/Lumbering Industry Traffic in Isolated Areas

Parameter	**Daily Traffic**	**UFT Truck Traffic[1] (% of mine/mill traffic)**
Mine average truck traffic	43	16
Mine truck traffic range	10 to 80	70 to 9
Lumber mill average truck traffic	45	15
Lumber mill truck traffic range	10 to 110	70 to 7

[1] 7 trucks per day.

SOURCE: (MTC, 1983a, 1983b)

TABLE 7-25
Contribution of Used Fuel Transportation (UFT) Traffic to Yearly Dangerous Goods Traffic in Ontario

	UFT	All Dangerous Goods
ROAD		
Number of shipments	938	8 240 000
Tonnage	4 690[1] Mg	39 517 000 Mg
UFT gross payload	32 600[2] Mg	
RAIL		
Number of shipments (railcars)	313	132 800
Tonnage	4 690[1] Mg	8 076 000 Mg
UFT gross payload	26 300[2] Mg	
WATER[(3)]		
Number of shipments	313[4]	---
Tonnage	4 690[1] Mg	309 000[5] Mg
UFT gross payload	26 300[2] Mg	2 707 000[6] Mg

1 bundles only
2 gross payload
3 although Ontario data was used for road and rail, no data were available for Ontario ports; Montreal and Halifax were used as examples.
4 assuming rail casks
5 tonnage handled in the port of Montreal
6 tonnage handled in the port of Halifax

Because of the small size of the transfer facility, any impact from the construction noise and traffic, and the land commitment would be small. A land use control zone around the site would serve as a buffer. Provided that known historical/archaeological sites are avoided, the transfer facility construction should also have negligible impacts on the culture of the area.

The potential impacts of the access road/railway construction would be of a short-term nature, and with proper construction practices can be minimized. The land commitment impacts depend on the extent of the road/railway. The impacts of provision of a new access to a previously isolated site could be minimized by proper control of access.

2. On Natural Resources

a) Magnitude of Commitments

The estimated diesel fuel commitments for operation of trucks, locomotives, tugs, and transfer facility are presented in Table 7-26. The reference used fuel transportation casks are made of stainless steel type 304L with 0.03% C, 19% Cr and 10% Ni. The commitment of stainless steel for each mode was based on the number of casks required. Iron, chromium and nickel commitments to stainless steel cask production are presented in Table 7-27.

Transfer facility construction would require carbon steel, mostly for reinforcement material, concrete for buildings and docks construction, and copper for the water supply. The small size of the facility indicates that the commitment of these resources should be small. The commitment of sand and gravel to the access road/railway construction would be proportional to its length.

b) Analysis of Potential Impacts

As illustrated in Table 7-26, the fuel commitments to used fuel transportation would constitute a small fraction of the Ontario consumption (maximum 0.05%) and a negligible percentage of the known Canadian oil reserves (maximum 0.0024%). The commitments of stainless steel constituent materials would constitute a small fraction of the known reserves of these metals as shown in Table 7-27. It is, therefore, expected that commitments of natural resources to used fuel transportation would have a negligible impact on their availability.

The small size of the transfer facility indicates that the commitment of resources to its construction should be small and would not affect availability. Canadian reserves of concrete constituent materials, sand and gravel are presented in Table 7-28. Given the size of these reserves, commitments of these materials for access road/railway and transfer facility construction should not affect their availability.

3. On Air Quality

a) Magnitude of Atmospheric Emissions

Annual emissions from road, rail and water transportation are estimated based on trip distance, duration and frequency, and published emission factors from the literature (U.S. EPA 1985). Results are shown in Table 7-29.

The amount of dust generated from transfer facility on-site construction activities is estimated to be 81 $Mg \cdot a^{-1}$ of construction, based on the size of the construction site and assuming average construction work intensity

TABLE 7-26
Comparison of Estimated Consumption of Diesel Fuel for Used Fuel Transportation with Oil Reserves and Consumption

Mode and Destination[1]	Annual Consumption (thousand litres)	Total Consumption for 10.1 Million Bundles Transportation[2] (thousand litres)
ROAD		
To Southern Region	350	20 500
To Central Region	790	46 000
To Northern Region	1 680	97 200
RAIL		
To Southern Region	550	31 900
To Central Region	1 060	61 300
To Northern Region	1750	101 300
WATER/ROAD		
To Central Region	1 660	96 000
To Northern Region	2 000	116 000
WATER/RAIL		
To Central Region	1 830	106 000
To Northern Region	2 060	119 000
TF Backup Generators Fuel Consumption (litres)		
1% usage	910	52 000
5% usage	4 500	262 000
10% usage	9 100	525 000
Canadian Oil Reserves (Procter et al., 1984):		
Conventional Oil Reserves:	1170×10^9 litres	
Non-Conventional Oil Reserves:	3900×10^9 litres	
Total	5000×10^9 litres	
Yearly Consumption (Statistics Canada, 1985b)		
Canadian Consumption:	15000×10^6 litres	
Ontario Consumption:	3900×10^6 litres	

[1] geometric centre of the region

[2] over the reference distances.

TABLE 7-27
Commitment of Iron and Stainless Steel Constituents and Current Estimated Reserves (Destination[1]/Mode)

Iron Commitment	To Southern Region (Mg)	To Central Region (Mg)	To Northern Region (Mg)
By Road	1 508	1 508	2 001
By Rail	1 488	2 232	3 720
By Water-Road	-	2 958	3 074
By Water-Rail	-	2 294	2 294
Total Annual Canadian Iron Production: 40 348 271 Mg (EMR 1985) Known Economic Ferric Content of Canadian Iron Ore Reserves: 4091 million Mg (U.S. Bureau of Mines 1985)			
Chromium Commitment	**To Southern Region (Mg)**	**To Central Region (Mg)**	**To Northern Region (Mg)**
By Road	287	287	380
By Rail	283	424	707
By Water-Road	-	562	584
By Water-Rail	-	436	436
World Reserves: 3 332 000 000 Mg (EMR 1983)			
Nickel Commitment	**To Southern Region (Mg)**	**To Central Region (Mg)**	**To Northern Region (Mg)**
By Road	151	151	200
By Rail	149	223	372
By Water-Road	-	296	307
By Water-Rail	-	229	229
Ontario Reserves: 5 337 000 million Mg (Laughlin 1981) Canadian Reserves: 7 178 900 million Mg (Laughlin 1981)			

[1] to the geometric centre of the region.

TABLE 7-28
Canadian Reserves and Production of Concrete Constituent Materials (EMR 1984,1985)

	Estimate of Reserves (million Mg)	Annual Production (thousand Mg)
Gypsum	372	7 507
Lime	vast	2 249
Sand and Gravel	virtually inexhaustible	300 000

TABLE 7-29
Comparison of Ontario Annual Emissions of Air Contaminants to the Annual Emissions from Used Fuel Transportation

Mode/Emission	To Southern Region (Mg)	To Central Region (Mg)	To Northern Region (Mg)	Ontario Emission from Transportation (Mg)
ROAD				
Nitrogen oxides	7.0	15.8	33.3	220.0×10^3
Carbon monoxide	3.2	7.0	14.6	75.2×10^3
Hydrocarbons	1.0	2.2	4.5	26.2×10^3
Particulates	0.8	1.8	3.8	14.3×10^3
Sulphur oxides	1.1	2.9	6.1	20.5×10^3
RAIL				
Nitrogen oxides	24.2	46.5	76.9	220.0×10^3
Carbon monoxide	8.8	16.9	28.0	75.2×10^3
Hydrocarbons	6.1	11.6	19.2	26.2×10^3
Particulates	1.6	3.2	5.2	14.3×10^3
Sulphur oxides	3.7	7.2	11.9	20.5×10^3
WATER/ROAD				
Nitrogen oxides	-	69.8	79.7	220.0×10^3
Carbon monoxide	-	15.4	18.4	75.2×10^3
Hydrocarbons	-	3.5	4.4	26.2×10^3
Particulates	-	4.0	4.8	14.3×10^3
Sulphur oxides	-	5.5	6.6	20.5×10^3
WATER/RAIL				
Nitrogen oxides	-	84.4	94.7	220.0×10^3
Carbon monoxide	-	20.4	23.1	75.2×10^3
Hydrocarbons	-	7.9	9.3	26.2×10^3
Particulates	-	4.7	5.3	14.3×10^3
Sulphur oxides	-	7.6	8.6	20.5×10^3

(Environment Canada 1983)

(U.S. EPA 1985). The dust generated on unpaved roads by hauling equipment is conservatively estimated at 11 kg per vehicle-kilometre travelled (U.S. EPA 1985). Yearly off-site emissions of dust cannot be calculated at this generic stage, but given the small size of the facility, emissions are expected to be small. The same can be said about construction and hauling equipment fumes. Emissions from open fire burning of forest-clearing residues and construction solid waste can be estimated based on published emission factors (U.S. EPA 1985) on a per cleared hectare basis and are expected to be small.

Since details on the diesel backup generators are not available at this generic stage, typical emissions for small internal combustion engines were calculated based on 1, 5 and 10% utilization per year (U.S. EPA 1985). The resulting emissions are shown in Table 7-30.

TABLE 7-30
Typical Annual Emissions from TF Backup Diesel Powered Generator

Pollutant	1% usage[1]	5% usage	10% usage
Carbon monoxide (kg)	10.92	54.60	109.20
Exhaust hydrocarbons (kg)	4.04	20.18	40.36
Nitrogen oxides (kg)	50.45	252.25	504.50
Aldehydes (kg)	0.79	3.80	7.60
Sulphur oxides (kg)	3.35	16.77	33.54
Particulate (kg)	3.60	18.02	36.04

1 Percentage of TF operating time of 231 $d \cdot a^{-1}$

Emissions from access road/railway construction activities should be proportional to the length of the access road/railway and depend on the topography in the vicinity of the site (i.e. road/railway routes going through unstable terrain and/or having to cross rivers or streams would require more intensive use of heavy equipment).

b) Analysis of Potential Impacts

In view of the small scale of the additional traffic, the added emission load should be negligible (estimated to be less than 0.1 $\mu g \cdot m^{-3}$).

Based on the available information, dust generated on-site during construction and off-site along the trucking routes would be expected to be more a nuisance than a source of damage. Any impact is expected to be visual and temporary.

Given the small size of the transfer facility, open fire burning of forest clearing and solid waste, fumes from the construction equipment and occasional operation of the diesel generators are expected to have minimal impacts on air quality.

Atmospheric emissions from access road/railway construction being of a temporary nature should have minimal impacts on the local air quality.

4. On the Natural Environment

If road, rail and water transportation lead to substantial increases in noise, traffic and pollutant emissions, they could affect wildlife and wildlife habitat.

Construction of the transfer facility, depending on its extent, could affect vegetation, water quality, aquatic life and wildlife. The effects of the construction of a possible access road or rail line to the TF would be similar to the effects of construction of an access road to the UFDC. Construction activities could result in the removal of and/or injury to vegetation, nesting habitat or food sources for wildlife and affect vegetation communities through alteration of terrain and ground water levels. Given the small size of the facility (100 m x 200 m), these effects should be minimal. Injuries to vegetation could also follow accidental chemical, fuel or oil spills. Construction activities near the shore could also cause changes in water quality and impact on aquatic plants. Sediment loading due to soil erosion or culvert installation could affect water quality, aquatic life and food organisms. Contamination of the water through accidental spill of hazardous substances could adversely affect water quality and the health of aquatic organisms. Activities such as dredging, blasting and pile driving in or adjacent to aquatic systems may affect the spawning behaviour and habitat of fish, and water quality for drinking water supply. Improved access to the site may increase angling activities by construction personnel and the public. Removal of bank vegetation could increase local water temperatures resulting in impairment of habitat and spawning/hatching success of fish. The building of a dock could improve long-term water quality by reducing shoreline erosion.

Maintenance dredging of the channel associated with the transfer facility operation could cause physical disruption of the bottom environment and aquatic habitat, generation of suspended sediments, and contaminant load of the sediment being disturbed and redistributed (Hirsch et al. 1978).

Construction and maintenance of an access road/railway could affect sensitive land or water features in the following manner:

i) construction can destroy the feature;

ii) noise, traffic and associated activities can disturb sensitive faunal features;

iii) silt- and pollution-laden runoff can disturb unique and sensitive aquatic communities, and drinking water quality; soil erosion, with the resultant sedimentation of water bodies, can cause the destruction of spawning beds, and drastic changes in benthic and aquatic communities as a whole, and could affect drinking water quality;

iv) dust and traffic may harm unique and sensitive vegetation;

v) sensitive biological features can be disturbed by recreational activities, which may result from road/railway providing easy access to the area;

vi) dust control and de-icing agents applied for access road/railway maintenance near sensitive water bodies could make the water unfit for human use;

vii) increased sedimentation, blockage of stream flow, impoundment of water, and disruption of fish migration could result from road/railway construction and stream crossings. Contamination of the water could result from runoff of salts, waste oils and herbicides used for road/railway maintenance;

viii) wetlands could be affected if roads/railways are placed in such a way as to block the natural flow of water. This can change the vegetative communities and wildlife may be affected as a result;

ix) improper disposal of waste material disposal generated by road/railway construction and maintenance can cause a localized degradation of water quality and create a fire hazard. It would also affect the aesthetics of the area; and

x) disrupt wildlife migration and cause road kills.

a) Magnitude of Impacts

The magnitude of impacts from transfer facility construction activities on the biophysical environment cannot be estimated at this generic stage. These impacts, however, can be correlated to various indicators for which information is specified in the reference design, such as: area affected by the activities, length of affected shoreline, and length and depth of dredged channel.

Maintenance dredging of the channel would affect the water quality and hence the aquatic life. The frequency and extent of the required dredging would dictate the magnitude of the impacts.

The length of the access road/railway would indicate the magnitude of impacts on vegetation and wildlife habitat. The location and extent of the water bodies along the access road/railway right-of-way, and the number and sensitivity of the streams crossed would determine the magnitude of impacts on the water quality.

b) Analysis of Potential Impacts

The increase in the number of road kills would not be expected to be large given the small increase in traffic due to the used fuel transportation (refer to Table 7-20). The equivalent noise level on the reference routes is less than 1 dB and is, therefore, imperceptible. For areas with low existing traffic, the maximum noise increase is 4.1 dB. This should have a minimal impact on the environment. Atmospheric emissions should not cause any measurable impacts on the environment given that they constitute a very small fraction of the Ontario emissions from transportation sources.

The reference location for the transfer facility is the northern shore of Lake Superior. It is expected that only areas along that shoreline containing sensitive natural features, could be affected significantly. Areas having significant importance for migration and for wintering of waterfowl have also been identified by the Ontario Ministry of Natural Resources and could be potentially affected. Given the small size of the transfer facility, it should be feasible to avoid the identified sensitive areas. The same can be said for the aquatic environment.

Provided that critical spawning habitat are avoided when locating the facility, and given that the dock and channel are relatively small, the overall impact on the fish population should be small. It is possible that the transfer facility may be located adjacent to an existing port facility with an existing channel, in which case incremental impacts on the fish population would be even less. Provided that the dredged material is disposed of at sufficient depth to avoid fish spawning areas and that dredging takes place at a time when local biota are at a low ebb, the impacts of the maintenance dredging of the channel on the fish population are expected to be small.

Provided that stream crossings are reduced to a minimum, and that route location on or near wetlands and sensitive areas are avoided, the impacts of access road/railway construction and maintenance on the vegetation, wildlife and water quality should be small.

7.4.2 Accident Conditions

Non-radiological accident consequences, such as material damage to vehicles, personal injury and in extreme cases loss of life, can disturb the existing land uses of an area by affecting transportation safety and people's concerns over safety (see Section 7.5 for socio-economic impacts related to health and safety risk). Traffic disruption due to an accident can have negative impacts on existing land uses.

1. Transportation Safety Concerns

The estimated number of accidents per year involving a used fuel transportation vehicle on the reference routes is shown in Table 7-31. These predictions are conservative because they assume standard vehicle maintenance

TABLE 7-31
Estimated Annual Number of Accidents Involving the Used Fuel Transportation Unit[1]

	Location	Annual number of accidents		
		Southern	**Central**	**Northern**
ROAD				
Involving UFT truck	Rural	0.8	1.7	3.6
	Suburban	0.03	0.05	0.11
	Urban	0.02	0.02	0.02
RAIL				
Involving UFT train (railcar accidents)	Rural	0.5	0.2	0.3
	Suburban	0.02	0.01	0.01
	Urban	0.03	0.02	0.01
WATER-ROAD				
Involving UFT tug/barge	Open Water	-	0.05	0.04
	Channel/River	-	0.11	0.11
Involving UFT truck	Rural	-	0.95	0.70
	Suburban	-	-	0.08
	Urban	-	-	-
WATER-RAIL				
Involving UFT tug/barge	Open Water	-	0.05	0.04
	Channel/River	-	0.11	0.11
Involving UFT train (railcar accidents)	Rural	-	0.07	0.83
	Suburban	-	-	-
	Urban	-	-	-

1 Note that in half of these accidents, the cask would be empty, and that accidents involving the rail buffer cars and the caboose are included in this number.

and driver training. With higher maintenance and driver training standards applied to the used fuel transportation operation, the expected number of accidents should be considerably reduced.

The expected consequences of accidents involving the public are determined based on average statistics for industry. The predicted consequences of road, rail and water accidents are presented in Table 7-32. Here again, because the safety standards applied to used fuel transportation operations would be higher than industry average, consequences of used fuel transportation road, rail and water accidents should be less than estimated. In contrast to the estimates in Tables 7-31 and 7-32, Ontario Hydro's transportation of radioactive materials over approximately 30 years (more than 22 000 shipments covering over 4 million km) has resulted in only three accidents, none of which led to any release of content or fatality.

2. Traffic Disruption Concerns

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.

3. Effects on the Biophysical Environment from Accident Conditions

Contaminants could be released in the water and air as a result of a used fuel transportation accident. Contents of diesel tanks or water radiators could be spilled as a result of impact. The diesel tank could also catch fire.

Damage to vegetation on road side and railway right-of-way would likely occur as a result of transportation accidents.

Given that these hazards would be of the same nature as for standard transportation activities, and the small amount available for release, it should have minimal impacts on the environment.

The establishment of an emergency response plan should also minimize the adverse impacts of used fuel traffic accidents on the environment.

The Ontario Environmental Protection Act contains provisions to ensure that operators carry the responsibility for abnormal spills that may adversely affect the natural environment.

7.5 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENT FROM USED FUEL TRANSPORTATION

This section summarizes the analysis of the potential impacts of siting/routing, construction and operation of the used fuel transportation system (transfer facility, access road/railway) upon the social and cultural vitality, economic viability and political efficacy of communities and regions. It includes a description of the methodology used in the analysis, a review of potential impacts from normal and abnormal activities, and a discussion of potential social and community impact management measures. Details of the socio-economic impact assessment research and case studies that were used in the preparation of this analysis are found in Lockhart-Grace (1993) and Paez-Victor (1993).

TABLE 7-32
Estimated Consequences of Accidents Involving a UFT Unit

Consequences	Location	Southern	Central	Northern
ROAD				
- material damage only (occurrences per year)	Rural	0.53	1.13	2.38
	Suburban	0.02	0.03	0.07
	Urban	0.01	0.01	0.01
- personal injury (occurrences per year)	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) (occurrences per year)	Rural	0.005	0.01	0.02
	Suburban	0.0002	0.0003	0.0007
	Urban	0.0001	0.0001	0.0001
RAIL				
- personal injury (persons injured per year)	Rural	0.35	0.14	0.2
	Suburban	0.014	0.007	0.007
	Urban	0.02	0.014	0.007
- loss of life (fatalities per year)	Rural	0.11	0.04	0.06
	Suburban	0.004	0.002	0.0002
	Urban	0.006	0.004	0.0002
WATER-ROAD				
- personal injury (persons injured per year)	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 (fatalities per year)	Open Water	-	0.004	0.0004
	Channel/River	-	0.008	0.0008
	Road-Rural	-	0.006	0.004
	Road-Suburban	-	-	0.0005
WATER-RAIL				
- personal injury (persons injured per year)	Open Water	-	0.0002	0.0002
	Channel/River	-	0.0004	0.0004
	Rail-Rural	-	0.05	0.6
- loss of life (fatalities per year)	Open Water	-	0.0004	0.0004
	Channel/River	-	0.0008	0.0008
	Rail-Rural	-	0.015	0.18

7.5.1 Methodology

The methodological approach is the same as for the socio-economic impact assessment for the UFDC (see Section 6.5). The analysis is based upon socio-economic theory and research; a literature review of case studies of transportation of hazardous materials and development projects; studies of public opinions and concerns regarding the transportation of used fuel and nuclear facilities in general; and community dynamics and the social processes which determine the nature and significance of these changes at any location. It discusses the kinds of community changes possible using the generic reference transportation design and reference environment data (described in Chapters 2 and 3, respectively).

In addition to case studies on transportation of hazardous materials, this analysis relies heavily on results of the socio-economic impact analysis performed for the UFDC. Some of the socio-economic impacts associated with the construction and operation of the transfer facility and access road/railway (if required) would be similar to that of the UFDC, albeit on a much smaller scale. Also, it is assumed that health and safety concerns about the UFDC would influence how communities along the routes assess the transportation of used fuel. The transportation of used fuel (up to seven trips daily by road for example, counting return trips) may cross from one end of the province to the other, and may be the subject of much publicized public debate at the Concept Assessment Hearings and during the siting stage.

As for the UFDC, this analysis is community-based and uses the three community characteristics of social and cultural vitality, economic viability, and political efficacy as the framework to describe the potential impacts. Any of the three modes of transportation under study (road, rail, water) would traverse a variety of settings and those who could be potentially affected would include other users of the right-of-way or mode, people and users in close proximity (both resident and non-resident) to the route, people and users in the vicinity of the transfer facility, and along the access road/railway. While this analysis recognizes that impacts will be experienced by individuals, the focus is on impacts that have a social character: i.e. felt not just by an individual or series of individuals, but by individuals as part of a social grouping defined as a community.

One of the reasons for predicting impacts is to prevent or mitigate negative impacts and to enhance positive ones, all through the implementation of impact management measures. This analysis attempts to predict a range of both negative and positive potential impacts, and identify the impact management measures that could be implemented in order to avoid, mitigate and redress negative impacts or enhance positive ones. Impacts associated with used fuel transportation development have been encountered before on different types of projects, and substantial experience exists in managing these impacts.

Socio-economic impacts associated with used fuel transportation require identification and management through joint problem solving and planning with the affected communities.

7.5.2 Definition of Socio-Economic Impacts

Every project has a discrete set of project characteristics which could be sources of environmental and socio-economic impacts. Project characteristics are responsible for the generation of effects, such as noise, or increased traffic, for example. Whether these effects constitute an impact, depends upon the interaction with and response of people and their communities, as well as that of the natural environment. Project effects, whether they are changes in the natural environment (see Section 7.4) or changes to community infrastructure, or any other types of change, are filtered through by the interpretation that they are given by the members of family, group, community or society. The characteristics of a community, in terms of social and cultural vitality, economic viability and political efficacy, will determine whether or not project effects result in impacts to those characteristics.

The first step of the assessment was, therefore, to describe the main characteristics of communities, and the main characteristics of the reference transportation design interacting with these characteristics. This description is summarized as follows.

7.5.2.1 Community Characteristics

Communities vary according to three main characteristics which will determine community capacity for evaluating, managing and/or enduring socio-economic and environmental impacts. These characteristics are based upon the type of social relationship that members of the community have with each other and their environment: social and cultural vitality, economic viability and political efficacy (see Section 6.5).

Social and cultural vitality is the process by which individuals become mutually bonded in reciprocal relationships of trust and obligation in order to share knowledge, obtain resources and resolve mutual problems. The degree of social and cultural integration is reflected through community culture, settlement patterns, interaction patterns and networks, history of past collective actions, attitudes towards project health and safety risks, political leadership and conflict resolution record.

Economic viability is the degree to which communities are relatively independent or dependent upon external economic initiatives. Information necessary to determine economic viability relates to: wage and traditional economy, labour force, size and diversity of local economic activities, and economic function of larger environmental base of the economy. Also important are the attitudes and values of the community with respect to the environment and resources, risks to health and safety, the job market, economic security, opportunity, fairness and equity.

Political efficacy depends on formal political institutions and processes, as well as the community's ability to legitimately resolve its own social and economic decisions and conflicts, and to effectively negotiate outside parties such as other levels of government, large industries and development project management. Political efficacy is measured by local expertise in planning, management and obtaining government funds, and on general local government administration; on formal and informal political structure and dynamics; on records of past public issues resolved or unresolved, and on methods and processes of decision-making. Community beliefs and attitudes towards these political successes or failures, political decision-making processes and challenges is also important information.

7.5.2.2 Project Characteristics

In order to identify how a project could affect the community characteristics described above, it is necessary to link them to the project characteristics. A thorough review (Lockhart-Grace 1993; Paez-Victor 1993) of the reference transportation design, the safety and environmental effects analysis and of relevant case studies indicated that the following project-related characteristics have in past projects been considered major sources of impact: potential health and safety risks; transportation system design; workforce requirements; off-site services and land requirements; resource use, emissions and waste; materials and services procurement expenditures; and safety, security and environmental protection requirements.

The used fuel transportation activities include: transportation of used fuel along existing transportation corridors (road, rail, and water), transfer facility construction and operation, and access road/railway construction and maintenance. A full description of the transportation system design and operation is given in Chapter 2.

Potential Health and Safety Risk

Research has shown that the potential risk associated with radioactive material can be an important source of socio-economic impacts from a project, and that concerns about radiological risk can also determine the intensity of many other socio-economic impacts. It is, therefore, important to understand how the public views radiological risk and what their concerns are.

The radiological safety analyses presented in Sections 7.1 and 7.2 of this report estimate that the level of exposure to radiation from properly managed used fuel transportation activities is well below regulatory limits and that the acute and chronic risks to human health are small. This does not preclude that high levels of concern may exist over these risks.

Focus group research and public opinion surveys regarding used fuel in Ontario confirm that the most frequently cited concerns are health and safety related (Greber 1986, 1985, 1983a, 1983b, 1982; Pieroni 1984; Decima Research Ltd. 1985). Much of the concern over used fuel transportation would be related to the possibility of an accident along the route or at the transfer facility, possibly with a release of radioactivity.

These concerns have been factored in the design of the transportation system. Chapter 2 contains a discussion of emergency planning in Ontario and of the safety record of radioactive material transportation experience of Ontario Hydro.

The socio-economic impacts from the health and safety risks associated with used fuel transportation are discussed in Section 7.5.3 under social and cultural vitality, economic viability and political efficacy.

Transportation System Design

The reference design specifies that used fuel could be transported by road, rail or water, or a combination thereof. The transportation operation would result in traffic, atmospheric emissions, and noise which could affect the population along the transportation corridor. However, as shown in Section 7.4.1.2, this traffic would be a small fraction of normal traffic likely difficult to distinguish from normal fluctuation in daily traffic.

The reference design include the possible need for construction of a transfer facility to transfer the transportation casks from the water mode to a land mode, either road or rail. Although this facility would be small, construction of the transfer facility would interact with the local community in the same manner as the UFDC construction (see Chapters 5 and 6 for details), albeit to a much reduced degree. Construction of an access road to the transfer facility might also be necessary and could also be a source of interaction with the community.

A description of the transportation system design is given in Chapter 2. The socio-economic implications of the used fuel transportation system design are discussed under the community characteristics of social and cultural vitality, economic viability and political efficacy.

Workforce Requirements

For the purpose of this analysis, it was assumed that the utilities that own the used fuel would be responsible for the transportation. The workforce would be a mixture of employees of the utilities and employees of transportation companies such as Canadian National Railway for rail transportation. Workers for operation and maintenance of the transportation system would train at the nuclear stations, as they do now. The workforce required to construct and operate the transfer facility has not been estimated at this concept assessment stage. It is assumed to be similar to a small building project. The workforce requirements for the access road/railway construction would depend on the length of required new access.

The size of the required workforce, the relationship between temporary and permanent employment, the mix of skills, and the project payroll can all impact a community or a region in both positive and negative fashions. Labour requirements for construction of the transfer facility, albeit small, could result in some economic and demographic changes in the host community and region. These impacts are discussed in Section 7.5.3 under the three community characteristics.

Site Layout and Land Requirements

Land requirements for the transfer facility would be small (see Chapter 2). They would have a proportional impact on community services and facilities, business activities and land use. For example, property values, municipal finances, planning and administration, and the quality of service to residents and other service users can be affected either positively and negatively.

The transportation of used fuel would be mainly along existing corridors and, therefore, would not require additional land. Other land commitments would depend on the need for and extent of an access road/railway. Improved access to previously isolated areas could result in positive and negative impacts for the community. These impacts are discussed in Section 7.5.3 under the three community characteristics.

Emissions, Resource Use and Wastes

Changes in the natural environment of a community, singularly or collectively, have the potential to affect the three community characteristics. However, as shown in Section 7.4, emissions, resource commitments, and wastes generated by used fuel transportation activities, including construction of a transfer facility and access road/railway, would be expected to have only small effects on the quality of the environment (e.g. air, water, land and resources), assuming appropriate impact management measures are used.

Demands on natural resources (diesel fuel, stainless steel, concrete, and sand and gravel) were found to be small compared to the availability of the resources.

The construction activities associated with the transfer facility and access road/railway, and to a lesser extent the transportation activities could affect vegetation, air quality, aquatic life and wildlife. Atmospheric and noise emissions from the transportation vehicles would have a small impact.

The possible resulting socio-economic impacts would be upon businesses, municipal services, land use, employment and population, property values, community services and facilities.

Material and Services Procurement Expenditures

Project expenditures such as the purchase of supplies and services could be a source of positive and negative impacts to the economic viability of communities. Construction material for the transfer facility and transportation hardware are examples of supplies that would be required by the transportation system.

Labour markets, businesses, price and sales levels, housing and other social services would be amongst the affected factors. However, because of the nature of the transportation activities, the impacts would be diluted throughout the region, and the province and, except for the transfer facility, not be concentrated in a community. These impacts are discussed in Section 7.5.3 under economic viability.

Off-Site Service Requirements

The need for off-site services such as water, sewers, waste disposal and utilities at the transfer facility could be a source of positive and negative impacts to the environment, municipal facilities and services, and the local economy.

The transfer facility demands for off-site services would be limited to electrical supply, and possibly supplementary water, and liquid and solid waste disposal services. These impacts are discussed in Section 7.5.3 under political efficacy and economic viability.

Safety and Environmental Protection Requirements

Special occupational health and safety training and equipment for emergency response would be required along the transportation routes and near the transfer facility. In addition, specific approvals from various levels of governments and their agencies are required. These requirements could impact on the three community characteristics.

The specific approvals required for used fuel transportation are described in Appendix B. Obtaining these approvals would require joint planning and thorough involvement of the local community.

Public concern about the used fuel transportation development would relate largely to the possibility of an accident along the transportation route or at the transfer facility site. A nuclear emergency plan would be developed, which would require commitment of time and resources on the part of federal and provincial government ministries, the facility operator and local communities. Plan development and practice emergencies would involve local officials and emergency response authorities (see Section 2.2.7 for details on contingency and emergency response).

7.5.3 Potential Social, Cultural and Economic Impacts

The following is a discussion of the kinds of socio-economic impacts that could arise from the transportation of used fuel. Although potential impacts are identified in this section, their significance could not be determined in this non site-specific assessment. Significance needs to be determined with input from affected communities during site and route specific studies. Some impacts may affect all characteristics, and some may pertain to some or one more than to others.

Most of the detailed generic description of the impacts given in Section 6.5 also apply to used fuel transportation. Unless otherwise stated, the impacts discussed in this section are for all aspects of the used fuel transportation development, and for any of the three modes of transportation under consideration: transportation along the route, construction and operation of the transfer facility and the access road/railway; and, throughout siting/route and mode selection.

Experience from hazardous materials transportation case studies indicated that transportation-related impacts have not been major problems in other projects, and that impact management and public involvement played a key role in these projects (Hardy Stevenson and Associates 1992b). As explained in Section 2.2.2.1, used fuel has been transported safely in Canada since the late 1940's, although only on a relatively small scale. Ontario Hydro typically makes over a thousand shipments each year of various radioactive materials, including some used fuel. During its many years of transportation experience, Ontario Hydro has had only three accidents, none of which resulted in any release of radioactive contents. However, in an effort to be comprehensive, and to address the fact that large-scale transportation of used fuel has not been done in Canada, a range of potential impacts is considered here.

7.5.3.1 Normal Conditions

1. <u>Potential Impacts to the Social and Cultural Vitality of Communities</u>

Given that the main community characteristics used as a framework for the analysis are integrated, the sources of impacts on one community characteristic might also affect the other community characteristics.

Impacts to social and cultural vitality could occur through: health and safety impacts, resident displacement, family impacts, demographic changes, housing impacts, nuisance impacts, impacts to community satisfaction and integration, impacts to recreational facilities, and impact upon Aboriginal communities. These potential impacts are discussed in turn. Impact management is discussed in Section 7.5.4.

<u>Public and Occupational Health and Safety Impacts</u>

The environmental and safety analysis presented in Sections 7.1 and 7.2 of this report shows that the level of public exposure to radiation from used fuel transportation activities is expected to be well below regulatory limits, a fraction of the exposure from natural background radiation, and that associated risk to human health is therefore very small. This is supported by a review of experience in the USA that concludes that there are no significant public health impacts from the transportation of radioactive waste (Impact Assessment Inc. 1987; Morell and Majorian 1982; Mountain View West 1987). However, whether such risks are acceptable or not is a decision of value pertaining to people and/or their legitimate representatives. Thus social dynamics, moral and ethical values, political and economic considerations, education and information dissemination all have a role to play in the way people appraise the possible health impacts of used fuel transportation. Public concerns about health impacts associated with nuclear facilities centre on the potential of induced cancer and genetic alterations in nuclear workers, their families, and/or the local communities (Section 6.5.3.1).

Public and occupational health and safety is a major concern with nuclear operations, including used fuel transportation, which can influence the social and cultural vitality of a community. Concerns about health impacts associated with nuclear materials and technology have the potential of being the most important source of all socio-economic impacts of used fuel transportation, and they can affect the nature and significance of a wider variety of socio-economic impacts.

a) Well-being and Stress

The prominent labelling of the contents of nuclear shipments could represent a source of concern, and conceivably alarm, at any point along the transportation routes. These concerns may be especially high when the vehicles are stopped or moving slowly, in areas where there are concentrations of activities and people, and in areas of commercial or symbolic importance for various populations.

High levels of concern over health and safety could also result in stress-related health effects, and in the attribution of stigma to a local community and region. The stigma associated with the community could directly affect an individual's satisfaction with the community as a place to live.

Furthermore, stigma could be attributed to a specific region resulting in negative impacts to economic activities such as marketing local produce or a decrease in local tourism.

The literature indicates that these concerns tend to manifest on a short-term basis related to serious accidents. Any potential effects related to stigma over the longer term seem to be mitigated through consistent safe operation and overall positive community-proponent relations. Over many years of nuclear operation and related transportation experience, Ontario Hydro has seen little evidence that such concerns persist. As indicated earlier, public involvement and impact management programs play important roles in addressing potential concerns and impacts (Hardy Stevenson and Associates 1992a).

b) Safety and Security

Much of the concern over the used fuel transportation development would be related to the possibility of an accident along the route or at the transfer facility, and the possibility of radioactive release. Chapter 2 (and Appendix J) contains a discussion of emergency planning of Ontario and radioactive material transportation of experience of Ontario Hydro. During its many years of transportation experience, involving many thousands of shipments, Ontario Hydro has never had an accident that resulted in any release of radioactive contents.

The development of an emergency plan would require commitment of time and resources on the part of federal and provincial government ministries, the facility operator, and local communities. Plan development and practice emergencies would involve local officials, Aboriginal authorities and emergency authorities. However, a broader involvement of workers, unions, and local and Aboriginal publics in the development of safety and emergency plans, their periodical testing as well as in the overall monitoring system, could mitigate risk and the stress it represents.

Health and safety monitoring, notification of hazardous events and awareness programs are measures that would minimize any public and occupational health and safety impacts.

<u>Resident Displacement</u>

Resident displacement refers to the possible forced relocation of residents due to the acquisition of property, if required.

Since used fuel transportation would use existing transportation infrastructure, resident displacement would not be expected. It could occur indirectly if there are demands for expansion of infrastructure (e.g. bypasses) or voluntary relocation could occur as a result of concerns about health and safety risks. The small size of the transfer facility would not likely require resident relocation; however, depending on the location of the access road/railway there could be some associated resident displacement.

Cooperative siting (as outlined in Section 4.1), avoidance and monitoring of health and safety impacts are measures that would minimize any impacts resulting from displacement.

Family Impacts

The main impacts to the family are those that pertain to the physical and mental health of its members.

Increased family tension could occur as a result of stress of family members due to concerns about health and safety risks of used fuel transportation.

The establishment of a good working relationship between communities and the proponent during siting/routing, monitoring of health and safety impacts, facility design optimization, awareness programs and community liaison measures would help minimize these impacts.

Demographic Changes

The in-migration of workers and their families for the construction and operation of the transfer facility could cause social change within communities.

The construction workforce requirements for the transfer facility (if required) and access road/railway, would result in a small temporary workforce that would not likely have permanent impacts to community size.

Construction camps would be able to accommodate the temporary workforce requirements.

Housing Impacts

The availability of housing in most communities is a function of the demand and supply of residential units.

As the construction workforce for the transfer facility would be similar to a small building project and requirements for the access road/railway would depend on the extent of access required, any impacts to housing availability would be few in number and short-term.

The use of construction camps is an impact management measure that could be used if there was no local accommodation available.

Nuisance Impacts

Nuisance effects such as noise, dust, vibration, night lighting, odour, traffic and visual intrusion can disrupt the day-to-day activities of residents and/or their use and enjoyment of property.

The natural environmental analysis concluded that there would be little impact from traffic, noise, and atmospheric emissions associated with transportation along the routes; and transfer facility and access road/railway construction activities (see Section 7.4). There would be nuisance effects associated with any expansion of infrastructure, if required.

Nuisance effects could be largely avoided or reduced to nominal levels through effective control technology, avoidance, and proper environmental practices.

Impact to Community Satisfaction

Disruption of residents' day-to-day activities can lead to a loss of satisfaction with the community.

Residents who experience a loss of satisfaction could respond in a variety of ways. Some residents could feel a greater level of stress, some could lose their commitment to the community, choose to withdraw from activities or even leave the community altogether. These responses could lead to other community-level effects. These impacts would be more likely to occur during the initial planning and construction phases.

Community Integration

Individuals and groups within a community or in communities along the transportation routes may be divided as to their support or opposition for used fuel transportation. In addition, even a small change in population (such as expected from the transfer facility workforce) in areas with distinctive ethnic or cultural heritage could be destabilizing to the community. In tourist and cottage/recreational areas, unique patterns of population are usually established which often contribute to the long-term stability of the community and region, and if altered could result in social disruption.

However, if affected communities have a real measure of control over the siting/routing and impact management process, it should be possible to avoid and/or minimize community conflict and loss of cohesion. Awareness programs would also assist in minimizing impacts.

Impacts to Recreational Activities

Impacts on recreational and community features may relate to changes in operational effectiveness and economic viability. They may also relate to changes in the participation in related activities, which can occur as a result of effects on the natural environment or changes in the use and enjoyment of these facilities and services.

Community and recreational features along the transportation route, in the vicinity of the transfer facility or access road/railway, could experience some disruption as a result of nuisances such as noise, dust, and traffic. The natural environment analysis (see Section 7.4) concluded that these nuisance effects would be within the daily variations along the reference routes. Some facilities and recreational activities could, however, suffer if negative perceptions of the area detract from their attractiveness. Community and recreational features which are more sensitive to these types of changes would tend to be outdoor and environmentally-based.

Impact management measures such as avoidance of sensitive features during routing of the access road/railway and siting of the transfer facility and mitigation of nuisances would minimize these impacts.

Impact Upon Aboriginal Communities

In addition to the impacts on individuals and families already discussed, Aboriginal people may experience different impacts. The centre of the traditional lifestyle and culture, or way of life for Aboriginal peoples is the land. The relationship Aboriginal peoples have with the land is very different from that of the dominant culture (Berger 1977).

Aboriginal people and their communities, while of varying cultures, do share in a common spiritual relationship with the land that transcends economic interests. The land, its flora and fauna form part of their system of beliefs concerning the how and why of Creation and their role within it. More so, the land is linked to their self-identity as a people.

In light of this unique relationship with the land, construction and operation of a transfer facility and access/road railway could be regarded as at odds with Aboriginal social and spiritual values. Aboriginal communities could be concerned about disruption of their traditional lifestyle and culture.

Disruption to traditional subsistence activities and other Aboriginal pursuits such as aquaculture could occur as a result of the development of the transfer facility.

The examples of impact management measures suggested to minimize impacts on non-Aboriginal communities may also be considered appropriate by the Aboriginal communities.

2. Potential Impacts to the Economic Viability of Communities

Economic activities are undoubtedly basic to the life of any community and is intrinsically linked to social, cultural and political activities and behaviours. It is only for analytical purposes that economic activities are separated.

Impacts on economic viability could occur through: workforce impacts, impacts on business activity, environmental quality impacts, impacts on local income and price structure, impacts on housing and property values, impacts on local taxes, and impacts to Aboriginal business and economy. These impacts are discussed in turn.

Workforce Impacts

Workforce impacts relate to workforce requirements in terms of size and type, employment and labour supply, and secondary employment. An influx of workers and their families impose pressure on community facilities and services in proportion with the size of the workforce. Workforce and expenditures on labour markets and services can induce a number of beneficial impacts to local business activity. Some temporary employment opportunities for local communities would exist from transfer facility and access road/railway construction. Operating staff at the transfer facility would be provided with longer-term employment.

Some secondary employment could be generated in local or regional retail and services sectors if the project obtains materials and services locally.

Impact management measures such as preferential hiring, and business activity enhancement would enhance the economic benefits.

Impacts on Business Activity

Purchases of project supplies and services, as well as workforce requirements, can change the volume of business sales, introduce new customers, and diversify local and regional markets. The operational effectiveness and viability of businesses can be changed, in the short-term as well as for long-term development opportunities, including tourism.

The limited workforce, and materials and services required for the transfer facility and access road/railway would result in limited increases in business activity.

Improved access to previously isolated areas created by the access road/railway could disrupt existing tourist enterprises by increasing local angling and hunting pressures, but also increase the opportunity for tourism-related development. If stigma were to be attributed to an area as a result of concerns about health and safety risks associated with used fuel transportation and the transfer facility, there could be a negative effect on tourism.

Cooperative siting (outlined in Section 4.1), avoidance of sensitive areas and business activity enhancement would minimize the negative impacts and enhance the positive ones.

Environmental Quality Impacts

There is a growing concern that economic benefits do not necessarily outweigh environmental damage, and that development projects should ensure the continued well-being of the environment.

The natural environmental analysis (see Section 7.4) concluded that there would be minimal bio-physical impacts as a result of the used fuel transportation activities. The highest potential for impact would be the eventual maintenance dredging of the access channel to the transfer facility, and its impacts on the local fish population. Also, depending on the extent of the access road/railway, there would be potential for displacing wildlife in previously isolated areas. These impacts could directly affect tourism, the local economy, and Aboriginal lifestyle and culture.

Given the extent of the Canadian Shield region affected by Aboriginal land claims, lands which are under treaty, used for subsistence purposes or regarded as homeland by the Aboriginal people, it is very likely that any impact on environmental quality from used fuel transportation activity would also affect Aboriginal peoples and their communities.

Avoidance of sensitive areas, nuisance effects management and environmental effects management strategies, devised and implemented continuously, and with the joint planning and management arrangements with potentially affected communities could help avoid and/or minimize these impacts.

Impacts on Local Income and Price Structure

New jobs and new people in a community can increase the average personal income, benefitting individuals, their families and their communities.

The temporary increases in jobs, new people and income would be relatively few in number as a result of the construction of the transfer facility and access road/railway. On the other hand, possible stigma effects on tourism, housing prices, and development opportunities could all have negative impacts on local prices.

Impact management measures such as cooperative siting, monitoring of health and safety impacts, business activity enhancement and preferential hiring would minimize the negative impacts and enhance the positive ones.

Impacts on Housing and Property Values

The impacts of housing on economic viability centre upon changes in property values. Studies of property value impacts around industrial facilities indicate that property values may either increase or decrease. Cases with decreased property value tend to predominate.

Concern over decreased property values as a result of stigma associated with the transportation of used fuel was raised during focus group research (Pieroni 1984). Increases in property values could be associated with greater accessibility brought about by new or improved transportation features such as bypasses along the route, or the creation of the new access road/railway.

Standard mitigation and nuisance effects management, monitoring of health and safety impacts, cooperative siting, avoidance and property value protection should minimize impacts.

Impacts on Local Taxes

To a resident, the residential tax plus the cost of all local services are considered to be the best measure of the cost of living in a community.

There would not likely be community growth with a corresponding need for additional community infrastructure and services as a result of used fuel transportation activities, and, therefore, taxes should not be affected. However, concerns about health and safety risk could result in demand for expansion of community services, facilities and infrastructure requiring an increase in property tax.

Impact management measures of monitoring health and safety impacts, compensation and awareness programs would minimize impacts.

Impacts to Aboriginal Business and Economy

Aboriginal economy and business cannot be analyzed without reference to the context of land use, environmental concerns and cultural context. In the past, the Aboriginal economy was entirely land based, but now it is a mixed economy blending land-harvesting activities with that of the market/wage economy of the settlement, urban type. There are Aboriginal individuals and corporations operating a variety of businesses from stores to construction firms. However, values and attitudes are still traditionally governed.

The creation of an access road/railway to the transfer facility, improving access to an area may enable non-Aboriginal people to hunt, trap and fish in an area that previously may have been used solely by Aboriginal people. A loss of land, increased competition and decreased hunting, fishing, trapping and gathering success in one area may cause the over-exploitation of resources in another and create difficulties maintaining traditional hunting law. Increased visitation by tourists and project workers could increase the incidence of vandalism and pollution. New access to areas previously difficult to reach could prove to be beneficial, however, if the ability to conduct subsistence activities is enhanced.

Cooperative siting, avoidance, direct financial compensation and in-kind replacement/restoration could reduce impacts on Aboriginal communities.

3. Potential Impacts to the Political Efficacy of Communities

Due to the absence of a real community, this conceptual assessment of political efficacy must rely less on the particular dynamics of legitimate decision-making, informal political processes, leadership style or participation, than on the formal political structure of municipalities, regions and provinces, and Aboriginal communities.

The expressed concerns of regulatory and potentially interested and affected agencies can have socio-economic repercussions in the sense that they can either alleviate or reinforce the impressions and perceptions of interested and affected members of the public, groups and communities. The institutional arrangements themselves, both formal and informal, which are established to ensure compliance, facilitate coordination, and share information and experience also represent an impact on political efficacy.

A community could change as a result of changing roles and relationships between communities, and between the community and larger society. Furthermore, existing community groups, new groups which could form in response to used fuel transportation activities and the transfer facility, and organizations involved in project development could also establish extra-local ties to provincial or national organizations.

Used fuel transportation could result in basic changes to the roles people play within their community groups, organizations and institutions.

Impacts to political efficacy could occur through impacts on: municipal facilities and services, municipal finance and administration, political activity, labour unions, and political activity of Aboriginal people.

Impacts to Municipal Facilities and Services

Municipal facilities and services, such as health and safety facilities and services, social services, police and fire services, and transportation and communication, can all be affected by development projects.

Used fuel transportation could result in demands being placed on health and safety services for special emergency preparedness training and possibly even stress and related health effects. There could be a need for health care professionals along transportation corridors to become more knowledgeable on health effects of radiation. Some health and safety personnel, and school authorities would have to be involved in emergency response planning. These impacts would affect communities adjacent to the transfer facility and the transportation routes. Depending on the extent of concern about health effects, and any resultant stress, there could be demands on regional health services and social services.

Impacts on transportation features could be decreased quality and level of service, and physical deterioration due to increased construction traffic to the transfer facility. The changes associated with the opening up of new access in an undeveloped area may be viewed as both positive and negative. Section 7.4 concludes that the traffic impact from used fuel transportation would be small.

Depending on the amount of concern about risk, it could be necessary to expand or upgrade some transportation features, such as bypasses, for used fuel transportation activities and the transfer facility. New or improved transportation features could result in increases in property values, but decreases are also possible as a result of stigma.

Impact management measures including awareness programs and impact assistance grants would minimize impacts.

Impacts to Municipal Finance and Administration

The efficient use of municipal funds to suit a community's needs is a function of political skill and the community's overall political efficacy. Project development impacts upon municipal finance and administration, relates to changes in planning and administration, land use policies, capital and operating costs, and the tax base.

Participation in studies and approvals related to used fuel transportation would place additional administrative pressures on staff. Any expansion of transportation infrastructure, changed traffic patterns and population redistribution could result in land use changes. There would also be a need for special land use policies, particularly with respect to the transfer facility, and to a lesser extent with new access and used fuel transportation.

If municipal services or facilities were to be expanded, debt and increased operating costs would result.

Payments in lieu of taxes, local planning and technical assistance are impact management measures that would minimize impacts.

Impacts to Political Activity

A host community for the transfer facility and communities along the transportation routes, particularly from the outset of the siting process, but also throughout the different stages of the project development, can undergo a range of political events and challenges. This can be a consequence of the community's role as a recipient of socio-economic impacts.

Pressures on community leadership could occur as a result of the used fuel transportation activities. It could be necessary for community leadership to be able to manage the social changes. Political ability would be needed to champion the needs of the community vis-a-vis the demands of the project.

Increased involvement and membership in public interest or citizen organizations could also be expected. New organizations could form both supporting and opposing project-related decisions. Civic and social organizations could find it necessary or desirable to adopt positions on project-related issues. National or international public interest groups could take on a greater role in local affairs. Local governments could promulgate by-laws intended to influence routing or siting, or regulate used fuel transportation activities, and adopt resolutions in support or opposition to the project.

Cooperative siting and community involvement in monitoring and mitigation processes would minimize impacts to political activity.

Impacts to Labour Unions

During the early project stages, there is typically a need for labour organizations to participate in negotiations and planning efforts. These activities can increase workloads and change responsibilities of union officials and administrative staff.

Although there would not be many used fuel transportation development employment opportunities requiring extensive involvement by labour unions, labour unions involved in negotiations for the transfer facility and access could express concern or take action based on occupational health and safety concerns.

Agreements with labour unions would be required to allow for Aboriginal people to either be employed as non-union members or for special arrangements for their incorporation into unions. Awareness programs would minimize other impacts to labour unions.

Impact to the Political Life of Aboriginal People

Aboriginal people have a unique legal and cultural status in Canadian society, largely due to signed treaties and agreements. It also stems from the guarantees provided in the Canadian constitution, from court decisions and from their distinct cultural identity, heritage and lifestyle. Furthermore, the Province of Ontario, in signing the Statement of Political Relationships with the Chiefs of the First Nations in Ontario recognized the inherent right of self-government and is committed to its implementation (Government of Ontario 1991).

The access road/railway could infringe upon Aboriginal use of land traditionally used for subsistence purposes. The response of Aboriginal communities and/or political organizations could be governmental, legal or political action, including use of existing policies and agreements in the form of a land claim, negotiation, litigation or political lobbying.

Aboriginal self-government is an issue in some jurisdictions in Canada; in Ontario, for example, preliminary negotiations are presently in progress. Self-government could mean a new level of government with particular emphasis placed on the issues of land, land use and resource development. However, it is premature at this time to speculate on the outcome of these discussions.

7.5.3.2 Accident Conditions

This section describes the impacts associated with the used fuel transportation activities under potential accident conditions. This includes impacts that could be associated with any transportation accident, impacts associated with radiological emissions and releases, and the concerns about the transportation activities and/or the risk involved. Unless stated otherwise, these impacts could be associated with any or all of used fuel transportation, transfer facility construction and operation, and access road/railway construction and operations.

1. <u>Potential Impacts to the Social and Cultural Vitality of Communities</u>

Accidents during construction and operation of the used fuel transportation system could result in a small number of occupational and public injuries and fatalities over the life of the project (see Sections 7.1 through 7.4). Any accident, however minor, could result in stress and related health impacts, health impacts, if notification and information/awareness programs were not established (as outlined in Section 7.5.4.2). The safety analysis shows that the likelihood of a transportation accident severe enough to require an evacuation is extremely small, based on protective action levels under the Ontario Provincial Nuclear Emergency Plan. As stated in Section 2.2.2.1, Ontario Hydro has made many thousands of shipments of radioactive materials over the years of its nuclear operating experience, but has never had an accident which resulted in release of any radioactive contents.

If an accident were to occur nevertheless, it could result in significant social and cultural impacts. Residents in the immediate vicinity of an accident could experience short-term disruption of day-to-day activities, regardless of whether or not an evacuation occurs. Resident dissatisfaction with community and the potential for voluntary out-migration (and associated impacts) could be greatest after an accident.

Changes in Aboriginal land use, lifestyle and culture could occur if effects on the natural environment are, or are perceived to be, serious. However, research indicates that in the absence of physical destruction and widespread displacement, a loss of community integration in the long-term is unlikely.

2. <u>Potential Impacts to the Economic Viability of Communities</u>

There could be economic impacts even if an accident is minor, without radioactive release. Health and safety concerns could lead to resident out-migration, which could eventually lead to economic impacts on the ycommunity, but this is not expected based on the safety analysis or relevant socio-economic research literature.

Nevertheless, it can be postulated that a serious accident would disrupt directly-affected business operations. These businesses could experience production and sales losses. Dependant businesses and other operations affected by the possible closure of the transportation route could also suffer. Local residents could be expected to suffer losses in income and costs associated with an evacuation (e.g. transportation and accommodation). Declines in prices of local agricultural products and manufactured goods would be possible if a stigma were to be attributed to the local area or a particular product. This could represent a significant risk to Aboriginal food harvesting activities, both for their own consumption and that which they sell commercially. This could result in damage to the traditional, land-based economy of Aboriginal communities. An accident could also cause decreased tourist visitation and expenditures in the short term.

3. Potential Impacts to the Political Efficacy of Communities

The intensity of political activity would likely increase, if a serious accident were to occur.

Although considered unlikely based on the safety analysis and actual experience, service disruption could potentially occur if local facilities were to be directly affected by an accident. The full range of service workers could need to be mobilized to assist with access control, security and provision of medical care. Increased demands for local health care and social services could occur.

The social structure and culture of a community could change as a result of changing roles and relationships between the community and other communities/larger society, although it would be difficult to discern any such change attributable to a used fuel transportation accident from the influence of other factors in and around the community. Existing community groups or new groups which form in response to an accident could establish extra-local ties to provincial or national organizations in order to legitimate their role and gain support in the community. New emergent groups who have gained legitimacy within their community could become a permanent component of this social structure.

Effects on municipal finance, planning and administrative services would be largely limited to the disruption of routine activities and the financial burdens associated with participation in emergency response, overtime wages for service workers, equipment rental and such costs. Land use changes and a loss of stability could result if resident out-migration were to occur, or as a result of change in planning controls.

7.5.4 Impact Management

7.5.4.1 The Process of Impact Management

The impact management process is basically the same as for the disposal facility (see Section 6.5), except that it would involve a greater number of communities on a narrower range of impacts.

Impact management is a strategy for impact mitigation, enhancement, compensation, monitoring and contingency measures developed jointly with the community. A joint impact management program is designed to allow communities themselves to take part in the protection and enhancement of their natural and social environment.

Institutional arrangements for the communities affected by used fuel transportation would most likely be required after the site for the UFDC has been determined, in order to facilitate joint fact finding and other planning activities with the communities. The features of community impact agreements are not fixed but are agreed to between the proponent and the community. In addition to formal impact agreements, effective liaison measures can provide the means for continued community participation in decision-making (see Section 6.5).

Due to the significant time lag between the initial project study and project construction and operations, many changes can occur with the project and the community, which would influence the nature of the resultant socio-economic impacts. Therefore, the establishment of continuous socio-economic impact studies or monitoring program within the framework of an impact management program is recommended.

7.5.4.2 Impact Management Measures for Used Fuel Transportation Activities

Impact management measures can take several forms: minimizing adverse impacts, information/communication regarding public concerns about health and safety, workforce and other standard mitigation and nuisance effects management, compensation, and benefits and enhancement. The specific measures that may need to be implemented will depend upon detailed impact studies, impact monitoring and proponent-community negotiations.

These measures could be combined within a comprehensive impact management program aimed at resolving the potential socio-economic impacts associated with used fuel transportation. It must be recognized that a single impact management measure can serve a number of functions and no single measure is the best response to an impact.

1. Minimizing Adverse Impacts

The following are some measures which past case studies show can minimize adverse impacts (see Lockhart-Grace 1993):

i) Facility Design Optimization

The inherent safety of the cask design, employee training and provision of an extensive emergency preparedness program are aspects that address concerns about risks.

ii) Avoidance

The location of the transfer facility and access road/railway can be adjusted locally to maximize the geographical distance from community, a unique local feature or resource, and/or tourism area. This would take place in the context of public participation, in the process of siting, incorporating voluntarism, and would serve to avoid or reduce concerns about health and safety related impacts and risk.

2. Information Regarding Public Health and Safety Concerns

i) Health and Safety Monitoring

As part of the impact management program, communities adjacent to the transfer facility and along the route may wish to monitor changes in selected health and safety aspects during operations.

ii) Notification of Hazardous Events

This would mean the establishment of a notification procedure, prior to operations, for non-routine operating events. This procedure would specify which key individuals to contact in the communities along the route and adjacent to it. These could include people in the news media who can provide a channel to the general public, fire and police chiefs, municipal politicians and administrators, medical officers of health, hospitals, and government environment ministry representatives. Such notification would minimize speculation, uncertainty, and associated stress in the community following non-routine events involving radioactive and non-radioactive releases.

iii) Awareness Programs

During the initial planning phase, a general information program can be established in conjunction with the communities to ensure that the information is culturally appropriate and socially approved. The aim is to ensure that residents, community groups and people using the area are aware and knowledgeable of the risks and benefits associated with used fuel transportation, emergency response procedures and impact management efforts. Communication products and special outreach programs can be undertaken independently or introduced in conjunction with community services. Media programs, training for specialized personnel (e.g. police, fire-fighters, health care workers) can also be undertaken.

3. Workforce Impact Measures

Temporary accommodation can be provided by means of construction work camps, worker dormitories and mobile home parks. These are typically restricted to single status accommodations in order to discourage the in-migration of families for the planning and construction stages.

4. Standard Mitigation and Nuisance Effects Management

Measures to manage nuisance effects can include: use of quieter equipment, imposition of vehicle speed restrictions, and restriction of hours of operation. For the transfer facility construction effects, in particular, measures include: careful location of equipment and facilities, and use of dust suppressants or road watering. These measures serve to avoid, prevent or reduce the severity of health and safety, and disruption impacts caused by dust, increased traffic associated with transfer facility and access road/railway construction activity.

i) Access Route Modifications and Restrictions

Access route modifications would involve the construction and/or improvement of roadways in order to ensure adherence to recognized standards prior to operations. Such improvements could include changes to lane widths, shoulder widths, road surface types, creation of additional lanes or bypasses, and the installation of traffic safety features such as signal lights and appropriate signalization.

Access route restrictions would involve the designation of specific routes. In addition, vehicle speed restrictions could also be imposed. These restrictions could be implemented through the enactment of municipal by-laws or by means of proponent-community understanding and agreements.

5. Compensation

i) Payments-in-Lieu of Taxes

Payments are based on the valuation of property and the taxing authority's mill rate. The actual payment for transfer facility would be dependent upon the type and size of the property along with the type, number and size of buildings on the property, and typically commences after completion of construction activities.

ii) Impact Assistance Grants

Impact assistance grants take the form of direct service subsidies to local government or a relevant authority to undertake the necessary measures within their jurisdiction. Service subsidies usually take the form of cash payments to support the necessary mitigative measures. Timely provision of adequate services helps to avoid adverse impacts on residents and their community, in terms of satisfaction with place, community stability and attractiveness.

The specific nature and amount of assistance provided by the proponent will vary according to specific community needs as identified through impact studies and proponent-community negotiations. Impact assistance may be offered as a one-time payment, regular on-going payments, or funds could be released as the need for additional assistance is detected through the continuous socio-economic impact monitoring program.

iii) Local Planning and Technical Assistance

Planning and technical assistance may be provided through direct involvement of the proponent's staff in the local activities, or through the provision of funds to offset their costs of hiring experts and consultants, to help the community carry out the advance planning required to manage changes associated with the project. Special liaison or joint planning committees may also be established for these purposes. The provision of assistance to the local community may be negotiated as part of the initial community impact agreement or provided as required at the request of the local community.

iv) Property Value Property Protection

A property value protection program could initially be designed during the planning stage to include, for example, a guaranteed purchase or compensation provision, a buy-out option and provisions for "hardship cases".

v) Direct Financial Compensation and In-Kind Replacement/Restoration

Compensation or replacement/restoration measures can be undertaken as a result of a demonstrated or expected impact (e.g. contamination of water supply, loss of trap lines, impairment of commercial fisheries etc.). This may include direct payments to the community.

6. Benefits and Enhancement

i) Preferential Hiring

A preferential hiring program would require the negotiation of collective agreements with appropriate labour unions for hiring of local workers and a firm commitment by the proponent to hire local workers to non-union positions. This would help to ensure that local residents would have the opportunity to share the economic benefits associated with the construction of the transfer facility and access road/railway.

ii) Business Activity Enhancement

Local firms and Aboriginal businesses can be given preference in procuring goods and services required by the construction and operation of the transfer facility and access road/railway. Such preferences may be expressed verbally or informally, or formally incorporated into a negotiated agreement or project contract awards.

iii) Community Liaison Measures

An important link that the proponent can have with the community is that which is forged through joint community-proponent monitoring activities aimed at assuring health and safety, and the co-management activities aimed at avoiding and mitigating impacts.

Community liaison measures can include the establishment of liaison committees, hiring of independent experts and/or the establishment of an information hotline and complaints procedure. These measures can help to develop and maintain positive relationships between the community, government agencies and the proponent.

7.6 ECONOMIC IMPACT

The economic assessment considers direct, indirect and induced effects on the provincial economy. The terms used are described in Section 6.6.

7.6.1 Objective and Scope

The eight reference transportation scenarios analyzed for economic impact in this subsection are shown in Table 7-33. For the road and rail modes, only the shortest and longest distance scenarios are analyzed. Since the expenditures and resultant economic impacts are proportional to the distance travelled, the economic impacts of the intermediate distances can be inferred from the two extreme cases.

A nominal "base case" is indicated: this is a case selected as having an impact in the middle of the range, used to facilitate comparison between the cases.

TABLE 7-33
Transportation Scenarios Analyzed

(1)	Road	400 km to Southern Region Centroid
(2)	Road	1900 km to Northern Region Centroid
(3)	Rail*	400 km to Southern Region Centroid
(4)	Rail	1400 km to Northern Region Centroid
(5)	Water-Road	1300 km to Central Region Centroid
(6)	Water-Road	1700 km to Northern Region Centroid
(7)	Water-Rail	1300 km to Central Region Centroid
(8)	Water-Rail	1600 km to Northern Region Centroid

* Base case

7.6.2 Evaluation Methodology

The evaluation methodology is the same as described in Section 6.6.2.

7.6.3 Impact Analysis

1) Cost Data

The Ontario Hydro computer code SCUFF (System Costing of Used Fuel Facilities) was used to generate the cost data. A detailed description of the code can be found in Reynolds and Cipolla (1985) and Wong (1987a, 1987b, 1987c). Detailed SCUFF results can be found in Cheng (1993b).

2) Potential Economic Impacts of Used Fuel Transportation

The impact results were estimated using effects on production in two industries: the transportation equipment industry which produces tractors, trailers, barges, tugs and rail cars; and the metal fabricating industry which manufactures steel casks. A sensitivity analysis was also carried out at a more detailed level, using other industries so as to capture the impacts on the manufacturing process completely. The results are included in the sensitivity analysis section in Cheng (1993b).

Table 7-34 presents the calculated Gross Domestic Product (GDP), and employment multipliers for Operation, Maintenance and Administration (OM&A) and capital expenditures. A multiplier of 24 in employment for OM&A expenditures means that for every million (1990) dollars spent, 24 person-years of employment are generated in Ontario.

Table 7-35 presents a summary of the cost input data for each option used to calculate the direct, indirect and induced economic impacts. The data span the entire study period (2010 to 2067). As can be seen from the table, expenditures are dependent on two factors: the distance travelled and the transportation mode. Costs are directly proportional to the distance travelled, while the mode influences cost because of intrinsic differences in maintenance and operating costs (Cheng 1993b).

The economy-wide GDP and employment impacts are shown in Table 7-36 and Figures 7-11 and 7-12.

In general, the option with the greatest initial expenditure demonstrates the greatest economy-wide GDP and employment impacts over the study period.

TABLE 7-34
GDP and Employment Multipliers for Ontario
per 1990 Million Dollars of Direct Expenditure

Nature of Expenditure	GDP Economy-Wide	Employment (Person-years)
OM&A	1.259	24.00
CAPITAL		
Cask	1.08	18.56
Tractor	0.30	5.22
Trailer	0.30	5.22
Rail Car	0.30	5.22
Barge	0.30	5.22
Tug	0.30	5.22

(Cheng 1993b)

TABLE 7-35
Summary of Cost Input Data (2010 - 2067)
(1990 Million Dollars Net Present Value)

Transportation Scenario	OM&A	Capital	Total	Total 1990 Constant $
Road - 400 km	29	8	37	211
Road - 1900 km	75	12	87	497
Rail - 400 km	136	34	170	915
Rail - 1400 km	235	34	269	1499
Water-Road - 1300 km	42	37	79	406
Water-Road - 1700 km	53	36	89	477
Water-Rail - 1300 km	161	40	201	1124
Water-Rail - 1600 km	167	55	222	1202

TABLE 7-36
Economic Impact (net present value, 2010 - 2067)

Transportation Scenario	GDP Impact (1990 million dollars Net Present Value)	Employment Impact (person-years)
Rail 1400 km	331	35,675
Water-Rail - 1600 km	257	25,226
Water-Rail - 1300 km	238	23,578
Rail- 400 km	206	21.474
Road- 1900 km	104	11,371
Water-Road - 1700 km	103	9,904
Water-Road - 1300 km	69	7,231
Road- 400 km	44	4,671

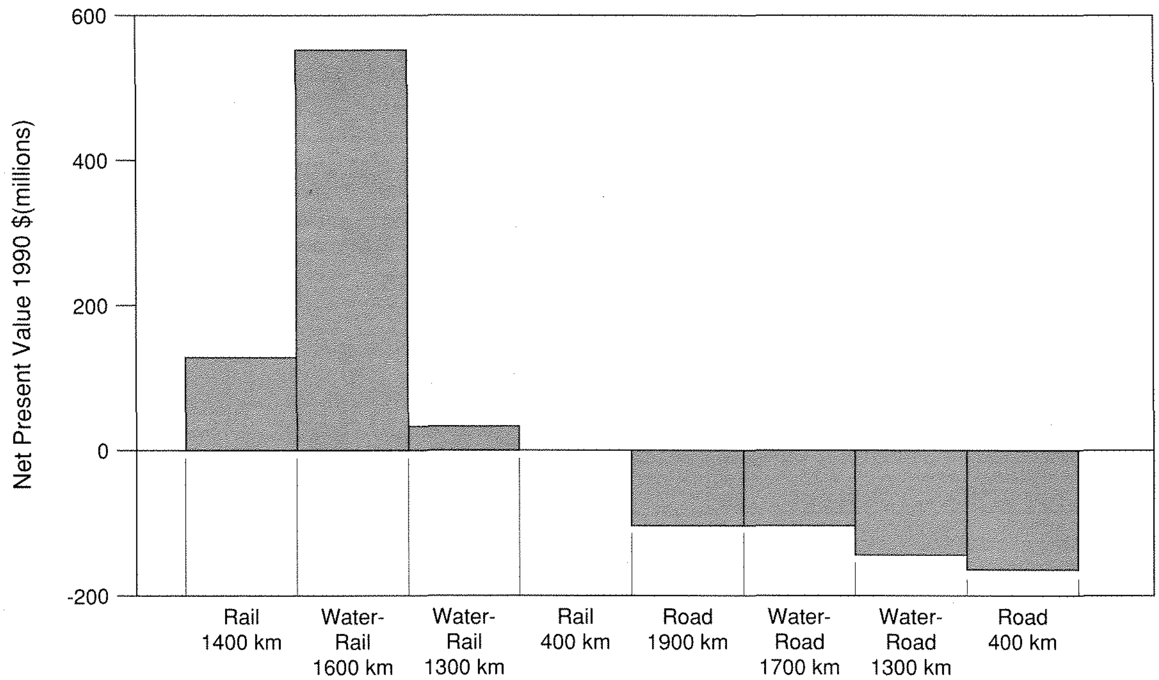


FIGURE 7-11: Economy-Wide GDP Impact All Manufacturing in Ontario
Difference from Rail 400 km Case

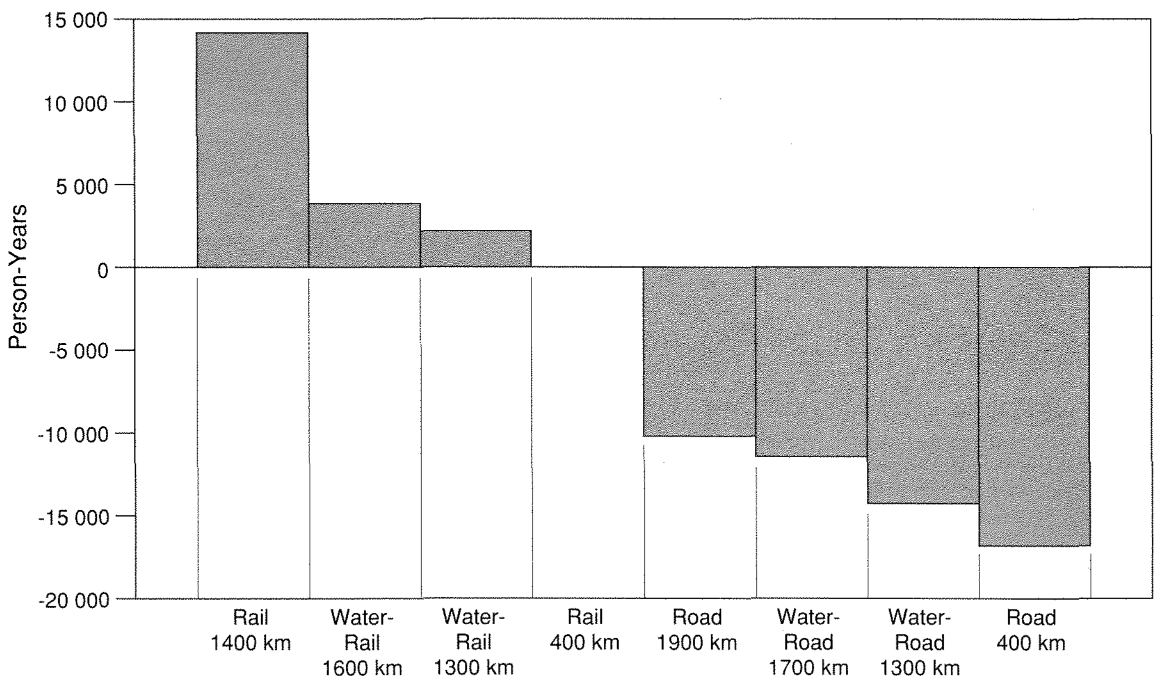


FIGURE 7-12: Economy-Wide Employment Impact All Manufacturing in Ontario
Difference from Rail 400 km Case

7.7 SECURITY AND SAFEGUARDS

General security and safeguards background and requirements are described in Section 6.7.

7.7.1 Specific Transportation Requirements

1) Safeguards Requirements for Used Fuel Transportation

   i) The used fuel transportation safeguards design must meet the requirements of the IAEA/Canada Safeguards Agreement (IAEA 1972a) for all transportation activities - fuel loading/unloading, cask transportation and transfer, if required;

   ii) material accountancy procedures, including fuel bundle verification;

   iii) containment and surveillance systems provide some information to the IAEA to help determine whether movement of nuclear materials into or out of a material balance area has occurred;

   iv) safeguards seals for both material accountancy and containment/surveillance; and

   v) safeguards equipment should be as required: tamper-resistant, require minimal maintenance, have self-diagnosis features to alert the IAEA inspector to the equipment's status, store data for retrieval only at the inspector's request, and have the capability to transfer data easily to IAEA headquarters.

2) Security Requirements for Used Fuel Transportation

The AECB Physical Security Regulations for fixed facilities specify security procedures for unirradiated nuclear material (i.e. nuclear material with a radiation level equal to or less than 1 $Gy \cdot h^{-1}$ at a distance of 1 m from the material). The security procedures for the used fuel with a higher radiation level is specified by the AECB on a case-by-case basis.

The same criteria are assumed to be applicable to used fuel transportation. Material is considered to be self-protecting if the exposure rate at one metre from the unshielded material is greater than 1 $Gy \cdot h^{-1}$. Under this provision, used CANDU fuel is self-protecting as long as the out-of-reactor time does not exceed 90 years.

In general, the used fuel transportation system, whether it is road, rail or water-based, requires measures to:

   i) ensure that the used fuel shipment does not normally deviate from the intended route;

   ii) keep base personnel informed of the status of the shipment;

   iii) provide the capability to enable the drivers to call for assistance from emergency response groups if necessary;

   iv) maintain ongoing contact with external response groups to ensure that the latter are prepared to deal with possible incidents involving used fuel shipments; and

   v) minimize the possibility of unauthorized removal of, or deliberate damage to, the used fuel during transportation.

7.7.2 Analysis of Possible Safeguards and Security Measures for Used Fuel Transportation

7.7.2.1 Safeguards

Safeguards provisions and measures for transportation of used fuel to the disposal facility would probably be similar to those being used now for used fuel shipments. They will conform to current IAEA requirements for timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to possible manufacture of nuclear weapons or other nuclear explosive devices or purposes unknown (IAEA 1972a). They will also conform to the reporting requirements for fuel shipments stipulated by the AECB (AECB 1988b).

Currently, Canadian nuclear utilities and other organizations involved in transporting used nuclear fuel provide for the use of safeguards measures by the IAEA (IAEA 1972b). These provisions are:

- Providing all necessary design, fabrication and operating information about the transportation cask and system to the AECB/IAEA for review and verification,
- Maintaining proper records of inventories and transfer of used nuclear fuel, for inspection by the IAEA,
- Reporting to the AECB/IAEA when used nuclear fuel is being transported, including the particulars of the fuel, and if the safeguard seals are inadvertently broken underway,
- Providing access and support to IAEA personnel for performing their inspections and for servicing their safeguards systems and equipment.

Currently the IAEA employs the following safeguards:

- Transportation Cask and System Design Verification,
- Material Accounting, which may involve inspection of records at the shipping and receiving facilities and verification that the specified fuel bundles are shipped and received,
- Containment and Surveillance: At the shipping facility, loading of fuel is monitored by optical surveillance, and Safeguard Seals are attached to the cask prior to shipping. At the receiving facility, the seals and cask are inspected prior to unloading the fuel to ensure that bundles have not been removed during transportation.

The above safeguards measures and provisions will also apply for the transfer facility (the facility where the used fuel casks are transferred from the water mode to either rail or road, see Chapter 2).

<u>Conclusion on Adequacy</u>

It is concluded that the most up to date safeguards measures and provisions, that may be similar to current practices and which meet AECB/IAEA requirements, will be used for fuel shipments. The actual safeguards approach would be approved and implemented by the AECB and IAEA.

7.7.2.2 Security

Several characteristics of the used fuel itself, and of the used fuel transportation cask, make the transportation package a relatively unattractive target for unlawful action:

(1) direct used fuel radiation fields that are so high as to be potentially lethal if the used fuel is removed from the transportation cask without using complicated shielded and remote handling equipment;

(2) low plutonium content of the used fuel (less than 0.4%);

(3) complex, expensive facilities and time consuming operations required to extract plutonium, if extraction is desired for a subversive activity;

(4) considerable technical knowledge of complex processes needed by a subversive group to construct and operate such a plutonium extraction facility;

(5) the inherent physical security of the transportation cask: its size and weight (35 Mg) are such that a large crane would be necessary for cask handling and removal of the impact limiter and lid;

(6) The cask has been designed and tested to withstand very stringent accident conditions which would be a deterrent to its destruction.

Properly applied security measures commensurate with the potential threat, the characteristics of the used fuel and the transportation system, are expected to reduce the probability of unlawful action and frequency of successful sabotage to very small values.

The consequence on public health and safety of even a successful sabotage of the transportation cask is likely to be similar to that of a very severe cask transport accident, and no acute health/safety effects would result from a sabotage scenario (Kempe 1993a).

The proposed security provisions for used fuel transportation are based on existing security procedures for off-site used fuel transportation in Canada, AECB (1983) and IAEA (1989) documentation, and consideration of used fuel transportation system operational requirements. The following proposed provisions were assessed against the security requirements presented earlier:

i) each cask would be sealed at the shipping facility. This seal would indicate any attempt to open the cask;

ii) each cask would have a permanent fire-resistant embossed metal plaque showing the trefoil radioactivity symbol, Ontario Hydro name and logo, and a serial number providing a unique identification of the cask;

iii) external response groups, such as police, fire and ambulance departments and hospitals, would have the appropriate training to cope with used fuel cask transportation incidents (Ontario Hydro 1991b);

iv) police, fire and transport authorities would be informed of the route, approved stopping places and emergency procedures for the used fuel transportation operation. They would be given written guidelines for responding to assistance requests and emergency situations;

v) an emergency plan would be available, for example, Ontario Hydro already has an emergency plan (Ontario Hydro 1991b) to handle any emergencies involving radioactive materials, such as a cask accident. The response procedures already in place would permit an appropriate response to be made to a threat, sabotage or other event that could jeopardize the security of the used fuel shipment;

vi) cask emergency drills and exercises would be carried out periodically (Ontario Hydro 1991b) at various locations along the possible cask transportation routes with the full cooperation of appropriate provincial and federal transport regulatory authorities, fire departments, various police forces, ambulance services, hospitals and Ontario Hydro staff;

vii) all personnel connected with used fuel transportation would be screened to ensure that they are not a security risk;

viii) for all modes of transportation, drivers, co-drivers and all other crew members would be trained as specified by the Transportation of Dangerous Goods Regulations and in the implementation of radiation protection and other safety measures. This training would be repeated periodically;

ix) the transport unit would be equipped with a communications system which would provide vehicle tracking capability. The communications link would also ensure that Ontario Hydro radiation protection staff could be rapidly on hand if an accident occurs;

x) a transportation log would be maintained to be used in transportation operation/design optimization for possible representation to regulatory authorities and for responding to public enquiries; and

xi) security measures similar to those at the nuclear generating stations and the UFDC would be in place at the transfer facility.

Conclusion on Adequacy

It is concluded that the proposed used fuel transportation system security provisions would meet the AECB licensing requirements and would adequately protect the public, transportation personnel and the environment from wilful terrorist action (theft or sabotage).

7.8 IMPACT OF USED FUEL TRANSPORTATION FROM OTHER PROVINCES

Section 2.3 reviewed the possible regulatory differences between used fuel transportation in Ontario using the reference transportation systems and transportation through the New Brunswick and Québec road, rail and water transportation network. It was found that all the provincial regulations had the same regulatory basis: the AECB packaging regulations and the TDG regulations. That section also reviewed the applicability of the reference transportation system to the local transportation network.

Except for weight regulations in New Brunswick, it was found that transportation of used fuel with the reference transportation system was feasible in both New Brunswick and Québec.

This section would discuss the applicability of the analysis results/conclusions to the transportation environments in New Brunswick and Québec.

7.8.1 Number of Bundles to be Transported

The forecast for the cumulative arisings from 40 years of nuclear power generation in Québec and New Brunswick are: Gentilly 2 - 182 400 bundles; Point Lepreau - 182 400 bundles. The Gentilly 1 reactor generated 3 213 used fuel bundles before it was shut down. The total number of used fuel bundles to be disposed of from these two provinces is 368 013 bundles. This would represent about 4% of the reference capacity of the UFDC.

7.8.2 Public Radiological Safety

During normal conditions, given the wide range of population densities used in the safety analysis (from sparsely populated rural density to the high population densities found near Toronto), it is expected that the population densities along the transportation corridors in New Brunswick and Québec would be similar to those used for Ontario. The same can be said for traffic. The rest of the parameters used in the analysis would be generally applicable in the two provinces. It is, therefore, assumed that the maximum dose would be similar for the other provinces. The annual population dose, for a given shipment distance, would be smaller because of the reduced number of shipments from these provinces.

During accident conditions, the dose to individuals on the transport route would depend on the severity and the frequency of accidents along the transportation corridors in Québec and New Brunswick. Although no exhaustive research has been done in this area, it is assumed that, given the similarities in transportation infrastructures and weather conditions, the accident statistics in Ontario (severity and frequency) should be similar to the accident statistics in the other two provinces. Therefore, the maximum dose during accident conditions would be fairly similar. The population dose should also be fairly similar, given the range of population densities used in the present analysis.

Water transportation might be an exception, at least for New Brunswick, where transportation would need to be done at sea and not in the interior waters. The difference in accident statistics would need to be investigated.

7.8.3 Occupational Safety

During normal conditions, since the same transportation system would be used to transport fuel from Québec and New Brunswick, the radiological and non-radiological effects on workers should be the same on a per km basis. As the number of shipments from these provinces is only a fraction (less than 10%) of the Ontario shipments, the total impact of transporting used fuel from these other provinces, even accounting for the larger distances, should be smaller. The impacts of transporting the total 250 000 bundles would, however, be larger.

During accident conditions, the arguments used above for the public safety analysis also apply to occupational safety.

7.8.4 Natural Environment Analysis

It is evident that the natural environments surrounding the transportation corridors in Québec and New Brunswick are different than the ones encountered in Ontario. However, the variability is not greater than that found between transportation in southern Ontario and transportation in northern Ontario. As for transportation in Ontario, the most severe impacts on the existing environment would be from transportation noise and traffic. Given the reduced number of shipments from Québec and New Brunswick, the effects should be proportionally smaller.

7.8.5 Social Impact Analysis

The types of impact identified in the reference analysis for Ontario were generic impacts that could result from large-scale transportation anywhere in Canada. Similar impacts could, therefore, be expected from transportation from the other provinces.

7.9 EFFECTS OF INCREASING SYSTEM CAPACITY TO 250 000 BUNDLES PER YEAR

The reference transportation system logistics, yearly capacity, years of operation and length of operating season assumed in the Ontario Hydro Used Fuel Transportation Assessment (Grondin et al. 1993) are different than those for the conceptual UFDC (Simmons and Baumgartner 1994).

The UFDC conceptual design assumed an operating life of about 41 years which implies a disposal capacity of 250 000 bundles per year for the estimated inventory of 10 million bundles.

The length of the transportation operating season would be governed by external constraints such as weather conditions and unavoidable transportation vehicle breakdown, and in the reference transportation system it depends on the transportation modes (231 days for water, and 275 days for road and rail). The operating season for the used fuel packaging plant was assumed to be 230 days per year.

7.9.1 Radiological Impacts - Normal Operations

The collective and individual doses to the public for the road and rail modes vary linearly with the number of shipments per year (assuming, for the individual dose, that shipments are always along the same route). On that basis, the collective and maximum individual doses from transporting 250 000 bundles per year were calculated by scaling the 180 000 bundles per year base case results. For the water mode, the maximum dose was for members of the public following a shipment through a lock, and would not vary with the number of shipments.

Results are shown in Tables 7-37 and 7-38. Doses are well within the current regulatory limits for members of the public (5 $mSv \cdot a^{-1}$). The largest collective dose was 0.13 person-$Sv \cdot a^{-1}$ for the water mode transportation to the Northern Region or about 5.4 person-Sv for the 41 years of operation of the facility. Using a risk factor of 5×10^{-2} fatal cancers per Sv, the maximum annual risk would be 0.0065 fatal cancers, for a total of 0.27 fatal cancers over the operating life of the facility. The fatal cancer risk to individuals in the critical group would be a maximum of 5×10^{-6}. As discussed in Section 7.1.1.3, doses to critical groups could, in practice, be controlled to a lower level than calculated here.

TABLE 7-37
Collective Doses to the Public during
Normal Transportation of 250 000 Bundles per Year

Mode	Destination	Collective Dose person-Sv·a⁻¹			
		Off-link[1]	On-link[2]	Stops	Total
Road	Southern	0.0050	0.0097	0.021	0.036
	Central	0.0032	0.0085	0.042	0.053
	Northern	0.0047	0.0128	0.092	0.110
Rail	Southern	0.0046	0.00076	-	0.0054
	Central	0.0061	0.00046	-	0.0065
	Northern	0.0061	0.00056	-	0.0067
Water-road	Central				
Road		0.00043	0.00018	0.017	0.018
Water		0.029	-	0.042	0.071
Total		0.029	0.00018	0.059	0.089
Water-road					
Road	Northern	0.0021	0.00278	0.032	0.038
Water		0.029	-	0.065	0.093
Total		0.031	0.00278	0.097	0.131
Water-rail					
Rail	Central	0.00018	0.00006	-	0.00024
Water		0.025	-	0.050	0.075
Total		0.025	0.00006	0.050	0.075
Water-rail					
Rail	Northern	0.00054	0.00117	-	0.0017
Water		0.025	-	0.058	0.083
Total		0.025	0.00117	0.058	0.085

(Kempe 1993a)

[1] off-link: on the side of the road, rail line or shipping lane, i.e., the surrounding population.
[2] on the transportation link, i.e., in vessels using the road, rail line or shipping lane.

TABLE 7-38
Summary of Maximum Individual Dose to the Public during Normal
Transportation of 250 000 Bundles per Year

Mode	Dose (mSv)
Road	0.09[1]
Rail	0.0004[2]
Water	0.05[3]

[1] Dose to persons present at a truck stop used by the shipments
[2] Dose to persons living beside the rail link
[3] Dose to persons following a shipment through a canal

The collective doses to workers during transportation of 250 000 bundles per year are shown in Table 7-39. Over the operating life of the transportation system, using a risk factor of 4×10^{-2} fatal cancers per Sv of exposure, the maximum annual total fatality risk for the water mode to the Northern Region would be around 0.05, for a total of 2 fatal cancers over the 41 years of operation. The individual doses to workers would not increase with an increase in transportation capacity to 250 000 bundles per year because proportionally more workers would be assigned to operate the transportation system. The maximum annual individual worker dose remains at 2.4, 1.2 and 10 $mSv \cdot a^{-1}$ for road, rail and water transportation, respectively, and 11 $mSv \cdot a^{-1}$ for the cask handling dose. Note that these estimates are based on a conceptual design and that application of the ALARA principle at the implementation stage would work to further reduce the maximum individual dose to workers.

7.9.2 Radiological Impacts - Accident Conditions

Individual and collective doses to the public following an accident are not affected by a change in transportation system capacity. Only the annual frequency of a member of the public receiving a given dose is affected. Increasing the number of bundles transported from 180 000 to 250 000 per year would increase the probability of receiving any dose by 39%. The annual expected radiological impact due to accidents is shown in Table 7-40. The individual doses in accident conditions are summarized in Table 7-41, with the appropriate probabilities for transportation of 250 000 bundles per year.

The annual average collective dose to workers from normal and accident conditions during transportation of 250 000 bundles per year is shown in Table 7-39, and is 39% higher than for 180 000 bundles per year. These doses would result in a total fatality risk to workers due to radiological impacts of accident conditions of much less than 1 over the operating life of the transportation system.

7.9.3 Non-Radiological Impacts

Annual emissions from used fuel transportation, presented in Table 7-29, would increase by about 40% for a transportation capacity of 250 000 bundles per year. These emissions would still be a small fraction of the emissions from the transportation sources in Ontario, shown in Table 7-29.

The increase in used fuel transportation traffic for a 250 000 bundles per year design capacity is higher than for 180 000 bundles per year, but should not invalidate the results of the reference analysis. The same can be said about the increase in noise from used fuel transportation activities, which depends on the added traffic flow.

The annual consumption of diesel fuel from transportation of 250 000 used fuel bundles per year would be increased by about 40% from the quantities shown in Table 7-26. The total consumption would be the same. Note that the numbers assumed transportation over the reference distances for the reference transportation system designs (400, 900 and 1900 km for road; 400, 800 and 1400 km for rail; 1300 and 1700 km for water-road; and 1300 and 1600 km for water-rail).

Variations in the used fuel transportation system capacity and reference distances would lead to proportional changes in the usage of non-renewable resources, for example, via an increase in the number of vehicles required. The small magnitude of the commitments with respect to available reserves indicate that conclusions based on the used fuel transportation reference design would be applicable for UFDC design parameters.

TABLE 7-39
Annual Average Collective Dose to Workers Under Normal Transportation and Accident Conditions, for 250 000 Bundles per Year

	ANNUAL DOSE	
	Normal Transportation (person mSv·a^{-1})	Frequency Weighted Expected Annual Dose Accident Conditions (person mSv•a^{-1})
Rail		
Southern	210	2.1×10^{-3}
Central	210	6.4×10^{-4}
Northern	210	9.6×10^{-4}
Road		
Southern	590	3.8×10^{-4}
Central	650	1.5×10^{-3}
Northern	710	3.2×10^{-3}
Water-Road		
Central	940	4.9×10^{-4}
Northern	980	4.2×10^{-4}
Water-Rail		
Central	370	6.1×10^{-4}
Northern	380	4.4×10^{-3}

TABLE 7-40
Annual Expected Radiological Impact on the Public Due to Accidents during Transport of 250 000 Bundles per Year

Mode	Destination	Person-Sv·a^{-1}
Road	Southern Central Northern	2.9×10^{-8} 3.3×10^{-8} 6.0×10^{-8}
Rail	Southern Central Northern	8.6×10^{-8} 4.7×10^{-8} 4.6×10^{-8}
Water-Road	Central Northern	[1]1.2×10^{-8}/ [2]2.08×10^{-6} 2.6×10^{-8} / 2.08×10^{-6}
Water-Rail	Central Northern	[3]1.5×10^{-9}/ 2.08×10^{-6} 4.6×10^{-8} / 2.08×10^{-6}

[1] Road
[2] Water
[3] Rail

TABLE 7-41
Summary of Maximum Individual Doses due to Transportation Accidents for 250 000 Bundles per Year Capacity

Mode	Maximum Individual Dose (mSv)			Annual Frequency of worst case
	90th percentile	Worst Case Adult	Worst Case Infant	
Road	9	9	13	4×10^{-6}
Rail	30	28	40	5×10^{-7}
Water	30	28	40	1×10^{-6}

The annual number of traffic accidents involving the used fuel transportation unit would be increased, as shown in Table 7-42.

The non-radiological hazards to workers associated transporting 250 000 bundles per year are shown in Table 7-43. These hazards would result in a maximum fatality risk to workers of 1.8 (for road, northern destination) over the life of the transportation system (41 years).

7.9.4 Socio-Economic Impacts

Given the wide range of social impacts covered by the study, the analysis would be equally applicable to a transportation system operating at 250 000 bundles per year.

In sensitivity analysis of economic impacts, transportation of an additional 100 000 bundles per year resulted in net present values of GDP and employment 33 to 55% higher depending on the transportation mode (Section 9.9.3). It can, therefore, be inferred that transportation of 250 000 bundles per year would result in a GDP impact approximately 30% higher and employment impact approximately 50% higher that the results presented in Section 7.6. In fact, some of this economic impact would take place in other provinces, as some of the additional fuel accounts for transport from other provinces.

7.10 SUMMARY OF IMPACTS OF TRANSPORTING USED FUEL IN ONTARIO

The section summarizes the estimated impacts for a system transporting 250 000 bundles per year.

7.10.1 Impacts on the Public

7.10.1.1 Normal Conditions

All the collective doses calculated are small, the largest being 0.13 person-Sv per year to an estimated exposed population of 10^5 persons. The expected number of fatalities per year due to exposures in normal conditions are shown in Table 7-44, based on a risk coefficient of 5×10^{-2} fatal cancers per Sv (ICRP 1991).

TABLE 7-42
Annual Total Number of Traffic Accidents involving the Used Fuel Transportation (UFT) Unit for Transportation of 250 000 Bundles per Year

	Location	Annual Number of Accidents		
		Southern	**Central**	**Northern**
ROAD Involving UFT truck	rural	1.1	2.4	5
	suburban	0.04	0.07	0.15
	urban	0.03	0.03	0.03
RAIL Involving UFT train (railcar accidents)	rural	0.7	0.3	0.4
	suburban	0.03	0.01	0.01
	urban	0.04	0.03	0.01
WATER-ROAD Involving UFT tug/barge	open water	-	0.07	0.06
	channel/river	-	0.15	0.15
Involving UFT truck	rural	-	1.3	1.0
	suburban	-	-	0.11
	urban	-	-	-
WATER-RAIL Involving UFT tug/barge	open water	-	0.07	0.06
	channel/river	-	0.15	0.15
Involving UFT train (railcar accidents)	rural	-	0.10	1.15
	suburban	-	-	-
	urban	-	-	-

TABLE 7-43
Non-radiological Hazards[1] to Workers Associated with the Transportation of 250 000 Bundles per Year

	Injury Rate (per year)	Fatality Rate (per year)
Road		
Southern	4.03	3.9×10^{-3}
Central	9.44	1.4×10^{-2}
Northern	13.47	2.6×10^{-2}
Rail		
Southern	1.53	2.6×10^{-3}
Central	1.53	3.5×10^{-3}
Northern	1.93	4.7×10^{-3}
Water-Road		
Central	6.25	1.5×10^{-2}
Northern	7.08	1.7×10^{-2}
Water-Rail		
Central	3.61	1.3×10^{-2}
Northern	4.03	1.4×10^{-2}

1 rounded

TABLE 7-44

Annual Risk to Public due to Radiation Exposure in Normal Conditions (in fatalities per year)[1]

Mode	To Southern Region	To Central Region	To Northern Region
Road	1.8×10^{-3}	2.6×10^{-3}	5.5×10^{-3}
Rail	2.7×10^{-4}	3.3×10^{-4}	3.3×10^{-4}
Water-Road	-	4.4×10^{-3}	6.5×10^{-3}
Water-Rail	-	3.8×10^{-3}	4.2×10^{-3}

1 Based on a risk factor of 5×10^{-2} Sv^{-1} (ICRP 1991) and transportation of 250 000 used fuel bundles per year. The total radiological risk over the entire transportation operation for a UFDC capacity of 10.1 million bundles would be about 40 times the above figures.

The maximum individual doses are 0.09, 0.0004 and 0.05 mSv for the road, rail and water modes respectively, and are all well below the regulatory limit for members of the public of 5 $mSv \cdot a^{-1}$ (AECB 1978). The highest figure found, 0.09 $mSv \cdot a^{-1}$, is for persons exposed to all the shipments at a truck stop, and could be controlled in practice by monitoring, use of alternative truck stops, and choice of parking location. The maximum dose of 0.09 $mSv \cdot a^{-1}$ may be compared with the dose due to natural background of approximately 3 $mSv \cdot a^{-1}$ (Neil 1988). The maximum individual dose due to design basis leakage during tested (rough handling) conditions is 3 x 10^{-6} mSv per year. This is 1000 times less than the dose to groups living beside the route from direct external radiation from the cask.

7.10.1.2 Accident Conditions

The maximum individual dose calculated for severe accident conditions is 10 - 40 mSv, as shown in Table 7-41. The frequency associated with this level of dose is 10^{-6} or less. It is emphasized that conservative parameters have been used in the assessment, and that this dose may be taken as an upper bound. The significance of the individual doses found may be evaluated by comparison with the regulatory limits, and the emergency reference levels used in emergency planning.

The doses found are 2 - 20 times higher than the regulatory limit for members of the public (AECB 1978). If we assume that the radiation dose limits, as used for the UFDC safety analysis, also apply to the used fuel transportation analysis, the limits in Table 6-17 can be used. The worst case transportation accident, with a frequency of 10^{-6}, would fall in event class 5. Even the 40 mSv dose would only be a fraction of the 250 mSv limit for that event class. It may also be noted that the figure of 40 mSv is less than the upper Protective Action Level of 100 mSv, given in the technical bases of the Ontario Provincial Nuclear Emergency Plan, at which members of the public would be automatically evacuated, although it is above the lower Protective Action Level of 10 mSv, at which evacuation would likely be undertaken (Government of Ontario 1984).

The collective dose due to a very severe transport accident with a frequency of ~10^{-6} a^{-1} might be of the order of 1 person-Sv with an estimated exposed population of 10^5 persons. Again, this may be regarded as an upper bound. To give some meaning to this figure, the potential impact on the health of the population may be tentatively examined by estimating the number of delayed cancer deaths that might result. This calculation has been carried out in other assessments (e.g. Clarke and Shaw 1983, Neuhauser et al. 1984). Using the ICRP risk coefficient of 5 x 10^{-2} fatal cancers per Sv (ICRP 1991), the number of fatal cancers resulting from a very severe transportation accident is 0.05. Because this is much less than one, no fatal cancers would be expected. In addition, this number is likely to be far outweighed by the number of deaths from conventional causes in such a severe accident (Grondin 1993b).

The risk, in terms of fatalities per year due to exposures in accident conditions, derived from the numbers of Table 7-40, is shown in Table 7-45 (note that these numbers represent the total expected number of fatalities, not the individual risk).

TABLE 7-45
Annual Risk to Public due to Radiation Exposure in Accident Conditions (in fatalities per year)[1]

Mode	To Southern Region Centroid	To Central Region Centroid	To Northern Region Centroid
Road	1.5×10^{-9}	1.7×10^{-9}	3.0×10^{-9}
Rail	4.3×10^{-9}	2.4×10^{-9}	1.2×10^{-9}
Water-Road	-	1.0×10^{-7}	1.1×10^{-7}
Water-Rail	-	1.0×10^{-7}	1.1×10^{-7}

1 Based on a risk factor of 5×10^{2} Sv^{-1} (ICRP 1991)

7.10.2 Impacts on the Workers

An estimate was made of the number of potential fatalities due to exposure to radiological hazards. The ICRP risk coefficients are adopted for this analysis. For a working population, this coefficient is 4×10^{-2} Sv^{-1}. The risk factor is different than that for the public because occupational safety considers only the working age population, i.e. between 18 and 65 years old. Multiplication of this coefficient by the total annual effective dose equivalent for radiological hazards yields an estimate of radiological risk.

7.10.2.1 Normal Conditions

The radiological risks of fatalities are shown in Table 7-46. The total collective dose for transportation of 10.1 million bundles over the same distances as for the reference transportation routes, during the 41 years of operation, would be between 8.7 person-Sv and 38.5 person-Sv depending on the mode. Over the operating life of the transportation system, the total fatality risk due to radiological hazards varies from less than one to around two fatalities.

7.10.2.2 Accident Conditions

The maximum acute radiological dose to a worker was found to be 190 mSv, or approximately 4 times the limit for radiation workers. This assumed that the worker (driver or crew) survived the conventional hazard of the accident, and credited the emergency response team for removing the worker from the accident scene in the first hour following the accident. The value of four times the limit is, however, less than the event class limit discussed above, under Section 7.10.1.2.

Table 7-47 presents the expected number of fatalities per year amongst workers resulting from radiological hazards during used fuel transportation accidents, obtained using a risk factor of 4×10^{-2} fatal cancers per Sv. Table 7-43 shows the expected number of fatalities per year among workers resulting from non-radiological causes in accidents.

TABLE 7-46
Estimated Annual Transportation Radiological Risk[1] to Workers from Normal Transportation Activities
(in fatalities/year)

Mode	to Southern Region Centroid	to Central Region Centroid	to Northern Region Centroid
	(fatalities per year)		
Road	0.023	0.026	0.028
Rail	0.008	0.009	0.009
Water-Road	-	0.038	0.039
Water-Rail	-	0.015	0.015

[1] Based on a risk factor of 4×10^{2} Sv^{-1} (ICRP 1991)

TABLE 7-47
Annual Risk Associated with Acute Radiological Hazards (in fatalities per year)[1]

Mode	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}

[1] Based on a risk factor of 4×10^{2} Sv^{-1} (ICRP 1991)

7.10.3 Impacts on the Natural Environment

Transportation of 250 000 used fuel bundles per year in Ontario would increase road traffic by a range of 10-12 trucks per day, rail traffic by less than 1 train per day and vessel traffic by less than 1 vessel per day. Although the significance of this increase in traffic would depend on the actual transportation link traffic, the incremental effects are expected to be small.

Small atmospheric emissions and small resource commitments would result from used fuel transportation.

7.10.4 Impacts on the Social, Cultural and Economic Environment

7.10.4.1 Normal Conditions

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

Concerns about risk to health and safety, and the resulting stress and community stigma, are especially important in the assessment of the impacts of used fuel transportation activities because they could induce or compound other potential socio-economic impacts. For example, they could:

(i) affect community cohesion, and family and community stability;

(ii) contribute to the loss of community satisfaction, increase community conflict and local political activity;

(iii) disrupt the way of life and day-to-day activities of certain population subgroups; and

(iv) create a feeling of reduced community control.

The highly interconnected nature of these types of potential impacts and their common source (radiological risk) suggest that collectively they represent key potential impacts.

Community culture and social structure impacts, especially with respect to Aboriginal peoples, and the additional burdens that project-related institutional arrangements may place upon administrative and planning capacity could also be important impacts.

It is therefore important that these potential impacts (especially risk, stress and community stigma) are adequately addressed, through route selection, public consultation and impact management. Other impacts such as reduced in-migration and increased out-migration, as well as additional economic impacts such as impacts on tourism, agriculture, property values, municipal services and finance, should be minimal. It is nevertheless prudent to consider them in the comprehensive analysis of the socio-economic impacts and impact management program associated with used fuel transportation that would take place during implementation.

In reviewing the transfer facility characteristics, as well as the general area where such a facility might be located, it would appear that the additional impacts for the transfer facility would not add appreciably to those for used fuel transportation activities. With such a small facility there may be some local employment and local purchase benefits. However, other economic, population, land use and growth-related municipal service impacts should be very limited, although road maintenance costs to the facility may be a concern. This latter potential impact is clearly mitigable.

In view of the small size of the transfer facility, off-site nuisance impacts from facility construction and operation could be minimized to reduce environmental effects and their associated socio-economic impacts to negligible levels, and to eliminate or reduce residents displacement as a result of these nuisances.

It is conceivable that the transfer facility could become a focal point for concern and a symbol for those opposed to used fuel transportation development. To avoid, or at least reduce the potential for such effects, close and on-going consultation with interested and affected publics would be required, regarding such matters as site location, impact management requirements, community monitoring and compensation.

As stated previously, impacts associated with access rail/road construction and maintenance would depend on the extent of the access. There would be some direct regional employment and purchase benefits. Secondary economic, population, land use and growth-related municipal service impacts would be very limited. The most significant impact is likely to be related to the creation of new access in an isolated area. This could result in both positive and negative impacts on tourism, and negative impacts on Aboriginal lifestyle and culture.

7.10.4.2 Accident Conditions

The probability of an accident that would result in even a minor release of radioactive material is very low. However, for those who are apprehensive about nuclear technology, even a minor accident would serve to increase their perception of risk and its associated stress and stress-related health impacts.

Both the conventional and radiological aspects of an accident would intensify impacts on community services and facilities, especially health and safety, and to a lesser extent social services, recreation and education. An accident might have significant impacts on community infrastructure. There might be increased demands for expansion of transportation facilities, decreased property values and out-migration of residents.

Fiscal and administrative impacts could also occur, mainly as a result of the heightened concerns about radiological risk. Heightened concerns about risk and any attribution of stigma to the area, could result in economic losses, particularly to tourism.

Again, it is emphasized that such impacts are very unlikely, as the probability of a serious accident is very low.

7.10.5 Economic Impacts

The analysis found that the economic impact of transporting used fuel was directly proportional to the initial expenditures on the transportation equipment used, the distance travelled and the maintenance/operating costs of the particular transportation mode under study.

The employment impacts varied from 4 600 person-years (road 400 km) to 35 700 person-years (rail 1400 km), while the contribution to GDP (in constant 1990 dollars net present value) varied from 44 million (road 400 km) to 331 million dollars (rail 1400 km). Transportation of 250 000 bundles per year would result in significant expenditures in Ontario and the other provinces involved.

However, these province-wide impacts are small relative to the size of Ontario's total GDP. It is likely that the transportation of used fuel would have a larger impact on local economies within the province. It is expected that the same conclusion would apply to the economic impact in other provinces.

7.11 RESIDUAL EFFECTS

As mentioned in other chapters, the residual effects discussed in this section are our best estimate of what effects might be left after the application of impact management measures. This estimation would need to be validated with the potentially affected population and natural environment setting for used fuel transportation.

The maximum dose to the public during normal transportation was estimated to be a fraction of natural background.

The work activity that would contribute the most to occupational radiation would be cask handling at the nuclear generating stations. Although the annual doses are expected to be within regulatory limits, refinements to work procedures and tooling in accordance to the ALARA (As Low As Reasonably Achievable) principle would help reduce the dose even further.

In accident conditions, the maximum dose to the public was calculated to be a fraction of the regulatory safety criteria, and less than half the dose for which automatic evacuation is recommended by the Ontario Provincial Nuclear Emergency Plan. It is expected that, because of the inherent safety of the cask design, the impacts to workers in terms of injuries and fatalities from a transportation accident severe enough to result in significant exposure to the crew would be more severe than the impacts from radiation exposure.

It is expected that of all activities associated with used fuel transportation, construction of the transfer facility would be the most disruptive for the natural environment. Sound environmental construction practices have been established in other construction projects that contributed to a reduction of effects and should be followed for transfer facility construction (Prinoski et al. 1983). Given the small size of the facility, it should also be possible to site it in a location where effects on the natural environment would be minimum. The effect of the used fuel transportation traffic on the transportation network in terms of noise and public safety would also need to be examined as part of the siting process. This further assessment should determine whether there are segments of the routes operating at or near full capacity which would be more sensitive to used fuel transportation effects.

Concern about radiological risk and associated stress-related impacts, identified as a possible residual impact during siting, may very well remain to some degree throughout the used fuel transportation stage.

Other possible residual impacts specific to the used fuel transportation stage could be those related to community infrastructure and service demands along the routes. These residual impacts, as well as those resulting from measures to enhance local economic benefits can result in positive social and economic change if managed jointly with the affected communities.

CHAPTER 8

8. ANALYSIS OF UFDC DECOMMISSIONING, MONITORING AND VAULT CLOSURE

8.1 INTRODUCTION

The objectives of disposal are to protect humans and the environment, and to minimize the burden on future generations for the continued management of waste. The disposal vault would, therefore, be sealed after it was filled, and regulatory and institutional approvals had been obtained. AECL's Public Consultation Program (Greber et al. 1994), and public input to the FEARO scoping meetings (Dowell 1991a), indicate that society may wish to utilize a period of monitoring following operations to gather further data on the long-term safety of the vault and to increase confidence in the predictions of safety analyses. The public also indicated that it is important that used fuel should be retrievable during the early monitoring period, if the monitoring data show that it is required.

As shown in Figure 2-6, the reference UFDC schedule specifies an extended monitoring period of undefined duration between completion of the used fuel emplacement operation and facility decommissioning. During this period, retrieval of used fuel would be possible. The schedule also specifies another monitoring period of undefined duration after facility decommissioning, but before closure of the vault. An overview of all disposal implementation stages, up to and including closure, is given in Section 2.1.1.5 of Chapter 2. More detailed descriptions of the reference design procedures for disposal facility decommissioning (Section 2.1.6), extended monitoring before and after decommissioning (Sections 2.1.5 and 2.1.7), and closure of the vault (Section 2.1.8) are also given in Chapter 2).

This chapter reviews the effects of activities that would take place during facility decommissioning, possible monitoring periods and vault closure.

8.2 POTENTIAL EFFECTS ON PUBLIC SAFETY

The reference design assumes that the criteria used in the decommissioning of the Gentilly I reactor would apply to decommissioning of the UFDC. These criteria, listed in Chapter 2, specify that the site surface should be suitable for public use after decommissioning. Permanent signs, referred to as permanent markers, would be placed at the site to indicate the location of the vaults, and information on the vault location would be archived in federal, provincial and municipal records and maps. An international committee is currently examining ways of preserving information about the disposal site over very long times.

Routine emissions of radionuclides from the facility and any resulting radiological impacts during decommissioning are expected to be small compared to emissions during the operation stage, since the primary source of radioactivity (the used fuel) would all have been removed from the surface environment. Dismantling activities, which could expose activated product sources, would not create sources of the same order of magnitude as when the UFDC was operating. The radiological impacts on the public from accidents occurring during decommissioning and closure are expected to be much smaller than the impacts of accidents during the operation stage described in Section 6.1.2.5.

The radiological impacts on the public following closure are discussed in the Postclosure Assessment Primary Reference (Goodwin et al. 1994).

8.3 POTENTIAL EFFECTS ON THE NATURAL ENVIRONMENT

In this section, experience in the decommissioning of nuclear facilities is reviewed with respect to environmental protection aspects. The analysis of effects of the decommissioning and closure activities on air quality, water quality, land use, flora and fauna, and non-renewable resources is also presented.

Environmental protection provisions in place during operation of the facility would continue in the extended monitoring, decommissioning and closure stages.

The pre- and post-decommissioning monitoring activities would be a continuation of the monitoring activities during the operation stage, which were, in turn, a continuation of the monitoring activities during the siting and construction stages. For that reason, no new effects on the natural environment are expected from pre- and post-decommissioning monitoring activities.

8.3.1 Decommissioning Experience and Environmental Protection

Although a used fuel disposal facility has never been decommissioned, there is considerable experience in the nuclear industry in all aspects of decommissioning of nuclear facilities.

In recent years, the submission of decommissioning plans for operating nuclear generating stations has become a licensing requirement (AECB 1988a). This requirement has led to a number of decommissioning studies at nuclear sites in Ontario. In addition, decommissioning of four nuclear reactors in Canada: the Gentilly 1 reactor in Quebec and the Douglas Point, NRX and NPD reactors in Ontario, has begun. In addition, a few reactors have been fully decommissioned in the United States (e.g. the Elk River Reactor). Experience indicates that nuclear facilities can be decommissioned within the stringent safety and environmental standards that are currently applied to their operation (Unsworth 1979; UNSCEAR 1981). It is reasonable to assume that a used fuel disposal facility could also be decommissioned within acceptable safety and environmental standards.

The following components of a decommissioning plan (Environment Canada 1992) aimed at enhancing environmental protection were assumed for decommissioning of the UFDC:

i) a review of the operating history to obtain detailed information about the location of and use of each area of the site, and to identify areas that might need clean-up;

ii) a review of the sampling and analytical program to characterize the site components with respect to possible contamination;

iii) classification and separation of the wastes for economic and safe disposal;

iv) an inventory of chemicals and fuels on site to identify hazards and resale potential; and

v) an evaluation of the geologic and hydrogeologic factors on completion of the decommissioning to ensure that the site has been returned to a safe and environmentally acceptable configuration.

The Ontario Ministry of Environment and Energy has issued three sets of environmental protection requirements and guidelines (see Appendix B for details) that would apply to UFDC decommissioning:

1. Policy for Management of Excess Soil, Rock and Like Materials

This policy proposes a classification system for soil, rock and like material, and responsibilities for generators (such as UFDC decommissioning) and receivers of such materials. These would have implications on management of the rock pile and any other material from the demolition of the UFDC, and site restoration.

2. Guidelines for the Decommissioning and Clean-up of Sites in Ontario

The guidelines (MOE 1989) detail a process for an efficient and effective decommissioning and clean-up of the environment. They contain clean-up guidelines for soils for various future land uses for the site.

3. The Ontario Waste Management Act

This Act (Government of Ontario 1992) will require that a waste reduction plan be in place during facility decommissioning.

8.3.2 Analysis Methodology

Because of the preliminary nature of the design description of decommissioning and closure activities, the potential environmental implications can only be addressed in general terms, using current experience and studies in nuclear decommissioning. The conceptual plan for decommissioning nuclear generating stations currently operating in Ontario (Dowell 1991b) was used as a basis for the analysis.

An interaction matrix was used to identify areas of potential environmental concerns prior to analysis. This matrix is shown in Table 8-1.

8.3.3 Effects on Air Quality

During the demolition of the site buildings, fugitive dust emissions could be expected from blasting and filling activities, and from the use of heavy equipment. Standard mitigation measures exist to reduce the effects of demolition to acceptable levels. The controlled access area would also help reduce effects on the surrounding land use.

The use of demolition and site restoration equipment, and the transportation of dismantled material would cause emissions from diesel engines. The magnitude of the effect would depend on the atmospheric dispersion at the site, and on the intensity and duration of the operations.

8.3.4 Effects on Water Quality

The demolition activities would change the site topography and possibly increase site run-off. This could lead to sedimentation in nearby waterbodies, and may affect water quality and aquatic life. Demolition of the water intake and discharge structures would temporarily disturb the water quality and aquatic life near the shore by increasing water turbidity and concentrations of sediment.

Waste water could contain radiological contaminants from decontamination activities, and non-radiological contamination from rock face cleaning (to remove oil, soot, etc.). Provisions for waste water management should help preserve water quality. Radioactive waste water would be treated in ion exchange columns and filters to remove contaminants. Water used for decontamination of non-radioactive facilities would be collected, treated and possibly recycled for further use in decontamination.

TABLE 8-1
Interaction Matrix for Decommissioning and Closure

Activity	Environmental Factor						
	Air Quality	Noise	Surface Water Quality	Groundwater Quality	Flora and Fauna	Non-Renewable Resources	Land Use
SURFACE FACILITY DECOMMISSIONING							
Demolition of buildings	✓	✓	✓		✓		
Changes to site topography			✓				
Waste rock pile decommissioning							✓
Use of heavy equipment for site restoration	✓	✓			✓		
Demolition of water intake and discharge structure			✓		✓		
Transportation of wastes and dismantled materials off-site	✓	✓				✓	
Blasting	✓	✓			✓		
Decontamination operation	✓		✓				
Disposal of decommissioning waste							✓
UNDERGROUND DECOMMISSIONING							
Sealing				✓		✓	
Rock face cleaning				✓			
Shaft reaming waste							✓

8.3.5 Effects on Land Use

During the decommissioning of the site, the waste rock storage area would be regraded or the waste rock used for local projects such as highway and foundation construction. Regrading would have an effect on site topography.

The site might be available for other uses once the facility has been decommissioned. However, depending on the policies developed at that time between the public, the regulators and the implementing organization, it is possible that some forms of land use would be excluded. In addition, low and intermediate level radioactive waste from decommissioning of the used fuel disposal facility would be disposed of off-site at an existing facility for disposal of such wastes (Simmons and Baumgartner 1994).

8.3.6 Effects on Flora and Fauna

Decommissioning activities could disturb the local wildlife. However, due to the temporary nature of decommissioning, these populations would be expected to recover and return to the site at the end of this stage. Dust from decommissioning could, however, seriously damage the surrounding natural vegetation to the extent that it might require revegetation or other mitigation measures. Natural indigenous species should be used in revegetation where possible.

The increased traffic could increase road kills.

8.3.7 Noise Effects

Blasting and other demolition activities that would increase ambient noise levels would be temporary and could be mitigated by establishing a noise control protocol, such as that established for construction of Darlington Nuclear Generating Station (Osman 1987). The controlled access area would help reduce the effect of noise on the surrounding land uses.

8.3.8 Effects on Non-Renewable Resources

Many components of a disposal centre could be reused or sold as scrap. If government regulations did not allow disposal in on-site landfills, non-radioactive solid wastes could be removed from the site or burned in an open pit according to regulations from the Ontario Ministry of the Environment of Ontario. Recyclable materials would be sold. A relatively small amount of nonrenewable resources would be committed for shipping and disposal containers for the radioactive and non-radioactive waste.

8.3.9 Possible Mitigation Measures

Possible measures to minimize effects of decommissioning activities on the natural environment are given in Table 8-2. These are based on construction mitigation practices used by Ontario Hydro (Prinoski et al. 1983; Ratchford and Chubbuck 1983).

8.3.10 Summary of Effects on the Natural Environment

The potential effects of decommissioning would likely be less than the effects during construction or operation. The availability of a low and intermediate level radioactive waste disposal facility to receive radioactive waste from decommissioning, and a policy for use of the site after closure, must be identified at an appropriate time during implementation.

TABLE 8-2
Possible Mitigation Measures for the Protection of the Natural Environment during Decommissioning

ENVIRONMENTAL EFFECTS	MITIGATION MEASURE
AIR QUALITY	
Equipment exhaust	- Avoid unnecessary engine idling - Ensure proper equipment maintenance
Dust	- Wet down dry soils
WATER QUALITY	
Sedimentation of waterbodies due to erosion from demolition activities	- Use mechanical erosion controls
Shoreline erosion from demolition activities	- Use mechanical and vegetative erosion controls
FLORA AND FAUNA	
Vegetation damage during demolition and site restoration	- Protect sensitive species if possible - Control dust levels
Aquatic life disturbance during water intake/discharge removal	- Schedule activities outside the spawning season
Wildlife disturbance during demolition	- Control noise - Minimize road kills by increasing driver awareness
NOISE	
Equipment noise	- Maintain equipment exhaust systems - Select transportation routes to minimize disturbance
Blasting noise	- Use blasting mats and limit amount of explosives per delay element
LAND USE	
Disposal of decommissioning waste	- Recycle and re-use as much as possible to reduce the quantity of waste and minimize land requirements for disposal - Where possible, remove from the site any material that could preclude the subsequent use of the property
NON-RENEWABLE RESOURCES	
For packaging decommissioning waste for transportation and disposal	- Decontaminate as much material as possible, recycle and re-use

8.4 OCCUPATIONAL SAFETY ANALYSIS

8.4.1 Analysis Methodology

As for the other stages, the first step in assessing the effects of decommissioning on occupational safety is to identify the radiological and non-radiological hazards associated with decommissioning activities. The non-radiological hazards during the decommissioning stage of the UFDC life cycle would be similar to hazards associated with comparable industries such as construction, forestry and mining.

Typical non-radiological hazards to workers would be noise, vibration, slips and falls, suspended or moving objects, and moving vehicles. Radiological hazards would be associated with the decontamination activities.

The exposure times (person-hours) to the identified hazards were then estimated mainly from experience in comparable industries. Any regulating requirements, limits, guidelines or procedures that affect worker safety were identified, and labour requirements were estimated from a review of Canadian experience in decommissioning the Bruce Heavy Water Plant A and the Gentilly I reactor (Delsan-Cleveland Inc. 1991; Denault and Le 1985).

The hazards were quantified where possible. For non-radiological hazards, the potential hazards are quantified based on experience in comparable industries, using equipment of similar sizes and types. When quantification was not possible, a qualitative analysis was performed. Acute non-radiological hazards were quantified using the risk factors for both injuries and fatalities associated with worker activities. The risk factors are the number of injuries or fatalities per 10^8 person-hours worked. For radiological hazards, the dose rate in each contaminated area was based on the estimated dose rates at these locations.

8.4.2 Analysis of Non-Radiological Effects

8.4.2.1 Normal Conditions

a) Standards, Targets and Guidelines

It is assumed that regulatory requirements for non-radiological hazards would be the same as those included in the Occupational Health and Safety Act of Ontario (Government of Ontario 1990c). All demolition activities are governed by Regulation 213/91 of the Act, and underground activities by Regulation 854. The safety standards and guidelines prepared by Ontario Hydro provide a wide range of methods and practices that can be used to ensure that the regulations would be met (Ontario Hydro 1978). Ideally, the high standards of safety set by Crown Corporations such as Ontario Hydro and Atomic Energy of Canada Limited, should be considered as targets during decommissioning and closure of the UFDC.

b) Hazard Identification and Quantification

i) Hazard Identification

Non-radiological occupational hazards would be similar to those encountered in any large demolition project, e.g. dust, exhaust emissions from engines, noise and vibration. Chronic exposure to dust can result in silicosis of lung tissue. However, the time of exposure of workers to dust would be relatively short during the decommissioning stage.

The major tasks associated with decommissioning and demolishing of buildings at the UFDC site at the end of its life would be retrieving machines and equipment, decontamination and transportation.

ii) Hazard Quantification

An accurate quantification of chronic non-radiological hazards associated with the decommissioning of the UFDC cannot be done because the response to human bodies to low levels of these hazards is not well documented and understood. It is assumed that strict enforcement of health and safety procedures, and use of protective equipment when necessary would be sufficient to minimize the effects of non-radiological hazards on workers.

8.4.2.2 Accident Conditions

The nature of acute non-radiological hazards can be inferred from injury and fatality statistics associated with industries which have tasks comparable to those at the UFDC and which use similar types of equipment. Forestry, construction, mining and light manufacturing industries are sources of statistical data on worker injuries and fatalities. Slips and falls, strikes by moving objects, trapping by or between objects, vehicle accidents, explosions and tripping accidents are the most prominent industrial accidents. Labour requirements (AECL CANDU et al. 1992) were used to estimate non-radiological risks for UFDC employees. The estimated annual acute non-radiological risks to workers are given in Table 8-3. The total risk from non-radiological sources during the decommissioning stage is estimated to be less than 1 fatality and about 81 (1.98/y x 41y = 81) lost-time injuries (Refer to Table 8-3).

8.4.3 Analysis of Radiological Effects

The estimated radiation field and exposure time in each area to be decontaminated is shown in Table 8-4. The total estimated dose to workers during decontamination is about 13 person-mSv, leading to a risk of fatal cancer of 5.2×10^{-4} using a risk factor of 4×10^{-2} fatal cancers per Sv. The average dose per worker was estimated 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 currently, 20 mSv proposed) and also well below the dose that would be received from natural background radiation over this period.

8.5 POTENTIAL IMPACTS ON THE SOCIAL, CULTURAL AND ECONOMIC ENVIRONMENTS

This section presents a summary of the potential socio-economic impacts during decommissioning and closure. Details of the analysis can be found and in Paez-Victor (1993).

TABLE 8-3
Estimated Annual Acute Non-Radiological Risks from UFDC Decommissioning

Activity	Labour (person-hours.a^{-1})	Fatality Rate per 10^8 person-hours	Injury Rate per 10^8 person-hours	Annual Fatalities	Annual Injuries
SURFACE DECOMMISSIONING					
Used Fuel Packaging Plant					
Equipment Salvaging	125	10	2 440	$1.3x10^{-5}$	$3.1x10^{-3}$
Decontamination	250	10	2 470	$2.5x10^{-5}$	$6.2x10^{-3}$
Other UFDC facilities					
Equipment Salvaging	250	10	2 440	$2.5x10^{-5}$	$6.1x10^{-3}$
Conventional Demolition	1 000	10	3 250	$1x10^{-4}$	0.033
Total	1 625	--	--	$2x10^{-4}$	0.05
UNDERGROUND DECOMMISSIONING					
Vault Sealing/Decommissioning					
Central Access Tunnels	428	30	4 700	$1.3x10^{-4}$	0.020
Panel Access Tunnels	2 060	30	4 700	$6.2x10^{-4}$	0.096
Perimeter Access Tunnels	563	30	4 700	$1.7x10^{-4}$	0.026
Ancillary Excavations	465	30	4 700	$1.4x10^{-4}$	0.022
Bulkhead Construction	318	30	4 700	$9.5x10^{-5}$	0.015
Post-Emplacement Support	4 369	30	4 700	$1.3x10^{-3}$	0.21
Equipment	2 730	30	4 700	$8x10^{-6}$	$1.3x10^{-3}$
Shaft Sealing					
Waste Shaft	7 019	30	4 700	$2.1x10^{-3}$	0.33
Service Shaft	3 602	30	4 700	$1.1x10^{-3}$	0.17
Downcast Shaft	3 736	30	4 700	$1.1x10^{-3}$	0.18
Upcast A Shaft	3 054	30	4 700	$9.2x10^{-4}$	0.14
Upcast B Shaft	3 141	30	4 700	$9.4x10^{-4}$	0.15
Support	1 219	30	4 700	$3.7x10^{-4}$	0.057
Equipment	2 590	30	4 700	$7.8x10^{-4}$	0.12
Sealing Vaults and Shafts - indirects	9 354	30	4 700	$2.8x10^{-3}$	0.44
TOTAL DECOMMISSIONING	41 945	--	--	0.0126	1.98

Note: The numbers in this table are pro-rated over the years during which the activities included take place, assumed in the analysis to be the 41 years of operation. Note that decommissioning includes vault sealing activities.

TABLE 8-4
Exposure Times and Estimated Radiation Fields

Area to be Decontaminated	Exposure Time for Decontamination (person-hours)	Radiation field ($\mu Sv \cdot h^{-1}$)
Cask Handling Accessible Area	500	< 0.1
Decontamination Area	500	< 1.0
Receiving-Pool Surge Storage Area	3000	< 1.0
Inclined Elevator	1000	< 0.1
Fuel Transfer Assembly	200	< 1.0
Used Fuel Packaging Cell, Front-End	4000	< 1.0
Used Fuel Packaging Cell, Back-End	4000	< 1.0
Active Liquid Waste Treatment Building	3000	< 0.1

8.5.1 Potential Sources of Impacts

During decommissioning, the main sources of socio-economic impacts would be:

i) the reduction of the workforce after many years of steady employment (from the beginning of construction to start of decommissioning);

ii) the reduction in materials and services purchased; and

iii) the possible impacts on the environment, and on occupational health and safety, due to activities such as the demolition of buildings, blasting and transportation of wastes, decontamination and removal of all surface facilities, and the placement of permanent markers to indicate the location of the vault.

These project characteristics could have a cumulative effect on a community, if they give rise to:

i) demographic changes due to the decrease in the workforce;

ii) changes to the local and regional economies due to a decrease in the project procurement of materials and services; and

iii) stress due to community changes and concerns over long-term health and safety.

Based on the schedule given in Figure 2-6 (Section 2.1.1.5), socio-economic impacts of decommissioning could begin after 48 years of construction and operation. Although the social dynamics during decommissioning are opposite those during the other project stages (Sections 5.2.4 and 6.5), the potential impacts could be similar. However, as indicated in Figure 2-6, there could be a period of extended monitoring between the end of operation and the beginning of decommissioning and, again, between the end of decommissioning and the beginning of closure. Although the duration of these periods cannot be defined at this time, any such additional time frames would contribute to the management of impacts. Impact management is discussed in Section 8.5.2.

8.5.1.1 Impacts on the Social and Cultural Vitality of a Community

The social and cultural vitality of a community could be affected by concerns over the long-term effects of radioactive waste upon the people and the environment. Even though the implementation of extended monitoring would work to alleviate these concerns, there could still be a stigma attached to the area, particularly after monitoring has ceased.

The demographic changes brought about by the decrease, and ultimately the end of employment at the facility, have been encountered before in resource-based projects. A broader exodus of residents whose livelihood or well being was dependent indirectly on project-related work (e.g. local people supplying goods or services to the workforce) would also be expected. This general exodus could contribute to community dissatisfaction and may affect community integration in general, as educational, recreational and cultural activities are diminished.

8.5.1.2 Impacts on the Community's Economic Viability

The economic viability of a community could be directly affected by the decrease in the workforce. The decrease could also create regional impacts. An increase in unemployment could be expected, if alternative job opportunities are not available. Local and regional business activity could be affected by resident relocation and unemployment and there may be a drop in local and regional incomes and prices. Surplus housing could bring about a drop in property values. Any reduction or depletion of the resource base of the local and regional economy would further erode economic activities. Planned economic diversification, over the relatively long lifetime of this facility, would mitigate any disruption of employment or business activity.

Any Aboriginal community which, over the duration of the project, had come to rely on project wages or contracts may now have to fall back on its traditional activities and knowledge. Some traditional knowledge might have been lost during the life-cycle of the disposal facility, since the project could have attracted the young members of the community. These potential effects can be mitigated through joint planning and economic diversification.

8.5.1.3 Impacts on the Community's Political Efficacy

The impacts to political efficacy of a community would be centred on negotiating the best possible terms for its withdrawal, and coping with the process of social change. If there are population decreases, there could be a surplus of municipal facilities and services. These changes could affect municipal finances. Labour unions could be affected as their leadership would be called upon to negotiate and protect their members. The impacts to Aboriginal political life would depend on their ability to negotiate impact management and to work with the implementing organization.

8.5.2 Social, Cultural and Economic Impact Management

Severe disruption of communities dependent on the disposal facility following closure of the facility could be avoided if, throughout the years, the disposal facility contributes to the economic viability of the communities by fostering:

i) policies of regional economic diversification; and

ii) economic activities aimed at resource sustainability.

It would be possible, within the framework of an impact management program jointly planned between the community and the implementing organization, to develop economic policies that reflect community values and long-term needs. The option of jointly developing a "closure plan" is discussed in more detail under Section 6.5.5.2. Any extended monitoring would provide more time for economic diversification and other measures to mitigate the impacts of disposal facility decommissioning and closure.

Some measures could be directed towards the employees of the disposal facility, such as: job transfers, job redesigning, skill upgrading, associate placements, early retirement, separation benefits, counselling and retraining.

The most important feature of impact management for decommissioning is the implementation, at the beginning of the disposal facility life-cycle, of economic policies that are: regionally oriented, intended to foster diversification and environmentally sustainable.

8.6 RESIDUAL EFFECTS

As mentioned in earlier analysis (Chapters 4, 5, 6 and 7), the residual effects discussed here are our best estimates of the effects remaining after the application of impact management measures, since the precise significance of effects cannot be determined without a social and ecological context. These estimates would need to be validated with the site-specific community and natural environment.

The radiological impacts on members of the public during operation are expected to be very small, and even smaller during decommissioning. The potential effects of decommissioning on the natural environment should also be less than those during construction or operation. The postclosure effects are addressed in the Postclosure Assessment Primary Reference (Goodwin et al. 1994).

Residual socio-economic impacts could remain from decommissioning and closure, particularly related to any concerns about the risk of radiological contamination. Extended monitoring and impact management programs might be required to address such residual impacts.

Radioactive waste from decommissioning of the used fuel disposal facility, like the waste from operation of the 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. However, it is relevant to consider that regulatory policy (AECB 1987a) requires that future use of natural resources not be prevented by any radioactive or non-radioactive contaminants from the facility.

CHAPTER 9

CHAPTER 9

9. SENSITIVITY AND SCENARIO ANALYSIS

9.1 PURPOSE OF THE SENSITIVITY ANALYSIS

The generic nature of this environmental and safety assessment required that assessment of all stages of the UFDC life cycle be determined based on a reference site of unknown location somewhere on the Ontario portion of the Canadian Shield. The assessment was based on reference environment parameters derived from environmental data for the Northern, Central and Southern regions of the Shield. These parameters were, for the most part, an average of the current environmental conditions in each region.

In addition, the conceptual and non site-specific nature of the UFDC and transportation system designs precluded detailed data and effects analysis. In some areas, assumptions were used for the analysis. These assumptions were based on experience in nuclear and other industries or were supported by an appropriate rationale.

The purpose of the sensitivity analysis presented in this chapter (Sections 9.2 - 9.10) was to identify how variations in environmental conditions or changes in design parameters and analysis assumptions would affect the analysis results.

Finally, specific scenarios were considered (see Section 9.11). The results of the sensitivity analysis were used to assess the potential effects of the facility on different natural and human environment scenarios. The results of the sensitivity analysis were also used to assess the potential effects of various nuclear generation scenarios (change in capacity of the system).

9.2 SENSITIVITY OF RADIOLOGICAL IMPACTS OF THE UFDC ON THE ENVIRONMENT AND THE PUBLIC

9.2.1 Normal Conditions

9.2.1.1 Methodology for Sensitivity Analysis

The estimated dose to members of the public from the operation of the UFDC during the preclosure phase depended on a large number of parameter values, assumptions and the environmental assessment model (PREAC) to calculate the dose. Since the code is designed to run in a deterministic mode, the base case analysis (presented in Chapter 6), used average or geometric mean values for parameters where possible. Many of the parameters in PREAC can vary over a large range of values and thus we have investigated the effect of such variation on the dose predictions.

The results of the base-case analysis indicated that the dominant radionuclides in determining the dose to the individual were ^{90}Sr, ^{137}Cs, ^{134}Cs, ^{60}Co and ^{129}I. The important environmental pathways were ingestion of vegetables, fish, water, and groundshine. Consequently, the model assumptions and parameter values that were considered important in calculating the dose to an individual from these radionuclides and pathways were analyzed. The sensitivity of the collective dose to the population data was also examined.

The sensitivity of the total dose to an individual to a change in a parameter P will generally be a function of the parameter. That is, for most parameters, the sensitivity will vary over the range of the parameter value. In order to simplify the analysis, the sensitivity to changes in a parameter value is estimated with respect to the base-case value of the parameter.

The sensitivity of the dose to parameter changes is represented by the sensitivity coefficient S defined as:

$$S(P) = \frac{\Delta D/D_b}{\Delta P/P_b}$$

where ΔD = change in the total individual dose rate ($Sv \cdot a^{-1}$)
D_b = dose rate using the base case value ($Sv \cdot a^{-1}$)
ΔP = change in the value of parameter P
P_b = value of the base case parameter P

The sensitivity coefficient is a measure of change in the total dose with respect to the base-case dose, as a function of the change in the value of the parameter under review with respect to the base-case value of the parameter.

The base case individual dose has been defined as the dose to an adult member of the critical group at the UFDC boundary in the Northern region (which has the highest individual dose of the three regions). The value of D_b is 3.4×10^{-7} $Sv \cdot a^{-1}$ (see Section 6.1.1.4).

The base case collective dose has been defined as the collective dose in the Northern region at 1.9×10^{-4} person-Sv per year.

If the sensitivity coefficient is greater than zero, then the dose increases as the parameter value increases. In this study, a sensitivity coefficient greater than ± 0.2 is assumed to be significant.

9.2.1.2 Sensitivity to Changes in Design Parameters

a) Radionuclide Releases

The radionuclide inventory and assumptions used to calculate the release of radionuclides to air and water at the UFDC are considered to be conservative (Villagran 1993). The leaching of radionuclides from failed fuel elements and from surface deposits has been measured for some of the key radionuclides, such as ^{137}Cs (Wasywich and Frost 1986, 1989c)). Although the measured release fraction varied by a factor of 5 to 10. The value used in the base case analysis was the highest measured value (Villagran 1993).

The estimated dose rate and total dose are a linear function of the radionuclide release rate, which in turn is a linear function of the rate at which containers are processed, radionuclide inventories and fuel element failure rate. It also depends directly on the removal efficiency of the filter for particulates in air and for ions in water. Thus, the dose at the UFDC boundary has a sensitivity coefficient of 1 to a change in the quantity of radionuclides available for release (source term). Also, the source term can have a wide range of values. However, given that the source term used in the base-case analysis was conservative, the estimated dose would be at the upper end of the range of dose variations as a function of the source term.

b) Length of Operating Period

The length of the operating period of the UFDC is assumed to be 41 years during which small quantities of radionuclides are assumed to be emitted to air and water. A change in the length of the operating period has no effect on the radionuclide concentration in air since it is not a function of time.

The radionuclide concentration in lake water is a function of the length of the operating period (Russell 1993a). However for the Northern region, the assumed lake flow rate and volume are such that half-life of water in the lake is about 2 years. Thus, a steady-state concentration in water would be achieved soon after emissions began, and varying the operating period would have a negligible effect on the radionuclide concentrations in lake water.

However, several transfer parameters in the terrestrial environment depend on the length of the operating period. These include the radionuclide transfer coefficient from air to soil (P_{13}) and from water to soil (P_{23}) (Russell 1993a). The value of these parameters increase with time and lead to a build-up of radionuclides in the soil.

The sensitivity of the dose to a change in the length of the operating period about the base case value of 41 years was found to be 0.2, which is just at the limit of significance assumed in this sensitivity analysis (see Section 9.2.1.1). Therefore, a longer operating period with the same release rate (base-case value of release rate) would lead to a slightly larger dose to the critical group.

c) Release Height

The radionuclide concentration in air is a function of the height at which the radionuclide is released (Russell 1993a). Using a Gaussian plume model, the airborne concentrations at ground level would decrease with the height of the release (Turner 1969). At the closest site boundary located 1500 m from the point of emission, the airborne concentration can vary by several orders of magnitude for release heights between 0 and 100 m.

With the UFDC reference stack height of 20 m, the sensitivity of the dose to a change in height was calculated to be -0.07, which is small. The dose for a ground level release height was 3.6×10^{-7} $Sv \cdot a^{-1}$ and the dose for a 100 m release height was 3.1×10^{-7} $Sv \cdot a^{-1}$. This small sensitivity is explained by the fact that the dose for the preclosure period is dominated by exposure via the water pathway (backyard vegetable irrigation plus ingestion, and fish ingestion). The sensitivity of the total dose to changes in the release height is, therefore, insignificant.

d) Controlled Access Area

Changing the size of the controlled access area at the UFDC would affect the radionuclide concentration in air since the downwind distance from the stack to the site boundary or controlled access area limit would change. For a 20 m release height, the radionuclide concentration in air peaks at about 200 m and falls off approximately as the square of the distance near the boundary.

The minimum land use control zone distance is assumed to be 3000 m. Therefore, the minimum distance from the release point to the UFDC boundary is assumed to be 1500 m, and the sensitivity of the total dose to a change in the land use control zone was calculated to be -0.11. The range in boundary doses from 500 to 5000 m was 3.9×10^{-7} to 3.2×10^{-7} $Sv \cdot a^{-1}$, respectively.

e) Filtration Factor

The chronic airborne emission rate from the UFDC was calculated assuming that the airborne effluent passes through a high-efficiency particulate air (HEPA) filter with a particulate removal efficiency of 99.97% (Burchsted et al. 1976). For waterborne emissions, a filtration and ion-exchange removal factor of 99.9% was assumed (Villagran 1993). Since the boundary dose is dominated by ^{90}Sr, ^{137}Cs and ^{134}Cs, which are affected by the aquatic filtration system, a change in the aquatic filter efficiency can have a significant effect on the dose to the critical group. (Note that airborne particulate filters would not affect the release of ^{3}H, ^{14}C, ^{85}Kr or ^{129}I. Also, waterborne filters and ion-exchange columns would not affect the release of ^{3}H).

A filtration factor defined as $f_\epsilon = 1 - \epsilon$, where ϵ is the fractional filter efficiency, can be used to assess the sensitivity of the boundary dose to a change in filtration efficiency.

For the HEPA filters with an efficiency ϵ_a of 0.9997 and, therefore, a filtration factor $f_{\epsilon a}$ of 3×10^{-4}, the sensitivity of the dose to a change in filtration was 0.09, which is small.

For the aquatic filters and ion-exchange columns with an efficiency ϵ_w of 0.999 and a filtration factor $f_{\epsilon w}$ of 1×10^{-3}, the sensitivity of the dose to a change in filtration was about 1, which is significant. For a filtration efficiency ϵ_w of 0.99, the dose to the critical group/individual was 3.0×10^{-6} Sv·a^{-1}. For an efficiency ϵ_w of 0.9999, the dose was 6.5×10^{-8} Sv·a^{-1}.

9.2.1.3 Changes in Reference Environment Parameters

a) Meteorology

The weather frequency data for the 3 regional reference environments on the Canadian Shield in Ontario are similar (Grondin and Fearn-Duffy 1993a, 1993b). The estimated radionuclide concentration in air in the direction sector with the maximum concentration of radionuclide in each region were the same to within a factor of 2 among the 3 regions. Within a given region, the difference in the estimated concentration in air among the 16 directional sectors was also within a factor of 2. These results, coupled with the low dependence of the boundary dose on the air pathways, suggests that the dose is relatively insensitive to the site meteorology.

b) Effects of Climate Change

The possibility of a climate change in Ontario as a result of the global warming from the increased greenhouse effect is reviewed in Appendix M. Many of the assumptions in the pathways analysis are steady state conditions. Alterations to these steady state conditions resulting from climate change may have implications on the estimated dose levels. Given that there is still so much uncertainty in the climate models' predictions and that dose levels are orders of magnitude below background, no quantitative assessment of the effects of climate change was performed. However, the qualitative review presented below identifies areas of concern that may need quantitative attention in the period leading up to concept implementation.

Based on Appendix M, effects of a short-term climate change could develop over the next 50 to 100 year period. Assuming a start up date of 2025 and a projected 41 year life span for the UFDC, effects of climate change might, therefore, occur during the preclosure phase. Five kinds of effects were identified that could affect preclosure assessment results:

1) Effects on Land Use

As a result of global warming, a shift northwards of climatic zones may be followed by a change in land use patterns, thereby changing the land use effect of the UFDC. Land use changes may include more agricultural lands in the northern portion of the province (with the longer growing season) and tourist functions (which would become more appealing with more favourable climate and changing forest composition).

2) Effects on Groundwater and Surface Water

A potential decrease in the amount of precipitation at the site may serve to heighten any effects on groundwater draw-down resulting from the shaft and cavern excavation. This could potentially affect surrounding wells and agricultural land uses.

3) Effects on Forest Fire Occurrences

A northward shift of forest ecosystems may increase harvesting activities in the vicinity of the facility, heightening the risk of forest fires. An increased potential for forest fires (under drier conditions) would represent a safety hazard for the facility and its operations. Care would have to be exercised to ensure that adequate fire suppression capabilities are available and that necessary safety precautions are taken during all stages of the facility's implementation to avoid fires induced by human activities.

4) Effects on Water Transportation

A net Great Lakes basin runoff decrease of 25-50% would reduce the maximum cargo per shipping vessel due to shallower channel depths (30-80 cm water level reduction) (Environment Canada 1991). Given that water levels in the Great Lakes are currently about 0.8 to 1.0 m above their average level, water transport of used fuel to the disposal site would likely not be affected.

5) Effects on Pathways Analysis

In addition to the direct physical effects, climate change would affect some of the data and assumptions used in the pathways analysis. The assumptions which are climate dependent include:

i) dilution assumption - both an increase or a decrease in the levels of precipitation and average temperature of the area would affect the rate of dilution of liquid effluent discharge from the UFDC into adjacent waterbodies. An increase in average temperature and a decrease in precipitation would lower water volumes in lakes and, therefore, increase radionuclide concentrations and increase the potential for uptake by humans. An increase in precipitation would have the inverse effect;

ii) washout assumption - a decrease in precipitation would reduce the amount of radionuclides washed into the groundwater and surficial water of the area from airborne deposition of radionuclides on the surface or from associated wastes;

iii) water ingestion assumption - a water ingestion rate of 300 $L \cdot a^{-1}$ for infants and 700 $L \cdot a^{-1}$ for adults is assumed for PREAC (CSA 1987). Increased average temperatures have the potential to alter this average by increasing the need for consumption. The same idea is applicable to animals which are raised and consumed by the inhabitants;

iv) irrigation assumption - the assumption is made that a very limited number of agricultural functions will require irrigation to be sustained. Changing climate and associated change in soil moisture patterns may result in irrigation becoming an integral component in a farm operation. This may, in turn, result in greater exposure of vegetation to radionuclides from water which is contaminated with the UFDC liquid effluent discharge; and

v) atmospheric dispersion - one of the potential effects of climate change, increased variability in weather patterns, would change the average atmospheric dispersion data used in the analysis.

c) Lake Size and Flow Parameters

Since one of the key pathways in the preclosure assessment is fish ingestion, the parameters that affect the concentration of radionuclides in lake water are important in determining the dose to the critical group. Several of the aquatic parameters for the 3 environmental regions are correlated, however, and care is needed in the analysis.

The two major parameters in the lake concentration equation are the volume and flow rate (Russell 1993a). The lake flow rate is a function of the drainage basin area and the precipitation runoff (Grondin and Fearn-Duffy 1993a, 1993b). A commonly used value for the drainage basin area is 5 to 10 times the area of the lake (Grondin and Fearn-Duffy 1993a, 1993b). A value of 7.5 was used in the preclosure assessment. Both the lake volume and flow rate depend on the surface area of the lake and are, therefore, not independent. As a result, the concentration of radionuclides in lake water is an inverse function of surface area, lake depth, drainage basin ratio and precipitation runoff (Russell 1993a).

1) Lake Area

The concentration of radionuclides in lake water is inversely proportional to the surface area. At the lake area cut-off of 5×10^5 m^2 (Grondin and Fearn-Duffy 1993a, 1993b), the dose was 6.8×10^{-7} $Sv \cdot a^{-1}$. Near the base-case (analyzed in Chapter 6) value of 1.04×10^6 m^2 (Grondin and Fearn-Duffy 1993a, 1993b), the sensitivity of the boundary dose to a change in lake surface area was found to be -0.99, which is significant.

2) Lake Depth

The lake water concentration is an inverse function of lake depth. Near the base-case depth of 6.2 m (Grondin and Fearn-Duffy 1993a, 1993b), the sensitivity of the dose to a change in lake depth was found to be -0.53, which is significant.

3) Sedimentation Removal Constant

The radionuclide concentration in the lake is an inverse function of sedimentation removal constant λ_{sed} for each radionuclide (Russell 1993a). The critical radionuclides for this parameter are ^{90}Sr, ^{134}Cs and ^{137}Cs, since they dominate the estimated dose via the water exposure pathways. The sedimentation removal constant λ_{sed} is used to model the sorption of radionuclides to suspended particulate matter in the lake water, sedimentation and diffusion into the lake bottom sediments. The values of λ_{sed} for the Canadian Shield lakes were taken from Bird et al. (1992) and cover a wide range of values. The most sensitive element was found to be Cs. Near the base-case value of 5.7×10^{-8} s^{-1} (Bird et al. 1992), the sensitivity of the dose to a change in sedimentation removal constant was found to be -0.33, which is significant.

4) Precipitation Runoff

The base-case value for the precipitation runoff was 0.3 $m \cdot a^{-1}$ (Grondin and Fearn-Duffy 1993a, 1993b). The sensitivity of the dose to a change in this parameter was found to be -0.42, which is significant. However, the range of values for precipitation runoff is between 0.25 and 0.35 $m \cdot a^{-1}$ (Grondin and Fearn-Duffy 1993a, 1993b), which is small.

5) Drainage Basin Area Ratio

The base-case value for the drainage basin area ratio was 7.5 (Grondin and Fearn-Duffy 1993a, 1993b) and the sensitivity of this parameter was calculated to be -0.44, which is significant. As with the case of precipitation runoff, the range of values for this parameter is small. The dose over the range of drainage basin ratio values from 5 to 10 (Grondin and Fearn-Duffy 1993a, 1993b) was found to be 4.1 x 10^{-7} Sv·a^{-1} to 3.0 x 10^{-7} Sv·a^{-1}, respectively.

6) Precipitation

The base-case precipitation rate in the Northern region is 750 mm·a^{-1} (Grondin and Fearn-Duffy 1993a, 1993b). The sensitivity of the dose to precipitation rate is small at 0.07. Over a range from 700 to 800 mm·a^{-1}, the dose remained at 3.4 x 10^{-7} Sv·a^{-1}. Thus, the precipitation rate dose not have a significant effect on the dose to the public.

d) Population Distribution

The base-case population distribution was determined by assuming that the highest population density areas were located closest to the facility (Grondin and Fearn-Duffy 1993b). The average population density and area of each county in the region were calculated from environmental data and used to fill the annulus around the UFDC with people. The population density among the 3 regions varied from 8 to 240 persons·km^{-2} (Grondin and Fearn-Duffy 1993b).

A change in the distribution of people surrounding the UFDC would not affect the dose to a member of the critical group, since this individual is assumed to reside at the UFDC boundary. The change, however, would affect the collective dose to the population.

The sensitivity of the collective dose to a change in the population distribution can be examined by assuming 2 extreme cases in the Northern region (total population within 100 km is assumed to be 2.01 x 10^5 persons):

Case 1 The total regional population is assumed to be distributed with a population density is 1000 persons·km^{-2} around the UFDC. The population exposure is assumed to be from both airborne and waterborne pathways.

Case 2 The entire population in the region is assumed to reside 80 to 100 km from the site. The population is assumed to be exposed via the airborne pathways only.

The collective dose for Case 1 was calculated to be 3.9 x 10^{-4} person-Sv·a^{-1} and the dose for Case 2 was 3.5 x 10^{-6} person-Sv·a^{-1} (compared to 1.9 x 10^{-4} person-Sv·a^{-1} for the base case). The lower dose for Case 2 was due to the absence of exposure via the water pathways. Therefore, the distribution of population about the UFDC can have a significant effect on the collective dose if the major exposure pathways are affected.

9.2.1.4 Changes in Biosphere Transfer Parameters

There are numerous transfer parameters in the environmental transport model in PREAC that could affect the dose to the public (Russell 1993a). The most important ones for the preclosure assessment are those parameters that affect the major exposure pathways of ingestion of vegetables with backyard irrigation, and ingestion of fish. The critical radionuclide for the vegetable pathway was ^{90}Sr and the critical radionuclide for the fish pathway was ^{137}Cs, followed by ^{134}Cs. Therefore, the sensitivity analysis has focused on the parameters for these radionuclides.

a) Bioaccumulation in Fish

The fish ingestion pathway accounted for over 40% of the dose to the individual at the UFDC boundary. Consequently, parameters that affect the concentration of radionuclides in fish are very important in the dose assessment. The important biosphere parameter for the fish ingestion dose is the transfer parameter from water to fish (P_{26}), or the freshwater fish radionuclides bioaccumulation factor, which can vary by several orders of magnitude. It can depend on water chemistry, turbidity, and the behaviour and species of fish.

The bioaccumulation factor for ^{134}Cs and ^{137}Cs has a wide range and is modelled using the ambient potassium concentration in the water (Poston and Klopfer 1986). The Canadian Standards Association (CSA) (1987) has provided graphs for estimating the bioaccumulation factor for ^{134}Cs and ^{137}Cs using the potassium concentration, and Vanderploeg et al. (1975) developed an empirical relation for calculating the value. For an average potassium concentration of 0.5 $mg \cdot L^{-1}$ in the Shield lakes (Zach and Sheppard 1992), the base-case value of the bioaccumulation factor for ^{134}Cs and ^{137}Cs becomes 10^4 $L \cdot kg^{-1}$. The sensitivity of the dose to a change in the bioaccumulation factor was found to be 0.36, which is significant.

The range of potassium concentration in the Shield lakes is from 0.1 to 6.0 $mg \cdot L^{-1}$ (Zach and Sheppard 1992), which is large. The dose over this range of values was found to be 8.3×10^{-7} to 2.3×10^{-7} $Sv \cdot a^{-1}$, respectively. Therefore, the dose can vary by a factor of 4 or so over the range of the potassium concentration, and thus over the range of cesium bioaccumulation, in lake water.

b) Vegetable Parameters

The dose from ingestion of backyard vegetables originates from two sources: airborne deposition of radionuclides and irrigation with contaminated lake water. Of the two pathways, vegetable irrigation contributes more exposure than does airborne deposition (Russell 1993a). Also, since the key radionuclide for this exposure pathway is ^{90}Sr, vegetable irrigation in the environment was examined in further detail. There are a large number of parameters that determine the dose from ingestion of vegetables irrigated by contaminated lake water. These include the irrigation rate, distribution coefficient between radionuclides in water and radionuclides in soil, the fraction of irrigated radionuclides that are retained on vegetation, the duration of deposition (growing season) and the physical removal constant of radionuclides from plants. These parameters are analyzed in further detail.

c) Irrigation Rate

The irrigation rate was assumed to be 2.3×10^{-5} $L \cdot m^{-2} \cdot s^{-1}$ (CSA 1987) and the range of this parameter is expected to be small. However, the sensitivity of the dose to a change in the irrigation rate was 0.44, which is significant.

d) Distribution Coefficient

The distribution coefficient for ^{90}Sr in soil depends on soil type, pH and other environmental factors. Since the concentration factor for radionuclides in vegetation from soil are correlated with the distribution coefficient (Sheppard 1986), a change in distribution coefficient should be accompanied by a change in the soil to plant concentration factors. Baes III et al. (1984) has established a generalized relationship between these parameters for a number of elements. The sensitivity of the dose to a change in the soil distribution coefficient about the base-case value of 3.5×10^{-2} $m^3 \cdot kg^{-1}$ was found to be 0.25, which is somewhat significant.

e) Irrigation Retention Fraction

The fraction of radionuclides that are retained on vegetation as a result of irrigation was assumed to be 0.05 (CEC 1979; CSA 1987). The sensitivity of the dose to a change in the retention factor about the base-case value was found to be 0.02, which is small.

f) Duration of Deposition

The duration of radionuclide deposition onto vegetables depends on the length of the vegetable growing season which is assumed to be 60 days (CSA 1987). The sensitivity of the dose to a change in this parameter value was found to be negligible.

g) Physical Removal Constant

The physical removal constant of radionuclides from plants was assumed to be 6.69×10^{-7} s^{-1}, corresponding to a 12 day weathering half-life (Zach and Sheppard 1992). The sensitivity of the dose to a change in this parameter value was found to be -0.03, which is small.

9.2.1.5 Changes in Human Exposure Parameters

The estimated dose to members of the critical group from exposure to environmental sources of radioactive contamination depends on a number of assumptions based on lifestyle, diet, climate and other factors. Since ingestion of fish and backyard vegetables are the major exposure pathways, the assumptions that affect the dose from these routes should be examined for their effect on the total dose.

a) Fish Ingestion

The fish ingestion rate for an adult residing on a farm at the UFDC boundary was assumed to be 5.5 $kg \cdot a^{-1}$ (Gorman 1986; Russell 1993a). The sensitivity of the dose to a change in fish consumption was 0.41, which is significant. For an Aboriginal population group on the Shield, the fish ingestion rate could be substantially higher than the hypothetical adult on the boundary farm. If the fish ingestion rate is as high as 100 $kg \cdot a^{-1}$ (Grondin and Fearn-Duffy 1993b), the individual dose becomes 2.8×10^{-6} $Sv \cdot a^{-1}$, compared to 3.4×10^{-7} $Sv \cdot a^{-1}$ for a fish ingestion rate of 5.5 $kg \cdot a^{-1}$.

b) Vegetable and Fruit Ingestion

The backyard vegetable and fruit ingestion rate for adults was assumed to be 203 $kg \cdot a^{-1}$ (CSA 1987). The sensitivity of the dose to a change in the vegetable consumption rate was 0.34, which is significant.

9.2.1.6 Discussion

The sensitivity of the estimated dose during the preclosure phase to changes in the values of various parameters in the PREAC model has been investigated. The results are summarized in Table 9-1.

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 (source term assumptions and aquatic filtration efficiencies), the concentration of radionuclides in lake water (lake area, lake depth, sedimentation removal constant, precipitation runoff and drainage basin area ratio), the bioaccumulation of radionuclides in fish, and the human ingestion rate of fish and vegetables.

TABLE 9-1
Sensitivity of PREAC Input Parameters

Parameter	Symbol	S	Range of Variation of Parameter
Facility Design:			
Radionuclide source term	Q_w	1.0	Wide range
Operating period	T_o	0.2	Wide range
Release height	h	-0.07	Wide range
Exclusion zone	x_b	-0.11	Wide range
Filtration factor - air	f_{ea}	0.09	Wide range
Filtration factor - water	f_{ew}	1.0	Wide range
Reference Environment:			
Meteorology	f_{ijk}		Narrow range
Lake area	S_ℓ	-0.99	Narrow range
Lake depth	z_ℓ	-0.53	Narrow range
Sedimentation removal constant	λ_{sed}	-0.33	Wide range
Precipitation runoff	P_r	-0.42	Narrow range
Drainage basin area ratio	$R_{b\ell}$	-0.44	Narrow range
Precipitation	P_o	0.07	Narrow range
Population distribution			Wide range
Biosphere Transfer:			
Bioaccumulation in fish	B_f	0.36	Wide range
Irrigation rate	L_v	0.44	Narrow range
Distribution coefficient	k_d	0.25	Wide range
Irrigation retention	r_i	0.02	Wide range
Duration of deposition	t_{ev}	0	Narrow range
Physical removal constant	λ_p	-0.03	Narrow range
Human Exposure:			
Fish ingestion	I_f	0.41	Wide range
Vegetable and fruit ingestion	I_v	0.34	Wide range

Over the full range of the parameter values examined in the sensitivity analysis, the dose to an individual at the UFDC boundary changed by more than an order of magnitude from the base case value of 3.4×10^{-7} $Sv \cdot a^{-1}$.

Parameters that affect the radionuclide concentration in air and transfer through the biosphere via the airborne pathways had only a minor effect on the dose.

9.2.2 Accident Conditions

The present discussion provides an indication of the result trends resulting from changes in assumptions and parameter values.

For sensitivity analysis of the postulated accident scenarios at the UFDC, the "base case" is assumed to be accident scenario S2 (scissors lift failure and ventilation system failure) (see Chapter 6) and the critical group for dose calculations is assumed to be an infant at the UFDC boundary. The base case dose is 2.0×10^{-4} Sv. The results for this accident scenario indicated that inhalation is the critical exposure pathway and the critical radionuclides are ^{241}Am, ^{241}Pu and ^{240}Pu. Therefore, parameters that can affect the dose from these radionuclide are important to the public safety assessment.

The sensitivity analysis also considers the dose from chronic exposure pathways such as food ingestion, groundshine, and immersion and inhalation of re-suspended radionuclides. Exposure to some of these pathways can be restricted by corrective actions.

9.2.2.1 Changes in Design Parameters

1) Radionuclide Source Term

A fraction of the radioactive material that escaped from the fuel was assumed to be carried out of the facility by the ventilation system and transported in the atmosphere to the closest point accessible to the public.

The radionuclide inventory and assumptions used to calculate the release of radionuclides following an accident at the UFDC are considered to be conservative estimates. The used fuel was assumed to be 10 years old (Villagran 1993; Tait et al. 1989).

Since the estimated dose is a linear function of the radionuclide release rate during an accident which in turn is a linear function of the number of failed fuel elements and their radionuclide inventory, the dose at the UFDC boundary has a sensitivity of 1 for a change in the radionuclide source term.

a) Fuel Age

The assumed age of the used fuel would affect the radionuclide inventory in the fuel elements and thus to public dose during an accident. The base-case assumes that all fuel to be disposed of would be at least 10 years cooled (10 years out of the reactor core). In general, the radionuclide inventory decreases with time. However, some radionuclides such as ^{241}Am can build-up in the fuel over time due to the decay of the parent radionuclide before decreasing in concentration (Tait et al. 1989).

The sensitivity of the estimated dose to a change in the age of the used fuel was assessed using 5 year and 20 year old fuel. The sensitivity was 0.08, indicating that the dose increases with the age of the fuel. This result was because the amount of ^{241}Am in the used fuel increases with time and ^{241}Am is the critical radionuclide for accidents that do not have air filtration.

b) Fuel Burnup

The used fuel is assumed to be 10 year old Bruce NGS fuel with a burnup of 685 GJ per kg uranium (Tait et al. 1989). However, some of the used fuel can have a higher burnup with a corresponding increase in long-lived radionuclides. The maximum burnup is approximately 1 008 GJ per kg uranium (Ontario Hydro 1986). At this value, the calculated dose to the infant during accident scenario S2 was 3.2 x 10^{-4} Sv and the sensitivity was 1.3, which is considered to be significant.

c) Number of Failed Fuel Elements

For the scissors lift failure, the estimated fuel element velocities upon impact for the modules in the road and rail cask were between 6.4 and 10.2 $m \cdot s^{-1}$, and the fuel element failure fraction for all modules was assumed to be 0.10. Since there are 7 104 fuel elements in the road cask and 21 312 fuel elements in the rail cask, the largest emissions occur when the accident occurs with the rail cask.

In the bounding case, where all the fuel elements in a rail cask fail, the calculated dose to the infant during accident scenario S2 was 2.0 x 10^{-3} Sv and the sensitivity of the dose to a change in the number of failed elements was 1, which is considered to be significant.

2) Release Height

The concentration of radionuclides in the air following an accident can be calculated using a Gaussian plume model for atmospheric dispersion (Turner 1969). At the closest site boundary (assumed 1500 m from source), the airborne concentration can vary by several orders of magnitude for release heights between 0 and 100 m. At the UFDC reference height of 20 m, the sensitivity of the dose to a change in h was calculated to be -1.0, which is significant. For a ground level release height, the dose was 3.3 x 10^{-4} Sv.

3) Controlled Access Area

Changing the dimensions of the UFDC site would affect the radionuclide concentration in air at the site boundary by changing the downwind distance from the release point to the site boundary. At 1 500 m, the sensitivity of the dose to a change in x was calculated to be -1.1, which is significant.

For a 20 m release height with Pasquill class F weather conditions and wind speed of 2 $m \cdot s^{-1}$, the peak radionuclide concentration at ground level was at about 1 000 m downwind, with an individual dose of 2.6 x 10^{-4} Sv. The boundary doses at 500 and 5000 m were 2.1 x 10^{-4} and 4.9 x 10^{-5} Sv, respectively.

4) Building Wake Effect

In the present analysis, the effect of a nearby building on the dispersion of the contaminants was ignored since the dimensions and exact configuration of the buildings at the UFDC are not known. However, the concentration of radionuclides in the wake of a building can be significantly affected by the size and shape of the building. The horizontal and vertical standard deviations of the plume can be modified to take into account the building wake effect by including a factor for the area of the building (CSA 1991a). Assuming a building area of 600 m^2 (20 m high and 30 m wide), the dose to the infant at the boundary during accident scenario S2 becomes 1.9 x 10^{-4} Sv compared to 2.0 x 10^{-4} Sv for the base case. The sensitivity of the dose to a change in area was calculated to be -0.03, which is small.

5) Filter Efficiency

The acute airborne emission rate from the UFDC for accidents with an operating air filtration system was calculated assuming that the airborne effluent passes through a high-efficiency particulate air (HEPA) filter with a particulate removal efficiency of 99.97% (Burchsted et al. 1976). Since the boundary dose is dominated by ^{241}Am, ^{241}Pu, ^{240}Pu, ^{239}Pu, ^{238}Pu and ^{90}Sr, which are usually retained by the filtration system, a change in the filter efficiency can have a significant effect on the dose to the critical group.

The emission rate for these radionuclides is directly proportional to the filter efficiency and consequently the dose has a sensitivity of -1, which is considered to be significant.

9.2.2.2 Changes in Environmental Parameters

1) Meteorology

The weather during an accidental release can have a significant effect on the atmospheric transport and dispersion of radionuclides. The concentration and boundary dose are inversely proportional to the wind speed. At a wind speed near 2 $m \cdot s^{-1}$, the sensitivity was -1.0, which is significant.

A change in the weather stability class can also have a significant effect on airborne concentration and the dose at the boundary. Since the stability class is a discrete function, the doses for the default weather classes and associated wind speeds have been examined (CSA 1987) (see Table 9-2). The results show that the dose can vary by over an order of magnitude for weather classes A to F, and that the default weather class for this assessment (Class F) is the most conservative. The base-case dose estimate would, therefore, be at the upper end of the range.

Two potential effects of climate change could also affect the analysis of radiological accident at the UFDC: the possible increased variability of the weather and the possible increased frequency of storms, hurricanes and severe weather events. Given the lack of confirmed predictions about the magnitude of these changes, no quantitative analysis could be performed.

2) Terrain Roughness

The roughness length (a parameter used in the dispersion model to represent the friction of the underlying surface) of the terrain near the UFDC can affect the vertical dispersion of the emission plume. Since the values of the parameters associated with vertical dispersion are given for discrete values of terrain roughness, the dose has been examined for the default values of terrain roughness (CSA 1987). The results in Table 9-3 indicate that the boundary dose is not very sensitive to the roughness length.

3) Precipitation

Precipitation (either as rain or snow) would deplete the radionuclide concentration in air, and increase the concentration of radionuclides deposited on soil and vegetation. However, since the groundshine dose during one of the postulated accident scenarios was several orders of magnitude less than the inhalation dose, the net effect of precipitation is a decrease in dose.

TABLE 9-2
Default Weather Stability Data

Weather Class	Wind Speed ($m \cdot s^{-1}$)	Dose (Sv)
A	1	9.3×10^{-6}
B	2	1.2×10^{-5}
C	5	9.8×10^{-6}
D	5	1.9×10^{-5}
E	3	6.5×10^{-5}
F	2	2.0×10^{-4}

TABLE 9-3
Default Terrain Roughness Data

Roughness Length z_o (cm)	Description	Dose (Sv)
1	Lawn grass, bodies of water	1.5×10^{-4}
4	Ploughed land	1.8×10^{-4}
10	Open grassland	1.9×10^{-4}
40	Rural areas with mixed farming, woods, small villages	2.0×10^{-4}
100	Cities and forests	2.0×10^{-4}
400	Cities with tall buildings	1.9×10^{-4}

The concentration of radionuclides in air, including the effects of precipitation, has been modelled using a plume depletion factor (Van der Hoven 1968). For a light rain at 0.25 $mm \cdot h^{-1}$, the depletion factor was 0.88. For a heavier rain at 2 $mm \cdot h^{-1}$, the depletion factor was 0.70. For a typical precipitation rate of 1 $mm \cdot h^{-1}$, the sensitivity of the estimated dose to a change in precipitation was calculated to be -0.13, which is somewhat significant.

9.2.2.3 Changes in Exposure Parameters

The estimated dose to members of the critical group from exposure to the radioactive plume depends on a number of assumptions such as location during the accident, lifestyle, breathing rate and other factors. Since inhalation was found to be the critical pathway, the assumptions that affect the dose from inhalation were examined.

1) Breathing Rate

The inhalation rate was assumed to be 4.44×10^{-5} $m^3 \cdot s^{-1}$ for infants (CSA 1987). Since the dose depends directly upon the inhalation rate, the sensitivity of the dose to a change in inhalation is 1, which is significant.

2) Exposure Time

The exposed group at the UFDC boundary was assumed to be located outdoors for the duration of the postulated accidents. Since the dose depends directly upon the exposure time, the sensitivity of the dose to a change in exposure is 1, which is significant.

3) Building Ventilation Rate

If the exposed individuals are located indoors during the accident, then the dose from radionuclide exposure can be reduced depending upon the ventilation rate of the dwelling. Typical ventilation values for conventional houses are 0.7 to 1.0 air changes per hour (Burkart 1983; Bruno 1983). At 1 air change per hour, the sensitivity of the dose to a change in the ventilation rate was found to be -0.14.

Homes with energy-efficient windows and doors can have air changes as low as 0.1 per hour. A low ventilation rate would produce a lower radionuclide concentration inside the building, but would also retain the radioactivity for longer periods of time since the flushing rate is low.
The results of the sensitivity analysis of the assessment model are listed in Table 9-4.

9.2.2.4 Changes in Food Ingestion Assumptions

The exposure pathways for the base case accident analysis did not include food ingestion. However, the impact from ingestion of food contaminated by radionuclide deposition from the acute emission plume can be estimated using backyard vegetables. Food ingestion via other pathways such as milk and meat ingestion are less hazardous due to radionuclide dilution along the food chain. Therefore, vegetable ingestion can be used as a conservative indicator of dose from the food chain (Russell and Villagran 1993). This is a realistic assumption which, combined with the conservative assumptions mentioned above, would still lead to a conservative dose estimate.

For the purposes of this analysis, it was conservatively assumed that the vegetables were harvested immediately after the accident (scenario S2) with no washing of contamination. A day's supply of vegetables was assumed to be consumed before food interdiction was established.

TABLE 9-4
Sensitivity of Input Parameters

Parameter	Sensitivity (S)[1]
Design Parameters:	
Radionuclide Source Term	1.0
Fuel Age	0.08
Fuel Burnup	1.3
Release Height	-1.0
Land Use Control Zone	-1.1
Building Wake	-0.03
Filter Efficiency	-1.0
Environmental Parameters:	
Wind Speed	-1.0
Weather Stability Class	High Sensitivity
Terrain Roughness	Low Sensitivity
Precipitation	-0.13
Exposure Parameters:	
Breathing Rate	1.0
Exposure Time	1.0
Building Ventilation Rate	-0.14

1 A sensitivity coefficient value of less than ± 0.2 is not assumed to be significant (see Section 9.1.2.1)

For accident scenario S2, the dose from ingesting a day's supply of backyard vegetables was calculated to be 1.3 x 10^{-5} Sv for adults and 2.5 x 10^{-4} Sv for infants. These ingestion doses can be compared with the short-term exposure doses of 1.3 x 10^{-4} Sv for adults and 2.0 x 10^{-4} Sv for infants from immersion in air, inhalation and groundshine.

These ingestion doses can be compared with the calculated short-term exposure doses for 1.3 x 10^{-4} Sv for adults ad 2.0 x 10^{-4} for infants for immersion in air, inhalation and groundshine during the accident.

9.2.2.5 Changes in Long-Term Exposure Pathways

The dose to the critical group at the UFDC boundary has been assessed for the acute exposure pathways and from ingestion of backyard vegetables contaminated by the primary emission plume. In this section, the long-term exposure pathways of groundshine, immersion, inhalation and vegetable ingestion (based on root uptake and the re-suspension of radioactive soil) are considered for long-term dose estimates (Russell and Villagran 1993).

After the primary radioactive plume from the accident had passed, most of the deposited radionuclides would remain on the surface of the soil. Over a period of time, the radioactivity would disperse and become diluted in the soil through erosion, precipitation, mechanical mixing (e.g. ploughing) and radioactive decay.

In steady-state, or equilibrium transfer with a specified models, the soil can be represented as a well-mixed compartment with a specified depth, where the removal or leaching of radionuclides from this soil compartment to deeper layers is driven by the downward flow of infiltrating groundwater from precipitation and modelled with a single decay constant (Baes III and Sharp 1983). A simple, modified equilibrium transfer model was selected to estimate the time-behaviour of contaminated soil (Russell and Villagran 1993).

The long-term exposure pathway doses from accident scenario S2 were dominated by vegetable ingestion. For example, one year after the release, the annual doses to infants at the UFDC boundary from vegetable ingestion, inhalation, groundshine and immersion were calculated to be 1.0 x 10^{-6} Sv, 2.0 x 10^{-8} Sv, 2.5 x 10^{-13} Sv and 1.4 x 10^{-13} Sv, respectively. The total annual dose was 1.1 x 10^{-6} Sv and the most important radionuclide was ^{241}Pu.

For adults, the doses from vegetable ingestion, inhalation, groundshine and immersion one year after the release were calculated to be 1.1 x 10^{-7} Sv, 1.4 x 10^{-8} Sv, 1.7 x 10^{-13} Sv and 9.1 x 10^{-14} Sv, respectively. The total annual dose was 1.3 x 10^{-7} Sv and the most important radionuclide was ^{90}Sr.

The total annual doses to adults and infants from the postulated exposure pathways are listed as a function of time after the accident in Table 9-5. As expected, the doses decrease with time since the radionuclide concentrations in soil decrease as a result of weathering and radioactive decay.

Both the calculated adult and infant doses were much smaller than the expected annual natural background radiation dose in Ontario of 3 x 10^{-3} Sv (Neil 1985; NCRP 1987).

TABLE 9-5
Annual Dose From Long-Term Exposure After Accident Scenario S2

Time (years)	Annual Dose to the Critical Group ($Sv \cdot a^{-1}$)	
	Adults	Infants
1	1.3×10^{-7}	1.1×10^{-6}
10	8.2×10^{-8}	8.6×10^{-7}
20	5.7×10^{-8}	7.2×10^{-7}
50	3.3×10^{-8}	5.6×10^{-7}
100	2.6×10^{-8}	5.0×10^{-7}

9.2.2.6 Discussion

The sensitivity of the estimated dose to the critical group during the postulated accident scenario (S2) to changes in the values of various parameters has been investigated. The results are summarized in Table 9-4.

The estimated dose to infants at the UFDC boundary was most sensitive to changes in the parameters that affect the radionuclide concentrations in the environment and exposure to humans. The key parameters were the source term assumptions, release height, boundary distance, particulate filter efficiency, wind speed, weather stability class, exposure time and breathing rate.

As each parameter value changed over its range, the infant dose changed by up to an order of magnitude from the base case value of 2.0×10^{-4} Sv.

Changes in short-term ingestion assumptions for accident scenario S2 were examined. The dose from ingesting a day's supply of backyard vegetables immediately after the accident was calculated to be 1.3×10^{-5} Sv for adults and 2.5×10^{-4} Sv for infants. These ingestion doses were similar to the acute exposure doses of 1.3×10^{-4} Sv for adults and 2.0×10^{-4} Sv for infants from the primary plume exposure pathways of immersion in air, inhalation and groundshine. The analysis results were, therefore, found to be robust to changes in the short-term ingestion assumption.

The effects of changes in the long-term exposure pathways were also examined. The estimated doses from long-term exposure to radionuclides after the accident were several orders of magnitude less than the doses from the primary plume exposure pathways, and at least 3 orders of magnitude less than the dose from natural background radiation.

9.3 SENSITIVITY OF UFDC RADIOLOGICAL IMPACTS ON WORKERS

9.3.1 Normal Conditions

Radiation exposure is the product of radiation dose rate and the time spent in the radiation field. Thus, radiation dose rates and exposure times would have a linear relationship with radiation doses at the UFDC. Reduction of either or both of the two variables, would reduce the radiation dose to UFDC workers. In actual fact, the dose rates in the working areas of the facility, and the dose received by workers would be controlled and monitored to ensure that the dose to workers are managed well within the bounds of the AECB Atomic Radiation Worker Limits.

The external dose rate to a worker is inversely proportional to:

i) the distance from the source;

ii) the shielding thickness; and

iii) the used fuel cooling time.

The distance from the source can be increased by use of remote handling equipment. The shielding thickness can also be increased as long as it does not hinder efficient handling. As mentioned in Section 9.4, an increase in the cooling time to 40 years would reduce the external dose from transportation cask handling by a factor of 2.

There is some uncertainty in the labour estimates, and, therefore, in the exposure time since many of the tasks have not been performed before. These exposure times would be refined by a demonstration set up prior to implementation. Such a demonstration project would be used to reduce the dose to workers according to the ALARA principle.

9.3.2 Accident Conditions

Radiological risks to UFDC workers could arise from abnormal operation. Risk is defined as the product of severity and frequency. The severity of postulated radiation accidents is measured in terms of resulting radiation dose to workers and a dose-to-risk conversion factor.

Some of the sensitivity input parameters presented in Table 9-4 also apply to the occupational safety analysis since the accident scenarios and radionuclide releases are the same as for the public safety analysis. They are:

i) the radionuclide source term;

ii) the fuel burnup;

iii) the workers' breathing rate; and

iv) the exposure time.

Given that the estimate of the radionuclide source term used in the analysis is conservative, the base-case dose to workers would be at the upper end of the range.

An increase in the fuel burn-up from the average value of 685 $GJ \cdot kg^{-1}$ U to the 90-percentile value of 1 008 $GJ \cdot kg^{-1}$ U would result in an increase in the individual dose during accident conditions in the same proportion as for the public dose (less than a factor of 2). The dose would still be well under the current quarterly dose limit of 30 mSv, which has been used as a guide for exposure of workers during accident conditions.

Since the dose from inhalation depends directly on the breathing rate, an increase in breathing rate would translate into a direct increase in the dose. The same can be said about the exposure time. Emergency response training would contribute to a rapid evacuation of the working area in the event of an accident and act to reduce exposure time.

9.4 SENSITIVITY OF USED FUEL TRANSPORTATION RADIOLOGICAL IMPACTS ON THE ENVIRONMENT AND THE PUBLIC

9.4.1 Normal Conditions

9.4.1.1 Sensitivity of Collective Dose

The INTERTRAN code used for calculation of the collective dose under normal transportation conditions, was used for sensitivity analysis. Results are given in terms of the percentage change in the annual collective dose for a 1% change in the input parameter. Table 9-6 shows an example of an INTERTRAN sensitivity analysis output.

Three important parameters are the number of bundles shipped per year, the distance travelled (equivalent to the time spent on the route) and the population density. The annual collective dose varies linearly with these parameters.

Both individual and collective doses vary linearly with the external dose rate on the outside of the cask (i.e. the transport index). The major factor affecting this external dose rate is the cooling time of the transported fuel. Figure 9-1 shows the variation of external dose rate (transport index) with cooling time. The reference cooling time of the fuel is 10 years. An increase of the cooling time to 40 years would reduce the external doses by a factor of 2.

9.4.1.2 Sensitivity of Maximum Annual Individual Dose

The maximum individual doses calculated for the base case (analyzed in Chapter 7) are for specific exposed groups. For example, for the road mode, the critical group is persons at truck stops. The sensitivity to variations in input parameters may, therefore, depend on the transportation mode.

The relationship between changes to various parameters used in the calculations and the resulting dose was established for each parameter. Results, for parameters to which the individual dose is sensitive, are shown in Table 9-7 for the three modes of transportation: road, rail and water.

9.4.2 Accident Conditions

Both the doses resulting from a transportation accident and the probability of an accident occurring, may be affected by variation in the model (TADS) input parameters. This is why the results of this sensitivity analysis are presented in the same form as for the base-case analysis: a downward cumulative distribution curve. A number of TADS (see Chapter 7) runs for the case of rail transport to the Central region were carried out with varying parameters (see Table 9-7) to illustrate results sensitivity.

In addition, the effect of varying the factors affecting the radioactive release of the important nuclides ^{137}Cs and ^{239}Pu was examined (Figures 9-2 and 9-3).

TABLE 9-6
Parameter Sensitivities from INTERTRAN, for Transportation to the Central Region - Normal Conditions

Parameter	Sensitivity[1]		
	Road	Rail	Water
Design Parameters			
Distance	1	1	1
Shape Factor[2,3]	1	1	1
Transport Index (external dose rate)	1	1	1
Packages per shipment	1	1	1
Shipments per year	1	1	1
Velocity in rural zone	-0.997	0.24	-0.46
Velocity in sub. zone	-0.079	0.20	-0.54
Velocity in urban zone	-0.080	0.62	-
Stop time	0.78	-	0.67
Environmental Parameters			
Fraction of travel in rural zone	0.87	0.18	-2.0
Fraction of travel in sub. zone	0.061	0.011	0.21
Fraction of travel in urban zone	0.053	0.62	-
Population density in rural zone	0.015	0.12	-
Population density in sub. zone	0.015	0.20	0.33
Population density in urban zone	0.030	0.62	-
Suburban shielding factor	0.013	0.20	0.33
Urban shielding factor	-[4]	0.62	-
Traffic count in rural zone	0.12	0.063	-
Traffic count in suburban zone	0.016	0.003	-
Traffic count in urban zone	0.023	0.002	-
Number of people at stops	0.78	-	0.67
Distance at stops[2]	-1.6	-	-1.3
Passengers per vehicle	0.16	0.068	-
Fraction of travel on city streets	0.032	-	-
Pedestrian density ratio	0.005	-	-
Fraction of travel on freeways	0.0	-	-
Fraction of travel during rush hour	0.21	-	-

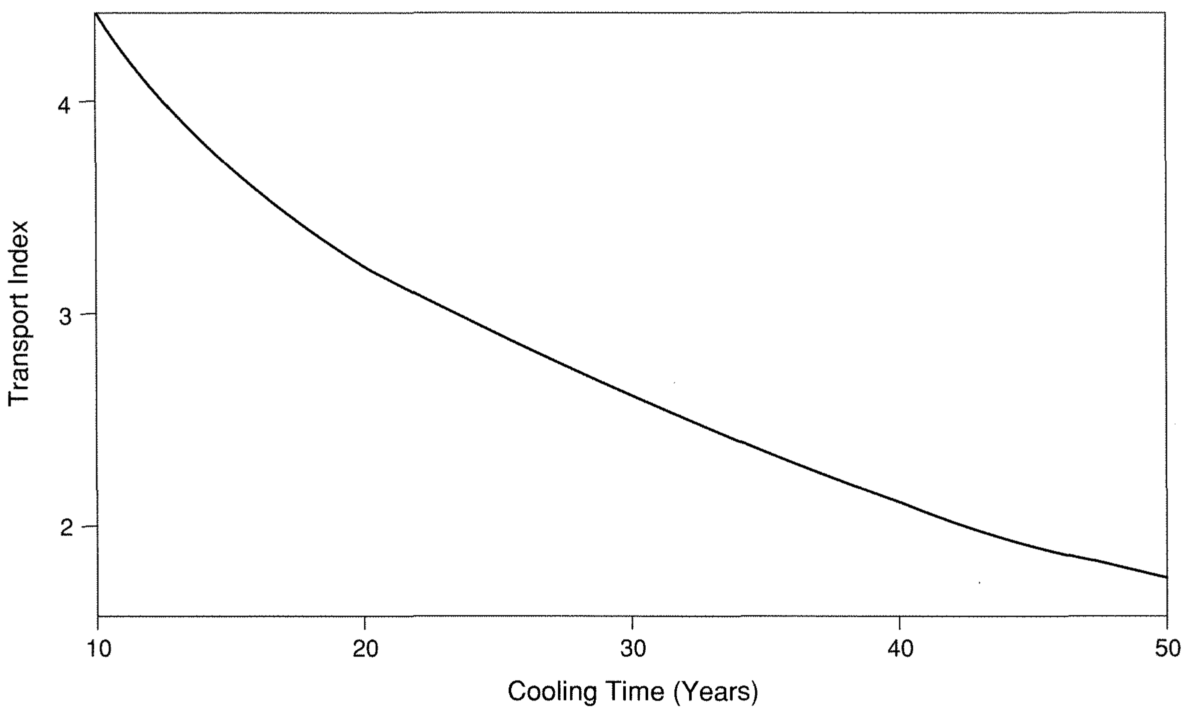
(1) Percentage change in annual collective dose for a one percent change in parameter value

(2) Non-linear variation.

(3) The shape factor is related to the dimension of the package = $(1 + d_p/2)^2$

(4) Option selected in which no shielding applied.

A sensitivity factor of less than ± 0.2 is assumed not to be significant.



Note: The transport index is a number, defined in the regulations, equal to the radiation level at one metre from the package surface in units of microsieverts per hour, divided by ten (equivalent to millirem per hour).

FIGURE 9-1: Variation of Transport Index with Cooling Time

TABLE 9-7
Parameter Sensitivities for Maximum Annual Individual Dose in Normal Conditions for the Three Transportation Modes

Parameters	Relationship to Dose	Comments
ROAD		
Shape factor	Linear	Unlikely to vary.
Transport Index (external dose rate)	Linear	Upper limit specified by the regulations.
Number of bundles transported per year	Linear, unless shipments use alternative truck stops	The base-case of 250 000 bundles per year is a maximum value. A realistic number, based on a 40 years operating period and the current used fuel production forecast, would be 100 000 bundles per year.
Stop time	Linear	The stop time would be specified by procedures
Distance at stops	Inverse square	Doubling distance from parked truck to occupied area would reduce the dose by a factor of 4. The range of distances could be determined by a survey of truck stop configurations along the route.
RAIL		
Shape factor	Linear	Unlikely to vary.
Transport index	Linear	Upper limit specified by the regulations.
Shielding factor	Linear	The base-case analysis assumed no shielding. Any shielding would reduce the dose.
Number of casks per shipment	Linear	Increase in the number of packages per shipment would imply a compensating decrease in shipments per year. The number of casks per shipment would be based on optimizing safety, and on operational and cost considerations.
Number of bundles transported per year	Linear, unless alternative routes are used.	The base-case of 250 000 bundles per year is a maximum value. A realistic number, based on a 40 years operating period and the current used fuel production forecast, would be 100 000 bundles per year.
Speed	Inverse linear	Doubling of the speed would reduce the dose by a factor of 2. Minimum of the speeds for the three zones used in the base-case. Speed limits along the rail line would apply in reality.
Distance from track to dwelling	Inverse linear	The range of distance could be determined from a survey along the proposed route.

continued...

TABLE 9-7 (concluded)

Parameters	Relationship to Dose	Comments
WATER		
Shape factor	Linear	Unlikely to vary.
Transport Index	Linear	Upper limit specified by the regulations.
Distance from vessels	Inverse square	It would depend on the traffic on the existing route and could be somewhat controlled by routing and navigating procedures.
Canal transit time	Linear	Speed through the canals is restricted.

For ^{137}Cs, none of the factors analyzed increased the release in the most severe accident categories (categories 9/10). In the accidents of intermediate severities (categories 6/7), releases of both ^{137}Cs and ^{239}Pu were increased if no retention by the cask was assumed, and if a fraction of all oxidized fuel was assumed to become airborne (see Figures 9-2 and 9-3). Prevention of significant access of air to the cask during the cooldown period after a fire could be helpful in reducing fuel damage, and reducing releases during subsequent handling.

The base case parameters, and the values chosen for examining the sensitivity, are listed in Table 9-8. The resulting individual and collective dose - frequency curves are given in Figures 9-4 to 9-7.

9.4.2.1 Changes in Parameters for Collective Doses

The overall shape of the curves of cumulative accident frequencies versus collective dose is changed little by variation in input parameter values. However, the maximum collective doses are sensitive to variations in the values of these parameters.

The most significant increase in collective dose (Figure 9-5) arises from an increase in the urban population density, and an increase in the distance to which collective dose is integrated. The population density was increased to the maximum for downtown Toronto, and the integration distance was arbitrarily increased to 50 km. Assuming a uniform population density to 50 km, particularly an urban population density, is not realistic.

9.4.2.2 Changes in Parameters for Individual Doses

The number of casks affected by an accident and the exposure distance have a significant effect on the maximum individual dose (see Figure 9-4). Other parameters (see Table 9-8) were found not to be significant.

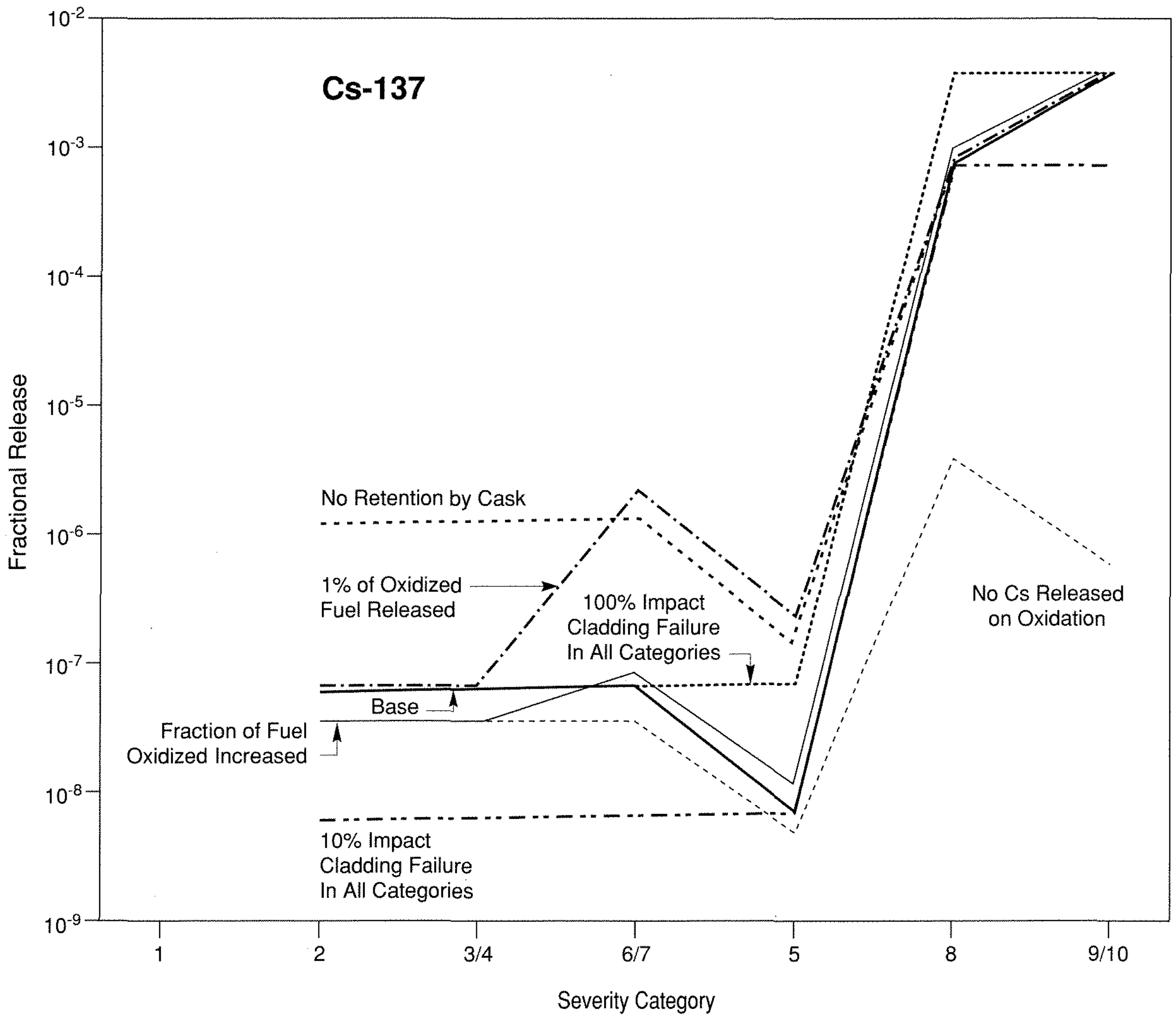


FIGURE 9-2: Sensitivity of Release of Cs-137, during Transportation Accidents, with Respect to the Fraction of Fuel Oxidized, the Cask Retention Factor, and the Cladding Failure Fraction Assumptions

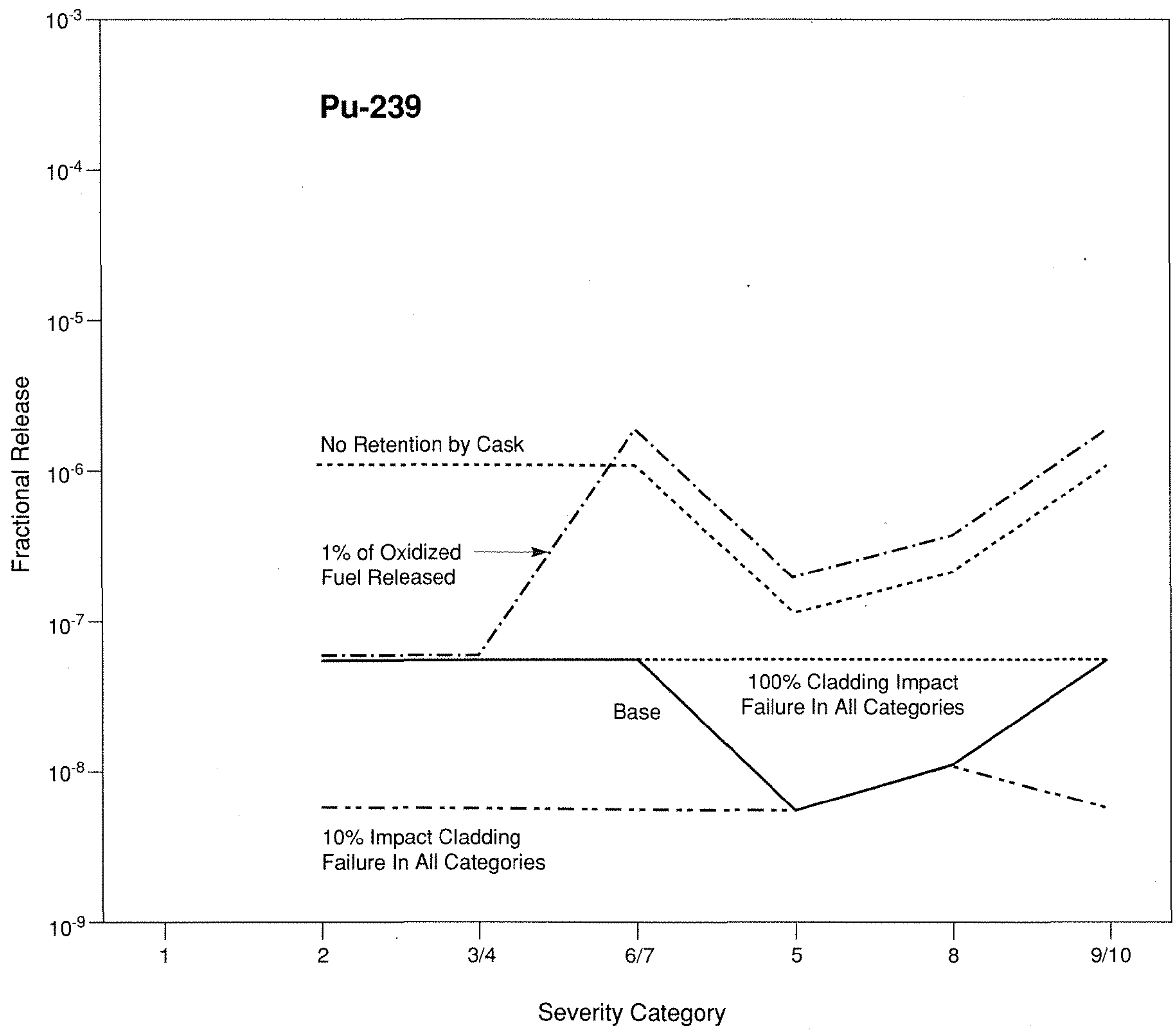


FIGURE 9-3: Sensitivity of Release of Pu-239 during Transportation Accidents, with Respect to the Fraction of Fuel Oxidized, the Cask Retention Factor, and the Cladding Failure Fraction Assumptions

TABLE 9-8
Parameter Values Used for Sensitivity Cases

Parameter	Base Case Value	Value Used in the Sensitivity Analysis	Parameter Affecting
Release height	100 m	50 m	Dose
Number of casks affected	1 or 2	2 or 3	Dose
Inner sector radii[a]	50 m, 100 m	25 m, 75 m	Dose
Outer sector radii[b]	10 km, 20 km	30 km, 50 km	Dose
Urban population density	1.5 x 10^3 persons·km^2	6 x 10^3 persons·km^2	Dose
Number of shipments per year	32	35	Probability
Distance per shipment	800 km	880 km	Probability
Fractional occurrence given an accident in each severity category[c] : 2 3/4 5 6/7 8 9/10	 10^{-4} 10^{-6} 10^{-5} 10^{-7} 10^{-5} 10^{-7}	 10^{-3} 10^{-4} 10^{-4} 10^{-5} 10^{-4} 10^{-5}	Probability
Deposition velocity for ^{137}Cs	3 x 10^{-3} m·s^{-1}	3 x 10^{-2} m·s^{-1}	Dose
Age of the fuel	10 y	20 y	Dose

a distance from accident at which members of the public are assumed to be present
b distance to which the integration of collective dose carried out; it assumes a uniform population density from the inner radius to the outer radius
c see chapter 7 for definition of severity categories (Figure 7-1)

9.4.2.3 Factors Affecting Probability of a Scenario

Both collective and individual doses are linearly dependent on the number of shipments per year and the distance per shipment (Figure 9-6 and 9-7). The effect of increasing the fraction of accidents in each severity category (see Chapter 7) is also shown on these figures. The values for the sensitivity analysis were selected by re-examining the events that contribute to the total probability for each category. Where event probabilities required assumptions, the probability was set to one. For example, given an accident in a location where there was a potential for a 9 m or 22 m drop, the probability of a cask fall over this distance was set equal to one. Similarly the probability of a cask being engulfed in a fire, given a fire had occurred, was set to one. This change in assumptions results in a major change in some of the severity category probabilities. The probability of receiving a dose increases from about 10^{-6} per year to 10^{-5} per year.

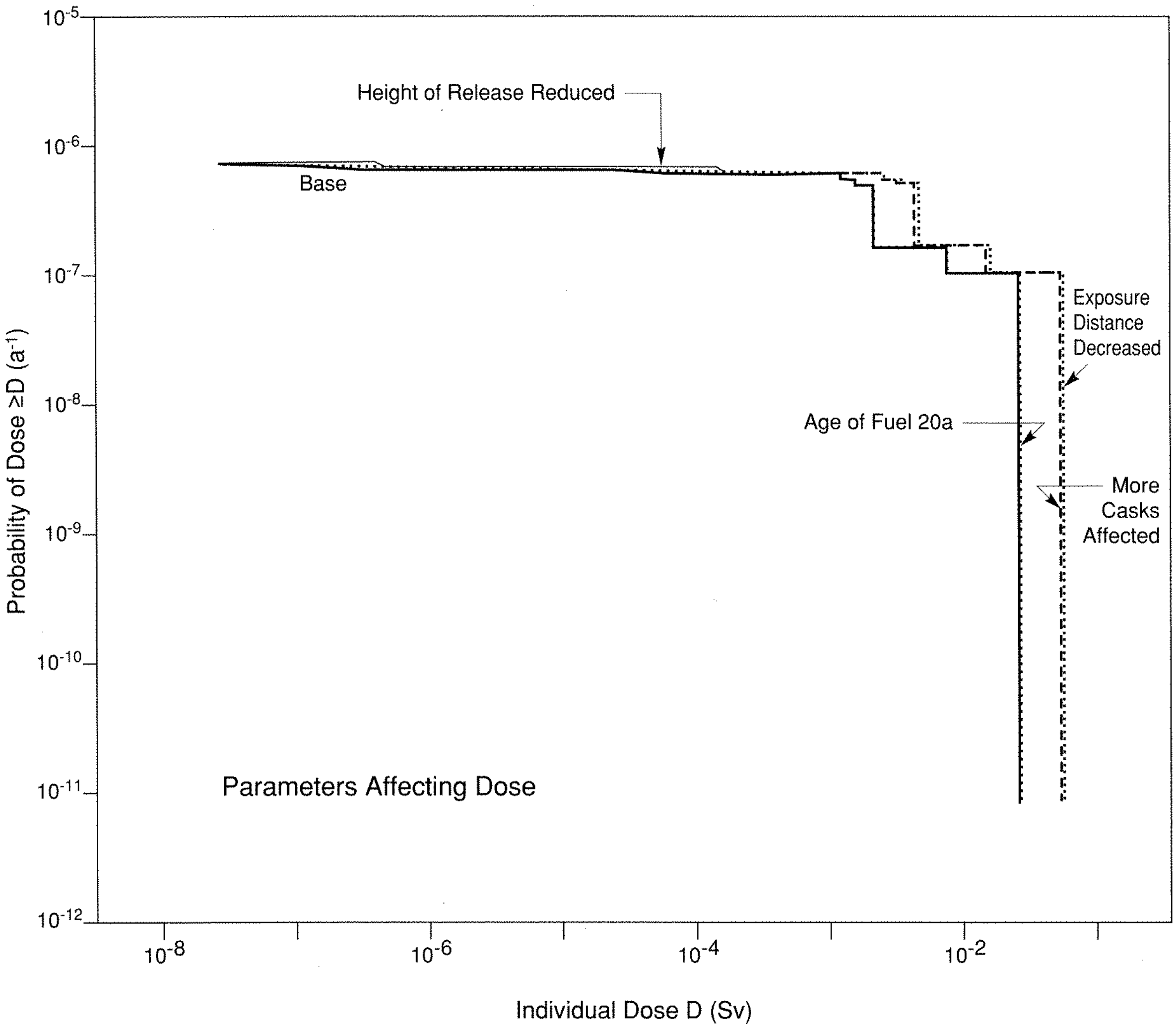


FIGURE 9-4: Variation in Individual Dose during Transportation Accident Conditions with Respect to the Height of the Release, Age of the Fuel, Exposure Distance and Numbers of Casks Affected by the Accident

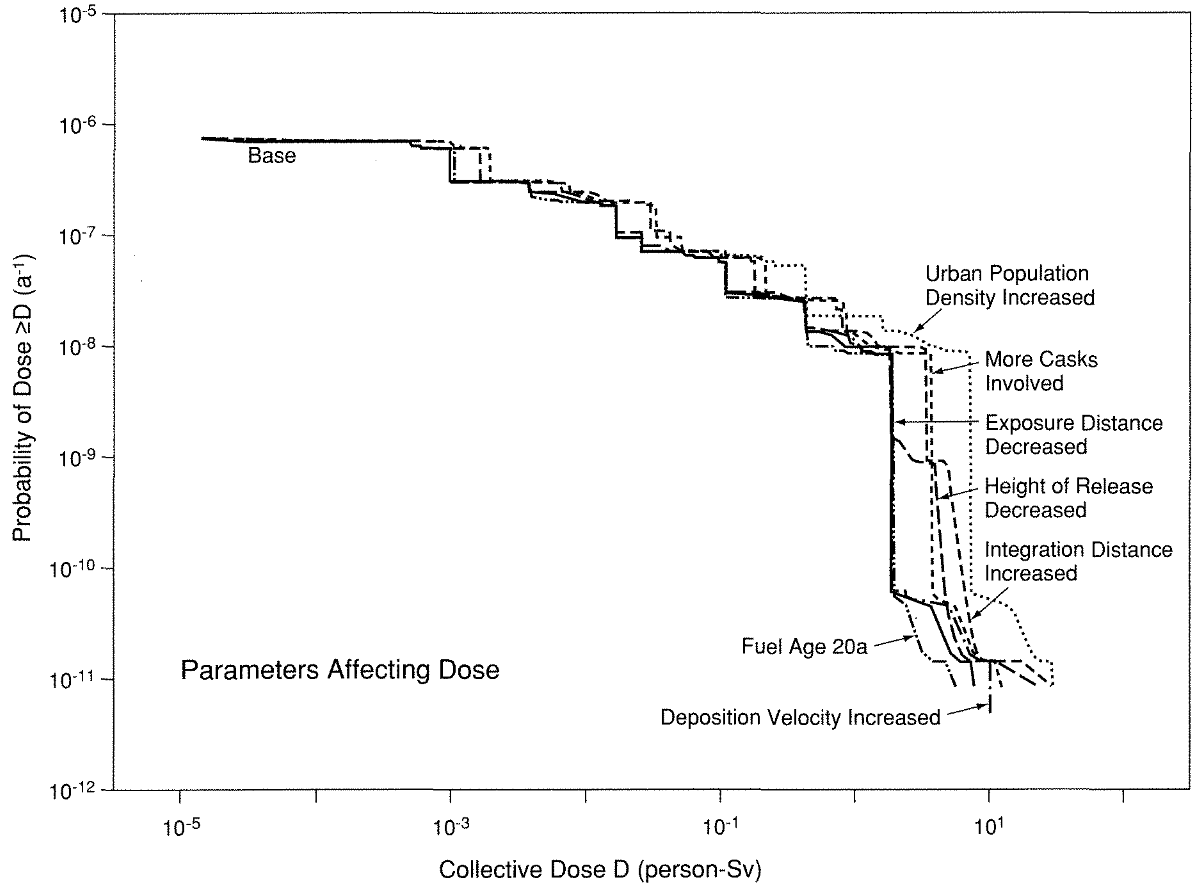


Figure 9-5: Variation in Collective Dose During Transportation Accidents with Respect to the Height of the Release, Age of the Fuel, Exposure Distance (to nearest population), Number of Casks Affected by the Accident, Urban Population Density, Distance to Which the Integration of Dose is Continued, and the Deposition Velocity.

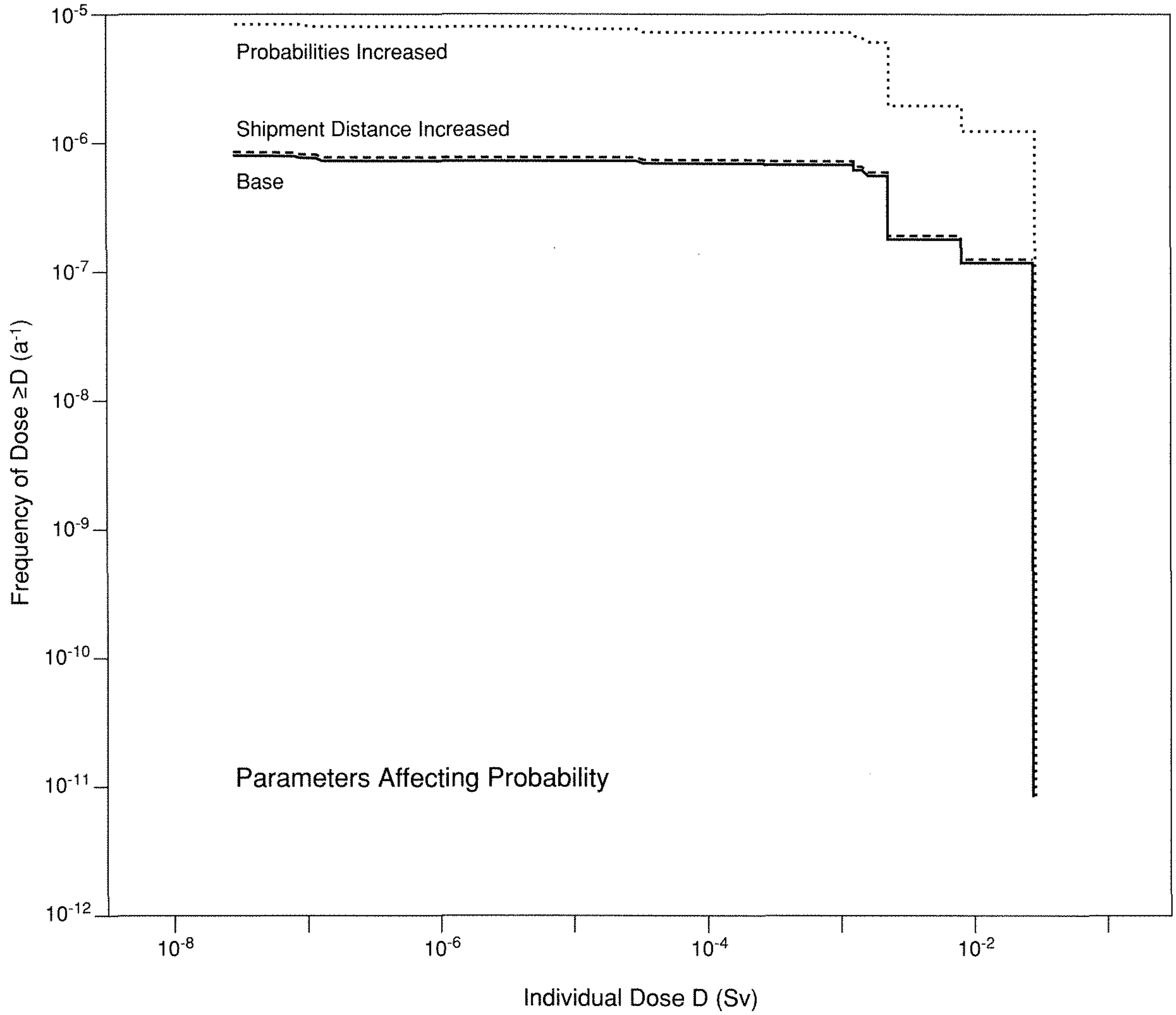


FIGURE 9-6: Variation in Individual Dose during Transportation Accidents with Respect to Shipment Distance and Severity Categories Probabilities

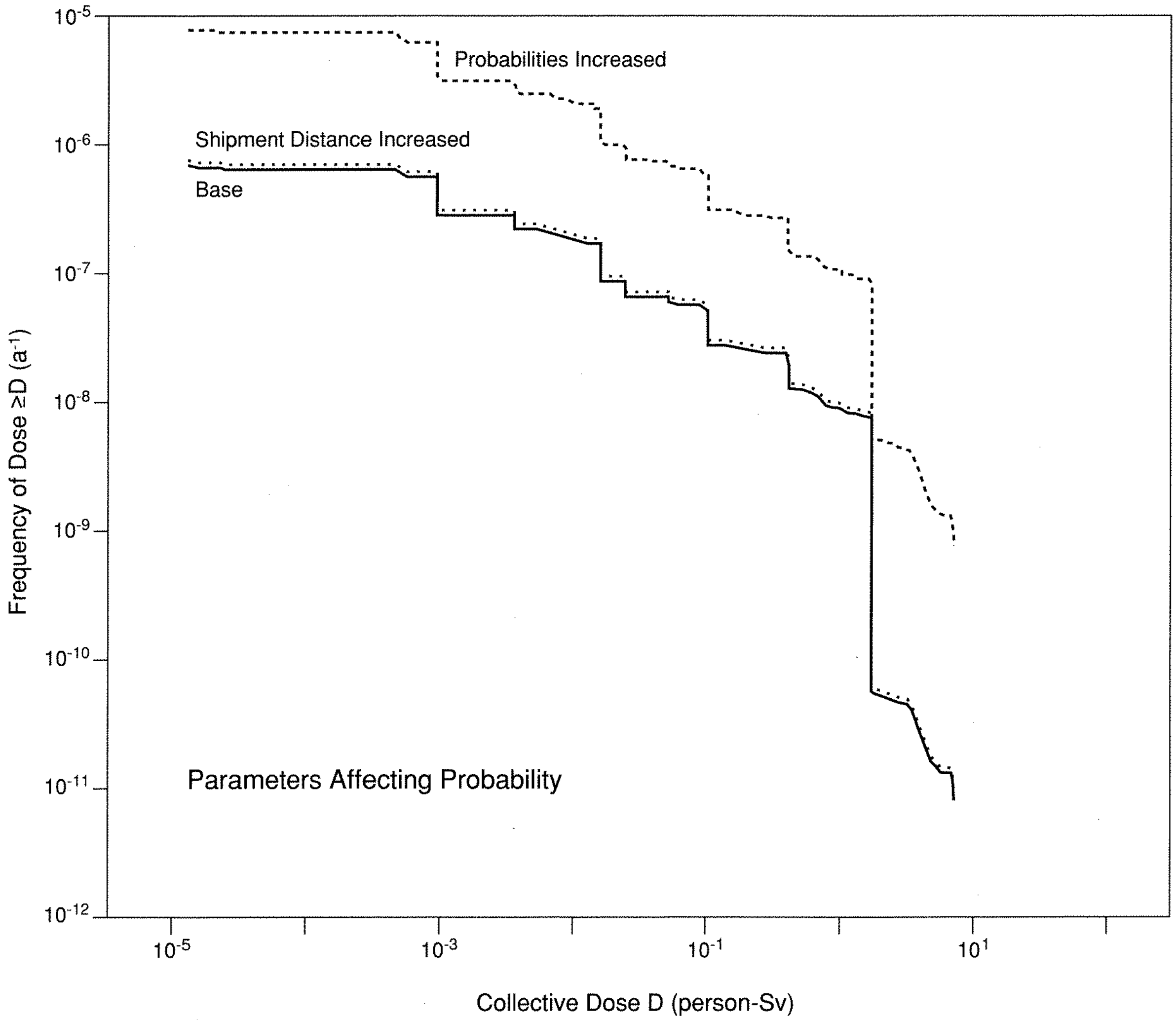


FIGURE 9-7: Variation in Collective Dose during Transportation Accidents with Respect to Shipment Distance and Severity Categories Probabilities

9.5 SENSITIVITY OF USED FUEL TRANSPORTATION RADIOLOGICAL IMPACTS ON WORKERS

9.5.1 Normal Conditions

The sensitivity of the radiological impacts on workers during normal used fuel transportation to changes in the following parameters was examined:

i) system capacity;

ii) fuel cooling time prior to transportation;

iii) length of operating season;

iv) cask size; and

v) distance travelled.

9.5.1.1 Changes in Annual System Capacity

The radiological hazards associated with normal system operations were first calculated on a per bundle basis. They are shown in Table 9-9. The annual collective doses are linearly related to changes in system capacity and can be calculated using the results in Table 9-9. This calculation is shown in Table 7-39 for a capacity of 250 000 bundles.

9.5.1.2 Changes in Fuel Cooling Time Prior to Disposal

The start of operation of the UFDC would not be before about 2025 and by that time, the used fuel then in storage would have a distribution of cooling ages. The majority of the stored fuel would have had a cooling period in excess of 20 years and a significant fraction would have been in storage for more than 40 years. As mentioned in Section 9.2, an increase of the cooling time to 40 years would result in halving all transportation cask handling external doses. During design refinements prior to implementation, the cask shielding thickness might be customized to the cooling time of the used fuel as part of the optimization. Another strategy could be to mix used fuel of various cooling times in each shipment in an attempt to minimize radiation dose rate from the cask.

TABLE 9-9
Occupational Collective Doses during Normal Used Fuel Transportation Per Bundle (base case analysis 180 000 bundles per year) (person-mSv)

Destination	Rail	Road	Water-Road	Water-Rail
Southern	0.85×10^{-3}	2.35×10^{-3}	----	----
Central	0.85×10^{-3}	2.59×10^{-3}	3.76×10^{-3}	1.48×10^{-3}
Northern	0.85×10^{-3}	2.85×10^{-3}	3.91×10^{-3}	1.52×10^{-3}

9.5.1.3 Changes in Length of Operating Season

By shortening or lengthening the operating season, the probable result would be a respective decrease or increase in the time during which workers handle and transport the used fuel. Assuming that the number of bundles transported remains the same, a shorter operating season might require more personnel to be able to do the same work in less time. The yearly workload of individual workers would be less and consequently the individual dose would be less. If a shorter or longer operating season has no effect on the yearly workload of individual workers, the yearly doses should not be affected.

9.5.1.4 Changes in Cask Size

Chronic radiological hazards are insensitive to changes in the cask size, provided the cask design requirements for contact dose rate at the cask surface remains unchanged. Labour requirements might, however, change with cask size, resulting in a change in annual dose.

9.5.1.5 Changes in the Distance Travelled

Changes in the distance travelled would affect the radiological hazards associated with cask movement, train inspection and train maintenance activities. Since most of the occupational dose during normal transportation is due to cask handling at the nuclear generating station (Zeya 1993b), occupational collective doses are only slightly sensitive to the distance travelled.

9.5.2 <u>Accident Conditions</u>

The sensitivity of the level of radiological hazards to changes in the following parameters was examined:

i) system capacity and years of operation;

ii) cask size; and

iii) distance travelled.

9.5.2.1 Changes in Transportation Annual System Capacity

The radiation hazard associated with accident conditions were first calculated on a per bundle basis. They are shown in Table 9-10. Using this table, the sensitivity of the frequency-weighted radiological doses to changes in system capacity is determined. Results are shown in Table 7-39 for a 250 000 bundles per year capacity. The total collective dose over 10.1 million used fuel bundles remains unchanged.

9.5.2.2 Changes in Cask Size

Dose rates would be linearly dependent on the number of used fuel bundles in a cask. However, short-term radiological hazards are assumed to be insensitive to small changes in the cask size.

9.5.2.3 Changes in Distance Travelled

The number of accidents is proportional to the number of vehicle-km travelled per year. Changes in distance travelled would, therefore, affect the expected frequency of occurrence of accidents and consequently the radiological hazards.

TABLE 9-10
Potential Short-Term Occupational Collective Doses
Following a Used Fuel Transportation Accident
(Frequency-Weighted)
(person-mSv/bundle)

Region	Road	Rail	Water-Road	Water-Rail
Southern	1.5×10^{-9}	8.3×10^{-9}	----	----
Central	6.1×10^{-9}	2.6×10^{-9}	1.9×10^{-9}	2.4×10^{-9}
Northern	21.0×10^{-9}	3.8×10^{-9}	1.7×10^{-9}	1.8×10^{-8}

9.6 SENSITIVITY OF UFDC NON-RADIOLOGICAL EFFECTS ON THE ENVIRONMENT AND THE PUBLIC

The natural environment analysis presented earlier in this document was based on the reference UFDC design, reference parameter values representing the environment in the Ontario portion of the Canadian Shield, and a number of conservative analysis assumptions. This section examines the significance of changes in design data, reference environment data and analysis assumptions on the conclusions of the analyses. An actual sensitivity coefficient such as that used in the dose sensitivity analysis (see Section 9.2.1) cannot be derived for the natural environment analysis because a large portion of the base-case analysis is qualitative.

9.6.1 Changes in Reference Environment Data

The reference environment database (Grondin and Fearn-Duffy 1993a) used real environmental data gathered over the study area (the Ontario portion of the Canadian Shield), and averaged. At the site specific stage, components not presented in this report, because of its regional non site-specific approach, may become significant. Examples of these would be rare or endangered species, or areas of natural or historic value.

Tables 9-11, 9-12 and 9-13 list the ranges of data for each of the three regions from which the assessed reference environmental data was chosen. This sensitivity analysis examined the effects of changing this reference data to the extreme of the range of values for the study area. Conditions varied only in the direction that would give worse environmental effects than the reference conditions. Because a large portion of the base-case natural environment analysis was qualitative, the sensitivity analysis is also mostly qualitative, and is, therefore, called a "trend" analysis.

Even at this non-site-specific study level, the analysis identified two important environmental parameters which should be given some attention at the implementation stage: lake size and depth, and availability of non-renewable resources.

9.6.2 Changes in Design Features

Some of the most significant features of the UFDC design and the possible effects of variations are presented in Table 9-14. Design conditions were varied in the direction that would give worse environmental effects than the value used in the base-case analysis.

TABLE 9-11
Trend Analysis for the Northern Region Reference Environment Data

Parameter	Value Used in the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
Water Parameters			
lake size (ha)	104	<50	the facility could not draw its water from a lake that small (assuming average depth still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
Lake depth (m)	6.2	<1	The facility could not draw its water from a lake that shallow (assuming the average lake size still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
River discharge ($m^3 \cdot s^{-1}$)	<1.5	<1.5	The analysis is already using the most conservative value for the region.
NON-RENEWABLE RESOURCES PARAMETERS			
Non-metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of materials used at the facility could reduce the availability of these materials and force design changes.
Metal ore reserves	See Chapters 5 and 6	Decrease	A decrease in the ore reserves for metals used at the facility could reduce the availability of these metals and force design changes.
Metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of metals used at the facility could reduce the availability of these metals and force design changes.

continued...

TABLE 9-11 (concluded)

Parameter	Value Used In the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
Land Use/Capabilities			
Timber Use Capability	Low	High	Given the small size of the capacity w.r.t. high timber use lands, minimal effects are expected. As much of the original forest should, however, be preserved within the fenced area.
Intensive Recreation Use	Low	Outstanding	The effect would need to be assessed at the site-specific stage in consultation with users.
Extensive Recreation Use	Low	High	Same as above
Forest fires (anthropogenic) (annual # per 1000 km^2)	<0.1	6	The annual risk of forest fire at the site would increase linearly.
Forest fires (lightning) (annual # per 1000 km^2)	0.25	6	Same as above.
Forest fires (average # per year)	484	545	Same as above.
Forest fires coverage (average ha per fire)	102	189	Same as above.

TABLE 9-12
Trend Analysis for the Central Region Reference Environment Data

Parameter	Value Used in the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
WATER PARAMETERS			
Lake size (ha)	151	<60	The facility could not draw its water from a lake that small (assuming the average depth still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
Lake depth (m)	5.2	<1	The facility could not draw its water from a lake that shallow (assuming the average lake size still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
River discharge ($m^3 \cdot s^{-1}$)	<1.5	<1.5	The analysis is already using the most conservative value for the region.
NON-RENEWABLE RESOURCES PARAMETERS			
Non-metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of materials used at the facility could reduce the availability of these materials and force design changes.
Metal ore reserves	See Chapters 5 and 6	Decrease	A decrease in the ore reserves for metals used at the facility could reduce the availability of these metals and force design changes.
Metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of metals used at the facility could reduce the availability of these metals and force design changes.

continued...

TABLE 9-12 (concluded)

Parameter	Value Used in the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
Land Use/Capabilities			
Timber Use Capability	Low	High	Given the small size of the capacity with regard to high timber use lands, minimal effects are expected. As much of the original forest should, however, be preserved within the fenced area.
Intensive Recreation Use	Low	Outstanding	The effect would need to be assessed at the site-specific stage. Acceptability would need to be negotiated with users during siting.
Extensive Recreation Use	Low	High	Same as above
Forest fires (anthropogenic) annual # per 1000 km^2)	1.3	>15	The annual risk of forest fire at the site would increase accordingly.
Forest fires (lightning) (annual # per 1000 km^2)	0.3	3	Same as above.
Forest fires (average # per year)	498	530	Same as above.
Forest fires coverage (average ha per fire)	4	5	Same as above.

TABLE 9-13
Trend Analysis for the Southern Region Reference Environment Data

Parameter	Value Used in the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
WATER PARAMETERS			
Lake size (ha)	211	<68	The facility could not draw its water from a lake that small (assuming the average depth still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
Lake depth (m)	4.6	<1	The facility could not draw its water from a lake that shallow (assuming the average lake size still applies) without disrupting the aquatic environment, unless the required water quantities are drastically reduced by water recycling.
River discharge ($m^3 \cdot s^{-1}$)	<1.5	<1.5	The analysis is already using the most conservative value for the region.
NON-RENEWABLE RESOURCES PARAMETERS			
Non-metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of materials used at the facility could reduce the availability of these materials and force design changes.
Metal ore reserves	See Chapters 5 and 6	Decrease	A decrease in the ore reserves for metals used at the facility could reduce the availability of these metals and force design changes.
Metal production rates	See Chapters 5 and 6	Decrease	A decrease in the production rates of metals used at the facility could reduce the availability of these metals and force design changes.

continued...

TABLE 9-13 (concluded)

Parameter	Value Used in the Base-Case Analysis	Value Used in the Sensitivity Analysis	Effect of Change on Analysis Results
Land Use/Capabilities			
Timber Use Capability	Medium	High	Given the small size of the capacity w.r.t. high timber use lands, minimal effects are expected. As much of the original forest should, however, be preserved within the fenced area.
Intensive Recreation Use	Low	Outstanding	The effect would need to be assessed at the site-specific stage. Acceptability would need to be negotiated with users during siting.
Extensive Recreation Use	High	High	Same as above
Forest fires (anthropogenic) (annual # per 1000 km^2)	1.3	>15	The annual risk of forest fire at the site would increase accordingly.
Forest fires (lightning) (annual # per 1000 km^2)	1.3	1.3	No change.
Forest fires (average # per year)	253	272	The annual risk of forest fire at the site would increase accordingly.
Forest fires coverage (average ha per fire)	4	2	No change.

TABLE 9-14
Trend Analysis of the Effects of Changes in the UFDC Design on the Natural Environment Analysis Results

Base-Case Design Feature	Affected Area of Analysis	Change in Design Feature and Effect
18 km^2 of area would be required for site development including the site boundary and a land use control zone.	All environmental factors especially land use/capability, and flora and fauna.	Larger land commitment would generally create a greater effect.
The length of access route would be 25 km (UFDC) (used for all aspects of the access route effect).	Especially significant for land use/capability, air quality, and flora and fauna.	The effects are directly proportional to the length of the access route.
A metal fabrication plant for manufacturing all of the containers and baskets would be located on-site.	Surface water and air quality.	Site effects would decrease if containers and baskets were fabricated off-site, but off-site effects would increase.
Over 90% of the initial blasted rock would have a diameter of less than 300 mm.	Airborne particulates and surface water runoff.	A blasting technique leading to smaller average particle size would increase effects.
The pumping capacity of the intake water system would be 0.222 $m^3 \bullet s^{-1}$.	Water quality.	Effects are proportional to the pumping capacity. Water recycling would reduce effects.
A sewage treatment plant would be constructed on site.	Water quality.	A septic system would be impractical. Using a municipal treatment plant would likely create less cumulative effects.
Smooth-wall blasting technique would be used in vault excavation activities.	Airborne particulates.	Use of a technique producing finer particles would have a greater effect.
The construction period will be 7 years and operations would continue for 41 years.	Intensity of disturbance.	Changes in schedule increase some effects, and decrease others. The magnitude of the effects depends on the intensity of the activities.
Sand, glass, crushed rock, titanium, steel, bentonite and glacial lake clays would be irretrievably consumed in the disposal operations.	Non-renewable resources and material transportation.	Effects depend on the availability of the resource and the quantities committed to the facility.
Sand and clay would be transported to the site in covered vehicles.	Airborne particulates and damage to roadside flora.	Transporting in uncovered trucks would have a greater effect.
The waste rock would be placed in a disposal area on-site.	Airborne particulates, site runoff and aesthetic effects.	Transportation off-site would lessen site effects and worsen off-site effects.

Even at this non-site-specific study level, the analysis identified three important design features which should be given some attention at the implementation stage: the amount of water withdrawn for water supply to the facility, the quantity of non-renewable material and the management of the waste rock pile.

9.6.3 Changes in Analysis Assumptions

Other assumptions necessary to the analyses made during the assessment are summarized in Table 9-15, along with effects of alternative assumptions.

Given the conservatism of most of the analysis assumptions, changes in these assumptions were found to lessen the estimated effects.

9.7 SENSITIVITY OF UFDC NON-RADIOLOGICAL EFFECTS ON WORKERS

UFDC workers would be subjected to occupational risks, resulting from non-radiological safety hazards that would exist at the disposal centre. Under abnormal conditions, the non-radiological effects on the workers were found to be dependent on the types of industries used to represent UFDC activities. Since average industrial statistics were used to estimate the injury and fatality rate, the analysis is a direct reflection of the safety record of these industries. The construction and mining industries had the worst record.

The actual work environment parameters that cause high risk in non-radiological hazards are difficult to identify at the conceptual stage of the project (without detailed layout and procedures for the activities). A sensitivity analysis of risk factors at the time of implementation would help focus on improving workplace safety and would be consistent with the ALARA principle.

The estimates of fatalities and injuries also depend on the labour estimates for each task. It is expected that the labour estimates would have a similar range of uncertainty as the cost estimates (+40%, -15%).

9.8 SENSITIVITY OF USED FUEL TRANSPORTATION NON-RADIOLOGICAL EFFECTS ON THE PUBLIC AND THE ENVIRONMENT

9.8.1 Air Quality Effects

Annual atmospheric emissions from used fuel transportation are directly proportional to the number of shipments. The incremental emission per kilometre and the emissions from transportation to the farthest corner of the Northern region (≈ 2 500 km) were calculated. Given the small magnitude of the emissions, base-case analysis conclusions that the effects on air quality are negligible remained unchanged.

9.8.2 Traffic Effects

Traffic estimates for used fuel transportation are related to two design parameters: the number of shipments per year, and the length of the transportation season. The effect of increasing the number of bundles shipped to 250 000 bundles per year and the operating season to 230 days was estimated.

TABLE 9-15
Trend Analysis of the Effects of Changes in Analysis Assumptions on the Natural Environment Analysis Results

Base-Case Analysis Assumption	Affected Area of Analysis	Change in Assumption and Effect
The facility would be located in the Ontario portion of the Canadian Shield.	All environmental factors.	The Ontario portion of the Canadian Shield is expected, at this generic analysis level, to be representative of the whole Canadian Shield.
Site clearing activities would be within first year.	Emissions from burning of slash.	It is the most conservative assumption for air emissions.
Heavy duty diesel vehicles (HDDV) would be used in all construction, and transportation activities.	Truck emissions from construction and transportation activities.	It is the most conservative assumption for air emissions.
Construction activities would produce similar noise levels as Darlington NGS construction.	Noise levels during construction.	Darlington assumption is already very conservative (a much larger site).
In the early stages of construction, all sewage would be trucked off site.	Water quality effects from sewage during construction.	Septic tanks on-site would be more conservative but unlikely given the terrain.
Water intake and discharge would be shoreline structures.	Effects on the aquatic life.	It is the most conservative assumption for damage to aquatic life.
All site vegetation would be cleared during site preparation.	Slash disposal quantities and effect on the site vegetation.	It is the most conservative assumption for both air quality and vegetation effects.
The existence of the facility would affect most of the common wildlife species native to the site.	Effect on the local wildlife.	Most conservative assumption for effect on fauna.
50% by weight of the concrete required for the facility would be foundation grade and 50% would be 27 MPa tensile strength reinforced concrete for wall construction.	Materials requirements.	100% 27 MPa tensile strength concrete would slightly increase non-renewable resource effects.
Some gravel, rock, stone, earth and clay would be found on site and would be usable in site development.	Requirements of these non-renewable resources.	No useable resources located on site would increase transportation, air quality and non-renewable resource effects.
10% of the facilities steel would be stainless steel.	Quantities of non-renewable resource additives.	100% stainless steel would increase chromium and nickel effects by a factor of ten.

continued...

TABLE 9-15 (concluded)

Base-Case Analysis Assumption	Affected Area of Analysis	Change in Assumption and Effect
Primary vault excavation blasting activities would precede the installation of the ventilation systems.	Airborne particulates emissions.	It is the most conservative assumption.
Site would be on the shores of a Canadian Shield river or lake.	Effects on the aquatic environment.	It is the most conservative assumption for effect on aquatic life.
The intake requirements of the facility would equal the pumping capacity, 0.222 $m^3 \bullet s^{-1}$.	Minimum river and lake flows and volumes.	It is the most conservative assumption. Water recycling would reduce effects.
Drainage basin area is 5-10 times (7.5 times) the surface area of the Canadian Shield lake.	Lake flows and flushing rates.	Lakes in a drainage basin series have cumulative flows with the highest lake having the least and the lowest having the most.
The 5% restriction of the total lake volume per year, recommended by the Environment Canada Code of Practice.	Maximum sustainable lake withdrawal volume.	It is a very conservative assumption.
The 15% of river flow maximum water withdrawal assumption	Maximum sustainable river withdrawal volume	It is a very conservative assumption.
Storage piles of rocks on site would be no more than 10 m high.	Effects to site aesthetics from operation.	Storage piles higher than 10 m would still be covered by normal height Canadian Shield forest, up to 27m, 25m and 15 m in the Southern, Central and Northern regions respectively.

Traffic estimates based on UFDC design parameters would be slightly higher than for the base-case. However, for the rail and water modes, this traffic would be well below 1 train or 1 vessel per day, and, therefore, estimated effects should not differ from the reference case. However, truck traffic would increase to 12 trucks per day, from 7, representing a four percent increase in traffic on the road segment with the smallest existing traffic (275 vehicles/day). Compared to traffic volume for a typical mining or lumbering operation, 12 trucks per day traffic is relatively small.

Normal traffic on the reference routes (road, rail and water) can be expected to have increased by the time used fuel transportation is implemented. This would further decrease the relative importance of the increase due to used fuel transportation traffic.

Conclusions based on the reference design traffic for used fuel transportation, therefore, should be valid for the UFDC reference design and for small changes in capacity or operating season for used fuel transportation.

9.8.3 Noise

The increase in noise from used fuel transportation activities would depend on the traffic flow. The average increase in road traffic noise resulting from a doubling of the used fuel transportation capacity (14 trucks per day compared to 7) would be small enough that it would still be within the accuracy limit of an equivalent noise level meter (1-2 dB) and below the MTC criteria of 5 dB for significant noise increase (Ministry of Transportation and Communications 1987). Assuming that the doubled used fuel transportation truck traffic is on a road with the smallest vehicular traffic in the database (see Grondin 1993a), and with no existing truck traffic, the increase in noise would exceed the MTC criterion for significant change. Mitigative measures might need to be considered.

The effects of increasing train traffic by 1 train per day (base-case traffic is about 1 train every four days) was found to be negligible. The effect on the rail segment with the lowest traffic would remain under the 5 dB criteria for significant change.

Because water acts as a noise barrier, noise from water transportation of used fuel should not be a problem even with an increase in capacity to 250 000 bundles per year (UFDC reference annual capacity).

Traffic on the reference routes (road, rail and water) is expected to have increased by the time used fuel transportation is implemented. This would increase the background noise level and decrease the relative importance of the used fuel transportation traffic noise.

9.8.4 Non-Renewable Resource Commitments

Variations in the capacity and reference distances for used fuel transportation would lead to proportional changes in the usage of non-renewable resource. Because this usage is small compared to available resources, small changes in it would not be significant.

9.9 SENSITIVITY OF SOCIO-ECONOMIC AND ECONOMIC IMPACTS

9.9.1 Socio-Economic Impact

Variations in project characteristics and the resulting changes in effects on the natural environment, on community infrastructure and other components of the environment, would influence the socio-economic impacts of the project. As mentioned in Chapter 6, the main community characteristics (socio-cultural vitality, economic viability and political efficacy) are integrated in the dynamics of a community: impacts on one characteristic affecting the others. In this context, without a site a sensitivity analysis of variation in project characteristics on socio-economic impacts is not very meaningful and was not included in the analysis. The socio-economic impacts assessment has identified a wide range of impacts.

9.9.2 Economic Effects of the UFDC

The accuracy of the UFDC costs estimates, based on the conceptual design, was given as -15% to 40% (Simmons and Baumgartner 1994). Since the variations of the cost components are not available at this preliminary design stage, all cost components are assumed to change in the same proportion. With the fixed effect multipliers, the variances of the effects are expected to be directly proportional to the variances of the costs estimates. In this case, the effects would vary by -15% to +40%.

9.9.3 Economic Effects of Used Fuel Transportation

A sensitivity analysis was undertaken to test the impacts of changes in three major design parameters: the transportation system capacity, the length of the operating season and the distance travelled. As well, other assumptions used in the analysis were examined.

The incremental impacts of transporting an additional 100 000 bundles per year were analyzed. This represents a 55% increase in capacity, and as expected has a significant impact on GDP in net present value. The present value of GDP are 16 to 25% higher depending on the transportation mode.

The effects of a reduction in the operating season from 275 to 225 days per year, with no change in the number of used fuel bundles transported, were also analyzed. The net present values of GDP and employment impacts increase by less than 0.03%. The impacts of additional road and rail casks for storage purpose would be negligible.

The incremental impacts for each additional 100 km in distance were found to be marginal in terms of GDP and employment. The net present value of GDP and employment impacts increase by about 1% on average over the study period.

The original impact results were based on production in two industries: the transportation equipment industry which produces tractors, trailers, barges, tugs and rail cars; and the metal fabricating industry which manufactures steel casks to be used for used fuel storage and transportation. The sensitivity analysis examines another case using more industries so as to capture the manufacturing process completely. The results indicate the differences in impacts are within 1%.

In the base-case, steel casks were assumed to be manufactured in Ontario. The economy wide impact of non-Ontario-made steel casks was examined. However, the non-Ontario-made steel casks can reduce the economic impact of capital expenditures for 10 to 54%. Table 9-16 presents the GDP and employment multipliers for this case. The option with the highest initial expenditures continues to have the largest impact on the economy. The differences in total GDP and employment impacts are insignificant.

The economy-wide impacts have been discounted by a real discount rate of 4.5%. This is the long-term Ontario Hydro corporate discount rate used in financial and economic evaluations. The rate is based on the weighted average cost of capital which includes cost of debt and return on equity. These weights reflect Ontario Hydro's forecast of capital structure.

TABLE 9-16
Economy-Wide GDP and Employment Multipliers
for Cask Manufacturing Outside Ontario

Type of Expenditure	GDP Multiplier (1990M$)		Employment Multiplier (person-years)	
	Ontario	Rest of Canada	Ontario	Rest of Canada
CAPITAL	1.08	0.49	18.56	11.63

9.10 SUMMARY AND CONCLUSION OF THE SENSITIVITY ANALYSIS

Summary

The sensitivity analysis presented in the previous sections was performed to evaluate the effects of variations in environmental parameters, reference design parameters and analysis assumptions on the assessment results.

The sensitivity analysis showed that for normal operating conditions, 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 affect the radionuclide concentrations in the environment and exposure to humans.

Radiation dose rates at working locations, and exposure time were found to be the dominant parameters for occupational dose during normal conditions. The dose rates depend mostly on shielding thickness, distance from the source and used fuel cooling time. Accident frequency and accident severity are the most important factors for occupational dose during accident conditions. The non-radiological effect on the workers were found to be dependent on the types of industries used to represent UFDC activities.

In estimating the used fuel transportation annual collective dose during normal conditions, the two most important parameters were the number of shipments per year, the distance travelled and the transport index. The important factors for estimation of the individual dose are shown in Table 9-7. Cooling time of the used fuel was an important parameter for both collective and individual dose estimates.

Under accident conditions, the fraction of inventory assumed to be retained in the cask and the assumed fraction of fuel that would be oxidized were important in determining the radionuclide releases. The number of casks assumed to be affected by an accident and the exposure distance (minimum distance from the cask assumed for a member of the public to stand during an accident) were also important for individual dose estimates. The population density was also 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 evidently most sensitive to the number of bundles transported.

Because the analysis of effects of the UFDC on the natural environment was not site-specific and was, therefore, fairly qualitative, effects of changes in the reference environment parameters, design features and analysis assumptions could only be examined in a qualitative manner. The design features were found to have more effects on the analysis results.

The effects on the natural environment from used fuel transportation activities, were mostly dependent on distance travelled, system capacity, and on existing noise and traffic estimates.

The purpose of the socio-economic analysis of the UFDC life-cycle activities, including used fuel transportation, was to identify a potential range of impacts. The nature and extent of impacts would depend upon the dynamics in the relationship between project characteristics and community characteristics.

Conclusion

The conclusions of the base-case analysis were found to be valid for variations in the design parameters, environmental parameters and analysis assumptions. Radiological impacts estimated with the varied parameters were still well below the regulatory limit. The cumulative effects of varying two or more parameters were not explicitly considered in this sensitivity analysis. It is emphasized that the design of the disposal system has not yet been optimized or fixed. The design would be adapted to specific environmental conditions which would become known at the site characterization stage, thus significantly reducing variability of parameters. Furthermore, variability of environmental parameters during the preclosure phase would be relatively small compared to the potential variability over the long term following closure.

9.11 SCENARIO ANALYSIS

The Environmental Impact Statement (EIS) guidelines (FEARO 1992b) require that particular future scenarios be considered to supplement the generic analysis presented in the earlier chapters. This section includes a discussion of the implications of certain natural environment and socio-economic scenarios. Energy production scenarios are also discussed. Northern communities and Aboriginal communities considerations were not dealt with through scenario analysis, but were integrated in the generic analysis presented in Section 6.5.

9.11.1 Natural Environment Scenarios

The natural environment analysis presented in this report is non-site specific. The base-case analysis, therefore, applies to a wide range of natural environment conditions. However, for completeness, the natural environment implications of the following scenarios for the Used Fuel Disposal Centre are discussed in this section: an urban location scenario, a wilderness area scenario and a sensitive environment scenario. The socio-economic implications of the first two scenarios are included in the range of reference community implications presented in Section 10.2.

9.11.1.1 Urban Location Scenario

The urban location scenario was simply defined as a town with a population density of 1 000 persons$\cdot$km^{-2} This would roughly correspond to the population density in the following towns of Ontario: Smith Falls, Pembroke, Brockville, Port Hope, Orillia, Orangeville, Aylmer and Brantford (Ministry of Municipal Affairs 1990).

a) Public Radiological Dose Effect

Based on the sensitivity analysis results presented in Section 9.2.1, for a population density of 1 000 persons$\cdot$km^{2}, the collective dose from UFDC routine emissions would be 3.9×10^{-4} person-Sv$\cdot$a^{-1}, compared to 1.9×10^{-4} person-Sv for the base-case.

In addition, the base-case individual dose results, based on an individual living on a self-sufficient farm, would be extremely conservative for an urban setting where most of the food is imported from more rural areas, and domestic water supply comes from a water treatment plant.

Under accident conditions, an urban setting would differ in terrain roughness. This would have implications on the dispersion of the radioactive plume. As analyzed in Section 9.2.2.2, dispersion over a city with tall buildings would lead to an individual dose of 1.9×10^{-4} Sv under accident conditions, compared to 2.0×10^{-4} Sv for the base-case. The estimated dose to members of the critical group would also depend on a number of other assumptions such as location, lifestyle, breathing rate and other factors (e.g. shielding). As shown in Section 9.2.2.3, if the individuals are located indoors during the accident, as would usually be the case for urban settings, the dose would generally be reduced depending upon the ventilation rate of the dwelling.

The radiological impact from used fuel transportation to an urban location should be of the same order of magnitude as the base-case which considers transportation through rural, suburban and urban settings.

b) Natural Environment Effect

The effects on land use of a UFDC located in a town would be the most important environmental effects. It is expected that such a populated area would not have very many natural features left and that most of the impacts would be on residential, commercial, industrial and recreational land uses.

The facility's water supply would likely be taken from a municipal water supply with existing infrastructure. This should reduce new effects on the natural environment.

The increase in traffic from used fuel transportation, construction material transportation, and buffer and backfill transportation could potentially cause congestion problems for a UFDC located in an urban setting.

c) Socio-economic Impact

The socio-economic implications of the urban location scenario are considered to fall within the range of impacts identified for different "reference communities" in Section 9.11.2.1.

9.11.1.2 Undisturbed Wilderness Environment Scenario

The undisturbed wilderness environment is defined as a location with no population in a radius of 80 km around the facility. This would roughly correspond to the population density in an unorganized territory where population would be dispersed throughout (e.g. Aboriginal population and trappers).

a) Public Radiological Dose Effect

Based on the sensitivity analysis results presented in Section 9.2.1.3, with no population residing within an 80 km radius from the facility, the collective dose from UFDC routine emissions would be 3.5×10^{-6} person-Sv·a^{-1}, compared to 1.9×10^{-4} for the base-case.

The base-case individual dose results, based on an individual living on a self-sufficient farm would change for a wilderness setting where most of the food would be from wild sources. As discussed in Section 9.2.1.5, for an Aboriginal population group on the Shield, the fish ingestion rate could be substantially higher than the hypothetical adult on the boundary farm. If the fish ingestion rate is as high as 100 kg·a^{-1} (Grondin and Fearn-Duffy 1993b), the individual dose becomes 2.8×10^{-6} Sv·a^{-1} compared to the base-case dose of 3.4×10^{-7} Sv·a^{-1}, still a very small dose.

The dose to non-human biota estimated for the base-case analysis already assumed a wilderness setting.

b) Natural Environment Effect

The effects of the UFDC on this totally undisturbed natural environment would not differ from the ones described in the base-case analysis. Given that the base-case analysis was non-site specific, possible effects on a wilderness area were included. Mitigation measures discussed in the analysis chapters would be in place to minimize potential effects.

In addition, it is strongly recommended that:

i) personnel involved in all aspects of the facility siting, construction, operation and decommissioning receive sufficient environmental protection training to raise their level of environmental awareness such that detrimental effects would be minimized;

ii) procedures be in place for the facility construction and operation that include as an objective - the protection of the natural environment; and

iii) an environmental policy (see Appendix C) be established early in the implementing organization's mandate which would provide environmental leadership throughout the facility life-cycle.

9.11.1.3 Sensitive Environment Scenarios

Although wetlands and endangered species habitat are protected in Ontario (see Appendix B), decisions to completely avoid or consider sites with such sensitive features would be taken during siting. It is, therefore, appropriate to review the potential effects of the UFDC on these features.

<u>Wetlands</u>

Wetlands are sensitive to disruption by human activities. Those actions which alter hydrology or substrate are generally more permanent than those which influence only the animal and plant life, although in extreme cases this may lead to extinction of local populations of species.

a) Sensitive Features of Wetlands

Some of the features of wetlands make them specially important to protect. They are:

i) wetlands provide habitat for wildlife; some wetlands provide the only environment to support certain unique or endangered plants, animals and internationally important migratory birds; wetlands are essential to waterfowl, providing nesting habitat for seventy percent of the waterfowl in North America;

ii) wetlands contribute to the quality of water through an active filtering process which takes up pollutants from run-off before it enters other water systems; they also reduce flooding by decreasing the velocity of water, and by holding rainfall during peak periods and releasing it over the following months;

iii) wetlands provide spawning grounds for marshes, pike, crappies, pumpkinseed, perch, carp, bullhead, and largemouth bass. They also form the nursery habitats for those species plus walleye and some migratory birds. Riverside marshes and swamps provide food for fish that live in rivers; and

iv) wetlands provide areas for outdoor recreation activities such as hunting, fishing and bird-watching.

The dynamics of water supply and loss are fundamental to the development, maintenance and functioning of wetlands. The hydrology of a wetland is defined by three factors: how much water enters it, how much water leaves it and how much water the wetland is able to store. While the inflow-outflow balance is influenced primarily by climate and catchment configuration, storage is controlled more by local geomorphology (that is, the configuration of the land) and geological characteristics (Finlayson and Moser 1991).

Hydrology, in turn, influences the physical and chemical characteristics of the wetland - salinity, oxygen and other gas diffusion rates, the reduction-oxidation (redox) state of ecologically important nutrients, chemical reactions and nutrient solubility - which have major implications for both flora and fauna, as well as for ecosystem dynamics.

The composition and diversity of species in the wetland influences the way in which nutrients and pollutants are cycled in the wetland ecosystem - all these are influenced by the hydrological regime.

b) Potential Effects of UFDC Life-cycle Activities

The adverse effects of construction on or near wetlands are primarily related to drainage impairment, vegetation removal, and soil erosion and compaction due to the use of heavy equipment (Prinoski et al. 1983). The removal of vegetation may result in a change in the vegetation pattern of the area, and in turn the wildlife-supporting capabilities of the area (Prinoski et al. 1983).

Construction of an access road across a wetland, with insufficient culverts, could result in impoundment of water in an area and drying in another. This could lead to drastic changes in the local vegetative communities and may also affect wildlife (MNR 1983).

Erosion and disturbance of the soil surface are probable during construction, resulting in ponding and channelling of water. This can affect the water regime of the wetland.

Increased runoff from constructed areas would affect the hydrological regime of the wetlands.

The excavation and its effects on groundwater could affect nearby marshes sustained by water sources other than direct rainfall.

The pumping of underground water with different chemical composition than the surface water could also affect wetlands if care is not taken in the discharge of this water.

Major changes could also occur as a result of nutrient inputs from the facility operation. Environmental protection provisions with respect to sewage and waste water would, however, ensure that wetlands are protected from nutrient enrichment from the facility operation.

c) Potential Mitigation and Wetland Management Measures

Mitigation measures could be used during construction activities to minimize drainage impairment, vegetation damage and soil disturbance in wetlands. Typical measures are presented in Table 9-17.

Construction of the Ontario Hydro's Wesleyville Thermal Generating Station and Bruce Nuclear Power Development can be used as case studies of wetland protection in an industrial construction setting (Sears and Chubbuck 1988).

TABLE 9-17
Possible mitigation measures for wetlands protection during construction

Effect to Mitigate	Possible Mitigation Measure
Drainage Impairment	- schedule construction to minimize effects (frozen conditions are generally preferable in muskeg, although low water conditions may be a desirable alternative in other wet areas) - use equalizing culverts - use clean granular fill on access road - avoid disposal of fill on or near wetlands
Vegetation Damage	- clearly marking off vegetation areas that are going to be removed - when clearing, felling timber toward the area being cleared to avoid unnecessary damage to remaining vegetation - installing temporary fences around sensitive areas to be avoided by vehicles during construction - whenever possible, using protection mats to cover blast sites in an effort to prevent scattering of material outside the work area
Soil Disturbance	- schedule construction in periods when the ground surface is best able to support construction equipment - use extra wide tracked equipment - keeping heavy equipment within boundaries of the work area - minimize clearing

Source: Prinoski et al. 1983, Ontario Hydro 1988a

The Wesleyville site, approximately 20 km east of Darlington NGS, has three separate wetland areas on site. The main wetland is a shallow marsh dominated by burweed and smart weed. Surrounded by thicket and wooded swamps, it provides forage for great blue heron, muskrat, blue-winged teal and other species. Its water levels are regulated by a barrier beach which is used by nesting snapping turtles. A proposed oil-fired station was never completed due to a change in the world price of oil, but the wetlands adjacent to the construction site were successfully protected by fencing and the provision of a natural buffer zone during construction.

The Bruce Nuclear Power Development site on Lake Huron contains part of the Douglas Point Swamp, regionally designated as an environmentally significant area due to its high plant diversity, and extensive use by deer and waterfowl. Two wetlands area are found on site. A shallow cattail marsh extends around part of the Baie du Dore, and lies adjacent to a lowland bog of black spruce and tamarack. Since 1984, studies have been undertaken during the construction and operation of Bruce NGS to identify the effects of station activities on site vegetation and wildlife. Deer and waterfowl associated with site wetlands have received the most attention. To date, few effects have been noted.

In the event that the disposal facility site were to contain wetlands or be located adjacent to wetlands, baseline studies and monitoring for any positive or negative effects during construction and operation, as well as cooperation with naturalist groups, conservation authorities, universities and government agencies, should be an essential part of wetland management.

Endangered or Threatened Species Habitat

This type of habitat is protected under both federal and provincial legislation (see Appendix B). However, if the underground geology was such that the location for the facility would coincide at the surface with endangered or threatened species habitat, and that the public and other decision-makers decide that this would be the preferred location, measures would be required to protect the habitat. The facility layout could be modified (e.g. by moving the shafts) to protect these surface features. Special provisions could be developed with staff from the Ministry of Natural Resources to ensure that the habitat is preserved.

Ontario Hydro's design and assessment of the Little Jackfish River hydroelectric potential is a case study of how mitigation measures can be developed to protect endangered species habitat that could be affected by a project (Ontario Hydro 1988b). A bald eagle (endangered species) nest was discovered during the environment inventory done to study the potential effects from construction of the Little Jackfish GS. It was found that the nest was located in an area that would be disturbed by clearing and eventually flooded. The Ministry of Natural Resources of Ontario endorsed a mitigation plan developed by Ontario Hydro to relocate the nest prior to reservoir development.

9.11.2 Socio-Economic Scenarios

The socio-economic impact analysis presented so far in this report is a generic analysis of the kinds of impacts that could occur if the disposal facility was to be sited, constructed, operated, decommissioned and closed in the Ontario portion of the Canadian Shield. This generic approach was prompted by external peer review comments received on the socio-economic analysis for the Second Interim Concept Assessment Document (Stevenson 1983). Reviewers argued that the reference communities used in the analysis (town, township, county and an area of unorganized territory within which a new town would be located), were not representative of all conditions in the study area.

However, since the EIS guidelines require analysis of specific socio-economic scenarios, the reference communities examined by the 1983 study are possible scenarios for the implementation stage. They are used in this section as illustrative scenarios of the kinds of impacts identified in the generic socio-economic analysis. Given that social impact assessment methods and focus have changed since the 1983 study was completed, limitations of this analysis are also discussed.

9.11.2.1 Illustrative Scenarios from the Interim Concept Assessment Study

1) The Reference Communities

The socio-economic analysis for the interim concept assessment (Stevenson 1983) assumed that the Used Fuel Disposal Centre (UFDC) 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. The study process for the reference communities is shown in Figure 9-8.

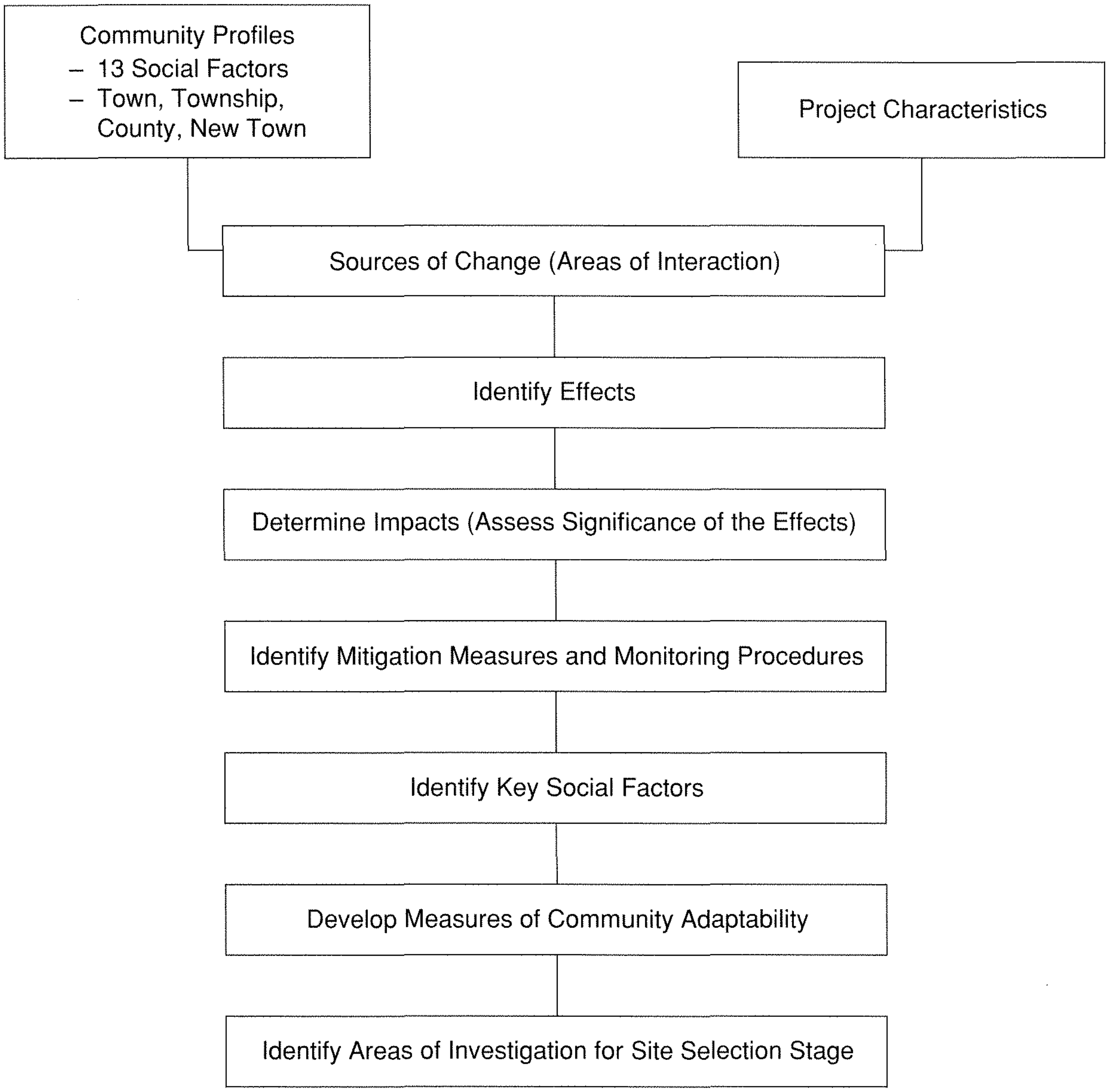


FIGURE 9-8: Study Process for the Reference Communities

2) Summary of Methods for the Reference Communities Study

Each reference community was analyzed based on social factors. Thirteen factors were used to describe the socio-economic aspects of the reference communities. These factors are:

1. population
2. economic base
3. employment and labour supply
4. municipal finance and administration
5. housing and property values
6. municipal services and facilities
7. transportation and communication
8. recreation and tourism
9. regional development/community planning
10. education
11. health and safety
12. social services
13. social aspects, lifestyle and culture

These factors were described in as much detail as possible to present a relatively comprehensive picture of the community. Selection of these factors is discussed in Stevenson (1983).

The sources of change in these social factors were then identified based on a review of the facility life-cycle activities. Note that the 1983 study was based on a UFDC design which was the ancestor of the current conceptual design (Simmons and Baumgartner 1994). The effects on social factors were then assessed for each of the four reference communities based on population influx and local employment projections.

3) Summary of Results from the Reference Community Study

Table 9-18 shows the social factors which would experience impacts during the construction and operation stages for each of the communities. This analysis was not deemed to be conclusive and the list of impacts, therefore, not definitive. The magnitude of some of the effects and the importance to the community were difficult to determine. Section 6.5.2 presents a methodology that would eliminate this problem at the site implementation stage. For certain factors it was impossible to predict whether the effects from impacts would be beneficial or non-beneficial. The prediction would need to be checked with the potentially-affected communities through community involvement at the site-selection stage. Each community would determine the importance/acceptability of impacts.

As mentioned above, not all of the thirteen social and community factors in the three existing reference communities were significantly affected by the project. Some factors were significantly affected in each of the communities, while others were not affected in any of the reference communities. In addition, certain factors were affected in some communities but not in others. The factors experiencing impacts differed somewhat between the existing communities and the new town.

According to the reference communities study, during the construction stage in the existing communities, the following social factors would experience impacts: economic base, employment and labour supply, health and safety, and social aspects. The data and criteria did not allow an evaluation of the significance of the effects on municipal finance and education.

TABLE 9-18
Comparison of Community Types Beneficial and Non-Beneficial Impacts from the Reference Communities Study

Community Type	Construction Stage		Operation Stage	
	Impacts	Evaluation	Impacts	Evaluation
Town	Employment & Labour Supply Social Aspects Education	+ - ?	Employment & Labour Supply Housing Transportation and Community Infrastructure Recreation/Tourism Social Aspects	+ - - ? -
Township	Economic Base Employment & Labour Supply Health & Safety Education Social Aspects	+ + ? ? -	Economic Base Employment and Labour Supply Health & Safety Housing Transportation Social Aspects	+ + ? - - -
County	Employment & Labour Supply Municipal Finance Education Social Aspects	+ ? ? -	Employment and Labour Supply Municipal Finance Municipal Services Transport Recreation/Tourism Social Aspects	+ - ? - - -
New Town	Population Employment & Labour Supply Social Services	- ? ?	Population Recreational/Tourism Health & Safety Social Aspects	? ? ? ?

+ beneficial impact
- non-beneficial impact
? unknown

(Stevenson 1983)

In the new town during the construction stage, the factor areas in which impacts would be likely to be felt were population, employment and labour supply, planning and social aspects.

In the operating stage, when all of the existing communities were considered, a total of eight of the thirteen social factors encountered impacts. These were economic base, employment and labour supply, municipal finance, housing and property values, municipal services, transportation and communication, health and safety, and social aspects, lifestyle and culture. Of these eight impacted factors, only three (employment and labour supply, transportation and communication, and social aspects, lifestyle and culture) were common to all three communities. The other impacts were specific to the communities.

In the new town, only three kinds of impacts were identified for the operating stage: employment and labour supply, education, and health and safety. From the analysis, using the preliminary criteria, these three factors appeared to be the major social and community factors to be considered when constructing a new town. However, these criteria were very limiting in this regard as they do not reflect the dynamics between community characteristics and project characteristics which ultimately determines socio-economic impacts.

4) Limitations of the Reference Community Analysis

The reference community study for the interim concept assessment (Stevenson 1983), although valuable at the time, has now been superseded due to changing approaches to social impact assessment. The following limitations of the study were identified:

i) the basic units of study were based on municipal structures (county, town, township). While these political jurisdictions must be taken into account in any impact assessment, they cannot be taken to represent the fundamental distinctions relevant to impact assessment. At the implementation stage, the community would be taken as the basic unit of study (see Sections 6.5.2.2 and 6.5.2.5). The community is defined, not in terms of political jurisdictions, but in sociological terms. Social structural characteristics and their indicators are considered necessary to the identification, evaluation and prediction of social impacts;

ii) the use in the study of 13 social factors as the framework for social impact assessment is divorced from the dynamics of the social context and, as well, are arbitrarily chosen, rather than analytically arrived at;

iii) in the reference community study, social change is considered as dependent upon external events (siting, influx of workers, decommissioning, etc.) as on social patterns within the life of the community or group that is undergoing change. In contrast, the implementation stage methodology presented in Sections 6.5.2.4 and 6.5.2.5 takes into account not only objective indicators of change, or impact, but also subjective ones. This means that a variable such as "influx of workers" (an objective measurement) will be complemented by the interpretation that the community members give of such an impact (for example: positive - "they will bring new vitality into our community"; negative - "our way of life will be ruined"; ambivalent - "we do not know what will happen".);

iv) the siting process assumptions of the 1983 study do not follow the principles of cooperativeness and fairness; and

v) radiological risk is not adequately addressed in the 1983 study. The present methodology incorporates risk as an integral factor in the analysis.

9.11.3 Discussion of Nuclear Energy Production Scenarios

Nuclear energy production in the future and the amount of used fuel produced will 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 will 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.

9.11.3.1 Present Status

In 1991, 50% of the electricity in Ontario and 16% of the electricity in Canada was being generated by CANDU reactors (Statistics Canada 1991). These reactors are operated by provincial utilities, as indicated in Table 9-19. As of March 31st 1992, 12.41 million kilowatts of total capacity was provided by

TABLE 9-19
Power Reactors in Canada (March 31st 1992)

Utility	Nuclear Generating Station	Number and nominal capacity of reactors with operating licences[1]	Rate at which used fuel is removed from reactors at 80% capacity[2] (bundles/year)
Ontario Hydro	Pickering A Pickering B Bruce A Bruce B Darlington A	4 x 500 MW (e) 4 x 500 MW (e) 4 x 750 MW (e) 4 x 840 MW (e) 1 x 850 MW (e)	13 900 13 700 25 340 25 340 6 335
Hydro Québec	Gentilly 2	1 x 600 MW (e)	4 560
New Brunswick Power	Point Lepreau	1 x 600 MW(e)	4 560
Total			93 735

[1] Data from AECB 1992
[2] Wasywich 1993

19 operating reactors and 2.55 million kilowatts of additional capacity would be provided by 3 reactors under construction. The typical rate at which used fuel is removed from these reactors has been about 94 000 bundles per year. Three other reactors, owned by AECL (Douglas Point, Gentilly 1, and NPD), have been permanently shut down at the end of their useful life.

A total of about 828 000 bundles of used fuel from power reactors were in storage in Canada as of January 1st, 1992.

9.11.3.2 Projections of Used Fuel Bundles Production

Three projections on future nuclear energy and consequent used fuel bundles production were made for purposes of the present analysis:

i) 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;

ii) there is a nuclear moratorium leading to the shutdown of all existing reactors by January 1st 1995; and

iii) 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.

These three nuclear energy production scenarios lead to the following used fuel bundles production:

i) the existing 828 000 used fuel bundles would be augmented by 93 735 bundles every year until the end of the stations' lives. For Ontario alone, this amounts to approximately 4 million used fuel bundles (Ontario Hydro 1988c);

ii) The existing 828 000 used fuel bundles would be augmented by 93 735 bundles every year until 1995, for a total of approximately 1.1 million used fuel bundles; and

iii) 10.1 million used fuel bundles would be produced.

9.11.3.3 Implications of Nuclear Energy Production Scenarios

The base-case analysis was conservatively based on a used fuel bundle production of 10.1 million used fuel bundles. The status-quo scenario or a nuclear energy moratorium by 1995 would drastically reduce this number. For most of the analysis, the impact would be proportional to the size of the facility, and to the number of used fuel bundles transported. It is, therefore, expected that for the other two scenarios of nuclear energy production, the impacts would be less than for the base-case analysis.

CHAPTER 10

10. POTENTIAL STRATEGIES FOR CONCEPT IMPLEMENTATION

This chapter describes the strategy and methods that would be used for the environmental and safety assessment at concept implementation.

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

i) the latter assessment would not be generic. Environmental and safety effects would be assessed based on site-specific project design; data from monitoring and sampling of a specific environment; and

ii) the latter assessment would be done in cooperation with local community/public, government agencies and scientist groups, and an ecological framework would be used for the environmental assessment (defined in the next sections); this would ensure that the assessment of the social and natural components of the environment would be integrated because decisions on parameters to study and monitor would take into accounts views and concerns of the community in addition to technical factors.

As undertaken here, both short and long-term effects of normal operation and accident conditions would have to be considered, as well as cumulative effects.

As discussed in Chapter 1, the objectives of an environmental assessment are:

i) to identify environmental effects;

ii) to identify practical measures that could be used to prevent, minimize and/or mitigate these effects; and

iii) to assess the significance of residual effects.

During concept implementation, the environmental assessment would be used as input to the decision-making. The assessment would start during the siting stage and lead to the submission, by the implementing organization, of an environmental assessment report to the appropriate provincial, federal or joint jurisdiction environmental assessment review process. The agency responsible for review of the environmental assessment would determine what further steps, e.g. public hearings, are necessary before a decision could be made on the project.

Because of its crucial role in the decision-making, it is important that an environmental assessment presents the relevant ecological and socio-economic information for consideration in siting and project planning. From an ecological perspective, a significant effect, within specific time and space boundaries, is 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. The assessment strategy should emphasize the role of the affected community in their determination of the significance of an effect on their local environment. In the same manner, significant socio-economic impacts also need to be determined with the participation of the affected public. The environmental assessment strategy would have to blend the ecological and social perspectives into an integrated environmental assessment process that would recognize the need to reconcile individual and community values with the scientific and technical requirements of an environmental assessment.

As mentioned in Chapter 1, the non-site-specific assessment presented in this report lacked both the ecological and the social context necessary for the prediction of full significance, and could only draw an indication of the potential significance of many of the identified effects.

10.1 ECOLOGICAL PERSPECTIVE

In order for the environmental assessment to have an ecological perspective, should adopt the following guiding principles:

i) consider the whole natural system, not just part of it;

ii) focus on the inter-relationships among the elements of the natural system;

iii) use a broad definition of environment, which includes the natural, social, cultural and economic environments;

iv) consider the natural ecological units and not just the political boundaries;

v) recognize the importance of species other than humans and generations other than our own;

vi) recognize the influence of local, regional and international activities; and

vii) recognize that there are limits to sustainability.

Following the approach outlined in Beanlands and Duinker (1983) for environmental assessments, the environment characterization at the site specific stage would be part of an assessment strategy with an ecological perspective. The strategy would consist of four basic steps:

i) ecological characterization;

ii) baseline studies;

iii) impact prediction; and

iv) monitoring of effects.

Within the four-step approach to environmental assessments, seven practical components are involved, also based on the above guiding principles. These components are:

i) Scoping and Ecological Characterization
At the beginning of the assessment process, an initial set of valued ecosystem components should be identified, in consultation with the regulatory agencies, the affected public, and scientific and technical experts to provide a focus for subsequent activities. This is normally accomplished through a scoping phase. In simple terms, it is necessary to find out what resources and natural environment components are important, and to whom.

ii) Establishing Baseline Conditions
The significance of changes in the valued ecosystem components needs to be determined with respect to existing conditions, referred to as the "baseline conditions". In simple terms, you need to find out what the current conditions of the important resources and natural components are. The baseline conditions are established through baseline studies. These must take into

account the high natural variability in many physical and biological phenomena. Use should be made of hypotheses of effects and studies should be designed to the required level of statistical certainty.

iii) Establishing Indicators for Monitoring Change and Baseline Monitoring
Indicators should be established to monitor change in valued ecosystem components. Baseline monitoring would be part of the overall long-term monitoring program that will eventually include emissions monitoring, environmental monitoring and effects monitoring.

iv) Establishing Temporal and Spatial Boundaries
Clear temporal and spatial boundaries should be established for the analysis of changes in valued ecosystem components. These boundaries must take into account the administrative boundaries of the potentially affected area, the spatial and temporal extent of the project (compared to those over which natural systems operate (the ecological boundaries)), and the limitations of the assessment and prediction methods.

v) Prediction of Effects
An explicit strategy for predicting effects should be developed to examine the interactions between a project and each valued ecosystem component, i.e. based on the results of the baseline studies, how the attributes would change as a result of the proposed project. Use could be made of conceptual and quantitative modelling to represent the natural systems and their relationships with project characteristics.

vi) Reliability of Predictions
Predictions of effects should be stated explicitly along with the basis on which they are made. The assessment should clearly distinguish between reasonably firm predictions, forecasts based on experience or professional judgement, and intuitive predictions.

vii) Monitoring of Effects
Recognizing the difficulties in predicting ecological events, it may be necessary to consider the entire project life-cycle in an integrated fashion and, therefore, design the baseline studies, predictions and monitoring programs around the need to verify hypotheses of effects.

10.1.1 Scoping and Ecological Characterization

Scoping of ecological and social factors can be done in an integrated fashion at scoping workshops, where technical, scientific and public concerns are taken into account. The early stages of the environmental assessment processes for the Little Jackfish River and Mattagami River Hydro-electric developments (Ontario Hydro 1988b; Ontario Hydro 1990b) provide examples of how these workshops shape the impact prediction studies.

Ecological characterization could include:

i) an identification of the key species on the basis of their ecological dominance, rarity, economic importance, and sensitivity;

ii) a definition of what could constitute a significant effect based on reductions in populations and the time required for recovery; and

iii) a basic knowledge of the spatial and temporal variability of measured variables that would help define the required baseline studies and the monitoring requirements.

Further details on ecological characterization are given in Appendix N.

10.1.2 Baseline Studies and Baseline Monitoring

Baseline environmental studies would be undertaken concurrently with the ecological characterization of the potential site(s). These baseline studies are designed to measure natural variation in the valued ecosystem components. The approach to baseline studies is defined in Appendix N. Results of these studies would be used for effect prediction.

In addition to the ecological characterization and the baseline studies, it is essential that a baseline monitoring program be established to document changes in specific indicators of the integrity of the "valued ecosystem components" identified during scoping. Details of baseline monitoring and its relationship with effects monitoring are included in Appendix N.

10.1.3 Predicting Effects

Social and ecological scoping will have determined the level of the ecological hierarchy to focus on for studies of effects and predictions. This is important because decisions regarding project approval and conditions of that approval would be based on predictions of changes resulting from the project.

Environmental effects would first be identified using standard methods, such as the following (Munn 1979):

i) checklists: comprehensive lists of environmental effects and impact indicators designed to stimulate broad thinking about possible consequences of proposed activities;

ii) matrices: a list of human actions are related to a list of impact indicators; the matrix can be used to identify cause-effect relationships; and

iii) flow diagrams: these are used to identify action-effect relationships - best suited for single project assessments.

The approach to predicting the magnitude or significance of effects should include:

i) adoption of a framework to determine the significance of effects in consultation with the public and other stakeholders; the reliability of a prediction should have a bearing on whether an estimated impact is considered significant;

ii) establishment of an approach to reduce prediction uncertainties;

iii) use of predictive models, as appropriate; and

iv) use of hypothesis testing.

As mentioned in Chapter 1, the determination of significance of identified adverse effects would be based on a number of factors such as:

i) magnitude of effects relative to some reference level(s) (e.g. regulatory criteria, guidelines, standards and practices, natural background levels, etc);

ii) geographical extent of effects (site-specific);

iii) duration and frequency of effects;

iv) degree of reversibility/irreversibility of effects;

v) ecological context (e.g. already affected by human/industrial development or fragile ecology with little resilience to additional stresses);

vi) case studies based on similar or relevant projects; and

vii) views and concerns of potentially affected public/community.

In addition, the significance of an effect can be determined using a number of methods, including:

i) many variables have established "stability windows" within which they naturally fluctuate. Exceeding these threshold values may be considered significant (Holling and Goldberg 1971; Holling 1973);

ii) the concept of "set value" determines the significance of an impact on the basis of magnitude. If a variable exceeds or is estimated to exceed a set value, then the effect is considered significant (Andrews et al. 1977);

iii) significance may be established with respect to the quantity or abundance of a resource or variable (Cooper and Zedler 1980). In this case, the boundaries beyond which a variable is considered excessive must be established early in the process; and

iv) significance can be established through the use of the resource allocation approach, where the maximum sustainable yield is allocated among competing uses. An effect would be considered significant if more of the resource were used than had been allocated (Sharma 1976).

10.1.4 Monitoring of Effects

Effects from a project should be monitored while they are actually occurring (in this case during the actual siting, construction, operation, decommissioning and closure of the facility). It is assumed that environmental assessment validation could also be part of the effects monitoring program. Impact predictions would be checked against results of the monitoring, and mitigation measures would be modified as appropriate. Such environmental assessment validations have been carried out as part of the Environmental Effects Reports for the Atikokan and Pickering Generating Stations (Ecological Services for Planning 1992; LGL Environmental Research Associates 1992).

The main benefits of environmental assessment validation are (Canadian Electrical Association 1985):

i) it enables predictions to be checked against real observations;

ii) it permits the environmental effects of the UFDC operation to be managed in a responsible and accountable manner;

iii) it improves the focus and cost-effectiveness of studies to monitor effects, and mitigation and compensation measures;

iv) it provides important information used to assess compensation claims; and

v) it minimizes ecological risk and costs: the cost-efficiency of operation would be improved by anticipating impacts and mitigation needs, thereby reducing the need for retrofit actions or technology to correct environmental problems.

Under the current Canadian Environmental Assessment Act, it is a requirement to examine the need for, and requirements of, a follow-up program for all types of environmental assessment, except screening. As well, the concept of auditing environmental assessments has been endorsed by the federal government (Munro 1987; Gardner 1989) and the Ministry of the Environment (1989). Since 1981, environmental assessment validation has been implemented for post-project evaluations of environmental assessment predictions (Munro 1987). Two other terms that have been used to refer to environmental assessment validation are post-development audit and environmental impact assessment audit. The first comparison of observed versus predicted effects in Canada was done for the Southern Indian Lake impoundment and diversion on the Churchill River (Heckhy et al. 1984). The scope was later expanded to other basins on the Churchill-Nelson Development (Bodaly and Rosenberg 1990).

10.1.5 Benefits of an Ecological Framework

An attempt to place the project in an ecological framework should result in a more focussed assessment by:

i) separating the project into manageable parts;

ii) providing a better focus on the nature and source of the perturbation;

iii) establishing time and space boundaries;

iv) recognizing the valued ecosystem components as the focus for the assessment;

v) allowing a logical progression in the study from physical-chemical to biotic attributes in the ecosystem; and

vi) taking into account functional ecological relationships, where possible.

10.1.6 Decision and Ecosystem Stress Models

During siting, it could be useful to use an environmental decision-making model to compare alternative sites. This type of decision model, based on a user-defined ranking system, is helpful in making the decision-making systematic and traceable. The other advantage is that it incorporates a large number of alternatives.

Following the ecological characterization and baseline studies, the environment under study will be known in sufficient detail to make use of an ecosystem stress model. Such models are being developed using existing databases of terrestrial and aquatic ecosystem stresses and ecosystem responses. The ecosystem stresses include pollution loading, land-use changes and resource extraction. The ecosystem responses include changes in productivity, number of species and species diversity, and disease incidence. This type of model would be a stress-response analytical framework for ecological decision-making. It is assumed that both types of models would have been fully developed and refined to support good ecological decision-making at the implementation stage.

10.2 SOCIO-ECONOMIC PERSPECTIVE

The analytical framework for a site-specific socio-economic impact assessment of the UFDC would be interactive and community based. Its main purpose would be to describe, qualitatively and quantitatively, the social and economic changes to surrounding communities that could result from the proposed UFDC. It would be designed to answer three basic questions:

i) what are the characteristics of the community?

ii) what impacts could the UFDC facility produce upon the community characteristics? and

iii) what capacity does the community have to mitigate or withstand, or otherwise manage, these impacts?

The main characteristics of an interactive socio-economic impact assessment framework would be as follows:

i) it would have a community focus and be rooted in the sociological concepts of social interaction and community (see Section 6.5);

ii) it would incorporate social science analysis and methods that would include both direct and indirect data (direct data is information directly obtained from people, and indirect data is information inferred from sources such as population statistics);

iii) it would be sensitive to people's values and concerns: an appraisal of the socio-cultural and moral values, as well as risk and concern over risk, is considered central to the framework; and

iv) it would be interactive: the input of those who form part of the social system that would be affected (communities, public) is indispensable and would be sought through social scoping and other methods, as outlined in Appendix N.

The social and natural environment analysis would be integrated by including the public in the decision-making process, thus allowing public concerns to be incorporated into the determination of the significance of effects on the natural environment. The "valued ecosystem components" approach is based on the value that people in the community, technical and scientific experts, and the regulators, attach to a given ecosystem component. The social impacts arising from changes in the environment would, therefore, be assessed at the same time as the environmental effects and the mitigation measures proposed would be directed at protecting all aspects of the environment.

The six objectives of the interactive socio-economic impact assessment of the UFDC are:

i) to provide a description of the social, cultural and economic life of the communities that could be affected by the proposed UFDC facility;

ii) to identify, describe and rank the direct and indirect impacts that the proposed undertaking would have on the communities;

iii) to indicate the capacity of the community to mitigate or manage negative impacts, and identify mitigating and other important impact management measures;

iv) to put this information in a format that can effectively be used in decision making;

v) to encourage information exchange and awareness in communities, and their involvement in the public discussion and decision-making process; and

vi) to distribute ownership of the problem and involvement in its solution to all stakeholders.

The assessment methodology would consist of:

i) describing the community: the community's self-description is a major component of the overall study;

ii) distinguishing the three main community characteristics: social and cultural vitality, economic viability and political efficacy. Each of these characteristics would be described using both direct and indirect indicators;

iii) describing impacts both in terms of direct (valuations) and indirect indicators obtained from the members of the community. These would provide categories of evaluation or significance; and

iv) rating communities according to these characteristics in order to determine their sensitivity to impacts, for purposes of siting and impact management.

A description of the standard methods used for human environment characterization and socio-economic impact assessment at the site-specific stage is included in Appendix N.

10.3 ASSESSMENT OF CUMULATIVE EFFECTS

Generally, environmental analyses of proposed development projects have, to date, examined the direct effects of a single action on a prescribed set of environmental components. Only recently have the accumulative nature of some effects, the nonlinear responses of some natural systems, and the linkages between single actions and other related development activities been recognized (Contant and Wiggins 1991). Thus, the assessment of cumulative effects has emerged, which expands the scope and scale of the environmental assessment process.

Cumulative effects (defined in Sonntag et al. 1991) are effects on the natural and social environment which:

i) occur so frequently in time or so densely in space that they cannot be "assimilated" individually; or

ii) combine with effects of other activities in a synergistic manner.

This section reviews the approach to the assessment of cumulative effects outlined in the FEARO guide (FEARO 1993), and its application to this non-site-specific assessment and to concept implementation.

10.3.1 Cumulative Effects and the UFDC

The Canadian Environmental Assessment Act requires the assessment of cumulative environmental effects of a project. The Federal Environmental Assessment Review Office has prepared a guide (referred to here as the FEARO guide) to help proponents in their assessment of cumulative effects for their project (FEARO 1993). Although the approaches and methods for assessing cumulative environmental effects are evolving, and much work remains to define the appropriate scope of assessments, the approach outlined in the guide has been considered for this concept assessment.

Environmental effects are often seen as isolated from one another. In reality, they interact and combine with each other in time and space. The importance of assessing cumulative impacts is closely linked to the assessment of significance of the environmental changes resulting from implementation of a project. In many cases, individual projects produce environmental effects that are insignificant in themselves but which, when combined with the effects of other projects, become important. In order to address cumulative effects, one has to take into account:

i) temporal and geographic boundaries;

ii) interactions between environmental effects of the project; and

iii) interactions between environmental effects of the project with those of other projects, including future projects that have already been approved.

Defining the temporal and geographical boundaries establishes a frame of reference for assessing the cumulative impacts (everything inside the boundaries is more important than everything outside) and may have implications for the depth of the analysis. According to the FEARO guide, if large boundaries are defined, only a superficial assessment may be possible, and uncertainty about the cumulative environmental effects would increase when long time frames are involved.

The geographic boundaries for the preclosure assessment are set by the host geological formation, i.e. the Ontario portion of the Canadian Shield. The temporal boundaries could extend for approximately 90 years, or more, from the beginning of the siting stage to the end of the closure stage. Assessment of cumulative effects from interactions between the UFDC and other projects occupying such extensive geographic and temporal boundaries would be speculative and is not attempted in this non-site-specific assessment. It can, however, be said (see Chapter 5 and 6) that the UFDC life-cycle activities may interact with a whole range of uses for the land surrounding the UFDC site (e.g. recreational, agricultural, industrial and forestry), and, therefore, the cumulative effects of UFDC activities on these land uses could vary widely depending on the actual location of the UFDC. Furthermore, the philosophy used for the UFDC was to minimize effects, and where quantitative assessment was possible (mostly for radiological impacts), the analysis showed that the environmental effects from the UFDC were only fractions of the regulatory limits. This implicitly allows for the possibility that there could be cumulative effects from surrounding land uses at the site.

The only cumulative effects that can be considered in this non-site-specific assessment are those arising from interactions between environmental effects of the UFDC itself. The cumulative effects considered were as follows:

Additive effects

Additive effects are effects from two or more independent activities associated with the disposal facility. The only additive effect that could be analyzed in a quantitative manner was the combined effect of used fuel transportation during the 41 years of operation of the facility, and of the transportation of buffer/backfill material to the facility during the same period.

The increase in truck traffic for road transportation of 250 000 bundles per year was estimated at a range of 10-12 trucks per day (accounting for full and empty trips). The buffer/backfill truck transportation traffic was estimated at 62-64 trucks per day. The combined activities would increase road traffic by about 72-76 trucks per day in the vicinity of the facility (assuming that the buffer/backfill and used fuel do not come from the same origin). The significance of this increase would depend on the existing traffic and the surrounding land uses. It is, however, large enough to warrant further investigation when the site location and traffic routes are known.

The increase in train traffic for rail transportation of 250 000 bundles per year is less than one train (4-6 railcars) per day. When combined with the 31-32 railcars per day that would be required for delivery of the buffer/backfill material to the facility, this would result in a total increase in rail traffic of 35-38 railcars per day. The significance of this increase would depend on the existing rail network traffic and the surrounding land uses.

Time-dependent Effects

Effects that could develop over time during the facility life-cycle, such as the socio-economic impacts of the build-up and decline of the workforce at the site, can be considered as cumulative effects. These are analyzed in Section 6.5 (and see below) as part of the socio-economic impact assessment.

Cumulative Effects in the Socio-Economic Impact Assessment

As mentioned in Section 6.5, the socio-economic impact assessment incorporates cumulative impacts because it looks at the holistic effect of the UFDC life-cycle activities on the dynamics of a community, as characterized through its socio-cultural vitality, economic viability and political efficacy. Given that these three main community characteristics are integrated, impacts on one community characteristic are often impacts on the other two (see Section 6.5 for examples).

Cumulative Effects in the Pathways Analysis

The pathways model, used in the public safety analysis under normal conditions (see Section 6.1), is in itself a cumulative model since it examines the cumulative impacts of radionuclides released to the atmosphere or to the lake on humans and biota. In that sense, the calculated dose is a cumulative dose.

10.3.2 Assessment of Cumulative Effects During Implementation of the Concept

Based on recommendations in the FEARO guide on cumulative effects (FEARO 1993), an approach should be devised for the assessment of cumulative effects during implementation. The approach would include the following steps: scoping; assessment of interactions within the project; assessment of interactions with other projects; determination of likelihood and significance; and mitigation and monitoring.

10.3.2.1 Scoping of the Cumulative Effects Assessment

Scoping of the cumulative effects assessment would be one aspect of the overall scoping exercise described in Section 10.1.1.

During this step, boundaries for the study of cumulative effects would be defined, based on :

- i) the size and nature of the project;
- ii) the availability of information and feasibility of collection of new information, if necessary;
- iii) the size and nature of past and future projects and activities, and the significance of their adverse environmental effects;
- iv) relevant ecological boundaries;
- v) relevant aquatic boundaries; and
- vi) relevant jurisdictional boundaries.

The FEARO guide emphasizes that the boundaries of a cumulative effects assessment should be reasonable. Consultation with the affected public during the scoping workshops would help to establish reasonable boundaries for the study. During scoping, issues would also be identified with stakeholders or participants in the project that would need to be addressed in the assessment of cumulative effects.

10.3.2.2 Assessing Interactions Within the Project

The implementing organization would consider the interactive effects of the following:

- i) changes that the project may cause to the environment;
- ii) effects on :
  - health and socio-economic conditions
  - physical and cultural heritage
  - current use of the lands and resources for traditional purposes by aboriginal persons
  - any structure, site or thing that is of historical, archaeological, paleontological or architectural significance, caused by changes in the environment;
- iii) changes to the project caused by the environment; and
- iv) the sum of the environmental effects caused by the project.

The interactive effects could be synergistic, additive or antagonistic.

The interactive and community-based framework discussed in Section 10.2 would help identify the cumulative interactions, since it would allow participants to bring their own perspective, expertise and focus together to develop a holistic view of the effects.

10.3.2.3 Assessing Interactions Between the Project and Past and Future Projects and Activities

Relevant past projects, their activities and their environmental effects must first be identified. The identification could be done using historical land use maps, fire insurance maps, assessment records, industrial directories, federal, provincial and municipal agencies' records, direct information from owners and operators of past projects, and data from local academic and research institutions. The absence of records of environmental effects could make this task difficult. Establishing good baseline conditions through baseline studies and baseline monitoring could achieve the same result: that is, an understanding of the state of the environment and the ecosystems present at the site prior to implementation of a project. The significance of the changes that would be imposed by the project could be determined if the remaining buffering capacity of these ecosystems is known (i.e. a fish species living in waters where the pH is at the maximum of its survival range would have no buffering capacity for a change in the pH of the water).

Next, future projects, their activities and their potential environmental effects must be identified. The identification could be done using the public registry of federal projects maintained under the Canadian Environmental Assessment Act, registries or files of environmental assessments maintained by provincial and/or municipal departments, and records of official plan amendments, zoning by-law amendments and other land use approvals held by municipal and provincial departments.

Assessment methods for cumulative effects assessments would vary depending on the scale and the estimated severity of projects' effects. At the simplest level, a qualitative assessment would be done using the best professional judgement based on experience. At the most sophisticated level, cumulative effects models would be used to predict impacts.

10.3.2.4 Determination of Significance and Likelihood of Cumulative Impacts

According to the FEARO guide (FEARO 1993), only the significance of cumulative environmental effects that are both likely and adverse need to be considered. It is, therefore, necessary to first determine if the effects are adverse, then to determine whether adverse effects are significant, and finally, to determine whether the significant adverse environmental effects are likely.

The determination of whether the effects are adverse is normally done by comparing baseline environmental data with predictions. The two most important parameters, when determining the likelihood of significant adverse environmental effects, are the probability of occurrence and the scientific uncertainty associated with the prediction of the effects. The determination of significance would be based on:

- i) the geographical extent of the adverse environmental effects;
- ii) the duration and frequency of the adverse environmental effects;
- iii) the magnitude of adverse environmental effects;
- iv) the degree to which the adverse environmental effects are reversible; and
- v) the ecological context.

Environmental standards, guidelines and objectives would be used to determine significance. If the level of an adverse environmental effect is less than the standard guideline or objective, then it may be considered insignificant. If it exceeds them, it may be significant. Such standards, guidelines and objectives do not exist for the full range of environmental effects (see Appendix C for a list of the standards that could be used during implementation).

10.3.2.5 Monitoring and Mitigation

Monitoring and mitigation of cumulative effects would be part of the impact management program for the disposal facility and the details of which would be negotiated with the community.

10.4 METHODOLOGY FOR PUBLIC SAFETY ANALYSIS DURING IMPLEMENTATION

The methodology used to assess the public safety for a particular site or group of sites would be basically the same as that in the generic analysis outlined in this report. During a site-specific assessment, it would be necessary to modify assessment models such as INTERTRAN, TADS, PREAC to suit the environmental characteristics of the site and transport routes under investigation.

At a particular site, local features such as terrain type, land use, weather patterns, aquatic and biotic data could be used to modify the assessment models, as necessary, and the measured data could provide site-specific values to the model parameters. For some exposure pathways, the models could be tested and validated at each site and compared with generic models and parameter values.

The site-specific analysis may remove some of the spatial uncertainty associated with the parameter values but it will not eliminate the need for probabilistic safety analysis, since many parameter values will continue to have some uncertainty due to temporal considerations and natural variability.

The following sections discuss some of the details of the site-specific assessment methodologies.

10.4.1 Routine Conditions at the UFDC

The behaviour of radionuclides in lake water has been modelled as a simple compartment with input from the used fuel disposal centre and output from water flow, radionuclide decay and sedimentation. In the latter process, radionuclides are removed from the water column to the bottom sediments, as a result of absorption of some radionuclides to particles in the water which settle to the lake bottom. Therefore, as radionuclides enter the lake water, they may build up in the sediments.

The radionuclide transfer from freshwater to fish has been modelled using a bioaccumulation factor (National Council on Radiation Protection and Measurements 1984; Canadian Standards Association 1987), which depends on radionuclide chemistry, water chemistry, turbidity, and the behaviour and species of fish (Poston and Klopfer 1986). The bioaccumulation factor can vary by several orders of magnitude (Poston and Klopfer 1986; Canadian Standards Assocation 1987) and, for some radionuclides, it is very dependent on water chemistry.

The bioaccumulation factor, or concentration ratio, has been defined using the ratio of the measured concentration of radionuclides in fish to the concentration of radionuclides in water. It could also be defined using the concentration of radionuclides in sediment instead of water. The conventional bioaccumulation factor is appropriate for pelagic, or open water species such as salmon and trout, and for radionuclides that do not absorb strongly onto sediments. A bioaccumulation factor based on sediment concentration may be appropriate for radionuclides that absorb strongly onto sediments, and for benthic fish species that feed along the lake bottom, such as catfish, or for fish species that feed on benthic organisms.

Consequently, the bioaccumulation factor for fish depends on the specific lake and associated chemistry, the radionuclides and their chemical form(s), as well as the particular species of fish. Therefore, more detailed and mechanistic modelling would be appropriate at the site-specific stage of the assessment.

10.4.2 Accident Conditions at the UFDC

A comprehensive assessment of risk from the UFDC operation was not possible at the generic stage because all the significant failure scenarios could not be identified from the conceptual design. Once a detailed design is available, fault tree analysis could be used to identify all the potentially significant accident scenarios (CSA 1991b). Furthermore, the UFDC is only one specific design.

10.4.3 Used Fuel Transportation Conditions

Detailed characterization of existing routes leading to potential used fuel disposal sites would be carried out during siting, to provide actual route data for the public safety analysis.

Typically, the data would include:

i) population densities in cities, towns and rural areas along the routes;

ii) number and locations of sensitive areas, e.g. nature reserves;

iii) number and locations of bridges, overpasses, river crossings etc.;

iv) potential accident black spots, e.g. intersections and other road features with high accident frequencies;

v) traffic characteristics and volumes; and

vi) potential stops, halts etc.

An assessment similar to that presented in Chapter 7 would be carried out for each candidate route.

1) Normal Conditions

The assessment would include an estimation of the maximum individual dose and collective dose from external exposure using, where possible, route-specific data on road widths, traffic densities, etc. Particular attention would be paid to stop locations and configurations. Any desirable operational constraints, such as restriction in parking locations, would be identified.

2) Accident Conditions

The assessment would include an estimation of potential radioactive releases in transportation accidents using updated information, an examination of accident frequencies, and calculations of individual and collective doses. Particular attention would be paid to accident frequencies for the candidate routes, accident causes and accident environments.

CHAPTER 11

11. SUMMARY AND 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 implementing the disposal concept. The assessment was based on a conceptual engineering design, the UFDC, which represents one technically feasible design. The assessment was to take into account practical prevention and mitigation measures. In addition, guidelines and analytical methods were to be identified for use in later site-specific assessments.

The reference environment under study was the Ontario portion of the Canadian Shield where the disposal facility was assumed to be located. For purposes of the generic analysis, the study area was divided into three regions: Southern, Central and Northern (see Figure 1-2). This study area was characterized at a generic level to provide some context for the analysis (see Chapter 3). Where possible, average environmental parameter values were derived for each of the three regions and used in the analysis.

The following factors limited the assessment:

i) lack of site-specific environmental data (i.e., no site selected);

ii) limited UFDC design details (i.e., only conceptual design);

iii) lack of precedent (this type of facility has never been built in Canada) although the conceptual design is based on available or achievable technology; and

iv) lack of consultation with local public (i.e., no site selected).

Given these limitations, the assessment was based on the available data, and standard safety and environmental assessment methodologies, and supplemented by analysis assumptions where necessary. These assumptions were explicitly acknowledged and uncertainties identified.

This chapter summarizes the potential effects on the natural environment (radiological and non-radiological) and socio-economic environment, as well as on workers, taking into account practical prevention and mitigation measures, based on the generic analyses and case studies presented in Chapters 4 to 8.

Finally, the conclusions at the end of this chapter take into account not only the results from Chapters 4 to 8, but also the results of the sensitivity analyses presented in Chapter 9.

11.1 SUMMARY OF POTENTIAL RADIOLOGICAL EFFECTS - NORMAL

11.1.1 Effects on the Public and the Environment

(1) Used Fuel Disposal Centre

No radiological impacts are expected during siting. The ^{222}Rn emission from UFDC construction is well within normal fluctuations in outdoor ^{222}Rn concentration and is, therefore, considered negligible. A dose rate in the order of 10^{-6} $Sv \cdot a^{-1}$ or less was calculated at the UFDC boundary from the routine operation of the UFDC. This is much less than 1% of the proposed AECB limit for the public. Using a risk coefficient of 5×10^{-2} Sv^{-1} (ICRP 1991), the health risk to the public of developing a fatal cancer from routine emissions from the UFDC would be about 10^{-7} a^{-1}.

The annual collective dose to the population within 100 km of the site has been calculated to be about 2 x 10^{-4} person-Sv·a^{-1} in each of the Northern, Central and Southern regions.

The annual doses to four general groups of non-human biota - fish, plant, mammal, and bird - were calculated to be 8.6 x 10^{-6}, 6.5 x 10^{-6}, 6.4 x 10^{-6}, and 6.4 x 10^{-6} Gy·a^{-1}, respectively, in all three reference environments, a few percent of the background dose from natural and fallout sources to aquatic and terrestrial organisms. The health risk to non-human biota is, therefore, minimal.

The radiological impact on the public and the environment from decommissioning activities are expected to be much smaller than during the facility operation since it would only be related to residual contamination when all the used fuel would have been emplaced (the used fuel, i.e. the major source of radionuclides, would have been emplaced).

(2) Used Fuel Transportation

For transportation of 250 000 bundles per year, the annual collective doses for various possible transportation routes are small, the largest being 0.13 person-Sv·a^{-1}. The maximum annual individual doses are 0.09, 0.0004 and 0.05 mSv·a^{-1} for the road, rail and water modes respectively, and are all well below the current regulatory limit for members of the public of 5 mSv·a^{-1} (AECB 1986). The highest estimated annual dose, 0.09 mSv·a^{-1} is for persons exposed to all the shipments at a truck stop, and could be controlled by monitoring, use of alternative truck stops, and choice of parking location. This maximum dose may also be compared with the dose due to natural background of approximately 3 mSv·a^{-1} (Neil 1985).

11.1.2 Effects on Workers

(1) Used Fuel Disposal Centre

The calculated annual routine radiological collective doses to workers associated with the operation of the UFDC vary between 6.3 person-mSv in the cask laydown area to 414.7 person-mSv in the transportation cask handling area. Using the ICRP (1991) risk factors, the chronic radiological occupational risks associated with used fuel disposal was estimated to be between 0.35 and 1.7 fatalities per 100 million person-hours worked. This is below the current Ontario Hydro occupational safety target of 3 fatalities per 100 million person-hours worked.

The maximum individual external dose received by workers at the UFDC has been estimated to vary from 6 mSv·a^{-1} to 17.5 mSv·a^{-1}. Although these doses were calculated using very conservative assumptions, and an over-estimate of dose rates and person-hours in some areas of the UFDC, they are lower than the current AECB regulations for Atomic Radiation Workers of 50 mSv·a^{-1} (AECB 1986). It is expected that the dose could be further reduced with design refinements following the ALARA (As Low as Reasonably Achievable) principle.

During decommissioning, the total estimated dose to workers for decontamination work is 13 person-mSv. 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 limit for Atomic Radiation Workers.

(2) Used Fuel Transportation

The maximum and average dose rate at 1 m from a road or rail cask, has been estimated to be 0.079 mSv·h^{-1}, and 0.044 mSv·h^{-1} respectively (Zeya 1993b). The AECB regulation dose limit of 0.1 mSv·h^{-1} at that distance, is therefore, not exceeded and a comfortable safety margin exists. During cask movement, the cab dose has been estimated to be 0.00153 $mSv \cdot h^{-1}$, a few percent of the International Atomic Energy Agency (IAEA) guidelines (IAEA 1990) limit. Although no specific limits exist for rail and ship crew locations, dose rates estimates in the caboose and on the tug/barge are well below the 0.02 $mSv \cdot h^{-1}$ specified for truck drivers.

The maximum annual individual doses received by members of the transport crews for road, rail and water are within the current Atomic Radiation Worker dose limit, currently set at 50 mSv per year (AECB 1986), and the proposed limit of 20 mSv (AECB 1991a).

Over the operating life of the transportation system, the total fatality risk due to radiological hazards varies from less than one to around 2 fatalities.

For each mode of transportation, the collective radiological risk of transporting the used fuel remains the same or increases slightly as the transport distance increases. This insensitivity to distance is because the majority of the dose (70-95%), and therefore the collective radiological risk, is incurred in handling casks at the nuclear generating station and at the transfer facility.

The rail cask, with its larger capacity and smaller number of shipments per year, results in the lowest labour requirements and, therefore, the smallest radiological risk. The water system, which requires additional cask handling at the transfer facility, has the highest labour requirement when used in conjunction with road transportation and, therefore, the greatest risk. Higher radiation doses due to the extra handling in the multi-modal water system is more than offset by use of the larger cask, for the water rail system. Maintenance and support labour contributes negligible risk in the transportation system. Although both worker groups would, in fact, receive a small yearly exposure, the nature of their work is such that it normally takes place in a non-radioactive environment.

11.2 SUMMARY OF POTENTIAL RADIOLOGICAL EFFECTS - ABNORMAL

11.2.1 Effects on the Public and the Environment

(1) Used Fuel Disposal Centre

The public adult and infant whole body doses from the postulated accident scenarios at the UFDC were estimated to be between about 10^{-7} and 10^{-4} Sv. The largest public dose was estimated to occur during accident scenario V2 (dropped fuel container in the vault and ventilation system failure) with an infant individual whole body dose of 2.5×10^{-4} Sv associated with an accident frequency of 3.0×10^{-4} a^{-1}. The largest thyroid dose was to an adult at 3.9×10^{-7} Sv. It is 10 times less than the annual natural background radiation dose in Ontario (approximately 3×10^{-3} Sv). The radiological impacts from the postulated accident scenarios are, therefore, expected to be very small.

When compared with the Protective Action Levels (see Table 2-2) in the Ontario Emergency Response Plan (Government of Ontario 1986), the estimated doses for each accident scenario are smaller than the lowest action level, corresponding to a ban on food and water consumption which would be triggered at a dose level above 5×10^{-4} Sv.

The preliminary analysis presented in this report shows that calculated accident frequencies and critical group doses are in compliance with the proposed regulatory limits accepted by the AECB for existing nuclear facilities. These requirements are considered to be a reasonable target for a disposal facility based on the conceptual design. Major potential hazards have been identified and it has been demonstrated that systems design using the quality standards and practices of the Canadian nuclear industry can ensure adequate protection of the public and the environment during the preclosure phase of the Used Fuel Disposal Centre.

A comprehensive assessment of risk from the UFDC operation is not possible unless all the significant failure scenarios are analyzed. In the present study, proven methods have been used to verify that the representative accident scenarios comply with the risk acceptance criterion. Further work is required with an optimized design to ensure that all the potentially significant accident scenarios have been examined.

(2) Used Fuel Transportation

The maximum individual dose calculated for severe accident conditions is 10 - 40 mSv. The annual frequency associated with the accident scenario leading to this dose is 10^{-6} or less. Since conservative parameters have been used in the assessment, this dose constitutes an upper bound. The significance of the estimated individual doses may be evaluated by comparison with the regulatory limits, and the reference levels used in emergency planning.

If we assume that the radiation dose limits used for the UFDC safety analysis also apply to the used fuel transportation analysis, the limits in Table 6-22 can be used. These limits are separated into event classes based on probability, class 1 being the more probable and class 5 the less probable. The worst case transportation accident, with a probability of 10^{-6}, would correspond to event class 5. Even the 40 mSv dose would only be a fraction of the 0.25 Sv or 250 mSv limit for that event class. The dose of 80 mSv is less than the upper Protective Action Level of 100 mSv, given in the Technical Bases of the Ontario Provincial Nuclear Emergency Plan, at which members of the public would be automatically evacuated, although it is above the lower Protective Action Level of 10 mSv, at which evacuation would be considered (Government of Ontario 1984).

The collective dose due to a very severe transport accident with a probability of $\sim 10^{-6}$ a^{-1} would be of the order of 1 person-Sv with an estimated exposed population of 10^5 persons. Again, this may be regarded as an upper bound. The potential effect on the health of the population may be examined by estimating the number of cancer deaths that might result. This calculation has been carried out in other assessments (e.g. Clarke and Shaw 1983; Neuhauser et al. 1984). Using the risk coefficient of 5×10^{-2} fatal cancers per person-Sv (ICRP 1991), the number of fatal cancers resulting from a very severe transportation accident is 0.05. This number is likely to be much smaller than the number of fatalities from conventional causes in such a severe accident, as discussed in Grondin (1993b).

The level of public risk associated with sabotage or theft and with barge sinking was also examined. The likely consequences of a sabotage or a barge sinking would be of the same order of magnitude as for a severe transport accident. Given the low probability of these events, the additional risks due to sabotage and barge sinking should not significantly increase the risk associated with transport accidents.

11.2.2 Effects on the Workers

(1) Used Fuel Disposal Centre

The worst case accident at the UFDC surface facilities (in the transportation cask handling area) was estimated to result in whole body and thyroid doses to an individual worker of 16.5 mSv and 7.5×10^{-3} μSv respectively, from the inhalation pathway. External radiation dose is not expected because the used fuel is still contained in the cask which provides appropriate shielding.

The worst case underground accident (at the bottom of the waste shaft) was estimated to result in whole body and thyroid doses to an individual worker of 20.49 mSv and 9.0 x 10^{-3} μSv respectively. The pathway for the radiation dose is again through inhalation because workers would be unprotected at that work location. External radiation dose from such an accident would be negligible since it is expected that only volatile radionuclides and particulates would be released.

There is no regulatory limit on the occupational radiation dose under accident conditions. Occupational dose and dose rate design criteria for nuclear facilities provide guidance to the levels of radiation dose that would be acceptable under accident conditions. Radiation doses estimated for UFDC workers under accident conditions are well below the limit of 30 mSv considered acceptable for nuclear generating stations.

(2) Used Fuel Transportation

The maximum acute radiological dose to a worker was estimated to be approximately 4 times the Atomic Radiation Worker limit. This is assuming that the worker (driver or crew) survived the conventional hazard of the accident, and crediting the emergency response team for removing the worker from the accident scene in the first hour following the accident.

Given the low probability of this accident, the expected number of fatalities per year amongst workers resulting from radiological hazards during used fuel transportation accidents was estimated to vary from 2 x 10^{-9} to around 50 x 10^{-9} depending on the transportation mode and distance travelled.

11.3 SUMMARY OF POTENTIAL NON-RADIOLOGICAL EFFECTS

11.3.1 Effects on the Public and the Environment

(1) Used Fuel Disposal Centre

The potential non-radiological effects on the environment from UFDC activities are summarized in Tables 11-1, 11-2 and 11-3 for the construction, operating and decommissioning phases respectively.

(a) Siting

Most of the effects from site characterization activities would be short term and could be mitigated with sound environmental practices.

(b) Construction

Air Quality

Dust would be the major emission from construction activities. These emissions should have minimal effects on air quality because their short-term and localized nature could be mitigated by using dust suppression techniques such as watering.

Water Quality

The major effects on water quality during construction are likely to be associated with the construction of the water supply intake and discharge facilities, specially if dredging and blasting are required. Depending on the characteristics of bottom sediments and the shoreline, these activities may result in prolonged elevated turbidity levels and in the localized impairment of benthic communities and fish spawning beds. Many of these effects are

TABLE 11-1
Potential Impacts of UFDC Construction

Affected Factors		Potential Degree of Impact** Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust	√			
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water	√			
	- Ground Water		√		
LAND USE	- Protected Lands*	√			
	- Med/High Yield Forest		√		
	- Agricultural	√			
	- Recreational		√		
FLORA/FAUNA	- Vegetation		√		
	- Wildlife		√		
	- Threatened or Endangered Species	√			
	- Forest Fires		√		
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Concrete			√	
	- Stainless Steel			√	
	- Other Metals			√	
	- Lime, Silica, Gravel			√	

* includes lands with identified important historical/cultural features, Indian lands, parks etc.

** the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

TABLE 11-2
Potential Impacts of UFDC Operation

Potential Degree of Impact**					
Affected Factors		Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust	√			
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water		√		
	- Ground Water			√	
LAND USE	- Protected Lands*				√
	- Med/High Yield Forest			√	
	- Agricultural			√	
	- Recreational			√	
FLORA/FAUNA	- Vegetation			√	
	- Wildlife			√	
	- Threatened or Endangered Species			√	
	- Forest Fires		√		
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Bentonite Clay		√		
	- Glacial Clay		√		
	- Titanium			√	
	- Carbon Steel			√	
	- Silica Sand and Glass			√	

* includes lands with identified important historical/cultural features, Indian lands, parks etc.

** the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

TABLE 11-3
Potential Impacts of UFDC Closure and Decommissioning

		Potential Degree of Impact**			
Affected Factors		Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust		√		
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water		√		
	- Ground Water			√	
LAND USE	- Protected Lands*				√
	- Med/High Yield Forest			√	
	- Agricultural			√	
	- Recreational			√	
FLORA/FAUNA	- Vegetation				√
	- Wildlife				√
	- Threatened or Endangered Species			√	
	- Forest Fires			√	
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Top Soil			√	

* includes lands with identifed important historical/cultural features, Indian lands, parks etc.

** the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

expected to be of a temporary nature and can be minimized by scheduling the blasting activities away from the spawning season. Experience from construction of thermal generating stations suggest that after construction activities cease, recolonization of disturbed areas would occur rapidly, generally within a month. The effects of the elevated turbidity levels would depend on the duration and methods of the construction activities, elevated turbidities from long construction activities being more likely to cause a lasting impact on the aquatic life.

Land Use

The construction of the UFDC would displace existing land uses or prevent the land from being used for other purposes. Potential effects on the following land uses have been examined: protected lands (parks, Indian lands), medium to high yield forest harvest areas, agricultural land, and land used for recreational purposes. Effects on forest harvest areas should be small given the small size of the facility compared to active timber harvesting areas. Assuming that lands of low intensive recreation use capability (>70% of regions) would be the most likely to be chosen for the disposal facility site, disruption of recreational activities should be minimal. Protected lands by definition would be protected under various legislations and should be avoided. Protective measures may be necessary to ensure that any sensitive natural or historical features identified near a site, are not damaged, degraded or destroyed.

Flora and Fauna

Construction activities would disrupt the natural vegetation cover, and displace wildlife. Most of the wildlife species in the study area are considered to be regionally common and their displacement should have a minimal effect. The habitat for threatened and endangered species of plants and animals should be avoided when locating the facility. Six, three and five species of plants are considered to be rare, threatened or endangered in the Northern, Central and Southern regions, respectively. Thirty, 34 and 39 species of wildlife are considered to be rare or threatened for these three regions, respectively. Off-duty hunting by the construction workforce could affect the local wildlife. Construction traffic could increase road kills.

Since forest fires can be directly influenced by the presence of humans in the environment, the construction activities and associated population influx into the area may contribute to an increase in the number of forest fires.

Noise

Access control around the disposal facility would attenuate site construction noise before it reaches any surrounding community. The noise from the construction vehicles, and access road/railway construction activities could have a short-term noise effect.

Non-Renewable Resources

Of the non-renewable construction materials (concrete, carbon and stainless steel (plus constituent materials), copper, bituminous paving and aluminium) required for the UFDC, a few of them (namely copper and chromium) may potentially be in short supply during the expected construction of the centre. This should be considered and alternative materials evaluated in order to prevent a significant impact on the future reserves.

(c) Operation

Air Quality

The sand, gravel and bentonite clay storage and the mined rock crushing and transfer operations are done in enclosed areas, thus reducing the potential for dust emissions during operations. The only source left is the waste rock area. The dust emissions would depend on the size of the rock particulates and consequently on the blasting technique used. This would need to be considered at the site-specific stage.

Water Quality

Any effects on the water quality would be associated with operation of the water supply system, in conjunction with site runoff. It is assumed that the facility would be equipped with sufficient water treatment capability and run-off control to prevent degrading of existing water quality. Moreover, water recycling would be part of the design philosophy and would reduce the water requirements.

Land Use

Provided that areas which have been cleared during construction are landscaped and planted with new vegetation to minimize any erosion potential, only soil stability may be altered in the operation stage by waste rock disposal and backfill storage activities.

Flora and Fauna

The same kinds of effects as during construction are expected in the operating phase of the facility, but to a much smaller extent.

Noise

Noise from vehicles travelling to and from the site is expected to be the most disruptive operational noise effect. Controls, such as muffling devices, would be employed as necessary to minimize excessive noise from these operations.

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 these 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 without affecting the current supply of bentonite.

(d) Decommissioning

In general, the potential effects of decommissioning would likely be less significant than either construction or operation. In many respects, much of the effect would have already occurred. Aspects such as the development of an active decommissioning waste disposal facility and the new use of the site after release are, perhaps, the only different environmental considerations which would need to be addressed at the site specific stage.

(2) Used Fuel Transportation

The transportation activities considered are the actual transportation, the construction and operating of a transfer facility (TF) to transfer fuel from the water mode to either the rail or the road mode, and the eventual construction and maintenance of an access road/railway to the disposal facility. The potential non-radiological effects are summarized in Tables 11-4, 11-5 and 11-6, for these three types of activities respectively.

(a) Air Quality

Combustion gases from the transportation vehicles are expected to have minimal effects on the existing air quality. Short-term dust emissions from transfer facility and access road/railway construction can be reduced by using control measures such as watering, and are not expected to be a problem.

(b) Water Quality

Channel dredging to provide navigable access to the transfer facility could affect water quality and cause disruption of the aquatic habitat. Soil erosion from access road/railway construction activities, with the resultant sedimentation of water bodies, can affect water quality and disrupt aquatic communities. Dust control, de-icing agents and herbicides applied near water bodies could affect the water quality. These effects can, however, be mitigated by careful siting of the transfer facility.

(c) Land Use

Given the small magnitude of the traffic (< 6% on average) and noise (< 1 dB(A) on average, < 5 dB(A) maximum) increases from used fuel transportation, they should have minimal effects on existing land use. Roads operating at or near full capacity might, however, be affected even by the small used fuel transportation traffic (7 trucks/day including return). Local populations could become annoyed with the increased noise and traffic in residential areas with low existing traffic.

(d) Flora and Fauna

Provided that environmentally sensitive areas are given special consideration, minimal effects on local biota are expected to result from transportation, and transfer facility and access road/railway construction and operation activities. The activity with the highest potential for effect is the eventual maintenance dredging of the access channel to the transfer facility. Provided that dredging is scheduled outside the spawning season, the effects on the local fish population are expected to be small.

(e) Availability of Non-Renewable Resources

Given that none of the non-renewable materials committed for used fuel transportation, and transfer facility, and access road/railway construction and operation are currently in short supply, and that they have substantial reserves for future use, no effect on their availability is expected.

(f) Traffic Accidents

It is expected that higher standards of driver training and vehicle maintenance would act to minimize the frequency and severity of traffic accidents involving a used fuel transportation vehicle. In the event of an accident, the transportation emergency response provisions should reduce disruption to the local traffic flow.

TABLE 11-4
Potential Impacts of UFDC Fuel Transportation

Affected Factors		Potential Degree of Impact*: Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust			√	
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water			√	
	- Ground Water			√	
LAND USE	- Residential	√			
	- Industrial/ Commerical		√		
	- Recreational		√		
	- Agricultural		√		
	- Historical/ Archaeological		√		
FLORA/FAUNA	- Aquatic Plants			√	
	- Fish			√	
	- Wildlife		√		
	- Waterfowl			√	
	- Vegetation			√	
	- Wetlands			√	
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Stainless Steel Constituents			√	
	- Other Metals			√	
	- Lime, Silica, Gravel			√	

* the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

TABLE 11-5
Potential Impacts of Remote Transfer Facility Construction and Operation

Affected Factors		Potential Degree of Impact*			
		Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust	√			
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water	√			
	- Ground Water			√	
LAND USE	- Residential		√		
	- Industrial/ Commerical			√	
	- Recreational		√		
	- Agricultural		√		
	- Historical/ Archaeological	√			
FLORA/FAUNA	- Aquatic Plants		√		
	- Fish		√		
	- Wildlife		√		
	- Waterfowl		√		
	- Vegetation		√		
	- Wetlands		√		
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Stainless Steel Constituents			√	
	- Other Metals			√	
	- Lime, Silica, Gravel			√	

* the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

TABLE 11-6
Potential Impacts of Access Road/Railway Construction and Maintenance

Affected Factors		Potential Degree of Impact* Sign Negative	Minor Negative	No Effect	Positive
AIR QUALITY	- Dust	√			
	- Emissions		√		
	- Noise		√		
WATER QUALITY	- Surface Water	√			
	- Ground Water			√	
LAND USE	- Residential	√			
	- Industrial/ Commerical			√	
	- Recreational		√		
	- Agricultural		√		
	- Historical/ Archaeological	√			
FLORA/FAUNA	- Aquatic Plants		√		
	- Fish		√		
	- Wildlife		√		
	- Waterfowl		√		
	- Vegetation		√		
	- Wetlands		√		
NON-RENEWABLE RESOURCES AVAILABILITY	- Diesel Fuel			√	
	- Stainless Steel Constituents			√	
	- Other Metals			√	
	- Lime, Silica, Gravel			√	

* the "Potential Degree of Impact" indicates areas where careful attention would have to be paid to mitigate the potential impacts, although the analysis has shown that, with appropriate mitigation measures, there would likely be no effect or, at worst, minor negative effects.

11.3.2 Effects on the Workers

(1) Used Fuel Disposal Centre

Work routines during all phases of UFDC activities are assumed to be such that the regulatory limits for other industrial risks, such as noise and pollution, to protect workers' health would be met. Protective equipment, such as hearing protection, would be provided in adverse environments. The routine non-radiological risk to workers is, therefore, expected to be negligible.

The projected occupational injury and fatality rates vary from 0.00004 to 0.06065 fatalities per year and from 0.009 to 12.295 injuries per year for above ground activities, depending on the specific activity. Similarly, the below ground activity figures vary from 0.00038 to 0.08627 fatalities per year and from 0.129 to 7.052 injuries per year. The rates are based on Ontario industry statistics (Myint 1989) and where relevant are adjusted to reflect the better safety record of the nuclear industry and crown corporations in general (i.e. Ontario Hydro fatal accident history vs the general Ontario industry).

(2) Used Fuel Transportation

The levels of atmospheric emissions, noise and vibrations are not expected to exceed the regulations limit. The majority of non-radiological risks of transporting used fuel results from the actual movement of the casks. The estimated fatality risks vary from 2.2 to 6.6 fatalities per 10^8 person-hours.

11.4 SUMMARY OF POTENTIAL SOCIAL, CULTURAL AND ECONOMIC IMPACTS

11.4.1 Impacts on the Community

As discussed earlier, the significance of the identified socio-economic impacts cannot be determined without the social context in which the project is taking place, i.e. without input from the potentially affected public and communities. A similar argument can be made about residual impacts.

It can, however, be said that unexpected, residual impacts are likely to occur, despite the application of impact management, as with any large-scale project. For this reason, it is necessary to have an impact management program that is flexible: i.e. open to the identification of new impacts and ready to be creative in finding and implementing appropriate mitigation measures. The key to this readiness lies in:

i) the active participation of the recipients of such impacts, that is, the community, in continuous environmental, socio-economic and health impact monitoring and management programs; and

ii) the periodic review of impact management strategies and programs.

Concerns over possible impacts to public health and safety can be considered an important source of residual impact, considering that the risk of radiological contamination, however very small, has been a source of public concern in the past. It is important, therefore, to have an impact management program that is responsive to health and safety concerns. Three possible measures are:

(i) continuing public and occupational health and safety monitoring, preferably linked to regulatory or academic health establishments;

(ii) continuing community laison and joint planning; and

(iii) encouragement of scientific research at the UFDC, especially radiological research by national or international scientific institutions.

11.4.2 Provincial and National Economic Effects

(1) Used Fuel Disposal Centre

The impacts on the provincial economy associated with expenditures and employment during the various stages of a conceptual UFDC are sizeable in Ontario. In comparison, however, the impacts stemming from the various expenditure categories have a small impact on the rest of Canada.

The economy-wide NPV GDP and employment impacts in Ontario would be about $4,789 million and 329,000 person-years. On average, these impacts represent less than 0.1% of the annual provincial GDP and labour force.

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

(2) Used Fuel Transportation

The employment impacts vary from 4 600 to 35 700 person-years depending on the transportation mode and destination, while the GDP impacts vary from $44 to $331 million (1990$ NPV). The analysis also shows that the economy-wide impact was directly proportional to the initial costs of equipment, the distance travelled and the maintenance/operating costs of the particular mode under study.

11.5 SUMMARY OF SECURITY AND SAFEGUARDS

(1) Used Fuel Disposal Centre

A review of the UFDC safeguards provisions, developed by AECL (Simmons and Baumgartner 1994; AECL CANDU et al. 1992) shows that they would satisfy the AECB and IAEA safeguards requirements in all the UFDC life cycle phases. Sufficient variety of overlapping safeguards provisions and equipment redundancy are provided such that instrumentation readings, failures and false alarms can be verified against other safeguards instruments and procedures. The safeguards system design would allow for reliability and availability of instrumentation when a disposal centre is constructed. These provisions are considered to satisfy the AECB and IAEA safeguards requirements.

Consideration is also given to the possibility that theft or sabotage of the used fuel or UFDC facilities could take place. Based on the current social climate in Canada, the incident-free application of nuclear power in Canada for about 40 years and the security provisions provided, the probability of a successful illegal act of theft of used fuel or sabotage at UFDC facilities is considered to be small. The dangerous radiological nature of the used fuel and the amount of technical knowledge necessary to extract plutonium from used CANDU fuel also make the used fuel an unattractive target.

(2) Used Fuel Transportation

Because of the highly radioactive nature of the used fuel, a module of used fuel is considered to be self-protecting under the AECB security regulations and as such does not require special security provisions. Nevertheless, security guidelines have been devised regarding cask labelling, emergency response procedures, personnel screening, drivers/escorts training, communication and maintenance of a transportation log.

Here again, the transportation package is a relatively unattractive target for theft or sabotage, primarily because of its weight (35 Mg for the full road cask) and of the highly hazardous nature of its content.

11.6 CONSIDERATION OF CUMULATIVE EFFECTS

The approach to cumulative effects assessment developed by the Federal Environmental Assessment Review Office (FEARO 1993) was applied, as much as possible, to this non-site-specific study and to concept implementation (see Section 10.3). The FEARO approach suggests that cumulative effects can be addressed by taking into account:

i) the temporal and geographic boundaries for the project;

ii) interactions between environmental effects within the project; and

iii) interactions between environmental effects of the project with those of other projects, including future projects.

Given the large extent of the geographical area (study area of 650 000 km^2), and of the temporal boundaries (the time frame for implementation is some time after the year 2000 and the duration of the project is some 90 years or more), it was not possible to assess the influence of other projects. The following interactions within the project are assessed in terms of cumulative effec ts:

(1) The additive effects of transporting used fuel and buffer/backfill material

The cumulative traffic increase was calculated to be about 72-76 trucks per day for the road or 35-38 railcars per day for the rail. The significance of this increase would depend on the existing traffic and the surrounding land uses, and cannot be determined in this non-site-specific assessment.

(2) The time dependent effects of work force fluctuations

The cumulative effects of the change in workforce from one stage of the project to the next are integrated in the socio-economic impact assessment.

(3) The cumulative effects of various pathways

The model used in the public safety analysis takes into account the cumulative effects of various pathways.

Considerations of cumulative effects during implementation are discussed in the next section.

11.7 STRATEGY FOR LATER SITE-SPECIFIC ASSESSMENT

The environmental assessment strategy would include the following elements:

1. Scoping and Ecological and Community Characterization

   Ecological and social scoping would be done at the beginning of the assessment process, in consultation with the affected public, scientific experts and regulatory agencies to identify an initial set of valued ecosystem components and to decide what to characterize. Starting with site screening, the strategy would be to involve potentially affected communities and other stakeholders in a shared decision-making process that would identify issues and involve all stakeholders in the resolution of issues.

2. <u>Establishment of Baseline Conditions</u>

Ecological and socio-economic baseline conditions would be established to provide some context for the assessment of significance of effects. Together with the characterization information, establishment of these baseline conditions would help determine the capacity of the ecosystems and community to withstand change.

3. <u>Establishment of Indicators for Monitoring Change and Baseline Monitoring</u>

Socio-economic and ecological indicators would be established to monitor change and baseline monitoring would take place.

4. <u>Establishment of Temporal and Spatial Boundaries</u>

Clear boundaries would be established for the assessment of effects. Boundaries for the study of cumulative effects would also be established.

5. <u>Effects Predictions</u>

Interactions between a project and 1) valued ecosystem components, and 2) the community social and cultural vitality, economic viability and political efficacy would be identified and effects estimated. Assessment of socio-economic impacts would be interactive and focus on the community. The appraisal of socio-cultural and moral values, as well as risk, and concern over risk, would be of primary importance. Significance of the identified effects would be determined based on a comparison with standards and guidelines, the geographical extent, the duration and frequency, the degree to which they are reversible, comparison with natural background levels, and the ecological and social context.

Cumulative effects assessment would be done by assessing the interactions between environmental effects within the project, and the interactions between the project and past and future projects and activities.

6. <u>Prediction Reliability</u>

The certainty of effects predictions should be clearly stated and would be taken into account in the decision making.

7. <u>Effects Monitoring</u>

Monitoring of effects, including cumulative effects, would be done to verify predictions and to ensure that impact management measures are effective.

The safety assessment methodology would be fairly similar to the one presented in this report, except for the use of site-specific environmental parameters and more detailed design parameters.

11.8 CONCLUSIONS

The following conclusions are based on the results of the analyses presented in earlier chapters and on the assumptions that the implementing organization, when finalizing the design and work procedures and setting up the management structure for the UFDC and transportation system, would adopt:

i) a defence-in-depth safety philosophy;

ii) an ALARA approach regarding emissions and exposure to public and workers;

iii) an environmental protection policy (as outlined in Appendix C);

iv) a health and safety policy and program (as outlined in Appendix H);

v) a public involvement policy (as outlined in Chapter 1); and

vi) a thorough quality assurance program.

(1) In general, the kinds of effects associated with the preclosure phase of disposal concept implementation, identified in the foregoing analysis, are not unique. They are similar to those encountered at large civil engineering projects, 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.

(2) With respect to handling and transportation of nuclear materials, there is also a large body of knowledge and experience to draw from, in Canada and worldwide. The proven safety record of transportation casks, designed to meet stringent regulatory performance requirements, provides assurance that used fuel transportation can be carried out in a safe manner. Driver training, equipment maintenance and safety standards should contribute to reduce the probability of transportation accidents. Emergency response provisions would reduce any potential consequences.

(3) More specifically, analysis has shown that, based on the reference UFDC design, the radiological impacts on the public under normal conditions at the UFDC would be well within the limits specified in the Atomic Energy Control Regulations. Radiological doses to individual members of the public from normal UFDC operation were estimated to be at least three orders of magnitude less than natural background radiation dose. Radionuclide concentrations in air, water and soil were estimated to be a small percentage of the naturally occurring concentrations. Radiological doses to non-human biota were estimated to be several orders of magnitude below background levels.

(4) Analysis of the safety features of the reference UFDC design has shown that public radiation exposure, in the event of an accident at the disposal facility, would still be below limits which the AECB has accepted for existing nuclear facilities. Based on analysis of a range of accident scenarios, the maximum exposure level would be less than 10% of the annual exposure from natural background radiation.

(5) The used fuel transportation system would be designed to meet all requirements of the Atomic Energy Control Board (AECB), Transport Canada and the International Atomic Energy Agency (IAEA). The analysis has shown that radiological impacts to the public during normal transportation would be well within the limits specified in the Atomic Energy Control Regulations. Individual doses from normal

transportation were estimated to be a small percentage of the background radiation dose.

(6) Safety against transportation accidents was addressed from several perspectives: package design and regulatory compliance, transportation accident statistics, the role of emergency response plans and radiological impacts of postulated accidents. The maximum individual dose calculated for severe accident conditions, with a frequency of 10^{-6} or less, is 10 - 40 mSv. This is within the safety criteria currently used by the AECB for nuclear generating station licensing.

(7) Radiation exposure of workers at the disposal facility, even with the conservative analysis used in conjunction with the current non-optimized reference design, would be expected to be well below the AECB limit for Atomic Radiation Workers under normal operating conditions. Exposure under accident conditions would be below the limit used at nuclear generating stations as an emergency safety guide. The refinement of system designs and work procedures at the implementation stage could reduce worker exposure further.

(8) Despite the foregoing conclusions, the potential for radiological impacts likely would be of concern to people who live in and around the UFDC site and along the routes. These concerns could remain a potential source of significant social, cultural and economic impacts.

(9) The socio-economic impact assessment has been limited by the absence of a site, routes 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 actual 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.

(10) The most positive socio-economic impacts of the UFDC would likely be (a) permanent isolation of hazardous materials from humans and their environment and (b) positive economic impacts associated with any large-scale project: employment and stimulation of the local economy. Due to the relatively long time span of UFDC construction and operation, there is the potential of long-term employment and associated economic development. The long time frame of the UFDC can represent an advantage over most large-scale projects which are more vulnerable to resource depletion and market fluctuations. There are, however, possible negative economic impacts which must be avoided or mitigated. Any positive impacts associated with the transporting of used fuel would be of smaller scale.

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

(12) Northern communities and Aboriginal communities have particular dimensions that make them more susceptible to impacts resulting from changes caused by construction and operation of a used fuel disposal centre, and used fuel transportation. Such potential impacts should be given special attention during implementation.

(13) The economic costs for the disposal system (including transportation) would be substantial. However, Ontario Hydro, Hydro-Quebec and New Brunswick Power are charging current electricity consumers to cover the future costs of used fuel management.

(14) Analysis of the non-radiological aspects of disposal system implementation has shown that the effects on the public, workers and the environment under normal and abnormal conditions would be mitigable with known technology and practices. Even at this conceptual design stage, it can be concluded that operation of a disposal system can protect the public, workers and the environment.

(15) Although the total land area required for the UFDC would be relatively large (17 km^2 including access road), most of it would not be developed, but used as a buffer. Protective measures may be necessary to ensure that any sensitive natural or historical features identified near a site are not damaged, degraded or destroyed during any stage of the UFDC life-cycle.

(16) The quantities of excavated rock to be disposed of would be large but not unprecedented in mining operations. However, no toxic runoff would be expected from the waste rock pile. Re-use of the rock as aggregate would reduce possible effects.

(17) Sensitive environmental areas, of ecological, geological, historical or cultural value, would be avoided as much as possible during siting. However, if any of these features were found on the site, protective measures and experience are available to ensure that the features would be preserved.

(18) Except for bentonite clay, none of the materials required for construction and operation of the UFDC 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.

(19) Provided that environmentally sensitive areas are given special consideration, minimal effects on local biota are expected to result from transportation, transfer facility or access road/railway construction and operation activities.

(20) In general, the potential effects of decommissioning would likely be less significant than either construction or operation effects. The possible extended monitoring period, prior to closure, would provide additional time for joint planning of a program to manage the impacts which may be caused by closure of the disposal facility.