NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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Nuclear Waste Management Organization

Incorporation of Seaborn Panel Recommendations and Insights in work of the NWMO

NWMO

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Introduction

The Seaborn Panel was an Environmental Assessment Panel chaired by Blair Seaborn which examined the disposal concept for used nuclear fuel management proposed by Atomic Energy of Canada Limited (AECL) between 1989 and 1998. Its report, entitled *Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel,* was published in February 1998. The report contained an assessment of the disposal concept proposed by AECL as well as a set of conclusions and recommendations concerning the path forward for Canada on this issue.

In the course of its work, the NWMO Advisory Council asked the NWMO to explain how it had incorporated the recommendations from the Seaborn Panel, and the insights from the Panel's hearings, in the design and implementation of the NWMO's study. This report contains the substance of the response of the NWMO to the Advisory Council to this series of questions. Much of this material was prepared and discussed with the Advisory Council in early 2005, anticipating the release of the *Draft Study Report*. It reflects the thinking of the NWMO at that time.

The response to the Advisory Council's questions was in four parts:

- Part I - The conclusions, criteria outlined, and recommendations from the Executive Summary of the Panel report are listed and briefly discussed in the context of the NWMO study.
- Part II – Review of key clauses in the Seaborn Panel report about 'safety', in particular the concept of 'social safety', and brief discussion in the context of the NWMO study.
- Part III - The *social issues or shortcomings* associated with the AECL disposal concept raised during the Seaborn Panel hearings are listed and briefly discussed in the context of the NWMO study.
- Part IV - The *technical issues or shortcomings* associated with the AECL disposal concept raised in the Seaborn Panel hearings are listed and briefly discussed in the context of the NWMO study.

As with all NWMO Background Papers, the NWMO invites comment on the material contained in this paper.

Part 1 - Response to Seaborn Panel Report Recommendations

In the text which follows, the conclusions, criteria outlined, and recommendations from the Executive Summary of the Panel report are listed and briefly discussed in the context of the NWMO study.

	Seaborn Panel Conclusions (in order of presentation in the Executive Summary of the Report)[1]	**NWMO Discussion**
Topic	***Key Panel Conclusions (page 2)***	
Broad public support	Broad public support is necessary in Canada to ensure the acceptability of a concept for managing nuclear fuel wastes	NWMO understands that in order to implement any approach for the long term management of used nuclear fuel in Canada, it will be necessary for the approach to enjoy a measure of public support. The Seaborn Panel was clear that broad public support is necessary, otherwise no decision of this sort can be taken at the political level and successfully implemented. However, the Seaborn Panel was not specific as to how broad public support should be measured, or the threshold which would constitute such support. Some analysts have suggested that 'broad public support' is best measured by a vote, plebiscite or public opinion poll taken among a citizenry which is informed on this issue. 'Broad public support' would be demonstrated by a simple majority of Canadians in favour, or in support, of the implementation of the management option. NWMO suggests this approach is not appropriate for the issue at hand, for two reasons. First, although all Canadians hold a stake in this issue, indications are that most Canadians can not be engaged in the issue. Public attitude research (Navigator 2003) suggested that irrespective of the amount of resources committed to involving Canadians on this issue, public engagement will necessarily be very low, particularly at decision points prior to siting. The reasons for this are documented in that public attitude research, but include the fact that this issue holds neither sufficient immediacy (or personal relevance) nor urgency to successfully compete with other day-to-day demands experienced by most Canadians. Although the long term management of used nuclear fuel is an area of great concern for many Canadians, once they are specifically prompted on this issue, and there is a demand for the public to be involved in decision making on this issue, very few Canadians indicate a desire for or likelihood of personal involvement. Second, although Canadians insist citizens must be part of any decision-

[1] Nuclear Fuel Waste Disposal Concept Environmental Assessment Panel. *Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel.* February 1998.

		making process, they also insist that any decision on a management approach be informed by knowledge and expertise which they feel they do not have and can not easily acquire. This same public attitude research revealed that the public feel ill equipped to formulate a judgment on this issue, even with readily available and accessible information, and look to trusted experts and a credible decision making process to protect their interest in selection of an appropriate approach. In this regard, citizens have said (Navigator 2003) that a credible decision making process would have the following characteristics: be transparent; be open; be inclusive of a broad diversity of voices; include the public; be informed by the best knowledge and expertise. NWMO suggests, and is operating on the basis of, an alternative approach to the question of how to determine whether a management approach has 'broad public support'. A management approach will be deemed to enjoy broad public support if: • It has emerged from a **decision-making process** which is appropriate and trustworthy, and seen to be so, as defined by citizens across Canada who form the **broad public** - reflected by a representative sample of Canadians and taking into account the perspective of the public and specialized groups who have chosen to become involved in this issue. • It has emerged from a **decision-making process** which is appropriate and trustworthy, and seen to be so, as defined by the residents of **communities in which used nuclear fuel is currently stored** - reflected by a representative sample of residents in these communities, political representatives, and those residents and specialized community groups who have chosen to become involved in this issue. • Is responsive to the **values and objectives** of the public, and seen to be so, as defined by the citizens across Canada who form the **broad public** - reflected by a representative sample of Canadians and taking into account the perspective of the public and specialized groups who have chosen to become involved in this issue • Is responsive to the **values and objectives** of known impacted communities, and seen to be so, as defined by the residents of **communities in which used nuclear fuel is currently stored** - reflected by a representative sample of residents in these communities, political representatives, and those residents and specialized community groups who have chosen to become involved in this issue. NWMO, therefore, suggests that 'broad public support' can be inferred upon meeting a process requirement or condition, and a substance requirement or condition. The Seaborn Panel suggested that public support, or the related concept of acceptability, needs to be demonstrated at multiple points of the decision-making and implementation process. The Seaborn Panel commented in their report as follows: "We note that, although public acceptance might be demonstrated at the conceptual stage, it would have to be demonstrated again at the site- and design-specific stages before the concept could be implemented." (page 34) The Panel did not comment specifically about the quality and nature of the support, acceptance or consent (a related term also used by the Panel) which would need to be demonstrated at each point in the process although the Panel did suggest that decision-making processes which

		will be used at each point must be clearly outlined well in advance. In response to this guidance provided by the Seaborn Panel, NWMO has understood that the most appropriate response to the objective of broad public support is the development of a *process* which will ensure that, at each phase in the implementation of the management approach, the decision-making process is trustworthy and credible to those most impacted, and the values and objectives of the public, and those most impacted, continue to drive decision-making even as these values and objectives may evolve over time. At a minimum, and as Seaborn suggested, the process built in to the implementation plan will need to include: • a process for informing and engaging residents of the proposed siting territory and individual members of the public in decision making, through to final implementation of the concept; • a clear decision-making strategy that defines key decision points, decision-makers and their jurisdictions, the level of public and community participation in each decision, and a mechanism for resolving disputes; and • public involvement in defining public participation and establishing decision-making strategies. As a key part of this work, the quality and quantity of support required, by community of interest, will be identified for each point in the process. While a measure of passive support among the broad public is considered appropriate for a decision on the concept, it is expected that a more active level of support from impacted communities will be required at subsequent stages.
Safety	Safety is a key part, but only one part, of acceptability. Safety must be viewed from two complementary perspectives: technical and social.	NWMO understands that notions of safety are social constructs. NWMO also understands that safety is the pre-eminent concern of Canadians, and therefore is critical to the acceptability of a management approach. Safety has emerged in NWMO's study as both a core value to inform all decision-making, and an objective in its own right. In fact, the public has said it is the most important of the eight objectives which it had said must be addressed by any management approach for Canada. Based on NWMO's understanding of what constitutes 'broad public support', the public's notion of safety, and the public's perception of the responsiveness of an approach to this notion, is fundamental to broad public support. NWMO has attempted, from the inception of its study, to identify the values and objectives of Canadians as they apply to this issue, and to use these as the frame for both designing and assessing practicable management options. NWMO has also attempted to describe and define these values and objectives as the public does. Therefore, the starting point for the definition of safety, as with the other values and objectives, is the public or social understanding. The role of technical knowledge and expertise in the NWMO study is to flesh out the objective as it has been socially constructed and to identify and build in due diligence components.

		NWMO is attempting to bring social perspectives on safety, and other values and objectives, not only to the definition and description but also to the assessment itself. It is understood that 'acceptable' risk requires, in the end, a social judgment to be made - albeit informed by technical knowledge and expertise. The assessment of the management approaches is understood to be a matter of informed judgment, rather than technical determination. NWMO has sought in its process to portray the assessment of approaches as an exercise in judgment, one which takes into account not only technical perspectives but social understandings. It has attempted to open this judgment process to broad public scrutiny and debate at multiple points: the nature of the problem to be addressed in the study; the values and objectives to be realized by a management approach for Canada; the application of the objectives on the approaches; and, the identification of the advantages and limitations of the approaches. It is understood that social notions of safety, and the state of technical knowledge which greatly influences these notions, may evolve over time. In order to ensure acceptability and broad public support over time, it is, therefore important for the management approach to continue to be responsive to these changing notions throughout its implementation. NWMO will suggest mechanisms to encourage this continual alignment of evolving values and objectives with the management approach over time in its recommended implementation plan. Because the timeframe for implementation of any decision in this area, and for management responsibility, is so long the dynamic nature of society and its ideas must be explicitly recognized and to the extent which we are able, be factored in to any decisions we make today.
	Criteria for Safety and Acceptability (page 2)	
Acceptability	To be considered <u>acceptable</u>, a concept for managing nuclear fuel waste must:	In response to what NWMO has understood from Seaborn to be the intimate relationship between safety and acceptability, NWMO has approached the matter of acceptability in a similar way as it has approached safety. Specifically, judgment as to the acceptability of an approach is dependent on notions of risk and safety as social constructs, as well as the state of technical knowledge. Both of these must be separately articulated for various dimensions of the decision at different points in the decision making process (i.e., concept, safety case, site, monitoring, reporting, continuous improvement, closure). Notions of risk and safety will also likely evolve over time. Acceptability is a characteristic that must be continually tested and demonstrated throughout the decision-making process. Therefore, rather than approaching acceptability as a fixed and one time only goal to be achieved, NWMO will suggest, as part of its implementation plan, a process in which decision-making on this issue might continue to be aligned with social norms as these evolve, until society has judged that this issue no longer warrants further resources and consideration.
	a) have broad public support	Discussed above.

	b) be safe from both a technical and a social perspective	Discussed above.
	c) have been developed within a sound ethical and social assessment framework	In commenting about the importance of a sound ethical and social assessment framework, the Seaborn Panel explained: "Hence, to assess the broad public acceptability of a concept for managing nuclear fuel wastes, one must first identify the predominant values held by Canadian society and then measure the concept against them. … As values change over time, the framework of values must be updated, and the concept remeasured against it and readjusted if necessary, to maintain ongoing public acceptance. Any concept for managing nuclear fuel wastes in Canada should be developed within such a framework." (page 35) As part of NWMO's study process, NWMO's Roundtable on Ethics has suggested an Ethical and Social Framework as a broad direction for the conduct of the study. This framework includes a list of ethical principles and a series of questions designed to sensitize the NWMO to a range of ethical issues as it conducts its study. The Assessment Framework, which has emerged out of dialogue with Canadians, represents an attempt to integrate social and ethical considerations, with technical considerations, in a systematic way. It forms the foundation of NWMO's study and for the design of any appropriate waste management approach. This Assessment Framework constitutes an integrated social and ethical framework in its own right.
	d) have the support of Aboriginal people	In commenting about the need for the support of Aboriginal people, the Seaborn Panel explained: "Thus, a concept should be developed with their [Aboriginal Peoples'] co-operation. To respect Aboriginal rights and concerns, a concept must allow Aboriginal people to have ongoing input, from its initial formulation through to its implementation. The participation process used must be appropriate to Aboriginal cultural practices, values and languages. Thus, Aboriginal people should design it." (36) NWMO has entered into agreements with Aboriginal Peoples for Aboriginal Peoples to design and conduct their own dialogue process, in the manner they deem fit, in order to help shape the NWMO study and recommendation. Mechanisms to ensure Aboriginal Peoples will have ongoing input as the management approach is implemented will need to be built in to implementation plans. These mechanisms will be in addition to mechanisms designed to ensure the public, and particularly those most impacted, will have a continuing role in shaping the implementation of the approach.
	e) be selected after comparison with the risks, costs and benefits of other options,	In explaining the importance of the comparison among practicable options, the Seaborn Panel explained their thinking as follows: "After considering the various approaches to the long-term management of nuclear fuel wastes, the Panel concluded that a key element of acceptability is allowing the public and decision-makers to make informed comparisons and a considered choice among reasonable alternatives." (page 36) The Nuclear Fuel Waste Act requires that NWMO study at a minimum three options, and specifies the options as those which were suggested by the Seaborn Panel. As a starting point for its study, NWMO examined a broader list of options than required in the Act, including the options which are

		frequently mentioned and internationally studied. In NWMO's study, the risks, costs and benefits of each of these options is being identified and assessed over the course of an iterative and reflective study process. In this process, the interested public is engaged in a dialogue which progresses through successive levels of detail from the questions which should be asked and answered in the study, through to values and objectives, inferences, trade-offs, advantages and limitations of the approaches and final judgment.
	f) be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator	Early on in the NWMO's study, it was apparent that NWMO would not be viewed as a trustworthy proponent by some interested Canadians because it is fully funded by the nuclear industry, who make up its Board of Directors. The nuclear industry is perceived by some interested Canadians to be secretive and self-interested. For these interested Canadians, the NWMO was tarnished with the reputation of the nuclear industry from its inception. The fact that the Government of Canada had not taken the Seaborn Panel's suggestion that the nuclear waste management organization be established as an independent organization with a clear mandate to serve the public interest, exacerbated scepticism about the integrity of the NWMO and the appropriateness of any recommendation it may make. In part for this reason, and from the inception of its study, NWMO has attempted to create a trustworthy *study process;* a study process which is transparent, and, the agenda for which is set by society at large and implemented and reported upon by third parties, rather than the NWMO itself. In this model, NWMO has attempted to play the role of 'facilitator of dialogue' and to provide a platform for the exchange of the diverse range of views which cover the breadth of opinion on this issue among and within segments of civil society.
Safety	***To be considered safe, a concept for managing nuclear fuel wastes must be judged, on balance, to (page 2)***	
	a) demonstrate robustness in meeting appropriate regulatory requirements	The short listed concepts and approaches under study have been designed to meet current and anticipated regulatory requirements. As part of the implementation process which NWMO will ultimately recommend, it is expected that the safety case for the management approach selected by Government would be scrutinized in detail. Any modifications to the design which would be required to meet social standards of safety would be identified and incorporated as part of that subsequent public dialogue and decision-making process.
	b) be based on thorough and participatory scenario analyses	The NWMO conducted a major scenarios initiative at the inception of its study using a formal scenarios exercise methodology. In this exercise, various futures were used to develop a sense of what kind of conditions might need to be faced in managing used nuclear fuel over the long term.

		In order to undertake the scenarios analysis, the NWMO convened a Scenarios Team consisting of 26 individuals drawn from a range of interests and locations across Canada. Four workshops of several days each were held. The Team's deliberations began with a brainstorm of all the key factors and drivers that influence the nature of used nuclear fuel and the conditions in which it will be managed. To span the kind of time frame needed, the group explored four time horizons: 25 years (1 generation) into the future, 175 years (7 generations) into the future; 500 years (20 generations) into the future and 10,000 years (400 generations) into the future. In all, the group described four detailed scenarios for the 25 year timeframe, 12 much less detailed scenarios for the 25 year timeframe, 12 much less detailed scenarios or "scenarioettes" for the 175 year timeframe, 16 sets of conditions for the 500 year time frame that came to be called "end-points", and a number of simple "what-ifs" for the 10,000 year timeframe. Throughout the development of these various perspectives on how the future might unfold, conditions were highlighted that would influence today's decision that Canada faces about the choice and design of a management approach for used nuclear fuel. These conditions were then captured in the ten questions to be asked in the study and formed the beginning framework for the assessment of each alternative management approach. Unlike scenarios development which have been conducted in the past largely by technical experts, NWMO's scenario exercise was deliberately multi-party, involving a wide variety of knowledge experts. The exercise was conducted at the beginning of NWMO's study process because it was designed to help set the framework to be used for the assessment of the approaches. The results of this work were then published on NWMO's web site and interested Canadians were invited to review the report, reflect on the contents from their own perspective, and share their insights concerning the report and implications to the questions which should be asked and answered in the study.
	c) use realistic data, modelling and	Since the release of the Seaborn report, the waste owners have conducted a substantial program of research and development to improve the data and models available to support decision making. For instance, since 1996, over $125 million has been spent by Ontario Power Generation (and Ontario Hydro), on behalf of the Joint Waste Owners, on research and development of technology for modelling the deep repository concept. In particular, expert reviews of vault modelling and geosphere modelling have been conducted by independent experts and their advice has been incorporated into the safety and performance assessment models and codes. Recently, a Third Case Study of the postclosure safety of a deep repository has been carried out to demonstrate recent improvements in safety assessment models, computer codes, data and analysis tools. An overview of the research conducted over the past 6 years is summarized, by year, on the NWMO website: http://www.nwmo.ca/Default.aspx?DN=979,611,608,237,199,20,1,Documents
	d) incorporate	An important part of the Canadian repository development program is

	sound science and good practices	interaction with the corresponding research and development programs conducted in other countries. OPG has formal agreements with Sweden (SKB), Finland (Posiva) and Switzerland (Nagra) to exchange information arising from their respective programs on nuclear waste management. These countries are considering used fuel repository concepts that are very similar to the Canadian concept, and their programs are advanced with respect to siting and approvals. In 2003, OPG signed a five-year agreement with SKB for participation in the Äspö Hard Rock Laboratory (HRL). The prime objectives of OPG's participation at the Äspö HRL are to enhance the Canadian technology base for a deep geologic repository through international co-operation projects, to improve our understanding of key processes in a repository, and to directly share lessons learned in disposal technology development and site characterisation. In 2004, OPG participated in the Äspö Pillar Stability Experiment and in the In-Situ Diffusivity Experiment, and joined the LASGIT Gas Migration Experiment and Engineered Barrier System (EBS) Modelling Task Force groups. OPG continues to participate in the international radioactive waste management program of the OECD Nuclear Energy Agency (NEA). Members of this group include all the major nuclear energy countries, both waste owners and regulators. In 2004, OPG was active in AMIGO - Approaches and Methods for Integrating Geologic Information in the Safety Case and Engineered Barrier Systems in the Context of the Safety Case. OPG also supported the NEA Thermodynamic Database Project. OPG is a funding member of the International DECOVALEX III Project, and is actively supporting research on the application of coupled thermo-hydraulic-mechanical numerical models in the geosphere. OPG is a participant in the European Commission's Cluster Repository Project (CROP), which documents experience in underground repositories to date. The final reports have been completed, describing lessons learned during design and construction, and performance modelling issues related to the application of engineered barriers in underground facilities. In addition to the substantial work conducted by OPG, the NWMO has itself engaged independent consultants to identify the state of knowledge and best practices in a broad variety of disciplines related to the long term management of used nuclear fuel. The more than 70 papers which have been commissioned include examination of both natural science areas and social science areas, including best practices, by those involved in these fields. NWMO has also established relationships with other waste management organizations and international organizations such as the NEA and IAEA to facilitate exchange of information and discussion of developing best practices.
	e) demonstrate flexibility	The 'flexibility' of a management approach has been identified as an important influencing factor concerning a number of the objectives in NWMO's Assessment Framework. Situating 'flexibility' in these influence diagrams will encourage the advantages and limitations of flexibility to be considered: in the context of a number of other influences; and, in the context of achievement of the eight objectives identified by Canadians.

	f) demonstrate that implementation is feasible; and	The work of the Joint Waste Owners in preparing conceptual designs for each of the options has gone some way in demonstrating there exists sufficient technical and scientific knowledge to be able to implement each of the options, at the conceptual stage of analysis. The 'feasibility' of implementation will depend in part on the extent to which the option can meet the objectives set by society at large. Through NWMO's study process, NWMO is assessing the extent to which each of the options can address these objectives. It is expected that 'feasibility' will continue to need to be demonstrated through successive levels of detail, and decision-making, as implementation proceeds, and will need to be factored in to any implementation plan.
	g) integrate peer review and international expertise.	See d) above. The work of the Joint Waste Owners in preparing conceptual designs for each of the options has gone some way to incorporating insight from various peer reviews in Canada and abroad, and international expertise from waste management research and programs in other countries. In addition to the work of the Joint Waste Owners, NWMO has initiated and completed peer review of several key study inputs, and has solicited and attempted to incorporate international expertise where appropriate. It is expected that peer review and international expertise will continue to be of value throughout implementation of the selected management approach and should explicitly be built in to any implementation plan ultimately recommended by NWMO.
Additional Steps	***Future Steps – Key Panel Recommendations (page 2 – 3)***	
	A number of additional steps are required to develop an approach for managing nuclear fuel wastes in a way that could achieve broad public support. These include	
	Issuing a policy statement on managing nuclear fuel wastes	The Government of Canada issued a policy statement (1996), followed by legislation in the form of the Nuclear Fuel Waste Act.
	Initiating an Aboriginal participation process	The Government of Canada has struck agreements with national Aboriginal organizations to assist them in building capacity to engage in NWMO's study process. NWMO has struck further agreements with these organizations, and others, to provide the resources necessary to these organizations to design and

		implement their own dialogue process, as they see fit, as input to the NWMO's study. The goal of NWMO's Aboriginal Dialogues is to build the needed foundation for a long-term, positive relationship between the NWMO and the Aboriginal Peoples of Canada. We have initiated agreements to support national, regional and local organizations in designing and implementing their own dialogue process as a means of providing input to our study. As a result of this support, more than 80 meetings, workshops, community retreats, presentations and discussions have been held, involving more than 3,000 people. Many others were involved through informal discussions.
	Creating a nuclear fuel waste management agency (NFWMA)	In the Nuclear Fuel Waste Act, the Government of Canada laid out the requirement for the creation of a nuclear fuel waste management agency. In response to the Nuclear Fuel Waste Act, the producers of used nuclear fuel have created the Nuclear Waste Management Organization.
	Conducting a public review of AECB regulatory documents using a more effective consultation process	Responsibility of the Government of Canada.
	Developing a comprehensive public participation plan	In the conduct of its study, the NWMO has developed and implemented a broad plan for public participation. In the spirit of the iterative and reflective approach which NWMO has taken to the conduct of its study, the plan for public involvement in each phase of the study has been influenced by the insight which emerged from the previous phase. A plan for public participation in decision-making as it proceeds will be a critical component of NWMO's recommended implementation plan.
	Developing an ethical and social assessment framework	Discussed above.
	Developing and comparing options for managing nuclear fuel wastes	Discussed above.
Waste Management Organization	***Basic recommendations to governments with respect to a management agency (page 3)***	
	That an NFWMA as described in Chapter 6 be established quickly, at arm's length from the utilities and AECL, with the	The Government of Canada did not follow the suggestion of the Seaborn Panel on this matter. A different governance structure was outlined for the waste organization in the Nuclear Fuel Waste Act.

	sole purpose of managing and co-ordinating the full range of activities relating to the long-term management of nuclear fuel wastes	
	That it be fully funded in all its operations from a segregated fund to which only the producers and owners of nuclear fuel wastes would contribute	The Government of Canada, in the creation of the Nuclear Fuel Waste Act, established the framework for funding of the implementation of the management approach decided upon by government. According to the Nuclear Fuel Waste Act, waste owners pay in to a segregated fund from which the implementation by the NWMO of any decision by government will be funded. For the conduct of its study, NWMO's activities are funded by waste owners directly, rather than through segregated funds.
	That its board of directors, appointed by the federal government, be representative of key stakeholders	The Government of Canada, in the creation of the Nuclear Fuel Waste Act, laid responsibility and control of the NWMO in the hands of the waste producers, including the Board of Directors. This, consistent with the "polluter pays" principle.
	That it have a strong and active advisory council representative of a wide variety of interested parties	The role of the Advisory Council was set in the Nuclear Fuel Waste Act. Concerning NWMO's study, the requirement is for the Advisory Council to comment on the recommendation of the NWMO and its study process. The NWMO has gone further than the requirements of the Act, and in so doing has attempted to be responsive to the intent of the Seaborn Panel's suggestion in this area. Rather than waiting until the end of the study process to establish and involve an Advisory Council, the NWMO established the Advisory Council at the inception of its work and has sought advice from this Council throughout the study.
	That its purposes, responsibilities and accountability, particularly in relation to the ownership of the wastes, be clearly and explicitly spelled out, preferably in legislation or in its charter of incorporation; and	The Nuclear Fuel Waste Act does not address the matter of ownership of the wastes. Nothing in the Nuclear Fuel Waste Act (2002) changes the ownership and liability of used nuclear fuel in Canada. Therefore, it is NWMO's understanding that the ownership of the waste remains with the waste producers as does the liability in perpetuity. The Act does, however, specify responsibilities for deciding upon the approach (government), and for implementing the approach (NWMO).
	That it be subject to multiple oversight mechanisms, including federal regulatory control	In its pronouncements to date, the Government of Canada has established a legislative framework to ensure adequacy of financial guarantees, and a regular reporting regime. As of yet, no mechanism has been established for federal regulatory control with respect to the NWMO's scientific-technical work beyond mechanisms

	with respect to its scientific-technical work and the adequacy of its financial guarantees; to policy direction from the federal government; and to regular public review, preferably by Parliament	which were in place at the time of the Seaborn Panel deliberations. Reflecting what Canadians have said about the nature of the checks and balances they would like to see in place in order to have confidence in a management approach, the NWMO may ultimately comment on the type of assurances which need to be delivered by the larger waste management system, of which NWMO is just one part.
	Until the foregoing steps have been completed and broad public acceptance of a nuclear fuel waste management approach has been achieved, the search for a specific site should not proceed	The Government of Canada, through the Nuclear Fuel Waste Act, has separated the decision about a management approach from the question of where any facility which may be required should be located. Only once a management approach has been deemed appropriate for Canada will work begin on the selection of a site, should the management approach require one. The Seaborn Panel has suggested that the determination of broad public acceptance requires a process in which acceptance needs to be demonstrated independently at multiple points in the decision-making and implementation process. As part of this larger discussion, Seaborn has suggested that acceptance of the concept is the first milestone and acceptance of a specific site is a further milestone along a path which anticipates there will be several milestones.
	If the AECL concept is chosen as the most acceptable option after implementation of the steps recommended above, governments should direct the NFWMA, together with Natural Resources Canada and the AECB or its successor, to undertake the following: review all the social and technical shortcoming identified by the Scientific Review Group and other review participants; establish their priority; and generate a plan to address them. The	Through the work of the Joint Waste Owners and the NWMO, a list of the social and technical shortcomings identified by the Scientific Review Group and other review participants has been assembled and posted on NWMO's website for public input and comment. The social shortcomings were posted on the website early in NWMO's study in the form of a report prepared by Mark Stevenson, a social scientist with experience in identifying and assessing public concerns on difficult issues such as this. The report summarizes and categorizes the issues raised which were deemed to be "social shortcomings", after having gone through both the transcripts of the hearings, and the written submissions by interveners. NWMO's study process was designed, in part, in response to the social shortcomings raised during the Seaborn Panel deliberations. Each of the shortcomings listed in this report will be dispositioned by the end of the study. The listing of social shortcomings is reproduced in Table 2 below. The technical shortcomings form an important part of the foundation on which the work of the Joint Waste Owners concerning the deep geological concept proceeded. Well before the formation of the NWMO, Ontario Power Generation, with the assistance of a third party contractor, reviewed the record of the hearings and written submissions, as well as the work of the Scientific Review Group, to assemble a list of what were deemed to be technical shortcomings. The list of social shortcomings and the list of technical shortcoming are understood to overlap, since the demarcation between the two in many cases is unclear. In preparation of these lists, an effort was made to err on the side of caution so that no important shortcomings would be missed. As part of the development of the deep geological option design, OPG made

	NFWMA should make this plan publicly available, invite public input, then implement the plan.	an effort to disposition each comment. The manner of disposition is reflected in the conceptual design, detailed information concerning which is posted on the NWMO website. In the weeks following the posting of the Joint Waste Owners' work on the conceptual designs, several individuals and groups asked to see in a more transparent way how the dispositioning task had been addressed. For this reason, NWMO posted the work of the Joint Waste Owners to address the technical shortcomings, a document of more than 600 pages, on its web site in December 2004 for public scrutiny and comment. The technical shortcomings have been organized into nine major sections, a brief outline of which is contained in Table 3 below.

Part II – Response to Seaborn Panel Report Concept of 'Social Safety'

The Advisory Council asked the NWMO to describe how it has factored "social safety" into its study. Because "Social Safety" was a term used prominently by the Seaborn Panel in its assessment of the AECL disposal concept, this paper reviews key clauses in the Seaborn Panel report about safety (highlighted below in the blue boxes) and uses these clauses as the launching point for discussion. [2]

4.1 OVERVIEW OF SAFETY AND ACCEPTABILITY

The Panel wrestled with two major issues: how to define safety and acceptability; and how to formulate criteria applicable to a concept, as opposed to a real project.

While some aspects of safety can be accurately calculated, in the broadest sense neither safety nor acceptability is an absolute or measurable construct. Both are relative, value-laden, and subject to differing interpretations by different people in any given situation or under different conditions. These considerations affect the members of this Panel as well as the public at large. In particular, conceptions of safety and acceptability are greatly influenced by an individual's or a group's perception of risk. Since there is often little correlation between the expert's and the public's perceptions of risk, it is not surprising that there are disparate views of what is safe or acceptable.

AECL defines safe as "meeting criteria, guidelines, and standards for protecting the health of humans and non-human biota." As the Panel heard, safety standards are not only a technical matter, because they explicitly or implicitly designate "acceptable" levels of risk or safety. Regulators often set risk levels in a particular standard by making them comparable to those calculated for everyday activities that the public generally – although often subconsciously – tolerates. However, considering that risk perception and acceptance are specific to each context and vary widely with the circumstances, safety standards set without broad consultation may not reflect general public acceptance.

It is clear that conceptions of safety, risk and acceptability are coloured by each individual's or community's perspectives. Hence, one person's definition of safety may correspond to another's definition of acceptability. Yet it seems to be universally agreed that safety is an essential component of the broader notion of acceptability.

Panel Conclusion

Safety is a key part, but only one part, of acceptability.

[2] See "4.0 Criteria For Safety and Acceptability" in Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel, February 1998,

Response and Discussion:

- Similar to the Seaborn Panel, the NWMO has assumed that safety and acceptability are so intertwined that they cannot be usefully distinguished. Rather than try to disentangle these two concepts, NWMO's focus has been on identifying a framework for assessment which transparently includes the objectives for a management approach which are most important to citizens, as these are defined by citizens. To the extent possible, the question of "what constitutes safety" has been explored through a multi-party and iterative dialogue involving experts, interested citizens, and the public at large in the context of exploring "what is important for a management approach".

- Similar to the Seaborn Panel, NWMO has approached notions of safety and risk as social constructs. Early in the study process NWMO stated,

  "Society as a whole, and not science alone, needs to shape the questions to be addressed in the study. And society, with the assistance of science, needs to judge the benefit or harm, and assess the social implications of a decision to implement a particular management option. It is understood that to a large extent, notions of benefits and harms are societally constructed. The assessment of risk is an important example of this. While science can speak to the probability of the occurrence of an event, science cannot speak to social tolerance for its occurrence. What poses risk, how the risk should be measured, and what is considered relevant for measurement are all decisions which are influenced by societal considerations.

  The objectives we set for the management options, and the values we weigh in making a decision, need to be consistent with our collective sense of how we should live. The challenge for the NWMO is to develop and apply, to the extent feasible, a societally directed framework to guide both the development of the management options, and also the assessment of these options. Without such a societally directed framework, implementation of any management option will be extremely difficult."[3]

- In the NWMO's Assessment Framework[4], two of the eight objectives explicitly address safety: 'Public Health and Safety', and 'Worker Health and Safety'. However, dialogue with citizens highlighted that one cannot ensure public health and safety without also ensuring the integrity of the environment, security, and community well-being.[5] In fact, citizens have suggested that all eight of the objectives relate to safety. Although each of the objectives are considered important,

[3] NWMO, "Approach to Development of Analytical Framework", July 2003, p. 2.
[4] See: NWMO, *Understanding the Choices*, August 2004, pp. 10-12, and pages following for fuller discussion..
[5] See: CPRN, *Responsible Action – Citizens' Dialogue on the Long-term Management of Used Nuclea*r Fuel; Navigator, *Phase 3 – Report on Discussion Group Findings*; DPRA, *Information and Discussion Sessions.*

citizens have said they are only "must-haves" to the extent they are considered important to ensure safety.[6]

- The citizen values and ethical principles[7] which underpin these eight objectives are also treated as important to understanding social requirements for safety. Taken together these elements of NWMO's assessment framework attempted to capture the essential social requirements, as well as technical requirements, of a management approach.

The Panel also faced difficulties formulating criteria to apply to a concept, as distinct from a site-specific proposal. Those who were familiar with the step-wise refinement and review of engineering designs from conceptual through final stages were relatively comfortable with devising criteria to judge a general concept in the absence of final details. Others concentrated on the way communities would evaluate what they would perceive as a risky undertaking. These people examined such a project's potential effects on communities, the equity of the distribution of its risks and benefits, its net benefit to society and the extent to which it incorporated participatory decision-making. Therefore, they found it impractical to establish criteria that did not also reflect the way a concept would be implemented, whom it would affect and how it would affect them. In this respect, the panel members' differing views reflect the broad cross-section of views of participants at our hearings.

Response and Discussion:

- In dialogue, citizens told the NWMO that as important as the selection of a management approach is, the way in which that approach is implemented is also very important[8]. Citizens see risk associated with each of the technical methods under study. The way in which we manage this risk through the manner of implementation is a critical factor for citizens in judging safety.

- Implementation considerations have been an important point of focus in the NWMO's dialogues. Citizens first raised these issues in discussion of NWMO's first discussion document, and dialogue on what needs to be included in an 'appropriate' implementation plan began. Subsequently, implementation issues were the focus of one of three questions posed for dialogue in NWMO's second discussion document[9].

- Although implementation considerations are factored throughout the influence diagrams for the eight objectives, note that the 'Community Well-Being' and

[6] NWMO Dialogue Report: Navigator, *Phase 3 – Report on Discussion Group Findings*
[7] See: NWMO, *Understanding the Choices*, August 2004, pp. 10-12, and pages following for fuller discussion.
[8] Reported from various sources in NWMO, *Understanding the Choices*, August 2004.
[9] The question read: "Are there specific elements that you feel must be built into an implementation plan? What are your thoughts on what a phased approach must include?"

'Fairness' objectives include as influences many of the criteria raised by the Seaborn Panel as particularly important ("a project's potential effects on communities, the equity of the distribution of its risks and benefits, its net benefit to society and the extent to which it incorporated participatory decision-making"). This list has been considerably expanded in the development of the more than 200 influences identified in the Assessment Framework.

4.4 Safety Criteria

Safety from both a technical and a social perspective, listed as the second acceptability criterion in section 4.3, is a key aspect of public acceptability of an approach to managing nuclear fuel wastes. Both perspectives are reflected not only within the Panel and among review participants, but also within Canadian society. They should not be viewed as competing, but as complementary, because they must both be satisfied if an approach is to be widely regarded as acceptable. While there are many similarities between the two perspectives, there are also subtle differences between them. The panel's seven criteria for evaluating safety are listed in this section, followed by explanatory text. The two perspectives are not evident in the criteria themselves, but in their application, as will be apparent in the next chapter.

To be considered safe, a concept for managing nuclear fuel wastes must be judged, on balance, to

a) demonstrate robustness in meeting appropriate regulatory requirements;
b) be based on thorough and participatory scenario analyses;
c) use realistic data, modelling and natural analogues;
d) incorporate sound science and good practices;
e) demonstrate flexibility;
f) demonstrate that implementation is feasible; and
g) integrate peer review and international expertise.

Response and Discussion:

The seven safety criteria identified by the Seaborn Panel are each examined separately in the discussion which follows.

a) Robustness in meeting appropriate regulatory requirements

"Robustness" refers to the ability of a system to continue to perform within acceptable limits despite unanticipated and possibly extreme conditions. Thus, this criterion refers to the degree to which a concept has been demonstrated to meet or exceed regulatory requirements for protecting human health and the natural environment under a range of conditions. Robustness refers to the resilience of the system which, as in a biological system, results primarily from diversity. In other words, the overall system does not fail due to an unanticipated failure of a single element. To be diverse, a system for managing nuclear fuel wastes would make reasonable use of defence-in-depth measures such as multiple barriers, passive and active safety features, mitigation and sound industrial practices.

This criterion also alludes to the appropriateness of regulatory requirements to assure safety, as interpreted from both a technical and a social perspective. From a social perspective, regulatory standards must: be developed through consultation processes involving varied groups and reflecting all relevant technical and social factors; protect generations living in the distant future; require quantitative analyses to include the periods of greatest risk; and present results and uncertainties clearly.

Response and Discussion:

- Technical perspective: Conceptual designs have been developed for the purpose of this study. These have been designed to meet or exceed current and anticipated regulatory requirements for protecting human health and the natural environment[10]. In conjunction with these designs, a body of research was developed which outlines the scientific and technical basis for confidence in these designs. This body of work has arguably incorporated the best knowledge and expertise available in Canada and abroad. The detailed conceptual designs and an overview of the research foundation for these designs is included on the NWMO's website for the review and scrutiny of interested Canadians[11].

- NWMO has had these designs reviewed by expert third parties for the integrity of the design work, in particular that the designs have been developed in a manner consistent with established engineering industry standards and practice.[12] All designs use defence-in-depth strategies - that is each use multiple barriers, passive and active

[10] See discussion in NWMO Background Paper 6 – 9 and associated documents: Ontario Power Generation, *Conceptual Designs for Used Nuclear Fuel.*

[11] Research foundation is outlined in the following attachment to NWMO Background Paper 6-9: Ontario Power Generation, *Response to Technical Comments raised during Environmental Assessment of AECL Disposal Concept*. See also: Ontario Power Generation, *Technology Program for Deep Geologic Repository*.

[12] See NWMO Background Paper 6-10: ADH Technologies Inc., *Review of Conceptual Engineering Designs for Used Nuclear Fuel Management in Canada (Final Report).* The report concludes, "The conceptual designs are assessed to be suitable for the intended purpose which is to assess the options presented and arrive at a recommended approach. The conceptual designs are well developed and documented and prepared in a manner consistent with established engineering practice. Accordingly, it is reasonable to expect that any of the options reviewed could be developed into a full detailed-design that would meet the requirements of the NWMO program. … (page 6)

safety features, mitigation and sound industrial practices - to contain and isolate used nuclear fuel, although designs differ as to the number and nature of the barriers.

- Social perspective: NWMO has attempted, through dialogue, to elicit from citizens the social factors related to safety and incorporate these into the Assessment Framework. Consistent with the type of process suggested by the Seaborn Panel, the objectives used for the assessment emerged from an iterative and participatory process involving a diverse cross-section of experts/ specialists and citizens. Efforts were also made to explicitly consider the potential needs of future generations (Scenarios Team), conduct both qualitative and quantitative analyses as appropriate (NWMO Assessment Team and Golder/Gartner Lee), and throughout to attempt to identify and explicitly address uncertainties. Each of the three management approaches, when assessed against the framework, was shown to have weaknesses.

- Assessment results: The NWMO has had these designs assessed for their likely impact on human health and the natural environment under a range of plausible extreme conditions: a preliminary assessment was conducted by the Assessment Team; a more detailed and rigorous analysis was conducted by Golder/Gartner Lee.

- Consideration of a range of conditions were incorporated into the assessment through the influences (bubbles in the influence diagrams) considered in the assessment and in the conduct of a sensitivity analysis against a range of scenarios.

- The NWMO's study has identified a fourth approach which better meets the objectives important to Canadians. The NWMO is confident that this approach best meets social safety requirements among currently practicable approaches. For a description of how this fourth approach is assessed against social safety criteria, please see discussion in the Draft Study Report.[13]

- **NWMO suggests that the fourth approach is the most resilient approach by virtue of its combination of: multiple barriers; built-in contingencies; incorporation of opportunities for both active management and passive safety; process of continuous learning as an integral element of the approach; and, opportunity for improvements as knowledge and circumstances over time allow.**

[13] See Chapter Four of NWMO, *Choosing a Way Forward – Draft Study Report*, May 2005.

b) Based on thorough and participatory scenario analyses

This criterion relates to the range of conditions or scenarios for which a concept must be demonstrated to be robust, and how those scenarios are identified and evaluated. The Panel believes that both specialist and non-specialist groups must be assured that all conditions that could significantly affect the long-term safety of the system have been adequately assessed, and that all biases and uncertainties have been adequately taken into account. In particular, there should be diverse public input to negotiating an agreed set of worst-case scenarios to be assessed, and it must be shown that acceptable emergency response and mitigation measures for these scenarios can and will be implemented.

Response and Discussion:

- Finding a way to appropriately address uncertainty has been an important theme in the NWMO's study - uncertainty associated with:
    - the technical performance of the management system over the long timeframe over which the material must be managed;
    - future extreme natural and human induced events;
    - evolution of scientific and technical knowledge over time; and
    - the capacity of future generations to take an active role in the management of the material.

- As the Seaborn Panel suggested as appropriate, the NWMO sought to involve specialists and non-specialists in the development of scenarios against which the management approaches should be assessed. This was part of the NWMO's effort to understand the broader context in which citizens view the long term management of used nuclear fuel. NWMO's efforts to collaboratively develop scenarios also recognizes that visions of the future are social constructs which warrant the same collaborative process of identification and understanding as notions of risk and safety.

- The Scenarios Team was deliberately designed to be a very diverse group. The scenarios exercise, lead by Global Business Network, explicitly explored the various sets of assumptions that are perceived to be "plausible" over different future timeframes.[14] In all, the team developed four detailed scenarios for the 25 year timeframe, 12 much less detailed scenarios or "scenarioettes" for the 175 year timeframe, 16 sets of conditions for the 500 year timeframe, and a number of simple "what-ifs" for the 10,000 year timeframe.

- The exercise was conducted at the beginning of NWMO's study process because it was designed to help set the framework to be used for the assessment of the approaches. The results of this work were then published on NWMO's web site

[14] NWMO Background Paper 8-5: Global Business Network, Looking Forward to Learn: Future Scenarios For Testing Different Approaches to Managing Used Nuclear Fuel in Canada. 2003

and interested Canadians were invited to review the report, reflect on the contents from their own perspective, and share their insights concerning the report and implications to the questions which should be asked and answered in the study.

- A subset of these scenarios, selected to span the continuum of the range of scenarios developed by the Scenarios Team, were used for a sensitivity analysis by the Assessment Team. This sensitivity analysis was factored in to the Assessment Team's discussion of the advantages and limitations of the management approaches studied and is described in some detail in their report .[15]

- A second, less formal, scenario development exercise and management approach assessment was conducted with Joint Waste Owner representatives. The scenarios developed in this exercise have been used to further test the robustness of the approaches to plausible future scenarios. These scenarios are briefly outlined in an appendix to the Draft Study Report as support for arguments of robustness contained in the main body of the report.[16]

- **NWMO suggests that the fourth approach is the preferred approach taking into account a wide range of plausible scenarios, developed through participatory approaches.**

c) Use of realistic data, modeling and natural analogues

Mathematical modeling is the primary means of predicting the long-term performance of a system for managing nuclear fuel wastes. Confidence in the predictions hinges on the degree to which the data and modeling represent the real system they are intended to simulate. Models must adequately capture all important aspects and interactions of the physical and biological systems under consideration; account for biases and uncertainties; and be independently verified and validated, where possible. Both generic and site-specific data must be scientifically adequate. Ultimately, site-specific data and designs must be used to validate the safety of the system.

- The NWMO independently contracted with a wide variety of experts to examine the state of knowledge as it applies to used nuclear fuel in a number of important areas to help understand the functioning of important physical and biological systems as important context and as a benchmark for understanding and assessment of this more detailed work. This includes an examination of, for instance: the status of biosphere research[17]; considerations in characterizing the geosphere[18]; natural and anthropogenic analogues[19]; the chemical and radiological

[15] NWMO Background Paper 9-1: Assessing the Options: NWMO Assessment Team Report. June 2004.
[16] See Appendix 12: NWMO. Choosing a Way Forward – Draft Study Report. 2005
[17] NWMO Background Paper 4-1: ECOMatters Inc., "Status of Biosphere Research related to High-Level Radioactive Waste Management".
[18] NWMO Background Paper 4-2: Sykes, "Characterizing the Geosphere".

toxicity potential of used fuel[20]; the possible implications of climate change[21]; the implications of microbiological factors[22].

- The preferred approach, as an adaptive management approach, has explicitly suggested a learning-by-doing process of implementation to generate site-specific data to support decision making at critical points in the process. Explicit decision points where this data is to be examined, and go – no-go decisions made, are identified as important elements of an implementation plan.

- Since the release of the Seaborn report, the waste owners have conducted a substantial program of research and development to improve the data and models available to support decision making. For instance, since 1996, over $125 million has been spent by Ontario Power Generation (and Ontario Hydro), on behalf of the Joint Waste Owners, on research and development of technology for modelling the deep repository concept. In particular, expert reviews of vault modelling and geosphere modelling have been conducted by independent experts and their advice has been incorporated into the safety and performance assessment models and codes. A Third Case Study of the postclosure safety of a deep repository has been carried out to demonstrate recent improvements in safety assessment models, computer codes, data and analysis tools. An overview of the research conducted over the past 6 years is summarized, by year, on the NWMO website. [23] This work is peer reviewed on an ongoing basis and as part of international cooperation and information exchange.

- **NWMO suggests that much work has been conducted since the Seaborn Panel to improve the data foundation for modelling system performance. This work provides a solid basis for the implementation of the adaptive management approach suggested.**

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[19] NWMO Background Paper 4-3: McKee and Lush, "Natural and Anthropogenic Analogues – Insights for Management of Spent Fuel".
[20] NWMO Background Paper 4-4: Hart and Lush, "The Chemical Toxicity Potential of CANDU Spent Fuel"; and, NWMO Background Paper 3-1: Sutherland, "Status of Radiological Protection Technologies and Operational Procedures related to High-level Radioactive Waste Management (HLRWM).
[21] NWMO Background Paper 4-5: McBean, "Review of the Possible Implications of Climate Change on the Long-Term Management of Spent Nuclear Fuel".
[22] NWMO Background Paper 4-6: Cullimore, "Review of the Implications of Microbiological Factors on the Long-term Management of Used Nuclear Fuel".
[23] See the following attachment to NWMO Background Paper 6-9: Ontario Power Generation, "Technology Program for Deep Geologic Repository". See also: Ontario Power Generation, "Response to Technical Comments raised during Environmental Assessment of AECL Disposal Concept"

d) Sound science and good practices

A system for managing nuclear fuel wastes must be based on: established scientific principles, including those of established social science disciplines; known or readily achievable technology; and sound engineering and industrial practices pertaining to safety and environmental protection. Suitable evidence would include, but not be limited to, documentation showing that

- Overall health and environmental impacts would be no worse than those achievable for conventional projects of comparable scale, using the best available technologies;
- Proposed technologies had performed safely and in compliance with regulations when employed in projects of a similar nature or magnitude
- Nuclear fuel waste handling, repackaging and transfer, as well as transportation distances, would be optimized to reduce risk; and
- Management practices could ensure compliance with safety standards.

Response and Discussion:

- Established scientific principles, including those of established social science disciplines: The basic technical methods under study are the culmination of a large and rigorously documented and peer reviewed research program founded on established scientific and engineering principles. Furthermore, the current state of natural science knowledge and principles, and best practices, that ought to be applied to assessment of any waste management approach was the subject of an extensive program of peer reviewed NWMO background papers[24].

- A similar exploration of principles and best practices from the perspective of a broad range of social science disciplines was also conducted[25]. An active discussion was sought with interested Canadians concerning how this learning might best be applied to the assessment of approaches. This discussion was solicited on the website concerning individual papers, and commissioned comment on them, and through the NWMO's discussion documents over the course of the study.

[24] Among the background papers published on the website are: 5 papers on health and safety related considerations; 6 papers on science and environment related considerations; 14 papers, and a host of ancillary documents, on technical method related topics; reports from a number of expert workshops. This is in addition to scientific advice received over the course of dialogues and captured in dialogue reports, and inputs to the NWMO through submissions.

[25] Among the background papers published on the website are: 15 papers on guiding concepts including sustainable development, risk and uncertainty, adaptive management, security, precautionary approach, Traditional Knowledge, nonproliferation and safe-keeping; 9 papers on social and ethical considerations including ethics, social issues, siting, and lessons learned in European initiatives; 4 papers on economic factors; 12 papers on institutions and governance related considerations. This is in addition to advice received over the course of dialogues and captured in dialogue reports, and inputs to the NWMO through submissions.

- NWMO's Advisory Council, including individuals expert in involving the public in public policy development and in scientific disciplines relevant to the management of used nuclear fuel, was instrumental in providing advice to the NWMO throughout the study on principles and best practices in public engagement and in integration of social, ethical and technical considerations into the study.

- NWMO's Roundtable on Ethics also provided advice throughout the study on principles and best practices to apply from the perspective of the discipline of ethics.

- Known or readily achievable technology: The initial screening of the fourteen technical methods early in the study process was designed to screen out methods which are contrary to international conventions and/or have insufficient proof-of-concept.[26] Whether 'Reprocessing Partitioning and Transmutation' is in fact an 'achievable' technology has been a source of much interest by citizens and dialogue throughout the study. As a result, it has been explicitly addressed by NWMO. The fourth approach attempts to put in place a waste management plan based entirely on currently implementable technology, while building in flexibility to allow for new learning and technological innovation (such as transmutation) which may come to fruition in the future.

- Sound engineering and industrial practices pertaining to safety and environmental protection: The third party review of the conceptual designs developed by the waste owners, which are a foundation element of the study, confirmed that the designs have been developed using established industry standards and practice appropriate for a conceptual stage of development.

- NWMO's assessment framework was explicitly designed to ensure socially important assessment areas are factored into decision-making. This includes those specifically mentioned by the Seaborn Panel: health and environmental impacts; compliance with regulations and safety standards; waste handling, packaging and transfer; and, transportation.[27]

- Overall health and environmental impacts: For each of the management approaches studied, the Golder/Gartner Lee assessment has suggested that, overall, negative health and environmental impacts would not be significant if the approaches were properly implemented and would likely be within known and anticipated safety standards.[28]

- Optimization of nuclear fuel waste handling, repackaging and transfer, as well as transportation distances for each approach, within the context of societal preferences, would be addressed in subsequent phases of work following a government decision.

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[26] Summarized in: NWMO, *Understanding the Choices*, August 2004.
[27] See Chapter 4 for listing of inclusions in the Assessment Framework in: *NWMO, Choosing a Way Forward – Draft Study Report*, May 2005.
[28] NWMO Background Paper 9-2: Golder Associates Ltd., Gartner Lee Ltd., *Assessment of Benefits, Risks and Costs for Long Term Management Approaches for Used Nuclear Fuel.*

- **NWMO suggests that the fourth approach has emerged as the preferred approach, at least in part, on the basis of the application of sound science and best practices.**

e) Flexibility

To be flexible, a concept must be capable of adapting to and incorporating new information. In conventional underground construction, when it is impossible to know all the details of the ground that lies ahead before it is exposed, this concept is known as "the observational approach," an "adaptive management strategy" or, more informally, "design-as-you-go." Such an approach is not an abdication of responsibility, but a wise expression of humility. It is also considered a prudent and practical approach to large, complex above-ground construction projects.

In the case of a long-term concept for managing nuclear fuel wastes, new information could pertain not only to site characteristics, but to developments in science and technology, or in societal and community values, especially those of the future generations that will eventually implement the concept. Thus, one aspect of flexibility would be the ability of a concept to adapt to the wishes of those generations regarding the appropriate balance between passive safety and active institutional control. For example, the system could be designed to achieve a high degree of passive safety after full implementation, while also providing for effective monitoring and retrieval.

Another aspect of flexibility would be the degree to which a concept could be implemented in stages. Thus, feedback loops must allow new information to be incorporated during each stage of development, starting with the formulation of a concept. This does not mean that changes will be massive, random or completely unforeseen. It simply means that as much room as possible must be left in which to maneuver.

Response and Discussion:

- The NWMO is recommending an adaptive management approach, which is consistent with the suggestion of the Seaborn Panel.

- The NWMO believes such an approach best meets the objectives identified as most important to citizens. It also meets the direction from citizens that a plan be put in place and initiated now, while leaving opportunity for future generations to influence the way in which used nuclear fuel is managed.

- The phased decision-making process will involve both experts/specialists and citizens in decision-making at multiple points along the path of implementation. The phased decision-making process is designed to allow for the kind of new information suggested by the Seaborn Panel to enter into and influence the process – such as, developments in science and technology, in societal and community values, and especially those of the future generations that will eventually implement the concept. With the fourth approach, future generation explicitly will control the pace of implementation – and in particular, the balance between passive safety and active

institutional control which is successively adjusted at each of the phases, including the last phase which involves closure of the facility.

- **NWMO suggests that, of the approaches studied, the fourth approach best incorporates flexibility within the broader context of an adaptive and precautionary approach.**

f) Feasibility of implementation

To meet this criterion, a concept must be based on known or readily achievable technology and must be able to meet the specific constraints of siting criteria as well as of an actual site. Adequate human, technological, financial, material and infrastructure resources to implement the concept must also be available. With regard to siting, feasibility could be demonstrated in part by showing that technically suitable sites are likely to exist. It could be demonstrated even more clearly by showing that the combination of features and processes contributing to safety actually exists at a range of potential sites in Canada.

Response and Discussion:

- NWMO has based its recommended approach on practicable technology, while at the same time leaving open an opportunity to take advantage of new technology should it become available. In conjunction with its recommendation, NWMO has outlined the human, technological, financial, material and infrastructure resources required to implement the approach and any supports to these which may be required[29].

- Feasibility of host geology has been explored and demonstrated for the purposes of this study of concepts. The feasibility of granitic rock has been investigated through design of the AECL Disposal Concept. This work was further built upon in the work by Ontario Power Generation in its subsequent work as documented on the NWMO website. The feasibility of sedimentary rock has been explored in the NWMO study process though a number of background papers[30] which build upon work conducted within Canada and internationally. It is designed to be further explored, in a site specific context, in the phased decision-making process suggested by NWMO in its recommendation.

[29] See Part Four of: NWMO, *Choosing a Way Forward – Draft Study Report*, May 2005.
[30] See NWMO Background Paper 6-12: Mazurek, "Long-Term Used Nuclear Fuel Waste Management – Geoscientific Review of the Sedimentary Sequence in Southern Ontario". See also NWMO Background Paper 6-13: RWE NUKEM, "Conceptual Designs for Used Nuclear Fuel Management – in Sedimentary Rock".

- **NWMO suggests that the feasibility of implementation of the fourth approach has been sufficiently demonstrated for the purpose of this study of concepts.**

g) Peer review and international expertise

To meet this criterion, a concept must reflect input from ongoing independent peer review processes, both technical and social, and all relevant international experience.

Response and Discussion:

- An important part of the Canadian repository development program is interaction with the corresponding research and development programs conducted in other countries. One of the waste owners has formal agreements with Sweden (SKB), Finland (Posiva) and Switzerland (Nagra) to exchange information arising from their respective programs on nuclear waste management. (See examples below.) These countries are considering used fuel repository concepts that are very similar to the Canadian concept, and their programs are advanced with respect to siting and approvals. Results from this collaboration and information exchange have been incorporated in the development of the conceptual designs which form the foundation for the NWMO's study. NWMO has, therefore, drawn heavily upon that information.

    - In 2003, OPG signed a five-year agreement with SKB for participation in the Äspö Hard Rock Laboratory (HRL). The prime objectives of OPG's participation at the Äspö HRL are to enhance the Canadian technology base for a deep geologic repository through international co-operation projects, to improve our understanding of key processes in a repository, and to directly share lessons learned in disposal technology development and site characterisation. In 2004, OPG participated in the Äspö Pillar Stability Experiment and in the In-Situ Diffusivity Experiment, and joined the LASGIT Gas Migration Experiment and Engineered Barrier System (EBS) Modelling Task Force groups.

    - OPG continues to participate in the international radioactive waste management program of the OECD Nuclear Energy Agency (NEA). Members of this group include all the major nuclear energy countries, both waste owners and regulators. In 2004, OPG was active in AMIGO - Approaches and Methods for Integrating Geologic Information in the Safety Case and Engineered Barrier Systems in the Context of the Safety Case. OPG also supported the NEA Thermodynamic Database Project.

- OPG is a funding member of the International DECOVALEX III Project, and is actively supporting research on the application of coupled thermo-hydraulic-mechanical numerical models in the geosphere.

- OPG is a participant in the European Commission's Cluster Repository Project (CROP), which documents experience in underground repositories to date. The final reports have been completed, describing lessons learned during design and construction, and performance modelling issues related to the application of engineered barriers in underground facilities.

- The NWMO has itself engaged independent consultants to identify the state of knowledge and best practices in a broad variety of disciplines related to the long term management of used nuclear fuel. The more than 60 papers which have been commissioned include examination of both natural science areas and social science areas, including best practices, by those involved in these fields.

- NWMO has initiated a number of key peer reviewed inputs to its study, including: the conceptual designs themselves, cost estimates, financial formulae, and assessment of the approaches. All elements of the study process have been described and published on NWMO's website for public scrutiny, review and input. NWMO has also established relationships with other waste management organizations, and international organizations such as the NEA and IAEA, to facilitate exchange of information and discussion of developing best practices.

- The NWMO has been an active participant in a number of international initiatives specifically designed to share information and further understanding on social research areas, including: ethical considerations; citizen involvement; and broadening the base for performance assessment. These initiatives include:

  - Forum for Stakeholder Confidence, an initiative of the OECD
  - Consultant meetings of the IAEA
  - CARL project: an international project focused on best practices concerning community involvement in decision-making

- The NWMO has also assembled an International Panel of eminent individuals to comment on each of its major discussion documents, including the Draft Study Report and recommendation.

- **NWMO suggests that the design of the fourth approach reflects broad and substantial input from independent peer review, as well as international benchmarking and review.**

Part II – Social Issues or Shortcomings

Through the work of the Joint Waste Owners and the NWMO, a list of the social and technical shortcomings identified by the Scientific Review Group and other review participants has been assembled and posted on NWMO's website for public input and comment.

A report outlining the social shortcomings were posted on the website early in NWMO's study. The report summarizes and categorizes the issues raised which were deemed to be "social shortcomings", after having gone through both the transcripts of the hearings, and the written submissions by interveners. NWMO's study process was designed, in part, in response to the social shortcomings raised during the Seaborn Panel deliberations. The listing of social shortcomings is reproduced in Table 2 below.

The list of social shortcomings and the list of technical shortcomings are understood to overlap, since the demarcation between the two in many cases is unclear. In preparation of these lists, an effort was made to err on the side of caution so that no important shortcomings would be missed.

TABLE 2

Social Issues or Shortcomings Associated with the Atomic Energy of Canada Limited Nuclear Fuel Waste Management and Disposal Concept Raised in the Seaborn Panel Hearings[31]

	Social Issue or Shortcoming	Discussion
1	**The Generic Concept**	
1.1	The generic concept was incomplete and could not be proved safe at the generic conceptual level.	Further work has been completed concerning the Deep Geological concept by the Joint Waste Owners in order to address the technical shortcomings which were raised by the Scientific Review Group and interveners. NWMO anticipates that dialogue about the safety of the concept, both the social requirement and technical efforts to respond, will continue after NWMO's study as the selected approach begins to be scrutinized in greater and greater levels of detail through a step wise decision-making process of implementation. Such a decision process will be outlined in NWMO's recommended implementation plan.

[31] The list of social issues or shortcoming is extracted from - *NWMO Background Paper 2-2: Social Issues Associated with the Atomic Energy of Canada Limited Nuclear Fuel Waste Management and Disposal Concept*, by Mark Stevenson

1.2	AECL did not adequately demonstrate the feasibility of the concept and did not provide a clear statement on the limits to the flexibility of the concept to adapt to changes	Further work has been completed to demonstrate the feasibility of the Deep Geological concept by the Joint Waste Owners, particularly with regards to technical shortcoming raised by the Scientific Review Group and interveners. In NWMO's study process, the limits to the flexibility of the concept to adapt to changes is a subject of current dialogue, as the advantages and limitations of flexibility are being examined in the context of a number of other potentially desirable characteristics of a management approach.
1.3	The implementing organization was not identified	The Nuclear Fuel Waste Act has identified the implementing organization. It is expected, however, that more consideration of the character of the implementing organization may be required to satisfy the public's underlying requirement that this organization be, and be seen to be, worthy of their trust.
1.4	The use of international experience and peer reviews was not maximized.	Further work has been completed to incorporate international experience and insight from peer reviews in the design of the Deep Geological concept by the Joint Waste Owners. This, in the course of addressing the technical shortcomings which were raised by the Scientific Review Group and interveners. International research and experience and peer reviews have also been used in the design of Reactor Site Storage and the Centralized Storage concepts. The NWMO has made an independent effort to review the best knowledge and expertise available in Canada and abroad as a foundation for its study in areas of social science and natural science relevant to the nuclear waste management decision. This is evident in the more than 70 background papers which have been produced by a variety of experts for the NWMO study. It is expected that the implementation plan recommended by the NWMO will suggest opportunities for peer review and international benchmarking at various decision points associated with the implementation of the selected approach.
2	**Need for and Timing of Disposal**	
2.1	The need for disposal was not addressed and the timing for disposal was not justified	The need for a long term management approach for used nuclear fuel, and the timing of a decision on this approach, was specified in the Nuclear Fuel Waste Act. In its recommendation, NWMO expects to comment on the extent to which there is urgency to implement any approach. It also expects to suggest the timing for implementation of the approach which would be most responsive to the values, objectives and concerns of Canadians.
3	**Alternative Management Options**	

3.1	The concept did not address alternatives to the disposal concept and alternative methods of disposal	The Nuclear Fuel Waste Act requires NWMO to study at least three used nuclear fuel waste management methods. These methods include those suggested by the Seaborn Panel, after having listened to Canadians on this issue.
3.2	The disposal concept lacked sufficient monitoring and retrievability	The modified concept proposed by the Joint Waste Owners has attempted to address these concerns. In NWMO's study process, the question of what constitutes 'sufficient' monitoring and flexibility is a subject of current dialogue as the advantages and limitations of monitoring and retrievability are being examined in the context of a number of other potentially desirable characteristics of a management approach. It is expected that, in response to its dialogue with citizens, the NWMO will suggest a monitoring program, and conditions for retrievability as part of the implementation plan for the management approach which it recommends to government.
4	**Involvement and Role of the Public**	
4.1	The public involvement process and the public's role in decision-making were inadequate	As discussed in more detail above, the NWMO has attempted to involve the public in both the shaping of the conduct of the study and the recommendation which will ultimately be made. It is expected that NWMO will recommend, and attempt to plan for, similar public involvement in subsequent phases of decision-making associated with implementation of the approach.
5	**The Environmental Impact Statement (EIS)**	
	The EIS was incomplete and did not adequately define important terms	Through its iterative and reflective study process and dialogue with Canadians, NWMO has attempted to identify the terms which are most important and to define these terms in a way which is meaningful to Canadians. A formal Environmental Impact Statement will be created once the Government has decided upon the management approach to be implemented.
	The EIS did not support the conclusion that the concept was safe	A formal Environmental Impact Statement will be created post Government decision on the selected management approach concept.
6	**The Impact Assessment**	
	There were omissions, inadequacies and deficiencies in the impact assessment	The Joint Waste Owners have conducted further work on the Deep Geological concept to address the omissions and inadequacies identified in the Seaborn hearing process and to better understand potential impacts. The NWMO has attempted to take a broader approach to the identification of possible impacts, and their assessment at a concept level. Through its study, NWMO has involved a broad spectrum of specialists and many citizens in the

		identification and assessment of potential impacts associated with each approach. NWMO expects this effort to be more inclusive of the social and ethical related impacts which were not considered to be well addressed by the earlier work.
	The assessment of the impacts on the social environment was incomplete and the social issues were inadequately addressed.	As mentioned immediately above, the NWMO has attempted to take a broader approach to the identification of possible impacts, and their assessment at a generic level. NWMO expects this effort to be more inclusive of the social and ethical related impacts which were not considered to be well addressed by the earlier work.
	The analysis of the biosphere component was seriously flawed.	The further work conducted by Ontario Power Generation on behalf of the Joint Waste Owners since release of the Seaborn report has attempted to address these deficiencies. Important additional work will be required once possible site locations have been identified. NWMO has also commissioned work to better understand potential impacts on the biosphere and build this in to the assessment of approaches.
7	**Site Selection**	
	The proposed site selection process was incomplete and incapable of leading to an acceptable site	NWMO believes the siting process will need to be developed collaboratively with those communities who are likely to be impacted by it. NWMO will, however, suggest a platform for this discussion which attempts to capture both the lessons it has learned through the study about effective collaborative engagement of citizens and the criteria which participants in the NWMO study have suggested are important for any credible process.
	The proposed voluntary siting process was flawed and inappropriate	NWMO expects that the collaborative development of the siting process with those communities who are likely to be impacted by it will help to ensure that any process which is used is appropriate in the eyes of those affected.
8	**Human Health and Safety**	
	The safety of the concept was not adequately demonstrated	The Joint Waste Owners have conducted further work on the Deep Geological concept to address the omissions and inadequacies identified in the Seaborn hearing process, and its work continues. NWMO has attempted to address assessment of the safety of the management approaches under study in a number of ways. First, it has attempted to define safety in collaboration with citizens, as well as specialists, so that the scope to be considered includes that which is relevant to citizens, and not simply the scope considered relevant by specialists. NWMO believes that, through this collaborative process, NWMO has identified and used a notion of safety which is more inclusive of what is important to Canadians than previous exercises. Second, NWMO has attempted to engage citizens, as well as specialists, in assessing the management approaches against this expanded notion of safety. In this way, both citizens and

		specialists have influenced not only the definition of safety but also judgment on the extent to which any of the approaches are able to demonstrate and ensure safety. Third, NWMO believes, and will suggest, that the demonstration of the safety of the concept requires a process which extends over a substantial period of time, rather than is the subject of a single and time limited decision. NWMO believes that the process must have as one of its core elements the systematic and iterative involvement of citizens as well as specialists. This, to both continue to identify relevant areas of concern and to contribute to the judgment as to whether these concerns have been addressed sufficiently to warrant moving to the next phase of implementation.
	The discussion of public and occupational health effects was inadequate and too restrictive.	Please see discussion immediately above.
9	**Acceptable Levels of Risk**	
	The process for and determination of acceptable levels of risk was inappropriate and deficient.	The NWMO has attempted to approach the question of risk in a way which: 1) encourages consideration of social dimensions and technical dimensions of any risk which may be posed; 2) portrays the decision on acceptability of risk as a social decision, informed by technical knowledge 3) encourages dialogue and debate among communities of interest as part of formulation of a social judgment.
10	**Risk and Uncertainty**	
	Measures for adapting to uncertain and unlikely outcomes were not adequately described.	The need to be adaptive and to address uncertainty, and the question of how best to accomplish this, has been a central focus in the NWMO study and in dialogue with citizens. Among the first concepts which NWMO explored as a basis for the study were adaptive management, precautionary approach, and risk and uncertainty. These concepts are expected to be key drivers for the approach which NWMO recommends to government. The extent to which the measures which NWMO suggests as part of its recommendation for adapting to uncertain and unlikely outcomes are adequate will be judged by citizens upon release of NWMO's draft study report. We expect this to be a focus of dialogue sparked by the draft study report, which will be used to refine the recommendation to government.
	AECL did not seek wide public input and input from other disciplines when developing scenarios or in developing and screening risk factors.	NWMO has deliberately sought to involve in its study a diversity of voices, including citizens and specialists in a wide diversity of knowledge areas. This includes the development of scenarios and the identification of relevant risk factors and assessment of approaches against these risk factors. Please see discussion above about NWMO's scenarios exercise and collaborative approach to the definition and assessment of safety and risk.

	The concept design did not provide sufficient protection for present and future humans and the natural environment.	The Joint Waste Owners have conducted further work on the Deep Geological concept to address the omissions and inadequacies identified in the Seaborn hearing process, and its work is continuing. NWMO has deliberately sought to assess the approaches for their impact on people and the environment. Public health and safety, worker health and safety, and environmental integrity were among the eight objectives against which the approaches were assessed. In order to explicitly consider the needs of future generations as well as the needs of the present generation, NWMO has attempted to conduct its assessment of approaches within two timeframes: the near term (considering the period of the next 175 years, or seven generations), and the longer term (beyond 175 years). The extent to which NWMO has identified an approach, and process for implementation of this approach, which enjoys sufficient confidence of Canadians to proceed will be judged by citizens upon release of NWMO's draft study report. We expect this to be a focus of dialogue following the draft study report. This dialogue will be used to strengthen the recommendation to government outlined in the final report.
	The risk analysis was inadequate and incomplete	The Joint Waste Owners have conducted further work on the Deep Geological concept to address the omissions and inadequacies identified in the Seaborn hearing process, and its work is continuing. NWMO has attempted to conduct an iterative, broad and inclusive risk analysis as part of its study. The identification of the dimensions on which risk should be considered began with dialogue about the questions which should be asked and answered in the study. This resulted in the ten questions outlined in NWMO's first discussion document. This dialogue was designed to ensure that the broad range of risk related issues of importance to citizens, as well as specialists, would be included in the study. This framework was elaborated upon by desktop analysis by specialists and further dialogue with citizens to both develop and confirm a more formal framework which could be used to assess the options. This Assessment Framework was used for the preliminary assessment of the approaches and reported on in NWMO's second discussion document. This framework was further elaborated upon and applied in a more robust manner by a team of specialists, to ensure that the knowledge and expertise of those who work in this area had been fully considered in the assessment. The result of this analysis (by Golder and Gartner Lee) was an important additional input to the draft study report.

		NWMO believes that through this iterative, broad and inclusive process, NWMO has conducted a more complete analysis of risk, appropriate for a concept level study, than was conducted in previous exercises. NWMO also believes, and will recommend, that risk will continue to need to be assessed at successive levels of detail through the process of implementation.
11	**The Limits of Science and Technology**	
	Scientific knowledge, analytical capabilities (e.g. computer modelling), engineering and current technology were insufficient to design, build and operate a safe disposal facility or to make predictions over the long time frame.	The Joint Waste Owners have conducted further work on the Deep Geological concept to address the omissions and inadequacies identified in the Seaborn hearing process, and its work continues. NWMO understands that there are natural constraints to demonstrating with certainty that a waste management facility will perform as designed. This is because of the long time periods over which a waste management approach must be effective, the uncertainties concerning how the future will unfold, and the inability to provide advance proof concerning how the management system will perform over the very long term. Despite these natural constraints and uncertainties, this generation has a great deal of knowledge concerning how to manage used nuclear fuel over the very long term. And this base of knowledge has grown since the release of the Seaborn report. With this knowledge comes a responsibility. In its recommendation, NWMO is seeking to find the path by which this generation can use its knowledge to the benefit of this and future generations, while recognizing the existence of uncertainty and the need to continue to learn and improve the management approach through the process of implementation.
12	**Transportation of Nuclear Fuel Waste**	
	The transportation of nuclear fuel waste would increase the risks of exposure to radiation.	The risk associated with transportation under normal operating scenarios is expected to be very small. Indications are that the risk can be managed through robust containers, and human systems, processes and oversight. Many “off-normal” scenarios have been identified and planned for. For these scenarios, through destructive and non-destructive testing, risk has been demonstrated to be very low. Testing and assessment of containers and systems, as part of a collaborative process in which potentially impacted communities of interest are involved in the design of the testing and assessment, is expected to build the level of public confidence which would be required to support the transportation of used fuel. The events of September 11 suggest that it may be difficult to anticipate all off-normal scenarios which may occur,

		particularly if they involve security threats of a type which have not been seen before. Any risk associated with these events is difficult to assess, although it is expected that a proactive process of continual review, re-assessment and improvement will minimize this risk.
	The transportation safety analysis underestimated the risks and consequences of transporting nuclear fuel waste.	OPG has conducted additional work since the Seaborn report in the area of transportation, as have waste organizations in other countries in the same period. This new knowledge has been built in to the design of the concepts and supporting systems which formed the basis for the NWMO study. NWMO has engaged multiple specialists in this area to help it understand the state of knowledge in this area and apply it to the assessment of the approaches. NWMO's study process has also involved citizens in the assessment of these risks at the conceptual level. NWMO is confident that the best knowledge and expertise in this area has been brought to bear on the design and assessment of the approaches. It expects that further work will be required in light of possible transportation routes and more detailed examination of containers and processes.
	The concept proposed inadequate or inappropriate security, safeguards and emergency response measures.	The adequacy of the transportation systems which have been suggested as part of the study will be the subject of comment, at a conceptual level, by interested citizens with the release of the draft study report. NWMO expects to suggest that safeguards and emergency response measures need to be the subject of further dialogue with citizens and collaborative decision making as part of the implementation of any approach selected.
13	**Policy and Decision-making**	
	Policy and decision-making processes used to select and approve the concept were not adequate	NWMO has attempted to use an open, transparent and inclusive study process in which citizens influenced the agenda for, design, conduct and outcome of the study.
14	**Trust and Credibility**	
	The proponent, the industry, the regulator and government did not have the trust or the credibility of the public to undertake, regulate or oversee this project	In the absence of full trust in the NWMO, the NWMO sought to implement a trust worthy and credible *study process* – a process that is open, transparent and inclusive, and for which NWMO's role for much of the study was as a 'facilitator of dialogue'.
15	**Ethical Aspects**	
	The ethical analysis component of the assessment was inadequate	Ethical considerations, along with value considerations, were the explicit starting point for the NWMO study. This was not the case in the previous exercise.
	The process for selecting, assessing and implementing the concept was not fair	An element of fairness has been introduced in the NWMO study through the study of multiple concepts. The previous exercise examined only a single concept which was deemed to be inadequate.

		'Fairness' was also one of the eight objectives against which the management approaches were explicitly assessed and discussed in dialogue with Canadians.
	The approach to compensation and incentives was unethical	NWMO plans to recommend that the approach to siting of a waste management facility should, at a minimum, be guided by the ethical and social framework which has emerged over the course of the NWMO's study. Although preliminary work has been completed by NWMO concerning the nature of compensation and incentives which have been used in comparable projects around the world, NWMO believes that a plan for compensation and/or incentives cannot be determined without further dialogue with potentially impacted communities of interest.
	The concept's predetermination of a location in the Canadian Shield is inequitable	There has been no such predetermination in the NWMO study.
	The concept would not provide adequate and equal protection for all future generations and would place an undue burden on future generations	Protection of future generations was an explicit area of analysis and dialogue in the NWMO study, as has been discussed above. The effectiveness of NWMO's work in this area will be judged by interested citizens with the release of NWMO's draft study report.
16	**Cost and Financial Deficiencies**	
	The information on cost and finances was inadequate and not credible	Cost estimates associated with each of the approaches being studied have been reviewed by an independent consultant and found to be appropriate, have been published on the NWMO website and have also been made available on CD for review and comment by interested Canadians. To this point in the dialogue, no substantive concerns about these cost estimates have been raised.
	Financial impacts were not fully addressed and there was no guarantee that a segregated or dedicated fund would be established to fund disposal	The Nuclear Fuel Waste Act has required the creation of segregated funds, independently held, to fund the implementation of any approach selected. Cost estimates associated with each of the approaches being studied have been reviewed by an independent consultant and found to be appropriate, have been published on the NWMO website and have also been made available on CD for review and comment by interested Canadians.
17	**Regulations and Standards**	
	The concept relied upon regulations and standards that did not adequately protect human and environmental health	Regulations and standards are under the purview of the federal government. However, although NWMO has attempted to ensure that any management approach which it recommends will meet existing regulations and standards, this is not the sole basis for determining acceptability of the approach. In its study process NWMO has attempted to capture citizen concerns, values and implicit standards and criteria through dialogue. It has used this, in addition to current regulations and standards, in the assessment of the approaches.

	The process of developing the regulations and standards did not adequately involve the public or address social concerns	Please see discussion immediately above.
18	**Scoping of the Problem**	
	The concept omitted consideration of energy policy, including alternative energy sources and the future use of nuclear energy	The Nuclear Fuel Waste Act has identified a mandate for the NWMO which does not extend to consideration of energy policy. NWMO has, however, attempted to listen to citizens on this issue, understand how decisions of energy policy may affect the appropriateness of used fuel management approaches, and report this in its public documents.
	There was inadequate discussion of reprocessing and disposal of reprocessed spent fuel and MOX fuel	In light of the interest expressed by many Canadians, NWMO explored reprocessing as a possible management approach for used nuclear fuel and included discussion on this topic in its public documents. Over the course of examination of possible future scenarios, and how this might affect the appropriateness of the management approaches under examination, NWMO did consider alternative fuel types.
	The potential for and consequences of importing nuclear waste from other countries was not addressed	Consideration of Canada's policy on importation of waste is beyond the mandate assigned to NWMO by the Nuclear Fuel Waste Act. However, over the course of examination of possible future scenarios, and how this might affect the appropriateness of the management of approaches under examination, NWMO did consider alternative fuel volumes.
19	**Aboriginal Involvement in Planning and Decision-making**	
	There was insufficient culturally appropriate, funded consultation and communication with Aboriginal peoples throughout the process	The NWMO has initiated agreements with Aboriginal organizations to provide funding and support for Aboriginal organizations to design and implement a dialogue to contribute to the NWMO's study. These agreements are designed to support Aboriginal organizations to conduct dialogues with their communities in the manner in which they consider appropriate. As discussed in more detail above, more than 80 individual meetings have been held and 3,000 participants have been involved in dialogues lead by Aboriginal peoples.
	The decision-making processes used by AECL and the government in defining the concept and in completing the Environmental Impact Statement (EIS) and those proposed for subsequent phases were inadequate.	NWMO's broad based, inclusive, transparent, iterative and reflective study process was designed to address the deficiencies identified with the earlier process.
	The concept omitted consideration of, or demonstrated a lack of respect for, Treaty and Aboriginal Rights and the constitutional rights of Aboriginal people	NWMO's approach to engaging Aboriginal organizations to design and conduct their own dialogue as they see fit was intended to engage Aboriginal peoples in a respectful and appropriate manner. NWMO has attempted to conduct its study in a way which is respectful of the Treaty and Aboriginal Rights, and constitutional rights, of Aboriginal people. NWMO is constrained in the mechanisms available to it to demonstrate

		this respect since the focus of responsibility in this area rests with the government.
	The concept is unethical because it will place undue risks and burdens on future generations, it is inequitable to locate the facility in areas where the people had not benefited from nuclear energy, and it would entice poorer Aboriginal communities to accept the facility through compensation or incentives.	Fairness to future generations and to regions was an explicit area against which the approaches were assessed. In light of what it has heard over the course of its study, NWMO will seek to plot a fair course in its recommendation to government. Dialogue following the release of the draft study report will help NWMO identify the extent to which it has been successful before having to finalize its recommendation and deliver to government.
	The procedure for assessing and deciding about the concept was not fair	As discussed above, NWMO has attempted to address the issue of fairness in a transparent and inclusive manner in the assessment of the approaches.
	The proponent, the regulator and government did not have the trust or the credibility to undertake, regulate or oversee this project.	As mentioned above, NWMO sought to implement a trustworthy and credible study process, in recognition that some stakeholders would not find NWMO to be trustworthy and credible due to its governance structure. This governance structure reflected the direction contained in the Nuclear Fuel Waste Act.
20	**Aboriginal Perspectives on Long-term Waste Management**	
	The concept was not proven to be safe and it conflicted with the Aboriginal beliefs about their responsibility to Mother Earth	Please see discussion about NWMO's efforts to define and assess the management approaches against safety. Note that NWMO attempted to incorporate the knowledge, wisdom and direction of Aboriginal peoples in both the definition of the concept of safety and the assessment of the approaches against it.
	The site selection process of the concept was deficient and inappropriate	Please see discussion above concerning NWMO's efforts and approach to siting.
	Alternative management options were not adequately addressed.	As mentioned above, the Nuclear Fuel Waste Act requires that NWMO study at least three approaches. NWMO has gone beyond this requirement to examine, at least at a high level, a broad list of approaches which are often raised and examined in other countries.
	The transportation assessment was inadequate	Please see transportation related discussion above.
21	**Aboriginal Perspectives on the Environmental Impact Assessment**	
	The assessment did not demonstrate the safety of the concept to present and future generations and to the environment	Please see discussion above concerning NWMO's broad based approach to safety, and efforts to assess the approaches from the perspective of the current generation in light of the next seven generations, and far future generations.
	The treatment of Aboriginal spiritual, cultural and social values was inadequate	In engaging Aboriginal organizations to design and conduct their own dialogue process, NWMO has sought guidance from Aboriginal peoples concerning how their spiritual, cultural and social values are best applied to the assessment of the approaches under study and formulation of a recommendation.

	The assessment did not adequately address the impact of the concept on traditional activities or on the natural environment.	In engaging Aboriginal organizations to design and conduct their own dialogue process, NWMO has sought guidance from Aboriginal peoples concerning how the approaches under study are likely to impact their traditional activities and the natural environment.

Part III – Technical Issues or Shortcomings

Since 1996 Ontario Power Generation, on behalf of the Joint Waste Owners, have conducted substantial work to address the technical issues or shortcomings raised during the Seaborn Panel process concerning the Atomic Energy of Canada Limited (AECL) disposal concept. Ontario Power Generations has prepared a more than 600 page report to document how it has addressed the technical issues and shortcomings in its deep geological repository design. This design is the basis for one of the approaches under study by NWMO.

This report was posted on the NWMO's website mid-way through the study process, in response to questions raised by interested Canadians and to facilitate broad review and scrutiny. The following table lists the technical issues or shortcomings raised during the Seaborn Panel process, and includes an extract from Ontario Power Generation's response which reflects work conducted up until 2003. Note that work has continued and is not reflected in this table. We encourage readers to review the full text of the report.

TABLE 3

Technical Issues or Shortcomings Associated with the Atomic Energy of Canada Limited (AECL) Nuclear Fuel Waste Management and Disposal Concept Raised in the Seaborn Panel Hearings[32]

Number	Technical Issue or Shortcoming	Extract from Ontario Power Generation's (OPG) Response
2	**Project Management**	
2.01	Timing of Disposal	OPG has conducted studies on implications to the timing of emplacing used fuel in a geological repository. The reference geologic repository concept is designed to receive 30-year old used fuel. … Studies of extended storage have also been conducted by OPG and the other waste owners to support the NWMO's assessment of the approaches. The NWMO is presently assessing these options. …
2.02	Timing of Design Decisions	The design of the engineered barrier system and deep geologic repository have been the subject of further study. However, major design choices for the reference concept have been made in order to focus the further development and assessment work. …

[32] The list of technical issues or shortcomings, and OPG's response, is extracted from a 600 page report posted on NWMO's web site – *Response to Technical Comments raised during Environmental Assessment of AECL Disposal Concept*, a document prepared by OPG in 2003 in support of *NWMO Background Paper 6-9: Conceptual Designs for Used Nuclear Fuel Management*.

2.03	Timing of Probabilistic Safety Assessment	… First, it should be stated that "modelling backwards" from a desired result would go against the professional and personal standards held by members of the safety assessment groups. Second, model development should occur in order to incorporate new results from ongoing research in Canada and elsewhere and to take advantage of improvements in computers. With respect to probabilistic safety assessments of conceptual site models, these can be useful in advance of a specific site. Such analyses can explore generic design or siting issues and test the safety assessment tools. …
2.04	Integration	… The NWMO was established in accordance with the Nuclear Fuel Waste Act to investigate approaches for long-tem management of Canada's used nuclear fuel. The study is to include public consultation. The description of each approach will also include a program for public consultation. OPG recognizes the importance of social process and public input. The five principles outlined by AECL provide a basis for a siting process. However, the need for a siting process and the details of what that process will consist of, are not determined at present. Next steps will have to be regularly re-evaluated in the light of new knowledge, new information, and social and political inputs. As required by the Nuclear Fuel Waste Act, the NWMO has an advisory council representing a wide range of stakeholders. It is anticipated that other groups such as a Community Liaison group, and special interest groups, would also be involved in an on-going program and would contribute to obtaining a technically and socially acceptable results. …
2.05	Multiple Barriers	
2.05.01	Multiple Barriers – Reliance	… Overall system safety depends on a series of barriers, and performance remains robust even if one barrier fails to function as expected. Within the multibarrier system, barriers may be natural or engineered features. The geosphere has an important role to play in isolating the used fuel from the human environment and providing a stable environment for the components of the disposal system. Safety assessments at the current stage of the program are using reference geospheres to study further the performance of the engineered barriers. …
2.05.02	Multiple Barriers – Redundancy	… The subsequent AECL SCS (1996) provides a different perspective on barrier redundancy. In this case, the geosphere was chosen to be less robust, while the vault design was made more robust. In this SCS case, the AECB risk criterion was also met. Furthermore, other barriers not considered in either study include Zircaloy cladding, matrix diffusion in the rock, and the stability dense saline fluids at depth. The range of possible barriers provides confidence that sufficient redundancy can be achieved through appropriate design and siting. Future safety assessments will continue to assess the redundancy of the barriers in the context of specific case studies, in part though explicit "what if scenarios". …
2.05.03	Multiple Barriers – Performance Criteria	… Preliminary system requirements under development as part of OPG's disposal technical program contain a requirement for the container to remain intact for 100 000 years. It is also planned to carry out safety assessment for time periods up until the time of the maximum dose, while recognizing the increasingly qualitative nature of these estimates. The question of biospheres to be used in such assessments is still a matter for discussion, however, it would likely be conservative for

		individual dose and risk to use the same critical groups as used for the nearer term analyses. …
2.06	Observational Approach	… OPG believes that siting, design, and safety assessment are complementary processes requiring integration and considerable iteration to arrive at an optimum repository system during facility design and siting and to evolve the repository facility design during its construction and operations in response to new information, regulations and technology developments. OPG fully expects that the design for a deep geologic repository will have multiple barriers and will accommodate the site features, as they become known during the site characterization period and during facility construction and operation. …
2.07	Technical Review	… OPG is encouraging involvement in the technical program of a wider range of institutions, particularly universities. OPG has Technical Exchange Agreements with SKB and Posiva, which include exchange of all technical reports and other cooperative efforts. The value of peer review via submission of papers to journals is recognized, and is encouraged within the OPG Program. Independent review, in the sense that the reviewer is not directly funded by the program, might be done through an external organization such as the Royal Society. The Advisory Council required as part of the NWMO's organization is not primarily a technical advisory committee; rather a forum for bringing together viewpoints from a broad range of interested parties. It is expected that the framework, methodologies and criteria for estimation of effects on non-human biota will be more fully-developed by the time of any future siting stage for a deep geologic repository. …
2.08	Quality Assurance	… Work carried out under the Canadian program has always been conducted so as to be of high quality, regardless of whether there was a formal QA program in place. The models and data used by OPG are consistent with those used internationally in similar studies or applications. However, it is recognized that formal quality assurance programs provide a high degree of traceability of result and their verification, and therefore leads to improved confidence in these results. With respect to a siting quality assurance program, the various international siting projects (e.g. Finland, Sweden, US) could provide a reference for establishing a Canadian siting QA program. …
2.09	Construction Management	… The NWMO would be responsible for the overall management and funding of the geologic repository facility. It is expected that the level of quality assurance associated with the construction, operation, decommissioning and closure of the geologic repository would be the same regardless of whether the NWMO or a contractor carried out the actual work. However, the details of the management systems and the applications of quality assurance and control would be developed for the specific mix of contractors and the NWMO operations at each stage during the repository facility project. …
2.10	Cost/Benefit	… Safety assessment and performance assessment models are used to provide an indication of the evolution of the geologic repository system and an estimate of the potential impact on humans and the natural environment for a variety of scenarios. Work initiated by OPG, and included in studies submitted to the NWMO by OPG and other waste owners, incorporates a long-lived copper container that is similar in

		design to the spent fuel containers in the Swedish and Finnish designs. A revised cost estimate accompanies the updated repository concept and can be used to compare with the previous repository design and cost estimate for the AECL concept submitted in 1994. …
2.11	Cost	… OPG believes that the costs of monitoring a deep geologic repository facility for used fuel can be predicted for a defined period of monitoring. Any costs associated with retrieval operations will depend on the time of and reasons for a decision to retrieve used fuel containers. OPG, together with the other waste owners, has submitted to the NWMO studies prepared by an independent consultant which provide an update to the repository concept and cost estimate, with an estimate of contingency. The Canadian cost estimates have been benchmarked against those for the similar repository designs in Sweden and Finland and will continue to be benchmarked as new information becomes available. …
2.12	Funding	… The federal Nuclear Fuel Waste Act required nuclear fuel waste producers to establish trust funds to finance the long-term management of nuclear waste. The nuclear utilities in Canada have provided financial guarantees for coverage of costs for the decommissioning of nuclear facilities, the long-term management of low and intermediate level wastes, and nuclear fuel waste. …
2.13	Schedule	… OPG has prepared a conservative estimate of the schedule for the siting, characterization, assessment, design and construction of a deep geological repository for used fuel which takes into account the anticipated time that it takes to reach agreement with communities, prepare and conduct an EA process, and to obtain approvals and licenses from the authorities for activities associated with the facility. OPG together with the other waste owners, has submitted to the NWMO studies prepared by an independent consultant which provide an update to the repository concept and cost estimate, and which include an updated planned schedule for implementation of the concept, pending a decision by the federal government of the preferred approach to the long-term management of nuclear wastes. …
2.14	Research	… In general, OPG agrees with the overview conclusion of the Canadian Geotechnical Society that the geotechnical aspects associated with the geologic isolation of used fuel on the Canadian Shield now have been studied to the point that further studies are hampered by not knowing the exact geological conditions of the candidate state. Ongoing studies can be usefully carried on certain aspects related to site characterization, visualization, and resolution of particular issues. …
2.15	Archive	RE: Archive to store physical samples and records obtained from a site evaluation process and make those available for public access at any time during the site evaluation and monitoring stages. … This looks like a good idea and will be noted. Implementation could begin, at the earliest, at the site identification stage. …
2.16	Institutional Controls	… Institutional controls are expected to continue far into the future. Two important aspects are: - maintaining knowledge of the repository

		- maintaining land use controls Together with permanent markings, safeguards against the use of the fissile material contained in disposed used fuel in weapons is an aspect which the subject of international co-operation, and will require further development in the future. The required effectiveness of the controls and markers likely varies with the kind of intrusion anticipated. …
2.17	Land and Resource Use	… The context for a deep geologic repository with respect to regional and municipal land use plans and provincial plans is an aspect which should be considered as part of siting feasibility studies. …
2.18	Occupational Health and Safety	… The issue of worker safety at a deep geologic repository for used fuel is discussed in the EIS support document "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System" and covers normal and abnormal (accident) conditions, and conventional and radiological events. OPG recognizes that more extensive assessment and discussion on worker safety would be required for further design, approval and licensing of a real facility. …
2.19	Emergency Response	… Emergency response capability would be part of the organization at a deep geological repository site, as at current nuclear sites. Under the Transportation of Dangerous Goods Regulations, an approved Emergency Response Assistance Plan is required for all transportation of dangerous goods. The plan would typically include notification, consideration of all potential accidents, and preparation for response. OPG believes that emergency response will not be required after closure of a facility. …
2.20	Maintaining Flexibility	… The NWMO was established to investigate approaches for the long-term management of Canada's used nuclear fuel. The storage and deep repository concepts have been developed to be flexible to accommodate site conditions and potential changes in regulatory criteria (which are currently (2003) under review by the Canadian Nuclear Safety Commission – CNSC). With respect to the deep geologic repository concept, the depth of the facility and layout of the vault are flexible to accommodate geologic features and environmental conditions at the site. …
2.21	Multiple Sites	… If the deep repository approach is selected by the federal government following the NWMO's study of alternatives, OPG expects that there will be a single facility in Canada for used CANDU fuel and other high-level radioactive wastes. …
3	**Licensing**	
3.01	Relevant Legislation	… The need for inclusion of Hazardous Products Act and its regulations among the applicable regulations is noted and agreed. At the outset of any disposal siting program, work would include a review of legal aspects, relevant legislation, agreements and commitments relating to the deep geologic repository. …
3.02	Provincial Approvals	RE: No mention has been made of the licensing approvals that must be gained from the appropriate Provincial government to whom surface and mineral rights are invested. … This comment is noted and will be taken into account. …

3.03	Criteria	
3.03.01	Criteria – Contaminant Concentrations	… The status of chemical toxicity data for used fuel nuclides is reviewed in the Goodwin and Mehta (1994) screening study. OPG plans to look further at chemical toxicity as part of the Third Case Study project and related reports. Criteria for future safety assessments will be developed considering toxicity data, as well as comparison with naturally-occurring levels. …
3.03.02	Criteria – Environmental Increments	… By definition, the standard deviation is within the normal range of background. Further work is required to establish the health of existing ecosystems under this variation. OPG agrees, as noted in its response to 3.03.01 that criteria based on environmental increments should be supplemented by an understanding of the toxicology and no-effect levels. It is expected that the repository program will be the subject of an ecological risk assessment (ERA) at a site specific stage, which will include identification of specific ecological receptors, assessment endpoints and measurement endpoints, and will use available appropriate methodology at that time. …
3.03.03	Criteria – Decommissioning and Closure	… Criteria for closure will be decided by the community, regulator, and other institutions involved at the time, and with the knowledge that exists at that time. Clearly the criteria should include a comparison of the repository behaviour with expectations via observations, monitoring, and measurements. It is expected that monitoring may be required for as long as the host community requires, in consultation with the regulator. …
3.03.04	Criteria – Comparability	… Criteria for radiation protection are based on those developed by ICRP taking into account of the risks which appear to be generally considered acceptable. However, there are a number of conservatisms in risk assessment methodology for radionuclides which lead to very low risks, in practice to, to people exposed via environment pathways. Regulatory criteria are the responsibility of CNSC, and requirements for disposal are expected to be further developed in future with public consultation. However, in addition to showing that designs meet applicable criteria, projections of potential health effects would be made as part of the EA for any future facility. …
3.03.05	Criteria – Protection of Humans	… Radiation protection standards are set by CNSC following international consensus. Knowledge relevant to the issue of radiosensitive individuals will likely advance over the next decades and may affect radiation protection criteria. CNSC is carrying out a review of its regulatory guidance documents and will seek public input. The methodology used for safety assessment involves the calculation of doses to the most exposed individuals. A number of "what if" scenarios will be explored. Temporal variation in doses is already done as part of identifying the maximum dose. Further review of ethical issues is being carried out as part of the review of options required by the Nuclear Fuel Waste Act. …
3.03.06	Criteria- Protection of Non-Human Biota	… For the preferred site, an ERA will be part of the EA required for the construction license. At this time, the latest international and CNSC guidance, methodology and criteria will be followed. There is no unique methodology required for disposal. OPG's current program includes review of developments in this area. Some work is being carried out on methodology. Additional expertise will be developed/acquired as

		needed, and development of a framework assessment will be the subject of future work. …
3.04	Demonstrating Compliance	… The lack of clarity in some aspects of the regulatory guidance available at the time the EIS was prepared is recognized, and will be brought forward when a consultative document on revised guidance is made available by CNSC. OPG agrees with the comment regarding human intrusion; this has received attention recently from ICRP in their publication 81. In addition to CNSC regulations, there are many regulations to be complied with in the preclosure phase, and review and compliance with these would be an important part of the project at the site-identification and subsequent site specific stages. …
3.05	Definition of Risk	… OPG's current safety assessment approach takes account of the risk of fatal cancers, non-fatal cancers and serious genetic effects as a consequence of dose, using the values of risk coefficient recommended by ICRP 1991. As part of the estimation of impacts for a future EA, non-radiological impacts would also be estimated. OPG anticipates that these risks will be assessed according to then-current Canadian best-practice for licensing of related types of facilities. …
3.06	Definition of Health	… It is anticipated that there would be future consultation with Health Canada and with other stakeholders during the development of submissions for EAs and licensing. …
3.07	Definition of Safety	… Radiation protection standards that would be used for the licensing of a deep geologic repository are developed taking into account of internationally-accepted dose-risk estimates and of consideration of other societal risks. The standard represents a very high-level of safety when compared with other risks. The safety case for a deep geologic repository is expected to include a number of complementary arguments which together constitute adequate proof of safety. The constitution of the safety case is to be developed and will be subject to ongoing discussion with the regulator and other stakeholders. …
3.08	Circumventing an Environmental Assessment	… A deep geologic repository, wherever sited, would be subject to the Canadian Environmental Assessment Act. If located completely within the boundaries of an existing licensed nuclear facility, the initial stage of the EA could be preparation of a screening report (screening EA). CNSC's determination following consideration of the screening report may be to allow the project to proceed, in whole, or in part, not to allow the project, or refer the project to the Minister for panel or mediator review. If located outside the boundaries of an existing nuclear facility, a comprehensive study would be required. The decision whether or not to carry out a formal panel review therefore rests with the CNSC and the Minister, not the proponent. Furthermore, there are many technical, social and financial factors to be taken into account in identifying a site and in obtaining approval to construct a facility. The time and cost of the EA process is a very significant factor. But social acceptance is also an important part of the siting and EA process. …
3.09	Radiation Emission Standards	… DEL's (Derived Emission Limits) are used in control of emissions from operating nuclear facilities. (OPG's DEL's have been replaced with Derived Release Limits calculated according to new

		methodologies.) They provide a means to relate emissions to the radiation dose received by the critical group. It is expected that emissions during the operational phase of a repository would be similarly monitored and controlled. However, for the control of postclosure exposures from a deep geologic repository, DEL's would not be the method used. Instead, CNSC set criteria, and safety assessment would be used to show that these criteria were met. The question of population exposures has yet to be resolved, since there are many uncertainties in projecting population distribution far into the future. …
4	**System Performance**	
4.01	Activities	
4.01.01	Activities – Outcrop Clearing	… Site characterization activities at a preferred site will include detailed geologic mapping of exposed bedrock crops. Dependent on the degree of bedrock exposure, it may be required that a thin (1m) veneer of soil be removed to expose the underlying bedrock surface. Locations at which outcrop clearing may occur are remote and unable to support and/or sustain agriculture development. Mitigating measures to avoid increased soil erosion and surface water sediment loading would be implemented, if site specific conditions dictated. …
4.01.02	Activities – Off-Site Activities	… The EIS and the supporting documentation (e.g., "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System") recognize that there will be off-site impacts from the construction and operation of a geologic repository facility for used fuel since resources such as bentonite clay, glacial lake clay, sand and other engineered barrier materials will have to be obtained elsewhere, processed and transported to the facility. …
4.01.03	Activities – Blasting	… The EIS support document, "The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility", discusses the control of hazardous material including detonators and explosives. These items would be stored separately on the surface in approved buildings or magazines at the geological repository facility. The requirements for the safe storage and handling of explosives and detonators, and many of other hazardous materials used in mining operations, are set out in legislation such as the "Regulations for Mines and Mining Plants" by the Government of Ontario. As described in "The Disposal of Canada's Nuclear Fuel Waste: Engineering for a Disposal Facility", the nuclear fuel waste container transportation and emplacement operations, and the explosives handling and construction activities would be widely separated within the repository. …
4.01.04	Activities – Alteration of Baseline Conditions	… The EIS support document, "The Disposal of Canada's Nuclear Fuel Waste: Preclosure Assessment of a Conceptual System", recognizes that the preclosure activities will have a small but measurable effect on humans and the natural environment, and has recommended activities to mitigate these impacts. …
4.02	General	
4.02.01	General – Breaches of Security	… Security measures and responses to threats would be discussed with the regulator at the time of implementation. …
4.02.02	General – Rock	… Rock burst is sensitive to the shape of the underground excavation,

	Bursts	the method used to create the excavation and the stress in the rock, and thus the openings can be designed and engineered to minimize the risk of rock burst. Experience gained by operation of the Underground Research Laboratory (URL) has indicated that significant rock burst is not probable and that only localized, small-scale strain bursts of rock slabs are likely to occur at an underground repository for nuclear fuel wastes on the Canadian Shield. …
4.02.03	General - Vault as Exploration Target	… OPG recognizes that the geologic repository may contain materials that may be of value to a future society. This feature was considered in the assessment of inadvertent human intrusion into the repository. …
4.02.04	General – Health Effects of Radiation	… OPG believes that current methodology and data for estimating radiation effects are conservative and suitable for assessing potential impacts throughout the lifecycle of a deep geologic repository. It is expected that at a future EA or development stage, a full discussion of the effects of radiation could take place. The discussion should focus on what are the expected impacts of this facility, e.g. acute radiation sickness is not an expected impact, although it might be discussed as part of a comprehensive picture. …
4.02.05	General – Thermal Effects	… For the EIS, thermal analyses were conducted with analytical model, with AECL's HOTROK (analytic) and MOTIF (finite element) codes, and by Ontario Hydro and Golder Associates (using finite element codes). The potential thermal effects on container materials, sealing materials (buffer, backfill, etc.), rock properties, ground water flow and containment transport were also considered as described in AECL's EIS (AECL 1994) and supporting documentation, and were factored into the vault layout design and safety assessment. In 2000, OPG reviewed the treatment of thermal effects in a repository and found that the potential effects are reasonably understood and conservatively treated. If a deep geologic repository is the approach selected for the long-term management of Canada's used fuel, additional analyses would be done to further advance and optimize the design of a repository. …
4.02.06	General – Microbes	
4.02.06.01	General – Microbes - General	… In the 1990's, there has been a substantial increase in the information available on microbes in deep rock suitable for used fuel disposal, in part as a result of research at underground laboratories around the world, including the Canadian URL facility in Pinawa, Manitoba. Microbial-related research is continuing in Canada and elsewhere. The general conclusion of these studies is that microbes will be present around the repository, and that they should be considered in both the design and the safety assessment of any proposed repository. The influence of microbes on system performance is formally identified in the OPG FEP Database, and so will be specifically considered in any future safety assessment. …
4.02.06.02	General – Microbes – Nutrients	… An inventory of bacterial nutrients that would be placed 'intentionally' with vault materials (fuel waste, waste containers, buffer and backfill materials) has been provided in Stroes-Gascoyne (1989). This report concluded that N would be the growth-limiting nutrients, and made conservative estimates for the possible microbial population. A subsequent report (Stroes-Gascoyne et al. 1996) assesses bacterial nutrients that would be added 'inadvertently' to a vault in the form of residues of material used to excavate and operate a vault. As part of a

		future site specific design or safety assessment, the microbial analysis can use this information to judge the importance of these nutrient sources at that specific site. …
4.02.06.03	General – Microbes – Mutagenesis	… There is ongoing research to better understand microbial activity in a repository. OPG will continue to support and monitor developments, and provide reports on microbes and their expected behaviour in a Canadian disposal vault. However, there are some arguments that indicate why mutation in particular is not likely to be significant. …
4.02.06.04	General – Microbes – In the Vault	… There is a broad international interest in microbial behaviour in the vault. In the Canadian program, the multi-year in-situ Buffer-Container Experiment and the Isothermal Test (Stroes-Gascoyne et al 2000) have had examination of microbial effects as an important part of their objectives. Work is presently continuing in Canada and elsewhere to improve understanding of microbial effects in the Canadian repository environment. It is expected that any future safety assessment would contain a current summary of the potential effects of microbes on the repository. …
02.06.05	General – Microbes – In the Geosphere	… There is broad international interest in transport fractures with a number of experiments underway in natural settings. In the Canadian program, the work in the MFR (Moderately Fractured Rock) experiment at the URL is one notable example. In such multi-year tests, biofilms and colloids can be active and influence the results. As part of any future safety assessments, a review of the current understanding of such processes would be required at that time. It is also likely that an underground test facility would be constructed at any candidate site, and tracer tests in fractures at site conditions would likely be carried out. …
4.02.06.06	General – Microbes – In the Biosphere	… Recent results are certainly consistent with the SRG view that colloids can be important in soils and sediments in the surface biosphere, as distinct from the overburden, where colloid levels may be low and not important. With respect to the possibility of periodic accumulation and sloughing of biofilms at wells, it is noted that the dose estimates of interest are over long time scales, which would tend to average out short term decreases or spikes in dose rates. In general, the possibility of microbial effects on transport and sorption in the biosphere needs to be considered in as part of any future assessment, taking into account current understanding of colloids and of site specific data. …
4.02.07	General – Radon Gas Production	… Preliminary occupational safety analyses were conducted for the 1994 EIS submitted by AECL, and found to be acceptable (Preclosure report p. 5-1). More detailed occupational safety analyses would be conducted when design and site specific data are available. Radon gas and its decay products are routinely encountered in underground mines. The repository is expected to be licensed by regulatory authorities who will require occupational doses to be acceptable. The normal process to deal with underground radon is to ensure that the ventilation is adequate to ensure that occupational doses to be acceptable. …
4.02.08	General – Colloids	… A good summary of the understanding of colloids at the time of the EIS is Vilks (1994). Since the EIS, there has been further work on colloids and their possible influence on radionuclide transport. Experimental work on colloid transport in buffer and geosphere is continuing, and the current understanding would be reflected in the data

		and models used for any future safety assessment. The status of colloids in the context of any specific OPG safety assessment can be found in the corresponding FEP's Database entry #3.2.04 Colloid Interactions and Transport. …
4.02.09	General – Glaciation	… The effect of glacial and peri-glacial conditions should be considered in geosphere performance assessment. In addition to qualitative arguments put forth in the EIS, the DGRTP has initiated several projects intent on re-examining the influence of long-term climate change and glacial cycles on engineered barrier systems and geosphere performance. These efforts include a re-assessment of performance assessment modelling techniques and strategies necessary to predict flow systems dynamics and geochemical stability under variable boundary conditions. …
4.02.10	General – Seismic Events	… In the EIS, one of the technical factors to be considered for site screening was rock mass stability and low seismicity/seismic risk. As stated in the EIS, the organization responsible for implementing the potential deep geologic repository option for nuclear waste management, may incorporate seismic design methods for surface and subsurface structures associated with the construction and operation of a repository. …
4.02.11	General – Contaminants from Explosives	… OPG has conducted studies examining the potential impact of microbial activity in a deep geologic repository with nutrients introduced by the construction process (see Ager and Jain 2000, Microbial gas production in mixtures of reference buffer material and standard Canadian Shield Saline Solution, OPG Report 06819-REP-01200-10021-R00). The impacts are expected to be very small. …
4.02.12	General – Sorption	… Sorption of radionuclides on transport through clays and rocks is a well-established process. A systematic, semi-empirical approach was used to select the radionuclide sorption coefficients. Experimental data, when available was used first. Otherwise sorption values were estimated based on mineralogical similarity, conservative estimates based on mineralogy, chemical homologs, conservative estimates based on chemistry, etc. It is intended that the reference sorption models and values should be systematically reviewed, taking into account data gathered since the EIS. Treatment of sorption in the context of any specific OPG safety assessment can be found in the corresponding FEP's Database entry #3.02.03 – Sorption and Desorption. …
4.02.13	General – Change in Discharge Location	… The role of geosphere performance assessment, supported by site characterization is to provide a reasoned basis to understand groundwater flow paths at time and space scales relevant to demonstrating repository safety. There are several key issues that must be addressed to achieve this including a description of the temporal and spatial variability of flow system properties and boundary conditions that could influence radionuclide migration. At present the DGRTP is re-evaluating performance assessment strategies for prediction of ground water flow and mass transport in fractured plutonic settings. Other current geoscience work program activities examining issues surrounding long-term flow system stability and groundwater flow system evolution include development of a Design Basis Glacier Scenario, participation in the DECOVALEX III coupled thermal-

		mechanical-hydraulic modelling program and the paleohydrogeologic WRA (Whiteshell Research Area) Fracture Infill Mineral Assemblage Study. These activities are intent on providing a revised basis to explore and demonstrate long-term groundwater flow and hydrogeochemical stability in a Shield environment, and in doing so, provide evidence of ground water residence times and flow patterns. …
4.02.14	General – Vault-Induced Fracturing	… Rock mass stability has been studied by the Canadian geologic repository program for two decades and in the Canadian mining industry for much longer. OPG agrees this is an important consideration in the engineering design of a repository. Present work includes use of combined thermal-hydraulic-mechanical models to improve the ability to predict the response of the rock mass to the repository. …
4.02.15	General – Ease of Retrievability	… The ease of retrievability of containers from an open or sealed repository should not be significantly affected by groundwater flow system within the range of groundwater conditions expected for a repository environment. The feasibility of the retrieval of used fuel containers from one conceptual repository design has been discussed by Acres et al. (1996), and is being addressed by a consultant CTECH for OPG in the 2003 update of a conceptual design of deep geologic repository. …
4.02.16	General – Open Bore Hole	… OPG is planning to conduct a number of "what-if" scenarios to assess the robust nature of a deep geologic repository for used nuclear fuel. The impact of an open borehole extending from the surface to the vault is one scenario that would depend on the conditions at the particular site, especially the location and hydraulic conductivity of major features near the vault and the density gradient of the water due to salinity. …
4.02.17	General – Barrier Degradation	… Failure of other barriers was not explicitly treated as a SYVAC scenario, as noted, although some degree of barrier degradation was considered as a result of the range of input parameters considered. However, it is clear that it would be important in future assessments to explicitly consider a range of scenarios. The nature of these scenarios would likely develop in consultation with the stakeholders, such as the CNSC or local communities. Various "defective barrier" sensitivity cases are explicitly considered in the most recent OPG Third Case Study safety assessment. …
4.02.18	General – Geosphere Discharge	… In the EIS and the SCS, realizations of the used fuel repository concept and the effects of catastrophic events such as earthquakes were not explicitly examined. A focus for the DGRTP is to re-examine this issue through field characterization and numerical experiments that attempt to demonstrate long-term flow system stability that would span such catastrophic events. The DGRTP continues to co-ordinate and advance site characterization methods used in evaluating long-term flow stability. Such tools coupled with numerical modelling provide a basis to address issues of conceptual flow system uncertainty and ground water flow system dynamics that could influence sub-surface radionuclide migration and the environmental performance of a used fuel repository. …
4.02.19	General – Volcanoes	… In developing a safety case for the repository concept, it will be necessary to demonstrate how long-term geologic stability of a host formation could influence repository performance. Disruptive geologic

		events, such as volcanism would be addressed based on current scientific knowledge with regard to their time and space of likely occurrence, influence on repository barrier systems and the critical group. Such evaluations would be subject to peer review and a comparison with international practice. …
4.02.20	General – Contaminants in Fuel	… The predicted concentrations of the chemically toxic containments in the biosphere are listed in Table 6-8 of Goodwin et al. (1994). The largest predicted concentrations are Sb and Br. Because the predicted concentrations of the chemically toxic contaminants are very low compared to their background concentrations, no explicit evaluation of health risks resulting from exposure to the chemical toxic contaminants was carried out in the EIS. Further review and assessment of chemical toxicity is also planned. …
4.02.21	General – Mining-Induced Seismicity	… OPG believes that the impact of mining induced seismicity on a deep geologic repository would be very small since one of the technical factors for site screening is "no known current valuable mineral resources". Studies at the URL have indicated that underground openings can be designed to minimize excavation-induced rock fracturing. The effect of heat on excavation-induced rock fracturing has also been studied at the URL. These studies indicate that the effect the expected temperature rise in the rock, less than 85^{o}C, will not result in significant changes in the rock mass that would affect long-term safety of a geologic repository. …
4.02.22	General – Contaminant Speciation	… It is true that the chemical form of a radionuclide affects how the nuclide moves. This is taken into account implicitly in the EIS. For example, migration through the biosphere is described based on experimentally derived data such as soil-to-plant transfer factors. Thus, if the experiments from which the data were obtained are representative of the conditions and biospheres considered in the EIS, then these transfer factors are also applicable in the EIS biosphere, without needing to know the chemical speciation of the radionuclide. For any future OPG safety assessment, the treatment of contaminant speciation is identified in the corresponding FEP Database, #3.2.02 Speciation and Solubility. …
4.02.23	General – Consideration of Other Waste	… OPG studies have focused on natural uranium fuel in CANDU reactors in Canada. If Canada ever produced used MOX fuel, the repository arrangement will have to be assessed and perhaps modified to ensure that all design criteria are met for the characteristics of the used MOX fuel. The safety of the deep geologic repository will not be compromised. …
4.02.24	General – Migration of Erosion	… The characteristics that would be favoured for a repository site include large bodies of sparsely to moderately fractured rock bounded by fracture zones, which have low hydraulic permeability. If a site had these characteristics it is very unlikely that there would be an "inundation" of groundwater. Rather, groundwater would move very slowly along fractures and would not cause significant erosion of the sealing materials in the vicinity of the nuclear fuel waste containers. The transport of colloids and other macroscopic materials, and any radionuclides attached to these materials, in the low permeability rock mass expected at the site of a deep geological repository is expected to be negligibly small. …

4.02.25	Meteorite Impact	… The impact of meteors on a hypothetical deep geologic repository in plutonic rock has been calculated to be very small in AECL's 1994 EIS (Wuschke et al. 1995). Further review of this would be conducted during the safety assessment of a real potential site for a repository. …
4.03	Vault	
4.03.01	Vault – General	
4.03.01.01	Vault – General – Gas	… There are four basic types of gases in the vault: (1) air trapped in the vault at closure; (2) gas generated from buffer/backfill materials, notably from microbes using the residual levels of organics; (3) gas generated by corrosion of the containers and any external residual metals in the vault; and (4) gas generated within the containers, notably by corrosion of steel components or radiolysis of water. The topic of gas generation and transport continues to be studied as part of the international long-term waste management program of many countries. OPG will continue to maintain an awareness of this issue. The suggestion for a set of bounding calculations on gas generation and transport within the Canadian concept is noted. …
4.03.01.02	Vault – General – Sand Annulus	… The composition of the gas backfill material in the annulus between the container and the buffer material has evolved. OPG is conducting engineering studies to assess the impact of the planned gap backfill layer surrounding a used fuel container in a deep geologic repository (see Baumgartner 2000). …
4.03.01.03	Vault – General – Mechanical Support	… In 2002, OPG completed its multi-year study into the thermal-mechanical stability of underground excavations in granite. The research suggests that stable rock openings can be constructed in granite and the stability of these excavations can be monitored and modeled using technology and codes. Additional detailed studies on rock mass stability for underground openings and the required mechanical support would be conducted in the detailed engineering studies for a deep geologic repository, as part of the normal site-specific evaluation assessment process. …
4.03.01.04	Vault – General – Radiolysis	… At the time of the EIS, it was believed that the redox potential at the fuel/groundwater interface would be controlled by the groundwater redox potential, which in turn would be controlled by the iron minerals present in the geosphere. In the SCS, however, a kinetic dissolution model, based on electrochemical principles and more recent experiments, was used to calculate the rate of fuel dissolution. In this case, the rate of fuel dissolution was controlled by the corrosion potential at the fuel/groundwater interface. The corrosion potential, in turn, was dependent on the gamma, beta and alpha radiation field strengths. In future assessments, it is anticipated that this kinetic fuel dissolution model, in which the dissolution rate is dependent on the radiation field strengths, would be used to predict the rate of fuel dissolution (Kolar et al. 2000). …
4.03.01.05	Vault – General – Transients	… The level of safety analyses conducted by AECL for the 1994 EIS was considered to be adequate for the concept acceptance phase. The assumptions of early saturation in the vault are conservative since they enable a transport pathway to the geosphere for radionuclides released

		from any assumed failed containers in the vault. OPG and other waste management organizations are continuing to conduct research into understanding the transient effects in the vault and the potential impact on the performance of the engineered barrier system. Further detailed analyses for short term transients would be conducted as part of the normal design update and site specific evaluation and assessment process. …
4.03.01.06	Vault – General – Precipitation in the Container	… The statements in the Postclosure PRD are not as precise as they should have been. In the EIS, precipitation of all nuclides (except U) is assumed to occur in the containers. In the EIS, the rate of fuel dissolution is calculated using a (UO2) solubility limited dissolution model. However, in theory, the solubility of UO2 could vary from location to location due to inhomogeneities. Because in this model, precipitation of uranium down stream of the fuel/buffer interface would enhance the rate of fuel dissolution, the possible effect of uranium precipitation in the buffer was accounted for in the EIS. In the SCS, a kinetic model was used to predict the rate of fuel dissolution. For such a model, precipitation of uranium outside the container would not affect the rate of fuel dissolution. It is anticipated that in future safety assessments, a kinetic model would be used to predict the rate of fuel dissolution. Consequently, neglect of nuclide precipitation outside the container, which is done in the SCS would be conservative. …
4.03.01.07	Vault – General – Redox Conditions	… The repository will be designed and sited such that reducing conditions in the vault will prevail, after the oxidants present at vault closure are consumed. Thus, the occurrence of oxidizing waters in the vault is highly unlikely. Because a solubility limited dissolution model was used to calculate UO2 dissolution rates in the EIS, the predicted dissolution rates was sensitive to the Fe(II) solid/Fe(III) solid couple assumed to control the redox conditions in the vault. It is expected that anthropogenic oxidants will have a relatively minor influence on the rate of UO2 dissolution, because the amount of oxidants formed by radiolysis of water within the container would greatly exceed the amounts available from anthropogenic sources. In the EIS, no estimate was given for the time needed to consume the trapped O2 in the buffer (which contains Fe (III) minerals and minor amounts of Fe(II)minerals) but it was noted that this O2 would be gradually depleted by reaction with the Fe2+ diffusing in from the backfill and surrounding rock and by diffusing of O2 out of the buffer. For the SCS, it was found that the O2 entrapped with the sealing materials would be mainly consumed by reaction with organic matter in the clays and corrosion of copper. …
4.03.01.08	Vault – General – Criticality	… Given that the reference used fuel container design has been revised (and recognized that the reference is still natural uranium fuel), it would be appropriate to revisit the criticality question. At that time, it would be desirable to consider other scenarios or conditions, to include more complete references to the literature and to also note the relevance of natural analogs. …
4.03.01.09	Vault – General – Toxicity of Barrier	… The release of copper from used fuel containers in a deep geologic repository in plutonic rock due to corrosion in the repository is expected

	Materials	to be very small and is not expected to be transported to the surface environment in quantities that would impact the natural environment. Further safety analyses for radiological and non-radiological contaminants in a repository would be conducted as part of the normal evaluation of a facility. …
4.03.01.10	Vault – General – Radiation Effects	… The radiation levels at the container are not strong enough to directly affect the metal (McMurry et al. 2003). Radiation may affect the chemical environment around the container through radiolysis of water or air – see response to comments in Category 4.03.01.04. …
4.03.02	Vault – Waste Form	
4.03.02.01	Vault – Waste Form – Fuel Sheath	… The zirconium sheath surrounding the used fuel pellets is recognized as a barrier to the release of radionuclides from used fuel. It has been conservatively ignored in safety assessments because the failure mechanism is difficult to accurately quantify. Further analysis of this barrier is being considered by OPG. …
4.03.02.02	Vault – Waste Form – Inventory	… The total amount and composition of used nuclear fuel wastes in Canada has been conservatively estimated in the 1994 EIS by AECL and is considered to be bounding. The previous estimate of 10 million used fuel bundles is significantly higher than OPG's current estimate of 3.6 million bundles from current or planned nuclear power generating facilities in Canada. The fuel age and burn up are variables that affect the radionuclide inventory in the used fuel bundles and they have been evaluated for a deep geologic repository (Tait et al. 2000). …
4.03.02.03	Vault – Waste Form – Dissolution	… Since the EIS was prepared, there have been several changes to the UO2 dissolution model: (1) development of a kinetic dissolution model rather than a UO2 solubility-limited model; and (2) revision of the thermodynamic data used in assessing solubility of U and other species. According to the kinetic dissolution model, the dissolution rate is primarily dependent upon the strength of the radiation fields near the fuel surface, rather than UO2 solubility. Experiments and computer models are currently being funded by OPG to support use of the kinetic fuel dissolution model. Independent of the dissolution model, element solubilities are still important in limiting the rate of release of low-solubility elements from the container. Regarding redox conditions within the container, the repository will be designed and sited such that reducing conditions in the vault will prevail, after the oxidants present at vault closure are consumed. There is substantive geochemical evidence that ground water conditions are reducing at relevant depths and have remained so for very long times; this would certainly be confirmed at any candidate site. With respect to nuclide release mechanisms, current models consider the two most likely processes: instant release and congruent release. …
4.03.02.04	Vault – Waste Form – Fatigue Failure	… The current design for used fuel containers for a deep geologic repository is based on thick walled copper containers with an inner support structure and no glass bead particulate (Maak, 1999 - The selection of Corrosion-barrier primary material for used-fuel disposal containers, OPG Report 06819-REP-01200-100200-R00). Therefore, no glass bead packing would be required. …

4.03.02.05	Vault – Waste Form – Toxicity	… Although the decrease in potential hazard of used fuel with time can be presented in various ways, OPG finds that the simple graph of total reactivity with time is generally sufficient. Other safety indicators are being evaluated in the Third Case Study. …
4.03.03	Vault – Container	
4.03.03.01	Vault – Container – Mechanical Failure	Copper containers for used fuel are being designed to withstand glaciation and other natural processes and are expected to last for at least 100,000 years. In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository. In addition, OPG reviewed the reference packaging material to fill the void space inside the container. The review concluded that glass beads could not provide assurance that the container would not collapse due to anticipated hydraulic pressures in the vault. OPG investigated a number of inner support structures for the container. In 2001, OPG replaced AECL's reference glass bead packing with a carbon steel inner vessel to provide mechanical strength to the used fuel container. …
4.03.03.02	Vault – Container – Corrosion	In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in deep geologic repository. The study examined a number of candidate corrosion-barrier materials (e.g. titanium, copper, steel and nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept. This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland. …
4.03.03.03	Vault – Container – Electrolytic Corrosion	… In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in deep geologic repository. The study examined a number of candidate corrosion-barrier materials (e.g. titanium, copper, steel and nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept. This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland. …
4.03.03.04	Vault – Container – Welds	… With respect to welds, a recent study by OPG on the preliminary structural analysis of used fuel containers found that the external surface of the electron-beam weld closure would be subjected to compressive stresses, which would minimize the risk of the initiation and propagation of stress-corrosion cracking of the container (Saidfar and Maak 2002) …
4.03.03.05	Vault – Container-Hydrogen-Induced Cracking	… In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in deep geologic repository. The study examined a number of candidate corrosion-barrier materials (e.g. titanium, copper, steel and nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept. This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland. …

4.03.03.06	Vault – Container – Growth of Flaws	OPG is conducting safety analyses to further investigate the performance of a copper container during handling and the long-term behaviour of a failed copper container with an inner steel supporting structure which would corrode. Analyses of the effect of pinhole size were conducted by AECL and have been recently conducted and documented by OPG. OPG's Third Case Study postclosure safety assessment of copper containers in a deep geologic repository on the Canadian Shield was initiated in 2002 and is expected to be completed in 2003. …
4.03.03.07	Vault – Container – Healing of Pits and Cracks in Titanium	… In 1999, OPG investigated the feasibility of selecting a corrosion barrier material for used fuel containers in a deep geologic repository. The study examined a number of candidate corrosion-barrier materials (e.g. titanium, copper, steel and nickel) and commissioned an international peer review of the report findings. The study recommended a change from AECL's reference titanium shell design to a copper shell design for the Canadian concept. This updated container design (Russell and Simmons 2003) is consistent with similar repository concepts in Sweden and Finland. …
4.03.03.08	Vault – Container – Material Performance History	… Natural analogues are not assumed to be ideal indicators of a deep geologic repository for used fuel, but merely one line of evidence in support of the case for the safety of the geologic repository concept. …
4.03.03.09	Vault – Container – Initial Defects	… In a previous study, Doubt (1984) reviewed the failure statistics for analogous nuclear sealed components. These failure data are not directly applicable to used-fuel containers because differences in materials and processes, but the data define a range of failure probabilities for high-quality vessels and piping that was judged to include that achievable for used-fuel containers. In 2001, OPG reviewed the current literature of reported failures of analogous engineering components in order to re-evaluate the estimated probability of early container failure for the container defect scenario. Overall, the data indicate that the container failure probability estimated by Doubt (1984) is still a reasonable value, although lower failure probabilities likely could be achieved. It is also similar to the value assumed by the Swedish Nuclear Fuel and Waste Management Company (1 in 4000) in their safety assessment of the canister defect scenario (SKB) 1999. …
4.03.04	Vault – Seals	
4.03.04.01	Vault – Seals – Upper Backfill Density	… OPG is considering a number of potential arrangements of engineered barriers for the in-floor borehole and in-room emplacement methods for used fuel containers. An alternative method of backfill placement, compaction of the backfill placed with a sloping face within a room, is being tested by SKB in the ASPO Hard Rock Laboratory. Further work on practical emplacement methods will occur during the siting and repository demonstration phase of the deep geologic repository program. …
4.03.04.02	Vault – Seals – Imperfections	… OPG has prepared preliminary design requirements for repository sealing systems. Using these requirements as the basis, OPG has initiated a program in repository seal engineering to define the issues and then develop the material properties and design tools/methods necessary to design repository effective seals that would satisfy the preliminary design requirements. As part of the siting of a geologic repository, the

		sealing systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted. …
4.03.04.03	Vault – Seals – Alterations	… Preliminary design requirements have been prepared for repository sealing systems. These requirements provide a basis for assessing the potential effects on seal performance in a repository environment. Recent conceptual arrangements for both in-room and in-floor borehole emplacement have assumed that compacted dense backfill material is used rather than concrete as the working floor in emplacement rooms. Therefore, there would not be any large amounts of concrete in close proximity to the buffer materials surrounding the used fuel container. OPG is planning to conduct detailed safety and performance assessments of repository seals, and to study the properties of repository sealing systems in an environment that is representative of repository conditions. …
4.03.04.04	Vault – Seals – Displacement	… OPG is planning to conduct detailed safety and performance assessments of repository seals, including buffer and backfill, and to define requirements for these seals. The mechanical displacement of the buffer and backfill from the used fuel container is expected to be very small. For example, work for the Japanese H12 repository project had indicated a mechanical displacement of the buffer by the container of less than 5.1mm over 10,000 years for vertical emplacement and less than 2.6mm for horizontal emplacement. …
4.03.04.05	Vault – Seals- Thermal Osmosis	… Based on previous studies (Mitchell 1976; Mitchell 1991), the effects of thermal osmosis on water flow are generally considered to be insignificant when compared with those of hydraulic conduction, electro-osmosis and normal osmosis. OPG is continuing to conduct detailed safety and performance assessments of repository seals, including buffer and backfill, and to define requirements for these seals. …
4.03.05	Vault – Excavation Damage Zone	… The excavation-damaged zone (EDZ) was considered in the vault release model for the SCS (see Wikjord et al. 1996) and in the Third Case Study (Gierszewski et al., in preparation). AECL and OPG agree that the in-floor borehole emplacement arrangement used in the EIS case study did not satisfy the specific stability criteria stated in R-Facility because the rooms and boreholes were not stable in the average stresses of the Canadian Shield. To further quantify the excavation damage around rooms at the URL, AECL reviewed the excavation damage studies that have been undertaken at the URL (see Martino 2000). The understanding and design tools developed in the rock stability studies are being applied in the repository sealing systems engineering program (Read and Chandler 2002). …
4.03.06	Vault – Borehole Stability	… AECL, and more recently OPG, have initiated studies into rock mass stability. One outcome of these studies has been the application of the Particle Flow Code (PFC) for simulating the failure processes in Lac du Bonnet granite. The PFC does simulate many of the processes involved in the failure of the rock at the URL and offers promise for application at a possible future repository site. Using the PFC calibrated to tests conducted at site would aid in establishing the failure envelope for the rock mass at the site. Other tools , such as numerical and analytical codes complement the use of the PFC in simulating the instabilities in rock. The need for further work in modelling thermoporoelastic effects is being considered. …

4.03.07	Vault – Container Emplacement	… OPG has set minimum requirements for vault sealing materials. OPG has continued to evaluate the in-room and in-floor borehole emplacement methods for used fuel containers from the perspective of design robustness, engineering feasibility, monitoring, retrievability, repository size, public safety, occupational safety, siting constraints and cost (e.g., see Maak and Simmons 2001). At the present time, both emplacement methods appear to be viable and the selection of a preferred method will be based on underground conditions at a potential site and on additional engineering design studies (Russell and Simmons). …
4.04	Geosphere –	
4.04.01	Geosphere – Channelling	… The DGRTP is presently undertaking research of mass transport in fractured crystalline rock at the fracture (1m) and fracture network (50m) scale. These projects include the Quarried Block Experiment and the Moderately Fractured Rock experiment, both conducted at the URL. A key objective of this research is to test alternative conceptualizations of mass transport within fractures and fracture systems. …
4.04.02	Geosphere – High Groundwater Pressure	… Geosphere Performance Assessment at a candidate repository site should be based on a conceptual model that will ultimately depend on site specific physical and chemical hydrogeologic conditions. Hydrogeologic features may include the existence of anomalously elevated or depressed hydraulic heads. If these anomalous head conditions are shown to be representative of the site specific conditions and/or long-term flow system boundary conditions they may provide useful insight of long-term flow dynamics and physical flow system properties. Further work related to understanding the significance anomalous hydraulic heads relative to permeability distributions and long-term boundary conditions is being pursued through the Regional Groundwater Flow System Analysis Program and DECOVALEX III. These work programs are examining the relationship of permeability distributions and transient hydraulic/mechanical boundary conditions to hydraulic head distributions and evolution in stylized and more detailed Shield settings. …
4.04.03	Geosphere – Salinity	… Incorporation of representative groundwater salinities will be an important aspect of developing future site-specific performance assessment models. This activity has been undertaken in the Regional Flow System Analyses which is exploring the application of new and innovative 3-dimensional (3-D) numerical codes for simulation of flow and transport at evolving time and space scales relevant to repository safety. A description of the Regional Groundwater Flow System Analysis program is provided by Gierszewski et al. (2001) and Sykes et al. (2002). …
4.04.04	Geosphere – Vault Location	… The location for a candidate repository site will likely be the result of an evaluation of an extensive selection criteria mix. One of these criteria must be demonstrated long-term flow stability, both hydrogeologically and geochemically. In 2001, OPG undertook a numerical modelling study, referred to as the Regional Groundwater Flow System Analysis. The purpose of this program is to further illustrate the influence of fundamental physical and chemical hydrogeological processes and

		property distributions and flow domain boundary conditions and geometry on ground water residence times and flow paths in a Shield like setting. The work program will yield a geoscientifically reasoned case to understand and discuss flow system characteristics. …
4.04.05	Geosphere – Additional Fracture Zones	… As part of the siting and design of a candidate site, detailed geotechnical information on bedrock and fracture characteristics would be required from the immediate and surrounding vicinity of the vault horizon (Davison et al. 1994). Critical information such as the geometry and transport properties of intersecting fracture zones would be incorporated into the conceptual site model and evaluated as part of performance assessment activities. …
4.04.06	Geosphere – Shafts	… Decisions on the inclusion of excavated features such as access shafts and vent raises in performance analyses will in part be dependent on site specific hydrogeologic conditions and on the ability to demonstrate the performance of sealing technologies. The Canadian program continues to monitor developments in sealing technology experiments such as the Tunnel Sealing experiment at the URL and the long-term ZEDEX tunnel backfill/seal experiment at the SKB Aspo Hard Rock Laboratory. In addition, preliminary 3-D numerical analyses have been performed to better understand the role of repository seals and the EDZs to repository integrity. …
4.04.07	Geosphere – Geothermal Energy	… The presence of potential geothermal energy sources would be taken into consideration during a repository site selection process. The presence of such heat sources would be considered unfavourable during site selection. …
4.04.08	Geosphere – Rock Properties	… OPG agrees that the assignment of permeability values to specific subregions within a site's conceptual model must be supported by reference to appropriate site-specific field and laboratory hydraulic test results. The process followed to incorporate these test results into the conceptual model must also be traceable and defendable. The permeability of fractured granite is primarily governed by aperture and frequency. …
4.04.09	Geosphere – Water Table Fluctuation	… The effect of water table fluctuations can be detected as transient pressure pulses to depths of several 100 metres in the low storativity fractured bedrock of the Canadian Shield (Vandergraaf et al. 2001). At the timescales of interest in performance assessment, water table variations on the 100 to 1000 year cycle are indeed of greater interest. In 2001, OPG began undertaking research into developing a Design Basis Glacier Scenario for the Canadian Shield, which would help to better define changes in long-term climate affecting flow system boundary conditions. Long-term water table fluctuations associated with changing precipitation/temperature patterns and changing surface water body geometries is also of interest in the prediction of biosphere performance. …
4.05	Biosphere	
4.05.01	Biosphere – Mine Drainage	… All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards (e.g., total dissolved solids (TDS) limit of 500 mg/L). For example, the URL near

		Lac du Bonnet in Manitoba routinely monitors and treats the water from underground operations. The TDS in the environment near the holding pond discharge are about a factor of 5 below the standard (see Ross et al. 2000, Underground Research Laboratory Environmental Monitoring Program and results for 1999, AECL Report RC-261-12, URL-GEN-R026). …
4.05.02	Biosphere – Fate of Contaminants	… The biosphere model for radionuclides in the environment (BIOTRAC) is a conservative model which accounts for the transfer and uptake of radionuclides in fish, vegetation, animal products, and humans. In general, the transfer coefficients from one compartment in the biosphere to another are based on empirical measurements and implicitly account for all processes, including bioaccumulation. Biomagnification refers to the occurrence of a contaminant at successively higher concentrations with increasing trophic level in the food web. Biomagnification is partially considered in BIOTRAC through the use of pathways analysis. As noted, the biosphere model uses many simplifications. For example, radionuclide losses from the soil layer due to plant uptake are not accounted for in the model. The fate of contaminants, after leaving the vicinity of the critical group, was not investigated in the EIS. The reason for this was that exposures to contaminants downstream from the discharge points from the geosphere would have lead to lower dose rates because of the dilution of the contaminants as they moved downstream from the discharge points. Given the increasing importance of ERA and the expressed desire to estimate exposure doses for different critical groups, determination of the fate of the contaminants in the surface environment may be required in a future assessment. As noted such calculations are already carried out for mining operations. However, such calculations would only be feasible after a repository site has been selected and the surface environment is defined. …
4.05.03	Biosphere – Discharge to a River	… In the EIS, dose rates to the most exposed humans are calculated. Doses to less exposed humans would be lower. Consequently, it is not necessary to consider the surface water drainage system downstream of the discharge location of the groundwater from the vault, if one is only interested in doses to the most exposed humans. Nuclides flushed to downstream lakes and rivers would be diluted by additional surface runoff. Individuals living downstream of the discharge location would thus receive lower doses than members of the critical group. Given the increasing importance of ERA and the expressed desire by many stakeholders to estimate exposure doses for different critical groups, determination of the date of the contaminants in the surface environment may be required in a future assessment. However, such calculations would be only feasible after a repository site has selected and the surface environment is defined. …
4.05.04	Biosphere – Discharge to a Wetland	… BIOTRAC was created mainly to calculate exposures to the most exposed individuals. Consequently, the human exposure scenarios in the EIS involve a self-sufficient critical group that grows food in contaminated soil and uses water from contaminated sources. For this self sufficient group, the most important exposure pathways involve usage of contaminated water for drinking, irrigation and drinking water for animals. In contrast, for a wetland discharge, the most important

		exposure pathway is likely to be due to use of the wet land for food production. Nevertheless, it is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. …
4.05.05	Biosphere – Waste Water	… All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards. For example the URL near Lac du Bonnet in Manitoba routinely monitors and treats the water from underground operations (see Ross et al. 2000, Underground Research Laboratory environmental monitoring program and results for 1999, AECL Report RC-261-12, URL-GEN-R026). …
4.05.06	Biosphere – Spills	… The accident scenarios conducted for the 1994 EIS submission were intended to be representative and bounding calculations (see PRD – Preclosure). More detailed accident scenarios on both human and non-human biota would be addressed as part of the normal evaluation of potential sites in the siting phase of the deep geologic repository program. …
4.05.07	Biosphere – Change	… By placing used fuel in a geologic repository 500 m or more below the surface, the fuel is isolated from the biosphere and inadvertent human actions. Thus, the fuel in the repository would be better protected from changes to either surface or human society. At present there are no credible models available to predict human activities. Thus, in the EIS and the SCS, the characteristics of the critical group are based on present day human behaviour. This is the approach used in the international nuclear waste management community. Future environmental and ecological conditions are difficult to define, e.g. there is still disagreement about the extent of global warming caused by human activities. It is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. In future assessments, consideration should be given to calculating human and non-human doses for a range of human and biosphere characteristics. Finally, it is expected that modelling methods will continue to evolve and there will be a greater variety to choose from by the time that assessments are carried out for a proposed disposal site. …
4.05.08	Biosphere – Sediment to Fish Pathway	… In the EIS, nuclide concentrations in fish are calculated using fish/water concentration ratio Bj, with j=FW FISH (Davies et al. 1993, p. 217). Since the Bj values are derived from field observations, the effect of the direct transfer of radionuclides from lake sediments to fish would be implicitly included in the derived values Bj, assuming that the nuclide concentrations in sediments and water column are in quasi-steady-state. If site specific Bj values are unavailable, another approach for taking into account exposure to lake sediments would be to assume that, for a fraction of their lifetime, fish are exposed to lake sediment pore waters rather than to the overlying lake water. Nuclide concentrations in fish flesh would then be calculated using the Bj value and the weighted average of the sediment porewater and lake water concentration, where the weighting factor is the fraction of the time fish spend in each media. …
4.05.09	Biosphere –	… It would be more conservative to assume that the contaminants are

	Retention in the Hypolimnion	retained within the hypolimnion of a stratified water column. However, in most Shield lakes, the water column does not remain stratified throughout the year but turns over (i.e. becomes well-mixed) after the temperature gradient weakens (in spring and fall). Further shallow lakes, which make up a large portion of Canadian Shield lakes, do not stratify during the ice-free season. Thus, because of the long-exposure times, the lake can, on average, be considered to be well-mixed for the calculation of human and non-human doses. …
4.05.10	Biosphere – Sediment Concentrations	… In the preclosure assessment, nuclide concentrations in sediments are calculated from the nuclide concentration in water using a radionuclide distribution coefficient (Russell 1993). However, in the preclosure assessment, doses to aquatic biota from external exposure to contaminated sediments (groundshine) are neglected (Russell 1993, p. 28). Since groundshine or sediment immersion doses are included in the calculation of fish doses for the postclosure period (Davies et al. 1993 p. 217), for consistency, consideration should be given to including these doses in the calculation of the total fish doses for the preclosure period. …
4.05.11	Biosphere – Food Chain Pathways	… The food-chain in the EIS includes ingestion of milk and dairy products, which are represented by the TE MILK food type. The transfer factors used to determine the radionuclide concentrations in TE MILK were assumed to be equal to those for milk, for which much data are available. However, the validity of using milk transfer factors for milk products was not discussed in the EIS and further investigation of this point is warranted, since radionuclide concentrations in milk products could be higher than those in milk (Till and Meyer, 1983). In the EIS biosphere model, a generic plant was used to model all plants. Since food chain transfers were treated probabilistically and transfer parameters were broadly distributed, it was argued that the EIS food-chain model implicitly includes ingestion of many food types. Explicit calculations using 11 alternative human lifestyles, such as all meat and vegetarian (Zach et al. 1996) indicated that the range of EIS probabilistic dose results included those for the 11 alternative lifestyles. It was concluded (Zach et al. 1996) that the EIS assessment was representative of the full spectrum of diets and lifestyles that might be encountered on the Shield. …
4.05.12	Biosphere – Suspended Sediment in Lake Water	… The surface water model used in BIOTRAC does not differentiate between nuclides dissolved in the water and nuclides adsorbed on suspended particles in the water. Rather, an equation describing the total nuclide concentration in the water column (dissolved + adsorbed) is derived (Davis et al. 1993, p. 89). Therefore, the water concentrations used in the calculation of water ingestion doses include contributions from nuclides adsorbed on suspended material and, consequently, the water ingestion doses also include contributions from ingestion and suspended particles. …
4.05.13	Biosphere – Sorption in the Mixed Sediments	… It is true that the mixed-sediment model in BIOTRAC does not explicitly treat radionuclide adsorption. However, the effects of nuclide sorption are implicitly included in the model. The nuclide concentration in mixed-sediments is calculated from the mass-balance equation for the mixed sediments. The nuclide flow into the mixed-sediments is equal to

		the rate of loss of nuclides from the water column, which is derived from studies of nuclide mass flows likely arise due to the deposition of suspended particles containing adsorbed nuclides. Consequently, although not explicitly present in the model, the effects of nuclide sorption into sediment particles has been incorporated into the model. Since compacted sediments are simply mixed sediments that have been buried, the compacted sediment layer will contain some nuclides that originated in the mixed sediments. However, this contribution is neglected in calculating the compacted-sediment concentration since in most cases it is expected to be very much less than the contribution from sorption from upward-moving ground water. When the sediment is used as soil for growing food or to calculate external fish doses due to immersion in sediment, a depth-weighted average of the concentrations in the two sediment layers is taken to give an effective sediment concentration in the top 30 cm. Hence, the biosphere model does include doses resulting from adsorption by sediments of nuclides in the ground water stream passing through the sediment layer. However, the approach used in BIOTRAC may not be conservative, since the mixed-sediment layer does not absorb nuclides from the groundwater stream passing through the sediments. The degree of non-conservatism should be ascertained. …
4.06	Receptors	
4.06.01	Receptors – General	… Future safety assessment will look in further detail at the distribution and fate of radionuclides released to the biosphere, and will also consider various groups who might be exposed. …
4.06.02	Receptors – Humans	… Guidance on critical group is given by ICRP (ICRP 81, 2000) where it is recommended attention focus on highest risk as well as highest dose. This, as well as points brought forward in the hearings, suggests that the distribution of radionuclides and possible release points should be examined in a future site specific assessment. Possibilities for the critical group should be examined. Regarding mishaps, it is OPG's intent to examine a range of "what-if-scenarios" as part of postclosure safety assessment. Operational safety assessment (i.e. of the preclosure stage) will also be required to obtain a construction license from CNSC, and would address a range of potential accidents. …
4.06.03	Receptors – Natural Environment	
4.06.03.01	Receptors – Natural Environment – General	… Any future site-specific safety assessment would be accompanied by consideration of ecological effects and protection of non-human biota using appropriate ERA methods, including identification of VECs (valued ecological components), surveys, endpoints, effects and criteria. OPG is aware of developments in treating non-human biota and is studying how to best incorporate them into models. Some initial examination of possible reference biota for ongoing non-site-specific assessments has been carried out (Sheppard, 2002). …
4.06.03.02	Receptors – Natural Environment – Generic Organisms	… At the time the work for the EIS was carried out, the data required for ERA for radiological contaminants had not been examined extensively. Pioneering work was carried out in calculation of dose conversion factors to permit estimation of doses to non-human biota and these are still in use (e.g. CEPA PSL2 Assessment dated July 2001). A future site-

		specific ERA would include surveys of potentially sensitive habitats, and identification of appropriate organisms and life stages, and use of the most appropriate data available. Some work has been done on identification of appropriate biota for use in ongoing non-site specific work. …
4.07	Assessment Endpoints	
4.07.01	Assessment Endpoints – Collective Dose and Risk	… The doses required to meet the CNSC risk criterion for the most exposed groups are very small (~1% natural background). International groups have also stated that there is little basis for projection into the future, and collective dose is of limited use in demonstrating safety. However, future safety assessment should consider whether and how useful information would be provided. Occupational collective dose during the preclosure phase was addressed in the EIS, and would be addressed in the future, as part of an ALARA assessment required for construction license. …
4.07.02	Assessment Endpoints – Cumulative Effects	… The disposal system is designed to contain the radionuclides in used fuel for a very long time, allowing most of the radioactivity to decay away. Any eventual releases would be released slowly and would be delayed and absorbed further into the geosphere. Dilution in a water body in order to meet the individual risk criterion would not be an objective in siting or design. It is planned to modify the biosphere model to calculate the (cumulative) concentration of radionuclides or other species of concern in water, soil and plants. …
4.07.03	Assessment Endpoints – Mental Well- Being	… The applicable definition of health included mental health. CEAA's EA requirements include only large effects on health that are caused by a change in the biophysical environment. However, as a large employer and an undertaking causing potentially a significant change in the socio-economic conditions of the host community, it would be responsible of an implementing organization to address this question. The technical program will estimate numbers of workers etc. to this end. Another factor is the psychological impact of living near a nuclear facility. Mitigation of this, e.g. by provision of information, would be the subject of negotiation during siting. …
4.08	Worse Cases	… As noted elsewhere in these responses (7.03.13.02), future safety assessment will include an explicit treatment of a number of "what if" scenarios that test the robustness of the concept to various assumptions. Ideally, there will be an opportunity for defining these scenarios with the stakeholders (e.g. regulators, local community) during the safety assessment process, rather than waiting for the final report to see if the results of interest are included. One class of cases of interest is the failure of barriers. However, it may only be possible to provide estimates of probabilities for these worst-case scenarios. …
4.09	Spatial and Temporal Boundaries	… OPG's safety assessment looks at peak risk (rather than limiting assessments to 10,000 years). However, increasing uncertainty with time is recognized, and a suite of performance measures may be appropriate. The spatial extent of radionuclide distribution should also be looked at, as described in other responses. …
5	**Siting**	

5.01	Criteria	
5.01.01	Criteria – Identification and Ranking	… Technical siting criteria must be developed and approved as part of each significant step in the siting process: from preliminary screening of siting regions, to comparative evaluations between candidate areas, and to between candidate sites within these areas. As the screening process proceeds into specific large siting regions, exclusion criteria would be developed to include concerns of each potential host community. As candidate areas within the siting regions are identified, comparative ranking criteria including detailed technical factors would have to be available to guide the characterization and evaluation process. As the understanding of factors critical to groundwater flow and contaminant transport in deep geologic environments continues to be refined, it can be anticipated that new suitability criteria will be developed or existing criteria modified. The organization responsible for the siting of a deep geologic repository would likely establish a stakeholder review procedure at key milestones in the siting process. A key objective of such siting process would be to identify candidate repository sites that are technically, socially and economically viable. …
5.01.02	Criteria – Recommendations	… The EIS presented a series of technical factors that were considered important in any future repository site screening process. These broad technical factors can be used to form the framework of a selection process for the purpose of identifying siting regions, and subsequently potential candidate areas within the Canadian Shield. The NWMO responsible for implementing the siting process could use these broad technical factors as part of the formulation of exclusion and acceptance criteria appropriate for the various stages of the selection process. In response to comments, the OPG work program has in part been directed toward improving the geoscientific basis for the Deep Geologic Repository concept. A major aim of this work is to foster the geoscientific basis and tools that illustrate issue of geologic and hydrogeologic stability in a fractured setting. …
5.02	Characterization Approach	… The overall objective of these site characterization studies must be to demonstrate the geomechanical and hydrogeologic suitability of the candidate site as well as the long-term stability of the groundwater flow system. It is anticipated that the NWMO will have to provide a detailed site investigation and interpretation methodology, coupled with traceable process for continuous refinement of the subsurface conceptual model, to ensure confidence in the resulting repository safety case. OPG is investigating several methods to facilitate the integration and interpretation of large, site investigation data sets. A 3-D visualization tool, VULCAN used extensively throughout the international resource exploration community, has been integrated into the moderately fractured rock experiment at AECL's URL for the purpose of facilitating and gaining confidence in the developing conceptual model of the subsurface. OPG is also exploring the applicability of using an immersive data visualization and interpretation centre to further enhance the integration of large 3-D, cross-disciplinary, data sets. …
5.03	Methods	
5.03.01	Methods – General	… Modern data interpretation and subsurface reconstruction techniques should be incorporated into the earliest possible stages of a siting process. Surface geologic and geophysical data can be input to 3-D

		visualization tools to aid development of an initial conceptual model of the subsurface environment. OPG is supporting activities to improve the interpretation and utilization of geologic data for siting purposes. A consistent methodology is being developed for the interpretation and presentation of surface lineament data within a GIS framework. …
5.03.02	Methods – Evaluation	… Siting methods are continuously evolving as a function of improving sensor technology, hardware computing/storage/visualization capabilities, data processing, numerical analysis and geostatistical techniques. The hierarchy of site characterization methods applicable to deep repository siting is therefore in a constant state of change and can only be formalized when actual siting activities begin. With regards to the siting of a deep geologic repository in the Canadian Shield, siting methods that improve the identification and characterization of groundwater pathways (fracture and fracture zones) are of great significance. OPG maintains close association with international organizations presently involved in repository siting technology development such as SKB in Sweden and Posiva in Finland. OPG is undertaking research to improve the understanding, characterization and numerical modelling of groundwater flow and radionuclide transport at various scales in fractured media. …
5.03.03	Methods – Geophysics	… The application of airborne, ground-based and borehole geophysical techniques play a significant role in providing characterization data during the various stages of the siting process. The benefit of applying various geophysical methods in the repository siting process is that large site-specific data sets can be generated in a relatively short period of time. The challenge is in the proper interpretation and integration of these data sets for the purpose of developing a proper understanding of the lithologic, structural and geochemical characteristics within a siting region, and the subsequent projection of these characteristics into the subsurface at a candidate site(s). The NWMO, responsible for undertaking the siting process, will have to develop a proper strategy for the application of airborne, ground based and borehole geophysical methods. …
5.03.04	Methods – Geochemistry	… Within OPG's geoscience program, further efforts have been taken to demonstrate the utility of geochemical methods for site characterization. This includes the WRA Paleohydrogeologic Study, the purpose of which is to examine WRA fracture infill minerals petrologic, mineralogic and isotopic evidence of past recharge by low salinity, oxygenated glacial recharge (McMurry 2000). Further work involves examining the influence of peri-glacial (i.e. permafrost) conditions on groundwater compositions and fracture mineraology in crystalline flow domains. Through a partnership with SKB, Posiva, Nirex and the Finnish Geological Survey, the evolution of elemental and isotopic groundwater compositions at the mine site will be assessed. This project is intent on examining the hydrogeochemical characteristics of flow system affected by glacial cycles and permafrost, as might be expected in a Canadian Shield Setting. …
5.03.05	Methods – Stress	… OPG is completing an evaluation of the Deep Doorstopper Gauge System (DDGS) as a viable alternative to the hydraulic fracturing method for the determination of in situ stress at depth. This project will

		also include a state-of-technology report on in situ stress determinations in shallow and deep boreholes. OPG recognizes the significance of high in situ stresses at depth in Canadian Shield environments and is pursuing the less sensitive in-room emplacement option in parallel with the in-floor borehole emplacement option. It is also recognized that the magnitude and orientation of the in situ stress field has an impact on geotechnical and hydrogeologic properties such as fracture aperture and therefore permeability. …
5.03.06	Methods – Hydrogeology	… The OPG program continues to focus on the development of site characterization skills required for conceptual flow system model development and the prediction of geosphere barrier performance. Key research areas examine technical issues surrounding long-term groundwater flow system evolution and the capabilities and limitations of numerical methods for predicting flow and transport relevant to repository safety. The technical program is aware of uncertainties inherent in site characterization and is focused on development of field testing techniques to provide bounds or constraints on such uncertainties. A key element of the safety case involves the rationalization of a conceptual flow system model. It is through this process that multi-disciplinary field characterization data is combined into an internally consistent framework. Work continues in the Regional Flow System Analysis to illustrate and define through numerical simulations hydrogeologic issues of importance to repository siting. …
5.03.07	Methods – Existing Information	… The comments in this category speak to two separate technical siting issues: i) the use of existing public domain data and ii) the presentation of existing geoscientific data gathered at research areas during the Canadian Nuclear Fuel Waste Management Program. With regard to the first, a key interest of the technical program is to maintain an awareness of public domain data sets relevant to siting. The geoscience information gathered at research areas throughout the Canadian Nuclear Fuel Waste Management program is available in separate AECL Technical reports (TR-reports). These data have not been interpreted or integrated with respect to the development of a rigorous conceptual model for individual sites (i.e. WRA, East Bull Lake, Atikokan). Given the unique nature of geoscientific studies at these research areas, development of comparable conceptual models as part of a Case Study may be warranted. This would better enable performance assessment to articulate the range of conditions observed in Shield settings. …
5.03.08	Methods – Geographical Information System	… The application of GIS and multi-dimensional visualization software is considered an important element in the OPG program. A key goal in application is to improve the traceability and repeatability of analyses that require integration of geometrically complex multi-disciplinary data sets. The OPG program will continue to foster the development and application of GIS, visualization and electronic data management systems that better enable the communication of sub-surface conditions relevant to demonstrating long-term repository and geosphere performance. …
5.04	Case Studies	… Development and implementation of a repository siting methodology will be the responsibility of the NWMO, should the federal government adopt deep disposal as the preferred long-term used fuel waste management strategy. This approach is consistent with the Nuclear Fuel Waste Act. With regard to siting case studies, the Canadian program

		continues to maintain ties and monitor developments in international radioactive repository programs. …
5.05	Research	… The Canadian program continues to conduct geoscience research and development to preserve and advance skills unique to the understanding of fractured-porous shield settings. Gierszewski et al. (2003) provides a description of geoscience research activities. These activities are divided into two primary areas i) site characterization and ii) performance assessment. A key focus involves conceptual model development and the application of performance assessment tools to illustrate long-term flow system stability. Conceptual model development involves the integration of multi-disciplinary data to describe flow system properties, geometry and boundary conditions relevant to repository performance. …
5.06	Quality Assurance	… The EIS discussed in broad terms the need for a quality assurance programme during the siting process. As stated in the EIS, the objectives of the quality assurance (QA) program would be to ensure that all site screening and site evaluation activities achieve the prescribed quality, provide complete documentation and traceability of records, and provide confidence that the data can be reproduced by independent auditors if necessary (Davison et al. 1994). The NWMO, following a federal government decision on the preferred long-term used fuel management strategy, would be responsible for undertaking the siting process and would have to adopt a quality assurance programme compatible with international norms (e.g. ISO 9001). …
5.07	Existence of Suitable Sites	… The EIS, the SCS and the Third Case Study (in progress) provide evidence that implementation of the repository concept can be achieved in a variety of geosphere settings. At a high level there are a variety of characteristics which may define a suitable site. As a basis for the concept, the geosphere must offer a stable geomechanical and geochemical environment, as well as act as a deterrent to intrusion. Site characterisation is tasked with conceptual model(s) development in which multi-disciplinary data are integrated into an internally consistent understanding of flow system properties, geometry and boundary conditions. Further work is planned by OPG to address the issue of site availability and to place into context the geosphere requirements for implementation of the deep geologic repository concept. …
6	**Engineering**	
6.01	General	… The engineering concept was illustrated for the EIS using a titanium container and in-floor borehole emplacement design. Technical issues with this design were partly overcome in the copper container and in-room emplacement design that AECL prepared and submitted during the public review process for the EIS (Wikjord et al. 1996). OPG has further advanced the design of a used fuel container and a repository. Additional work has resulted in the selection of a reference container with a copper corrosion barrier, a steel inner load-bearing vessel and a basket to support the fuel bundles. Although the exact dimensions and other details have not been finalized, this container design is very similar to that being considered in the Swedish and Finnish programs. OPG has not selected an emplacement method. The Canadian program is continuing to evaluate the materials and design. …
6.02	Container	

6.02.01	Container – General	… As a result of additional studies, OPG has selected a reference container with a copper corrosion barrier, a steel inner load-bearing vessel, and a basket to support the fuel bundles. Although the exact dimensions and other details have not been finalized, this container design is very similar to that being considered in the Swedish and Finnish programs. Therefore, the further development of the container can also draw on the extensive work undertaken by these programs (e.g., Wu et al. 2000) …
6.02.02	Container – Designs for Longer Lifetimes	… OPG has defined a preliminary design requirement for used fuel container lifetime of not less than 100,000 years (Russell and Simmons 2003). The present reference Canadian concept with copper shell on a steel inner vessel is expected to meet this requirement. This is consistent with the predicted lifetimes of the similar Swedish and Finnish containers for a deep geologic repository. …
6.02.03	Container – Fabrication	
6.02.03.01	Container – Fabrication – Methodology	… OPG is aware of the potential for residual stresses in the containers and has developed preliminary design requirements to address this issue. The present reference design uses an inner steel vessel for structural support, rather than a packed-particulate support (Russell and Simmons 2003). In a recent study, a preliminary structural analyses of used fuel containers found that the external surface of the electron-beam weld closure would be subjected to compressive stresses, which would minimize the risk of the initiation and propagation of stress-corrosion cracking of the container. The potential for stress corrosion cracking of the copper outer barrier material is being addressed in the technical work program at OPG. …
6.02.03.02	Container – Fabrication – Decontamination	… OPG has reviewed the options for corrosion barrier material for used fuel containers in a deep geologic repository (Maak, 1999). The study examined a number of candidate corrosion-barrier materials (e.g. titanium, copper, steel, nickel) and commissioned an international peer review of the report findings. The study recommended the use of high-purity copper. This is the same material selected for the Swedish and Finnish programs. Therefore, technical issues associated with titanium are no longer applicable. …
6.02.03.03	Container – Fabrication – Inspection	… OPG recognizes that non-destructive evaluation of electron beam welded copper containers would be challenging. However, studies and tests are being carried out by other countries to address this issue. In particular, there is a substantive effort to develop fabrication and testing methods for similar copper containers in Sweden and Finland. Alternative techniques for fabrication are also under consideration. OPG considers non-destructive evaluation of the welded copper container to be a resolvable issue. …
6.02.04	Container – Loading	… OPG has a database which identifies the burnup and age of a used fuel bundle. The used fuel bundles loaded in a container would be selected to ensure that the total heat loading of the container met the repository thermal design limits. Furthermore, since the reference container design holds about 300 bundles, it would be likely that a fraction of the bundles would accidentally be at a high thermal power. Finally, it is likely that monitoring methods could be incorporated into the packaging plant design as a final check, if appropriate. Early

		packaging and sealing might be considered as an option to allow off-site packaging and/or a period of surface storage before disposal in a repository. The present reference container design emphasizes durability under repository conditions; it has been designed to withstand the expected external pressure loads in a DGR and the handling load in the packaging plant and during emplacement operation in the repository. …
6.03	Excavations	
6.03.01	Excavations – Design Criteria	… A repository depth range of about 500 to 1000 meters is consistent with the range of depths being considered by other countries (e.g. Finland and SKB). It is considered to be deep enough to avoid the possibility of surface conditions (e.g. climate change, glaciation) directly affecting the repository, and deep enough to minimize the risk of human intrusion. At greater depths, the ambient rock temperature, overall stresses and groundwater salinity increase, making the repository design more difficult. The detailed design of a repository would be done in the context of a specific site. The repository depth (or depth range), extraction ratio and other design factors will be developed in the context of the specific site characteristics and rock mass properties. …
6.03.02	Excavations – Layout	… AECL has completed conceptual design/feasibility studies of various repository design concepts. These studies include some discussion of the advantages and disadvantages of each design alternative. However, this work is dated and would be repeated prior to or as part of the detailed repository design for a specific site. Presently OPG is considering various emplacement concepts and repository layouts; all similar to concepts presently under detailed consideration by other counties (e.g. Russell and Simmons 2003). OPG has conducted a number of thermal and mechanical studies to support the design of a deep geologic repository for used fuel, including the spacing of containers in boreholes or in rooms. Also, in 2001, OPG initiated a screening study of used fuel container geometries, capacities and layout in the vault for both in-room and in-floor boreholes emplacement methods. The detailed design of a deep geologic repository for used fuel is a site specific issue. …
6.03.03	Excavations – Methods	… In preparing the EIS, AECL chose repository engineering and construction methods that were proven to be applicable in the range of environments that could be encountered in the Canadian Shield. At that time, only the drill-and-blast method of construction provided the flexibility necessary to construct the repository arrangement. AECL did consider using either the pilot-and-slash or the full-face drill-and-blast excavation method. The Swedish program has examined excavating using the drill-and-blast method and a Tunnel Boring Machine at SKB's Aspo Hard Rock Laboratory. Both excavation methods are feasible and the method chosen at a specific repository site will depend on a number of site-specific conditions, the details of the repository design and the technical feasibility and cost of these methods at the time of construction (likely many years from now). …
6.03.04	Excavations Access	… AECL pointed out in R-Facility that Canadian mining industry practise was proposed for the design, equipping and operation of shafts. The single compartment and multi-compartment shafts with friction hoists (using some counterweights and some using balanced skips) were described and the safety mechanisms on the hoists were outlined. OPG

		is investigating both ramp and shaft access to a deep geologic repository. …
6.04	Seals	
6.04.01	Seals – Properties	… Clay-based materials meet the requirements for being impermeable to water, non-corrosive, plastic, and have proven durability on timescales of millions of years. Sufficiently dense clays also should be able to prevent significant microbial activity around the container for a long time. Presently no radioactive waste management organization is considering the use of tar (e.g. bitumen) as buffer/backfill in a used-fuel repository. In the absence of a clear advantage to tars, it would not be prudent for the Canadian program to take on the entire task of investigating and validating a new material. OPG has prepared preliminary design requirements for repository sealing systems. As part of the siting of a geological repository, systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted. …
6.04.02	Seals – Additives	… The addition of several possible chemical additives to the repository has been considered. However, given the long-time scales of interest, it is generally thought to be better to keep the design and materials simple and robust. With respect to the trapped oxygen in the repository, various calculations to date in both the Canadian and other programs have determined that this oxygen is limited in quantity and will be consumed reasonably quickly by various natural processes, even without additives. With respect to graphite, it has been considered as an additive, but primarily for purposes of improving the thermal conductivity of the clay buffer. The possibility of adding stable iodine to dilute any released I-129 has been considered. The main question is whether the added stable ion would be available at the time the I-129 would be released. …
6.04.03	Seals – Emplacement	… OPG and other countries are continuing to study the features of potential buffer materials and emplacement techniques. OPG is also developing specific design requirements for repository sealing systems and will use these requirements in establishing the specifications for preparation and placement of the components of these systems. Since the EIS, there have been a variety of laboratory-scale and full-scale tests of buffer emplacement, including the Tunnel Sealing Experiment at AECL's URL, and the Prototype Repository at the SKB Aspo Hard Rock Laboratory. With respect to fabrication of buffer blocks or pebbles, there is an appropriate amount of moisture that needs to be present during compaction depending on the desired final characteristics of the block, notably its density. …
6.04.04	Seals – Performance Criteria	… OPG has prepared preliminary design requirements for repository sealing systems. Using these requirements as the basis, OPG has initiated a program in repository seal engineering to define the issues and then develop the material properties and methods necessary to design effective repository seals. The Tunnel Sealing Experiment at AECL's URL will demonstrate the ability of both clay and concrete based room plugs to effectively seal off the EDZ. …
6.05	Managed Flooding	… The need for "flooding" or artificially providing groundwater to the vault sealing materials to ensure rapid saturation of the materials (e.g. bentonite buffer) has not been evaluated in detail. Possible advantages of not flooding are that dry buffer around the container would minimize

		microbial activity at the container surface, and also would make retrieval easier. The interaction of thermal-hydraulic-mechanical processes makes evaluating the benefits of flooding complicated. Suitable models are becoming available to address these questions, and are being incorporated into the Canadian program. To some extent, it is also a site-specific issue that would ultimately need to be addressed at a later stage of repository design. …
6.06	Monitoring	
6.06.01	Monitoring – General	… AECL presented a general approach to monitoring in Simmons et al. (1994). AECL also subsequently documented some of the methods that could be used for monitoring the performance of a geologic repository. The OPG reference concept includes monitoring during and after operations, with a duration of approximately 100 years. Whether and when the repository would be fully closed, and the extent of type of post closure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies. OPG has continued to work on developing monitoring concepts and instrumentation. …
6.06.02	Monitoring – Preclosure	… The OPG reference concept includes monitoring during and after operations, with a duration of approximately 100 years. This includes an extended monitoring period (nominally 70 year duration) where the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open. Whether and when the repository would be fully closed, and the extent and type of postclosure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies. …
6.06.03	Monitoring – Post Closure	… The OPG reference plan includes monitoring during and after operations, with a duration of approximately 100 years. This includes an extended monitoring period (nominally 70 year duration) where the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open to allow access for monitoring and for easier retrieval, if required. Whether and when the repository would be fully closed, and the extent and type of postclosure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies. …
6.06.04	Monitoring – Recommendations	
6.06.04.01	Monitoring – Recommendations – General	… The OPG reference plan includes monitoring during and after operations, with a duration of approximately 100 years. Whether and when the repository would be fully closed, and the extent and type of postclosure monitoring, would be decided after that period, in consultation with the stakeholders, based on the information available from the 100 years of prior monitoring and on then-available monitoring technologies. During this entire period, appropriate environmental monitoring would be carried out in the surface environment. Appropriate baseline data would be collected and presented in the EA, together with site environmental studies. A description of planned monitoring programs, tailored to the particular site, would be part of submissions for both EA approval and a CNSC construction license. …

6.06.04.02	Monitoring – Recommendations – Health	… AECL's 1994 EIS documents the baseline monitoring for a geologic repository facility. Monitoring would include human exposure pathways, and the natural environment. While subsequent monitoring of the health of humans or natural biota may be part of the long-term monitoring plans, no significant release of radionulcides from the repository is expected, and therefore simple monitoring for the presence of used fuel radionuclides in the environment and ecosystem components would provide sufficient indication of any potential problems long before any biological impact. …
6.07	Mitigation	
6.07.01	Mitigation – General	… OPG has planned for monitoring both during and following closure of a repository. During the extended monitoring period, the emplacement rooms are backfilled and sealed, but the access tunnels and shafts would remain open. This would make retrieval easier, if required. OPG considers retrieval to be the ultimate contingency response. Currently, SKB (Sweden) are conducting full scale container retrieval tests at their URL at Aspo (SKB 2000). Since the OPG reference container is similar to the Swedish concept, it is expected that much of this technology demonstration would apply. Normal contingency plans would be in place during the construction, operation, decommissioning and closure of a repository. Specific details would be presented as part of the EA and the subsequent applications for the relevant CNSC licenses (e.g. construction, operation). …
6.07.02	Mitigation – Retrieval	… In the 1994 EIS, AECL discussed retrieval of emplaced wastes during the preclosure and postclosure phases (see Simmons and Baumgartner 1994, Acres 1996). No significant technical issues were identified, although there would have to be engineering design and demonstration for the equipment. Note that currently, SKB (Sweden) are conducting full-scale container retrieval tests at their URL at Aspo (SKB 2000). Since the OPG reference container is similar to the Swedish concept, it is expected much of this technology demonstration would apply. There is a further expectation that similar test would be completed at the Canadian repository. …
6.07.03	Mitigation – Decommissioning	… AECL 1994 EIS discussed decommissioning at a conceptual level of detail. More detailed decommissioning plans would be developed and documented at the appropriate stages of the deep geologic repository program. …
6.07.04	Mitigation – Microbes	… There has been a broad international effort on microbial behaviour in a repository since the 1994 AECL EIS. In the Canadian program, the multi-year in-situ Buffer-Container Experiment and the Isothermal Test (Stroes-Gascoyne et al. 2000) have examined microbial effects as an important part of their objectives. Recent summaries of the state-of-knowledge of microbial activities around the repository are given in Pedersen (2000) and Stroes-Gascoyne et al. (1997). The main objective of this effort is to design the emplacement room seals so as to minimize microbial activity in the vicinity of the containers in order to expend the container lifetime. …
6.07.05	Mitigation – Preclosure Effluents	… All waste water from the operation of a deep geologic repository would be tested and treated, if required, prior to discharge to the

		environment, as required by federal and provincial standards. AECL's URL in the Canadian Shield granite in Manitoba provides a specific example of the possible nature of trace metals and treatment systems. The discharge waters and their treatment are described in the URL annual reports. …
6.07.06	Mitigation – Resilience of Ecosystems	… While the robustness of ecosystems should not be overstated, most natural systems have a significant degree of resilience as illustrated, for example, in their tolerance to the cycle of seasons, in their recovery from forest fires, and even their recovery around the Chernobyl site. It is therefore reasonably expected that, over time, natural and assisted regeneration after decommissioning would repair damage due to non-radiological stressors. However, impacts on the ecosystem, together with mitigative measures, certainly for any environmentally-sensitive ecosystems in the vicinity of a repository – would have to be considered as part of a site-specific EA. …
6.07.07	Mitigation – Groundwater	… In AECL's 1994 EIS, the impact of underground openings on groundwater flow in the vicinity of a deep geologic repository was illustrated for the WRA (see PRD-Geosphere). This evaluation included drawdown around the vault and effects on surface discharge areas. These changes would recover naturally after the repository is closed. Whether the changes require mitigation in the interim would require site-specific evaluations that would normally be part of the site-specific EA. …
6.07.08	Mitigation – Chemical Toxicity	… During operation, waste water from the repository and surface facilities would be tested and treated, if required, prior to discharge to the environment, as required by federal and provincial standards. For the long-term, chemical toxicity is minimized by use of appropriate material for the engineered barrier systems. In the OPG reference concept, the primary engineering materials are steel, copper, clays and concrete. Finally, the effects of any toxic elements present (notably in the used fuel) are minimized by the multiple barriers inherent within the design and location of the deep geologic repository itself. …
6.07.09	Mitigation – Premature Closure	… OPG does not believe that the deep geologic repository facility would be closed prematurely due to high radiation levels. First, it should be clear that the emplaced containers are well-shielded and do not pose a hazard. Second, the repository will be designed from the perspective of safety during the operational phase and will include redundancy; systems, processes and operations relevant to safety will be designed so that a single failure will not compromise environmental, public or worker safety. Finally, if there were an unexpected release from containers, it would be detected long before it became a personal hazard, and appropriate countermeasures could be taken, up to and including retrieval of the affected containers. …
6.08	Resource Availability	… In the reference Canadian design, (e.g. Russell and Simmons 2003), the main engineering materials required are copper, steel, clay and cement. Although significant amounts are used, these are all plentiful materials. Nonetheless, OPG is continuing to assess options that minimize the use of such materials. For example, the amount (cost) of copper is a factor in the selection of the present reference container size. Also, OPG (following the lead of Sweden and Finland) is evaluating a horizontal borehole emplacement concept, which would use much less

		clay than in-room emplacement. …
6.09	Case Studies	… In preparing the in-floor borehole case study presented with the EIS, AECL used the expertise of Canadian mining and geotechnical engineering consultants (Redpath et al 1992). AECL also had Acres International document some large construction projects that had been successfully completed in the Canadian Shield environment (Acres 1993). In any future design studies, OPG would continue to ensure that the appropriate mining and geotechnical engineering expertise was included on the study team. OPG agrees that it is reasonable to be aware of the experiences from similar underground facilities. As one activity in this area, OPG is a participant in the European CROP project, in which the practical lessons learned in the various national underground laboratories are being assembled. Reviewing and assessing the experience within the Canadian mining community may also be useful. …
6.10	Research	… The NWMO is reviewing approaches for the long-term management of used fuel, including long-term storage. OPG has conducted work to further the evolution of the AECL concept of a deep geologic repository. The reference container design is based on a copper corrosion-barrier outer vessel and a carbon steel inner vessel as the load-bearing component (Russell and Simmons, 2003). This updated container design is consistent with similar repository concepts in Sweden and Finland. Using these requirements as the basis, OPG has initiated a program in repository seal engineering. OPG is preparing preliminary design requirements for repository sealing systems. As part of the siting of a geologic repository, the sealing systems would be demonstrated and detailed safety and performance assessments of repository seals would be conducted. Designs would be tailored for site conditions. …
6.11	Security and Safeguards	… AECL's 1994 EIS discusses security and safeguards associated with the handling and transportation of used fuel. This system is considered to meet the stringent requirements set out by the CNSC and the IAEA, and would adequately protect the public, transportation personnel and the environment from wilful terrorist action, theft or sabotage. AECL described an approach to apply nuclear materials safeguards and nuclear facilities security to the used fuel repository presented in the EIS (see R-Facility). This was reviewed by CNSC staff and was judged to be an adequate approach for this conceptual stage. The IAEA has not yet established requirements for applying safeguards to used-fuel repositories, although this is under development. The detailed design of a geologic repository would satisfy the security and safeguard requirements that are required by the CNSC at that time. …
6.12	Quality Assurance	… OPG has developed preliminary design requirements for the engineered barrier systems, and is using these as a guide for the on-going material research and development program. Within the quality assurance system established for the project, quality control procedures would be prepared for all testing activities that are being undertaken, including testing associated with the evaluation, acceptance, preparation and application of the engineered barrier (i.e. protective) materials. For example, AECL has become ISO 9001 certified, and so all work presently undertaken at the AECL URL is compliant with this quality assurance program. …

6.13	Intrusion Resilience	… AECL's 1994 EIS assessed the impact from intrusion into a deep geologic repository for 72-bundle containers and in-floor emplacement (see PRD-Postclosure). Both the probability and consequences have been evaluated. The probability of inadvertent human intrusion is considered to be low and is reduced with increasing depth of a geologic repository. More recently, the human intrusion scenario is being re-evaluated for a different container and repository configuration (324-bundle containers and in-room emplacement) as part of the OPG Third Case Study. The results are generally similar to those observed in the AECL's 1994 EIS. From these analyses, it is inferred that the details of the container or vault layout have little effect on the consequence of intrusion, and some effect but less than an order of magnitude on the possibility of intrusion. …
7	**Safety Assessment**	
7.01	General	
7.01.01	General – Integration of Assessments	… The nature of the processes important in the vault, geosphere and biosphere are different, and so there are good reasons why different models would be appropriate for each. In the case of the biosphere, a difference between the pre- and postclosure models would also be reasonable because of the different timescales – for the preclosure there are specific communities that can be identified, whereas the postclosure must necessarily consider the impacts many years in the future when the current communities and biosphere will have altered in detail. Nonetheless, it is certainly important that the models themselves and their linkages be well-described, and common parameters used where appropriate in future safety assessments. The possibility of using a common biosphere model (and/or datasets) will be considered. …
7.01.02	General – Presentation of Risks	… Dose rates are usually used to present the results of pre- and postclosure assessments, as is internationally common practice. In part, this is because dose rates are a relatively well defined and calculable quantity. The conversion between risk and dose can be made using the ICRP risk-to-dose conversion factor. However, it is recognized that the CNSC criterion (R-104) is a risk-based criterion, and that some audiences prefer results presented in this form. Therefore, except for preclosure collective dose, the main results of the studies are also described in terms of risk in the conclusion of the EIS summary report, in the conclusion of the Postclosure report and in the executive summary of the Preclosure report. …
7.01.03	General – Baseline Data	… If disposal is selected by the federal government as the preferred option, then siting would likely proceed in a staged approach and these comments would naturally be addressed. For example, possible siting areas would likely be identified based on a variety of criteria, including ecological sensitivity. Specific candidate sites would be characterized better, including baseline data on the local environment and local populations. And any selected site would likely start with an underground test facility that would provide specific site-relevant data to support models. …
7.01.04	General – Assessment of Rare Events	… The complete submission associated with these comments discusses a number of topics with respect to the language of risk and the definitions of probability. … It is expected that experts in risk will be consulted, closer to the time of actual siting so that definitions and usage are acceptable with current standards. It is expected that risk would need

		to be expressed in different methods in any event, since ways to communicate with non-technical audiences may be different than those for the technical risk assessment community. …
7.02	Preclosure	
7.02.01	Preclosure – Methodology	… It is expected that any formal license applications would require an EA. It is anticipated that the preclosure portion of the assessment would be relatively standard, and would draw on experience with nuclear power plants, uranium mines and other relevant facilities. The preclosure portion would be carried out using acceptable methods and tools in use at that time (e.g. ERA methods have matured since the early 1990's when AECL's EIS was prepared). It is quite possible that the preclosure portion of the assessment would be substantially completed by a contractor with current experience in carrying out such studies for other similar scale projects. …
7.02.02	Preclosure – Models	
7.02.02.01	Preclosure – Models – Verification and Validation	… See the response to the previous comments (7.02.01). Use of currently accepted codes and standards would be expected in any future preclosure EA. …
7.02.02.02	Preclosure – Models – Probabilistic	See the response for the previous comments (7.02.01). …
7.02.03	Preclosure – Case Studies	… These comments suggest a number of areas where better information could be provided for the preclosure portion of an EA. As noted in earlier comments (7.02.01), it is expected that any future EA would be carried out using then-current methods and tools, and draw on the available case studies and epidemiological information as appropriate. …
7.02.04	Preclosure – Quality Assurance	See the response for comment 7.02.01.
7.02.05	Preclosure – Sensitivity Analysis	See the response for comment 7.02.01.
7.02.06	Preclosure – Presentation of Results	
7.02.06.01	Preclosure – Presentation of Results – Residual Effects	See the response for comment 7.02.01.
7.02.06.02	Preclosure – Presentation of Results – Significance	… These comments identify points where the presentation of the preclosure results was felt by the reviews to be inadequate. These will be reviewed as part of the preparation of any future preclosure assessments. …
7.02.07	Preclosure – Effects on Workers	… OPG has developed preliminary design requirements for handling used fuel in the packaging plant, container shielding cask and emplacement rooms. For example, the used fuel container design must limit the container surface dose rate to below 15Gy/h. OPG's container screening studies have specified a maximum dose rate on the container shielding cask to be 10 micro-Sv/h. OPG studies have been initiated to determine the maximum thickness of vault sealing materials and rock to reduce dose rates to 1 micro-Sv/h. …

7.02.08	Preclosure – Cradle to Grave Materials Analysis	… AECL's 1994 EIS discusses the effects of resources, including non-renewable resources that may have to be removed from the geologic repository facility and further managed following applicable federal and provincial legislation (see PRD-Preclosure). …
7.03	Postclosure	
7.03.01	Postclosure – Methodology – General	
7.03.01.01	Postclosure – Methodology-Scenario Analysis	… The methodology for long-term safety assessment has been evolving slowly, and there is no one correct method. Although the EIS may not have formally compared the procedures with other countries, the OECD/NEA review of the EIS provides some assurance that the EIS methodology was reasonable according to international practice. OPG remains very interested in international developments in safety assessment methodology, and would use current practices in any future assessment. OPG ensures that its methods are current in part through participation in the OECD/NEA radioactive waste program, which provides a forum for exchange of information between groups working in this area. Since the EIS (and the 1996 SCS) were issued, there have been several workshops on methodologies and lessons learned from international and postclosure safety assessments. OPG has also conducted independent reviews of its geosphere and vault models, in order to help determine the specific directions for improvement. An important result from a system model is that the uncertainties are put into overall context – do they affect the bottom-line impacts of concern or not. This requires that all processes be treated within a single model. OPG intends to continue to develop and apply such an integrated model. …
7.03.01.02	Postclosure – Methodology – Scenario Analysis	
7.03.01.02 .01	Postclosure – Methodology – Scenario Analysis – General	… It is clearly desirable that the scenario selection procedure be objective, transparent and traceable. OPG has reviewed possible procedures, including the EIS approach as well as those used internationally. This topic was also addressed at a 1999 NEA sponsored workshop on Scenario Development Methods and Practises (NEA 2001). A key conclusion is that the process will continue to rely on expert judgement. However, the results can be improved by checking the assessment of factors and of scenarios, including comparisons with similar international studies; by seeking feedback from the CNSC and other stakeholders to ensure that scenarios of special interest have not been overlooked; and by fully documenting the selection process. In advance of an actual siting process, OPG is revisiting the FEP database. A Microsoft Access database is being prepared that will form the basis for a more searchable and traceable Canadian FEP database. It is structured along the lines of the NEA International FEP database, rather than that used by AECL for the EIS, so that the specific FEPs developed or screened for any future Canadian safety assessment may be more directly compared with the screening in other international safety assessments (NEA 2000). …
7.03.01.02	Postclosure –	… The factors or "FEPs" list has been significantly updated for the OPG

.02	Methodology – Scenario Analysis – Participants	Third Case Study project. The FEPs are now documented in a Microsoft 2000 Access database that contains the screening analyses for any given OPG deep geologic repository safety assessment. The FEPs themselves are organized from an international FEPs list that was developed collaboratively among several national nuclear waste management organizations (NEA). Use of this international basis ensures that the OPG list is comprehensive. …
7.03.01.02 .03	Postclosure – Methodology – Scenario Analysis – Screening Criteria	… It is expected that any future siting –related safety assessment will include evaluation of a number of "what-if" scenarios, in addition to any probabilistic studies. The selection of these scenarios will depend in part on consultation with stakeholders. There have been, and are still on-going developments in guidelines for chemical contaminants and for handling non-human biota since the EIS. There would be a reasonable basis for assessing these questions at the time of any future safety assessment. …
7.03.01.03	Postclosure – Methodology – Analogs	… OPG has recognized the limits of natural analogues as noted in the various comments. Natural analogues are considered as several lines-of-reasoning behind the safety case. They provide some proof-of-principle that circumstances exist in which long-term containment can be achieved, and also information about processes or properties that are important. The analogues that demonstrate containment are of most interest because features that contribute to stability need to be understood; however analogues that do not demonstrate containment can also be useful for understanding processes. …
7.03.01.04	Postclosure – Methodology – Coupled Processes	… There has been a significant improvement in the availability and use of coupled and/or detailed models since the EIS. For example: • the AECL MOTIF 6.3 code with coupled T-H-M is being tested and applied in the international DECOVALEX study to address topics such as effects of glaciation and of scale-dependence (e.g Chan et al 1995) • the U. Cardiff COMPASS code with coupled T-H-M is being tested and applied to the desaturation/resaturation behaviour of the clay buffer/backfill (e.g. King and Kolar 2002) • the U. Waterloo FRAC3DVS code is being used to simultaneously analyze groundwater flow (including salinity effects) and solute transport; • the CCM model is being developed to explore detailed processes related to copper corrosion, including microbial activity. For a specific site, it is expected that these and other tools will be used to explore the candidate repository from a variety of technical aspects. …
7.03.01.05	Postclosure – Methodology – Precision and Accuracy	… It is thought that the use of more significant digits in intermediate calculations should not be of concern, to the extent that they are naturally produced in the course of calculations (and fitting function coefficients often require more digits that the final result accuracy). However, input data and conclusions should appropriately reflect the confidence in these values. For example, the EIS Postclosure Assessment report tends to quote number to one or at most significant figures, which is the level at which OPG would generally expect to provide quantitative results in any future assessment. …

7.03.01.06	Postclosure – Methodology – Source Term	… An artificial source term (geosphere to biosphere) was indeed used in the Biosphere report for the sensitivity analysis of the biosphere model. The main postclosure assessment results and their sensitivities, as described in Goodwin et al. (1994), were based on the biosphere with the reference source term reflecting the full vault-geosphere-biosphere system model. The actual screening process assumed that most barriers were not effective. This is documented in Goodwin and Mehta (1994) which might not have been available as part of the EIS documents. Furthermore, the engineering design was not particularly influenced by the specific radionuclides, but rather by more general criteria (e.g. the desirability of reducing conditions, the desirability of diffusive-limited buffer region). However, it is agreed that, it is desirable to check the conclusions from any screening analyses. …
7.03.01.07	Postclosure – Methodology – Identification of Incorporated Scenarios	… It is expected that any future siting-related safety assessments will include evaluation of a number of 'what-if' scenarios, in addition to any probabilistic studies. The selection of these scenarios will depend in part on consultation with stakeholders. It is expected that these will include explicit dose calculations to a wider range of human groups with different characteristics. This will make the impacts on these different groups clear. Also, OPG is in the process of developing descriptions of the evolution of the repository for two scenarios – the design basis scenario and a defective container scenario. …
7.03.01.08	Postclosure – Methodology – Data Discontinuities	… The comment was specifically prompted by the use of two soil model algorithms, which result in a discontinuity in plant concentrations at the switch between the models (not a discontinuity in the data itself). These soil algorithms have been revised since the EIS; however the discontinuity still exists because one soil algorithm is a deliberately conservative model for use when the water table is close to the surface. Thus the discontinuous model does not cause an error in any particular result. Rather, as noted by AECL in this case, it can make the results seem more sensitive to a parameter than it really is. There are no other discontinuities in the model of this type. However, there are other real physical discontinuities due to switches between distinct model state. …
7.03.02	Postclosure – Disposal System	
7.03.02.01	Postclosure – Disposal System – Conceptualization	… The deep geologic disposal concept explicitly uses the geosphere as a means to improve the isolation of the used fuel from the surface biosphere. Furthermore, these components of the natural environment must be incorporated into the system models in order to see the behaviour of contaminants in these components, whether they act as a barrier or as a receptor. Regarding the degree of treatment of the microbial population within the EIS assessment, there has been much more work on the microbial population in the repository and its effects since the EIS was issued. Post closure models compensate for simplifications in part through (1) the use of conservative models or data, (2) use of uncertainty ranges on parameters, and (3) validation of the models. …

7.03.02.02	Postclosure – Disposal System – SYVAC3-CC3	
7.03.02.02 .01	Postclosure – Disposal System – SYVAC3-CC3 – General	… The overall models were described in the EIS and its subsidiary documents and references. The link to the panel guidelines was not transparent, although the intent was to cover the listed topics from the Final Guidelines. In any future safety assessment, it is expected that there would be more explicit treatment of a number of the points noted, including long-term changes in the biosphere (e.g. glaciation) as well as of the processes and of the model uncertainties. The system model was generally consistent with the models developed by other waste management organizations around the world at that time. The link between the vault to biosphere was generally unidirectional since this reflected the processes that were important for radionuclides to have impacts on humans. However, important couplings in the reverse direction were also included in the models. Specific phenomena are treated linearly or non-linearly as is described in the model reports. These system models continue to be improved and tested. …
7.03.02.02 .02	Postclosure – Disposal System – SYVAC3-CC3 – Limitations on Models	… It is believed that the use of multiple runs to provide probabilistic information is a useful part of a safety assessment, and suspect that its absence would be noted by reviewers. It is also thought that the approaches used in the EIS to solve the transport equations have some non-trivial advantages. It is also important to distinguish between the SYVAC executive shell, and the CC3 and PR4 system models that were run under it. SYVAC provides a powerful capability for parameter sampling, probabilistic runs, and time series manipulations. It is nonetheless recognized that computer resources have changed substantively since the EIS. Therefore it is likely that any future safety assessment would include analyses using more than one code, and in particular including more detailed models. …
7.03.02.02 .03	Postclosure – Disposal System – SYVAC3-CC3 – Inflexibility	… These comments reflect to some degree a basic trade-off in computer program selection for which there is no one correct solution – adding more capability to the codes may allow more flexibility in responding to new information, but makes code harder to change. Also, working in a quality assured environment means that changes are made carefully, which again generally means a trade-off with speed of modification. SYVAC provides a powerful capability for parameter sampling, probabilistic runs and time series manipulations. As an executive shell code, it does not make any assumptions as to the specific system models. Future work can keep the useful SYVAC shell code, and improve those aspects of the CC3 or PR4 system models that were not satisfactory. The SYVAC3-CC3 followed a particular design emphasis that had a number of important advantages, including relatively fast execution, good QA and substantial numeric robustness, and a coupled vault geosphere-biosphere. However, it is recognized that one code does not satisfy all demands, and it is intend that future safety assessments would be supported by several codes. …
7.03.02.02 .04	Postclosure – Disposal System – SYVAC3-CC3 – Conservatism	… It is believed that conservative models and/or data are used in a wide variety of safety assessments, where it is sufficient to demonstrate that a consequence is below (or above) some criterion rather than how far from the criterion. It is desirable for the reference system model to be as

		realistic as practical, and not invoke conservatism widely. In this regard, the EIS models and data were often intended to be reasonable or average, and not conservative. OPG has proposed several approaches to address the general concerns regarding conservatism which include: provide more information on the degree of conservatism through further testing; further review of the models and data; use a range of models; and model and data reports should identify where they are intended to be conservative. …
7.03.02.02 .05	Postclosure – Disposal System – SYVAC3-CC3 – Vault-Geosphere Interface	… For the nominal EIS reference design (EIS Engineering, p.118), the buffer-filled boreholes are about 1.3m diameter, with 2.1 centre-to-centre spacing in a 7.5m tunnel. The ratio of buffer to total drift area in the vertical direction is 25%. Therefore, any correction due to the impermeable buffer should be much less than a factor of 2. Furthermore, if the backfill has higher permeability than the buffer, then it seems plausible that the groundwater flow would tend to flow around the buffer and fill in the "shaded" portion of the backfill, leading to a flow mass balance similar to Eqn.6.28. Overall, any correction for the buffer is likely not a significant factor. The groundwater transport model around the vault-geosphere model interface is clearly an approximation. However, it should be noted that the geosphere model takes an integrated flow from an entire vault sector as input into a single geosphere node, and so fine resolution of the vault-geosphere interface flows would not necessarily have produced more accurate results. …
7.03.02.02 .06	Postclosure – Disposal System – SYVAC3-CC3 – Geosphere-Biosphere Interface	… In the particular case considered for this EIS study, it was judged that the flow was essentially vertical to the discharge points based on MOTF modelling, and this is how the model was arranged. However, GEONET is capable of handling lateral flow connecting nodes; saturated layers of organic materials; or layers of permeable and impermeable materials or a variety of saturated flow systems containing advection and diffusion elements. If other unique features of a particular repository site are important, then they should be appropriately modelled in any future assessment. The geosphere and biosphere need to be strongly coupled because of the effect of well demand on the ground water flows. The well demand itself is defined by the biosphere model. With respect to "obscure processes deep in the subsurface", it should be noted that this was one of the first studies anywhere with this level of detail, and was also conceptual rather than site-specific, so identifying which processes were important was an output from the study. …
7.03.02.02 .07	Postclosure – Disposal System – SYVAC3-CC3 – Modelling Detail	… This is being addressed in two ways: 1) Improvement of the models in the reference system model to a more consistent intermediate level of complexity. One change incorporated for the SCS was the adoption of somewhat more detailed vault model called INROC. Another change recently included is a simplified transport model. 2) Development (or acquisition) and use of models with both simpler (e.g. RSM) and more detailed (e.g. MOTIF, FRAC3DVS) capabilities. …

7.03.02.02 .08	Postclosure – Disposal System – SYVAC3-CC3 – Inappropriate Parameters	… One of the purposes of sensitivity analyses is to provide a test of the "reasonableness" of the models. Most of the important parameters identified in the EIS Postclosure report – and in the SCS Postclosure reports (Goodwin et al. 1996, p.61) – are in fact measurable parameters and the sensitivity of the conclusions to these parameters is reasonable. The specific empirical parameters found to be important in the EIS study (anion correlation parameter and velocity scaling factor) were not used in the SCS, nor are they planned to be used in future assessments. …
7.03.02.02 .09	Postclosure – Disposal System – SYVAC3-CC3 – Ease of Review	… It is believed that any computer program able to analyze the range of features likely to be seen in a deep geologic repository will inherently be a large computer program, and therefore not readily amenable to easy review. OPG is continuing to improve the clarity of the models, computer programs and results as follows: • following a software quality assurance approach; • preparing separate reports for the model theory, code design, code verification and validation testing of the main safety assessment system model; • preparing alternative simpler models that should be able to reproduce the main features of the detailed model results; • providing nuclide fluxes at the vault-geosphere and geosphere-biosphere interface as useful intermediate information. …
7.03.02.02 .10	Postclosure – Disposal System – SYVAC3-CC3 – Comparison with UTAP	… There are limited opportunities for validation of the system models for used fuel disposal. Therefore, the approach is to use as many partial validations as practical. The overall confidence in the results should not depend on any one test of limited applicability, but on the results of a large set of tests that consider different aspects of the model. For the specific example cited of uranium and mine tailings, the solute transport process occurring in shallow ground (relatively homogenous, porous conditions) are not necessarily those in fractured rock. However, the geosphere model should work under these shallow ground conditions, and so it builds confidence in the model to know that this is indeed the case. Furthermore, such tests could potentially be used to directly validate other parts of the system model, such as the geosphere-biosphere system interface. …
7.03.02.03	Postclosure – Disposal System – Chlorine-36	… This comment, from a 1995 Environment Canada report, was issued before the SCS results were available to reviewers. The SCS did consider Cl-36 in much more detail, including the derivation of specific biosphere pathways. Its importance to humans and non-human biota are clearly acknowledged in the SCS reports. …
7.03.02.04	Postclosure – Disposal System – Technetium-99	… The presence of reducing groundwater conditions at depth, and the availability of a large rock mass of rock mass to help return conditions to reducing after vault closure, is an important characteristic of the deep geological disposal concept that would be confirmed as part of the siting process . Evidence continues to build, that conditions at vault depths in the Canadian Shield remain reducing, even under such perturbations as glaciation. Within the vault itself, the presence of copper, iron (in a failed container), and microbes and iron minerals in backfill should all contribute to development of anoxic conditions. Therefore, the assumption of oxidizing conditions AND groundwater access to the canisters should be considered as very unlikely, and the reference case

		should be based on anaerobic conditions. However, as has been noted in other responses in this database, (e.g. 7.03.13.02), future safety assessments will likely consider several specific "what if" scenarios that reflect the interests of the main stakeholders. …
7.03.02.05	Postclosure – Disposal System – Radionuclide Speciation	… Precipitation and sorption are dependent on the chemical conditions (e.g. Eh, pH, temperature, salinity) in the groundwater. In the EIS, the dependence of the solubilities of the elements U, Pu, Np, Th and Tc on the groundwater composition was explicitly taken into account. Furthermore, the nuclides contributing the most to the calculated total doses (I-129, Cl-36 and C-14) have large solubilities under potential vault conditions and have relatively simple aqueous chemistries. The absorption coefficients used in the assessment were derived from experiments carried out under the chemical conditions in the vault, geosphere or biosphere. Consequently, if the chemical conditions in the vault, geosphere and biosphere do not deviate greatly from the expected conditions, the measured absorption coefficients would already implicitly account for the chemical speciation of the elements in the various compartments. …
7.03.02.06	Postclosure – Disposal System – Dispersivity	… The transport paths adopted in the EIS model were based on particle tracking of solutes under a 3-D model (MOTF) that reflected a reasonable representation of the WRA model as was known at the time including spatial variability. However, the geosphere model (GEONET) used in the system code did treat uncertainty in an approximate manner and the extent of this approximation was not well defended. As a minimum, it is expected that a future safety assessment will consider more than one conceptual model of the site hydrology, so that there will be explicit consideration of factors as spatial variability in the properties of the geosphere. Furthermore, OPG is working towards a direct coupling between the site characterization geosphere model and the safety assessment model, so that the geosphere variability and uncertainties can be propagated directly into the safety assessment models. …
7.03.03	Postclosure – Vault	
7.03.03.01	Postclosure – Vault – Conceptualization	… It is acknowledged that vault conceptualization and optimization of vault design are important issues for geologic disposal. Detailed hydrogeologic modelling using the MOTIF finite element code had shown that placement of vault rooms above the fracture zone LD1 would have resulted in relatively rapid downward movement of contaminant released from failed containers. The contaminants would have by-passed the backfill, leading to larger predicted doses. Hence, for the EIS postclosure assessment case study the vault design was improved, in order to increase safety margins, by eliminating all vault rooms above the LD1 fracture zone and increasing the waste exclusion zone to about 50 meters. This optimization in vault design is reasonable. MOTIF hydrogeologic studies for the vault design in the EIS postclosure assessment case study indicated that groundwater velocities in the surrounding low permeability rock were upward and small. Consequently, in the EIS case study, nuclides migration from the vault was preferentially in the upward direction. For this reason, it was deemed that a simple 1-D sequential (fuel, buffer, backfill, geosphere) model would be appropriate for modelling contaminant transport in the EIS postclosure assessment study case. The 1-D model assumes that

		transport of nuclides is the upward direction only. The appropriateness of the 1-D model was evaluated by comparison with the MOTIF calculations. Although the MOTIF calculations showed that, in the pure diffusion case, some nuclides move directly through the buffer to the rock below the disposal room, thus bypassing the backfill, the comparison showed that both the MOTIF and 1-D models calculated the same breakthrough time for the I-129 to the overlying fracture zone. 3-D analyses were also carried out to investigate the sensitivity of convective groundwater transport between the vault and biosphere to the hydrogeological properties of the near-field region within and surrounding the disposal vault. These studies showed that the existence of a 3 m thick EDZ, with permeability up to 100 times that of the undamaged rock, had no significant effect on the convective contaminant transport from the vault, mainly as a result of the "hydraulic cage" effect. For these reasons, AECL claimed that the 1-D vault model accurately represented the contaminant transport at least for the particular EIS case study. The use of simple 1-D models, backed up by more complex 3-D model calculations is a common practise in safety assessments of deep geologic repositories. Although some assessment of the validity of the 1-D transport model used in the EIS was made, because of the importance of the backfill and the possibility that it could be bypassed, OPG agrees with the OECD/NEA Review Group and others that "more explicit justification of the adequacy and validity of the 1-D modelling would have been of value". It is acknowledged that a 1-D model may not be appropriate for all situations. In fact, in the SCS, an in-room emplacement vault was used and a 3-D boundary integral model was used to model nuclide transport in the vault. Transport in sealing materials (buffer and backfill) is assumed to be diffusion dominated. In fact, groundwater flow velocities are small in the backfill (1.0E-6 m/a) and zero in the buffer. Thus diffusion would be the dominant transport mechanism in these sealing properties because the hydraulic conductivities are less than 1.0E-9 m/s throughout the materials. Because a solubility limited dissolution model was used to calculate UO2 dissolution rates in the EIS, the predicted dissolution rates depends on the dimensionality of the transport model. However, it is expected that in the future, a kinetic fuel dissolution model will be used to predict the rate of the UO2 dissolution, following the approach used in the SCS. Finally, the procedure used to calculate the releases from all failed containers seems correct. …
7.03.03.02	Postclosure – Vault – Container	… The current reference disposal container is a copper shelled container with a carbon steel inner vessel. There is substantial theoretical and experimental evidence to indicate that copper corrodes very slowly under reducing conditions. Therefore, it is expected that such copper containers will last at least 100,000 years and likely more than 1 million years. Work is continuing to ensure that there are no copper corrosion mechanisms that would significantly reduce the lifetime of the copper corrosion containers. As noted, the number of expected manufacturing defects in the copper containers can only be estimated at this time based

		on analogy with other welded containers. Further container specific information will be available after the whole container fabrication sequence has been demonstrated. Work on relevant container fabrication is presently underway as part of the Swedish and Finnish programs. …
7.03.03.03	Postclosure – Vault – Parameters	
7.03.03.03 .01	Postclosure – Vault – Parameters – Instant Release Fraction	… OPG acknowledges the importance of the instant release fraction (IRF). In the EIS and SCS, conservative IRF values were estimated based on experimental data on release of fission products from spent fuel. Because of the importance of the IRF values, it is anticipated that they will be updated for a future assessment for a potential site, since experiments measuring fission product releases from spent fuel have been reported in the literature after publication of the EIS and SCS reports. The importance of new data was demonstrated in the SCS (Johnson et al. 1996), where new experimental data allowed a better and less conservative estimation of the C-14 IRF. Also, a recent review of the Tc IRFs indicates that the value used in the EIS is too conservative. Also, IRFs will be applied to all nuclides of a particular element e.g. and IRF for Cs-137 will be defined as was done in the SCS. The validity of the equations in the Vault PRD describing the instant release source term has been questioned in the review. These equations are valid, but the description of the model equations was not written clearly. The equations are correct, but the nomenclature may have been confusing. In any event this model has been replaced with a better model in the SCS. …
7.03.03.03 .02	Postclosure – Vault – Parameters - Diffusion Coefficients	… At the time of that the EIS was being prepared, new experimental data became available for the diffusivities and apparent diffusivities of nuclides in buffer and backfill materials. These experiments indicated that surface diffusion effects were not as important as previously thought. Therefore, the buffer and backfill diffusion models used in the SCS and, hence, the diffusivity and Kd data, differed from those used in the EIS. Because the two models are different, in the EIS model but not in the SCS model, the buffer porosity is nuclide dependent, the diffusion coefficients and capacity factors used in the two models are not directly comparable. The impact of the revised diffusion data on the EIS dose estimates was investigated in Johnson et al. It was found that the new diffusion data resulted in an increase in the mean-maximum I-129 dose and, hence, the mean maximum total dose, by about a factor of 2. The increase in the mean-maximum dose rates for C-14 and Tc-99 were larger – about a factor of 4 for Cl-14 and a factor of 10,000 for Tc-99. However, because the doses from these nuclides were small compared to the I-129 dose, particularly for the Tc-99, these latter changes did not affect the mean maximum total dose. In the SCS, the measured values of the intrinsic and apparent diffusion coefficients in the buffer and backfill materials were used, where available, in the mass transport calculations for the vault. …
7.03.03.03 .03	Postclosure – Vault – Parameters – Solubility Limits	… It is stated in the Postclosure PRD, that "In SYVAC3-CC3, we correlate solubility limits for uranium and technetium, and for plutonium, neptunium and thorium, by calculating them as a function of a basic set

		of sampled parameters that include the electrochemical potential and other fundamental sampled parameters." The meaning of this statement has been understood. What was actually meant is that the solubilities of uranium, technetium, plutonium, neptunium and thorium are calculated as a function of the fundamental sampled parameters describing the chemical composition of the groundwater in contact with the fuel, e.g. electrochemical potential, pH, temperature, salinity etc. The solubilities of these elements are, therefore, correlated in the sense that they pertain to the same values of the fundamental solution properties. …
7.03.03.03 .04	Postclosure – Vault – Parameters - Buffer Anion Correlation Coefficient	… In the EIS, the model describing diffusion in the buffer and backfill included a surface diffusion term. The surface diffusion term depended on the charge of the diffusing species as well as it Kd value. Because of these dependencies, diffusion coefficients of nuclides having charges of the same sign were correlated. This correlation was achieved was achieved by defining dummy correlation parameters, which were used to correlate the diffusion coefficient values of the nuclides in the same group and to correlate the diffusion values with the capacity factor values. After the EIS was prepared, additional information became available which suggested that surface diffusion is not an important as previously through in the buffer and backfill. Thus in the SCS, surface diffusion terms were not used and it no longer became necessary to correlate the different diffusion values. Consequently, the "buffer anion correlation parameter" was not used in the SCS. Recently, in their review for SR97, Yu and Neretnieks (1997) suggest that surface diffusion is important for Cs, Ps, Sr, and Ra in low ionic strength waters and that anion exclusion effects are important for anion such as I-. This would indicated that the buffer and backfill effective diffusion coefficients and capacity factors should be critically reviewed and revised, if necessary, for application to the next Canadian assessment of used fuel disposal in a geologic repository. …
7.03.03.03 .05	Postclosure – Vault – Parameters – Mass Transfer Coefficient	… OPG accepts the criticisms regarding the use of mass transfer coefficients in the MT code used to describe mass transport through the vault in the EIS. The current OPG vault model (INROC) does not use mass transfer coefficients but uses a coupled model i.e. the coupled mass transport equations for the buffer, backfill, EDZ and semi-infinite geosphere zone are solved simultaneously. This vault model is an updated version of the model used in the SCS. This new approach is clearer, more transparent and more defensible. Further developments to improve the geometric detail of this model are presently under evaluation. …
7.03.03.04	Postclosure – Vault – Research	… Some work on the effect of additives (rare earths, fission product elements, etc.) on the corrosion behaviour of UO2 fuel has already been carried out. OPG is currently funding a 5-year Chair position (2000-2005) at the University of Western Ontario. In the scope of work for the Chair position, additional electrochemical experiments using SIMFUEL electrodes will be done. It is suggested that the extent of radiolysis outside a container has not been treated in sufficient detail. (Radiolysis of water outside container produces oxidants which can reactor with the container.). However, the discussion in the SCS Vault report indicates that for a copper container, the current OPG reference container, gamma radiolysis effects would be minimal because of the low absorbed dose

		rates. OPG is currently reviewing the reference container design. One key parameter is the radiation field on the outside of the container. In all the current preferred candidates, the radiation field is even lower than in the SCS. …
7.03.04	Postclosure – Geosphere	
7.03.04.01	Postclosure – Geosphere – Conceptualization	… It is acknowledged that conceptual model development is a key component of future site characterization and modelling activities. The conceptual model provides a basis to articulate geometry and spatial distribution of flow system properties and boundary conditions relevant to flow and transport. Development of a conceptual flow system model requires the integration of a multi-disciplinary site characterization data using a systematic and internally consistent framework. To this end the Canadian program is exploring the application of visualization software and geostatistical tools to explore and define spatial correlation/up-scaling amongst data sets and better communicate spatial sub-surface geometry essential to performance assessment. In addition, geoscience research activities have focused on improving the understanding of flow system evolution. Further, research supporting fundamental assertions in the conceptual model regarding either groundwater flow or mass transport has also been undertaken. …
7.03.04.02	Postclosure – Geosphere – Models	
7.03.04.02 .01	Postclosure – Geosphere – Models – GEONET	
7.03.04.02 .01.01	Postclosure – Geosphere – Models – GEONET – General	… An independent review of contemporary geosphere performance assessment models was recently conducted for the OPG program. This review echoed the concerns noted in the above comments, and provided some additional perspectives and program recommendations. Some of the recommendations noted that line-element network geosphere models were employed as part of a number of other national safety assessments. But the use of such models should be dependent on inclusion of all relevant processes, an in particular solution to the flow equations. The use of improved line-element models should also be supported by more extensive validation tests, and by clear procedures to transfer information from detailed site models to these simplified models. The Canadian program is presently considering the usefulness of such improvements to the present GEONET code, or alternatives based on more faithful representation of the geometry. However, both the EIS reviewers and the above reviewer noted that 3-D models are available which can accommodate flow and transport through porous medial and discrete fractures in an integrated manner, including sampling of uncertain parameters. Although such models have been used as part of safety assessments in the past, they are expected to become a more important part of the analysis. It is intended that future Canadian safety assessments for a deep geologic repository will be more heavily based on such codes. …
7.03.04.02 .01.02	Postclosure – Geosphere – Models – GEONET – Velocity Scaling Factor	… This approach was used in the EIS assessment, but was not used in the SCS assessment, and will not be used in future assessments. …

7.03.04.02 .02	Postclosure – Geosphere – Models – MOTIF	… The application of numerical codes to predict groundwater flow and transport in a fractured plutonic Canadian Shield setting is a complex undertaking. The DGRTP has undertaken a number of initiatives to further advance and test the application of such 3-D codes in this regard. Key elements in the program strategy include: 1) continued Quality Assurance documentation of MOTIF, 2) evaluation of alternative and complementary 3-D performance assessment groundwater flow/transport codes; 3) application of alternative site characterization – modelling strategies, 4) increased national geoscience communication; and 5) maintain international PA program awareness. In addition to MOTIF, the DGRTP is exploring the application of alternative 3-D flow and transport codes. The purpose is to test and evaluate advances in numerical code developments that may improve application for geosphere PA. …
7.03.04.02 .03	Postclosure – Geosphere – Models – TRACK3D	… In developing the geosphere performance assessment model, GEONET a sequence of activities is conducted. While the performance assessment involving the application of MOTIF-TRACK3D-GEONET(SYVAC) provides a methodology to assess the performance of the geosphere barrier, the necessity for manual and subjective decisions at model interfaces can be problematic in terms of dimensionality and traceability. The DGRTP is examining the application of alternative 3-D performance assessment modelling approaches that lend improved continuity with site characterization data and flow system conceptualization, as well as an integrated code capability to estimate radionuclide transport at time and space scales relevant to repository safety. Examples of such DGRTP research activities in which models are being tested include the Regional Flow System Analysis and the Moderately Fractured Rock Modelling Task Force. …
7.03.04.02 .04	Postclosure – Geosphere – Model – Well Model	… Implementation of the well model in GEONET is confounded by site specific hydrogeologic conditions, specific well demands and well depths. Change in any of these parameters may require a re-assembly of the GEONET 1-D streamtube network, which is otherwise fixed in space and time. This approach to well simulation will not be adopted in future geosphere performance assessments. …
7.03.04.03	Postclosure – Geosphere – Data Usage	… The issues raised in this comment category speak to the development of a conceptual model and the transfer of the conceptual model into a technically defensible mathematical realization. These comments are consistent with an independent review of Geosphere PA methodologies conducted by the DGRTP. Conceptual model development, which includes the methodology by which multi-disciplinary site characterization data is combined to develop an internally consistent understanding of a fractured groundwater flow system, is a principle goal of the DGRTP. …
7.03.04.04	Postclosure – Geosphere – Parameters	
7.03.04.04 .01	Postclosure – Geosphere – Parameters – General	… This issue speaks to the development of the conceptual groundwater flow system model. This involves justification of the spatial and temporal flow system properties, parameter up-scaling and boundary

		conditions. The importance of conceptual model development is recognized in articulating the case for geosphere performance assessment. DGRTP activities taken in this regard are described in 7.03.04.01. …
7.03.04.04 .02	Postclosure – Geosphere – Parameters – Sorption	… In the model, the Kd data are described by an equation with 6 parameters that account for the dependence of Kd on TDS and nuclide concentration, 3 parameters that allow for uncertainties in the chemical conditions and nuclide concentration, and one parameter for the mineral density. However, with the information available at the time for the EIS, most nuclides and minerals were treated very simply i.e. most parameters were simply set to zero. As noted, only retardation factors are needed and calculated for GEONET. It is acknowledged that Kd values are important intermediate results and should have been presented in the EIS. Vandergraaf and Ticknor (1994) note that most Kd measurements are made on crushed materials rather than rock. They further devise a method for converting these measure Kd values to Kd values appropriate for intact rock. However, because of the importance of Kd values of the EIS assessment, the validity of this approach should be demonstrated by comparing the so-calculated Kd values with those obtained for intact rock in field studies or laboratory experiments on large blocks. OPG is currently funding work to measure apparent diffusivities in field experiments. OPG agrees that the effect of the dissolved organic complexes on radionuclide transport and solubilities have not been adequately addressed. At the same time, this is acknowledged in the EIS, as noted above, by used of wide distributed functions to describe the nuclide Kd in the geosphere. …
7.03.04.04 .03	Postclosure – Geosphere – Parameters – Groundwater Residence Time	… Radiogenic isotropic data to support estimates of groundwater residence times in excess of 1,000,000 years were not reported in R-Geosphere. The context for the noted text R-Geosphere p.182 was that given knowledge of the WRA flow system properties and stable isotope systematics it could be reasoned that resident times were on the order of 1,000,000 years below 500m. Although preliminary, attempts to corroborate this assertion were made through comparison of hydrogeochemical evidence with 3-D numerical flow simulations. The comparison indicated similar trends in estimated groundwater residence times. It is evident that a more rigorous statement of the conceptual flow system model and description of the numerical realizations would have aided confidence in resident time assertions. Gascoyne (2000) provides a compendium and integrated interpretation of WRA hydrogeochemistry data collected during 1980 to 1995. …
7.03.04.04 .04	Postclosure – Geosphere – Parameters – Hydraulic Properties	… The process through which the conceptual model is derived allows rationalization of flow system (flow/transport/boundary conditions) parameter uncertainty and spatial variability which improves development of performance assessment modelling strategies. This is a particular problem in parameter up-scaling, flow system abstraction and dimensionality that may influence performance assessment outcomes. In this regard, the DGRTP has focused efforts on improved conceptual model development which include: • development of revised hydraulic testing strategies and interpretative methods to better assess/estimate accuracy and precision; • creation of the Moderately Fractured Rock Modelling Task Force to

		assess the limitations and capabilities of alternative geosphere modelling techniques and conceptualizations; • the application of visualization methods to improve field data integration, interpretation and communication; • the development of geostatiscal approaches for quantitative analyses of spatially variable geologic/hydrogeologic data set; • the completion of a 3-D Regional Flow System Analysis that will illustrate the sensitivity of permeability distributions, and gravity and density gradients on groundwater flow paths and residence time relevant to repository safety; • the evaluation of Anomalous Hydraulic Heads and implication for existence of large domains of low permeability granitic rock; • continued flow system site characterization and conceptualization studies as part of the Moderately Fracture Rock Experiment; and • continued research into transport parameter critical to mass transport in crystalline rock In respect to specific comments, a revised interpretation of the WRA groundwater glow system is presented by Stevenson (1996). With respect to mass transport in sparsely fractured rock (SFR), the DGRTP has undertaken the In-situ Diffusion Experiment. …
7.03.04.04 .05	Postclosure – Geosphere – Parameters – Well Depth	… The characteristics of the well scenario will depend on site specific hydrogeologic properties, repository positioning and input into the geosphere. In developing a well scenario consideration of existing groundwater resource development, groundwater quality and quantity must be realistically taken into account. This should not, however, preclude the ability to conduct "what-if" type scenarios that may position a water supply well in plausible and less favourable positions. The DGRTP is currently exploring the application of alternative and complimentary modelling approaches that would avoid the difficulties cited above. This includes pilot projects which will test the utility of innovative mathematical performance and safety assessment codes that remain faithful to geosphere property distributions and geometry and thus provide increased flexibility for application. …
7.03.04.05	Postclosure – Geosphere – Research	… The DGRTP recognizes the need for continued geoscience research and model development that will further aid development of the repository safety case. In this regard, the DGRTP geoscience work program is focused on several key research areas include: 1) development and maintenance of numerical PA tools; 2) development of visualization and electronic database information system conceptualization; 3) advancing knowledge of mass transport in porous-fractured media; and 4)creation of a University Liaison Program. These programs, among others, are designed to address technical comments raised during the federal hearing and to preserve site characterization skills unique to fractured Shield settings. …
7.03.04.06	Postclosure – Geosphere – Scenarios	… The issue of dimensionality and inclusion of processes and mechanisms potentially influencing radionuclide migration into the geosphere is an important aspect of performance assessment. Various

		long-term geosphere scenarios, while not explicit or perhaps as transparent as reviewers would have wished, were to have been captured through assignment of Probability Density Functions (PDFs) for geosphere model input parameters under the SYVAC framework. The technical comments submitted on the EIS and SCS have been reviewed with key issues surrounding presentation of the Geosphere Performance Assessment identified (Jensen and Goodwin, 1999). In addition, an independent review of geosphere performance assessment strategies that generated 14 recommendations was undertaken by the DGRTP. Current work activities in the DGRTP involve the improvement and testing of alternative 3-D modelling techniques for geosphere performance assessment. In addition to these activities, OPG is an industrial partner in the Federal Government's Canadian Water Network initiative, which will foster the development and demonstration of alternative PA modelling strategies at universities across Canada. …
7.03.04.07	Postclosure – Geosphere – Waste Exclusion Zone	… Within the EIS realization of the used fuel repository system, the Waste Exclusion Zone (WEZ) enclosing the repository created a significant diffusive barrier to radionuclide migration. Geoscience issues surrounding the role of the WEZ on repository safety focus on the ability to characterize large domains of sparsely fractured rock and the assessment of long-term WEZ integrity. While these issues remain valid and continue to be examined as part of the DGRTP, they are not necessarily germane to the safety concept. As illustrated by the SCS, a modified system of repository-engineered barriers within a more permeable geosphere without a WEZ was demonstrated to satisfy regulatory criteria. Geoscience research at the URL continues to provide evidence for the existence of large domains of sparsely fractured rock within the Lac du Bonnet batholiths. Anomalous hydraulic heads observed in deep multi-level casing systems may also be indicative of large domains of sparsely fractured rock as discussed by Chan et al. 1998). Numerical insight modelling collaborative international program such as DECOVALEX III are examining the development of coupled Thermal-Hydraulic Mechanical codes necessary to understand rock stress and property response to repository excavation and heating. Diffusive transport in sparsely fracture rock continues to be investigated though the In-situ Diffusion Experiment. …
7.03.05	Postclosure – Biosphere	
7.03.05.01	Postclosure – Biosphere – Conceptualization	… In the context of postclosure assessment of used fuel disposal, the biosphere covers only the surface environment and does not include the vault and geosphere. This restricted biosphere definition focuses on those parts of the biosphere that are readily accessible to humans and other important target organisms that need protection. It should be emphasized that the scope and the purpose of BIOTRAC was very limited – to calculate the nuclide concentrations in the various environmental compartments resulting from used fuel disposal in a geologic repository and to estimate radiological doses to humans and non-human biota from all credible pathways. Because of the acknowledged difficulty in modelling the biosphere, empirical models and data are often used in BIOTRAC to determine the migration of nuclides through the environment. Consequently many biosphere

		processes need to be modelled explicitly because these processes are implicitly accounted for in the empirical models. In the EIS, only exposures to the most exposed individuals were calculated. Nevertheless, it is recognized that the EIS did not cover a sufficient range of human and biosphere characteristics of particular interest to some stakeholders. Consideration should be given, in future assessments, to calculating doses for a range of human and biosphere characteristics. Also, regulators may require the calculation of nuclide concentrations in the surface environments, downstream of the vault location and exposure doses to critical groups living at these downstream locations. It is expected that biosphere modelling methods will continue to evolve and there will be a greater variety to choose from by the time that assessments are carried out for a proposed disposal site. When the time comes, the most appropriate methods for the conditions at the proposed disposal site would be used. …
7.03.05.02	Postclosure – Biosphere – Models	
7.03.05.02 .01	Postclosure – Biosphere – Models – BIOTRAC	… It is recognized that the biosphere around any site would likely change over the next 10,000 years, as a result of human activities or natural forces. The approach to this situation in the EIS was through two steps. First by isolating the used fuel in a deep geologic repository, the fuel would be partially isolated from changes occurring on the surface. Second, the EIS biosphere model would examine a number of different but steady-state biospheres. With respect to this latter point, the EIS biosphere model, in accord with international practises, assumes that the biosphere remains constant throughout the simulation period. Thus, it is not suitable for examining changing conditions at a given site. BIOTRAC uses many simplifications. For example, radionuclide losses from the soil layer due to plant uptake are not accounted for in the model. In this way, recycling of radionuclides is implicitly modelled. Because of these simplifications, nuclide transfers in BIOTRAC are mainly unidirectional: from areas of a high concentration to areas of lower concentrations. Such simplifications should not result in an underestimation of exposure doses because they generally cause the nuclide mass in the biosphere to be overestimated. For future safety assessments, it is intended to review the status of biosphere models, particularly those used by other national nuclear waste management organizations, with respect to handling biosphere changes. …
7.03.05.02 .02	Postclosure – Biosphere – Models – BIOTRAC Soil Model	… As noted, the soil model used in BIOTRAC (Davis et al. 1993) is not transparent. This BIOTRAC soil model uses a set of regression equations developed by fitting the results from many simulations of the (validated) SCEMR1 soil model, to calculate soil concentrations given the nuclide inputs into the soil layer from irrigation, atmospheric disposition and groundwater seepage. In this sense, the soil model used in BIOTRAC is inconsistent with the simpler compartment approach adopted in the other BIOTRAC sub-models. It is acknowledged that a similar and more transparent soil model would have avoided some of the pitfalls identified in the comments. OPG has recently incorporated a simple physics-based soil model into its reference biosphere model, similar to that used in SR97. As stated in one of the comments, although a simple physics-based approach would perhaps not be more accurate than the regression approach, it would be more easily defended and more consistent with other parts of BIOTRAC. …

7.03.05.02 .03	Postclosure – Biosphere - Models – CALDOS	… The food chain model CALDOS used in BIOTRAC is similar to food-chain models used internationally for assessment of nuclear waste disposal. Consequently, the methodology used in CALDOS has widespread international acceptance. Furthermore, given the predicted low concentrations of nuclides reaching the biosphere from the waste fuel repository, the assumption that the food chain transfer and accumulation of radionuclides are independent of nuclide concentration is reasonable. However, it is recognized that it would have been useful if the limits of validity of this assumption has been stated in the BIOTRAC report (Davis et al. 1993). It is also accepted that further explanations should have been added to the report to clarify any statements that are unclear or difficult to understand. …
7.03.05.03	Postclosure – Biosphere – Data Usage	… The Site Screening Report (Davison et al. 1994) was mainly focused on the geotechnical issues of site screening and evaluation. Therefore, issues related to the biosphere were not addressed in detail. However, as stated in Section 3.7 (Surface Environment and Environmental Sensitivity) of the Site Screening report "Many of the features of the surface environment important to siting are most relevant to and are discussed in the context of the preclosure phases of the disposal project (Grondin et al 1994). For example, the recognition and avoidance of essential habitat for endangered species would be part of the siting process. This would be an immediate preclosure concern relevant to the site evaluation, construction and operational phases of the project." Further, a brief discussion of the attributes of a suitable site for the purposes of postclosure assessment is discussed in Section 3.7 of the Site Screening report (Davison et al. 1994). For example, a site with no valuable agriculture resources would be preferred (Table 3-1, Davison et al. 1994). However, a direct connection between optimal siting requirements and BIOTRAC is never made. It is recognized that such a connection should be made, i.e. how site characteristics will be used to derive the require biosphere model parameters. …
7.03.05.04	Postclosure – Biosphere – Parameters	
7.03.05.04 .01	Postclosure – Biosphere – Parameters – Dose Conversion Factors	… OPG accepts that the new ICRP risk coefficient of 0.073/Sv and the new ICRP 60 (or subsequent) DCFs will be used in future assessments. Palatto et al. (1997) studied how the results of the EIS postclosure assessment case study would have been affected if the ICRP 60 dose conversion factors had been used. It was concluded that the total dose at 10,000 years, which is dominated by I-129, would have increased by about 67% if the ICRP 60 DCF's were used. Use of the ICRP 60 dose and risk conversion factors would have increased the estimated risk from I-129 by about a factor 6. For a comparison, the maximum EIS estimated dose at 10,000 years was orders of magnitude lower than the regulatory dose limit. A discussion of the used of the ICRP reference man in the dose calculations is given in Zach et al. (1996), where it is concluded that, for radiation protection, ICRP reference man is an adequate description of all Canadians living on the Shield. …
7.03.05.04 .02	Postclosure – Biosphere – Parameters –	… In the EIS, the non-human target organisms i.e. plant, mammals, bird and fish, are not specific species but generic ones. Food chain parameters for these species were taken to be the same as for the

	Transfer Coefficients	corresponding domesticated animals and cultivated species. The applicability of these data to the non-human target organisms were briefly discussed in the EIS and it was generally concluded that the wide distributions used for the transfer meant that the selected values would include many wild species. It was, however, acknowledged in Zach and Sheppard (1992, p. 58) that there are limitations in using the human food types in BIOTRAC to represent plant and animal species of the Shield. Nevertheless, the results presented in the EIS indicated that: (1) the doses received by non-human target organisms would be much lower than background doses; and (2) the concentrations of chemically toxic elements in the biosphere, resulting from used fuel disposal, would be much smaller than the background concentrations of these elements. The subject of ERA has progressed greatly since the EIS was prepared and additional data on non-human target organisms have become available. It is acknowledged that the use of generic target organisms would probably not be acceptable, particularly after a repository site has been selected. …
7.03.05.04 .03	Postclosure – Biosphere – Parameters – Fish Ingestion Rate	… U.S. EPA (1997) recommends an average fish ingestion rate of 7.3 kg/year for the whole population and 25.6 kg/year for the Native American subsistence population. In the EIS model, the mean fish ingestion rate of 10kg/year. However, a range of fish ingestion rates were actually considered in the EIS probabilistic analysis. The 95th percentile fish ingestion rate in the EIS would have been about 200 kg/year. Therefore, the EIS judged that a range of human lifestyles and characteristics had been adequately addressed, including aboriginal. However, it is recognized now that it will be necessary in the future to analyze specific lifestyles of interest, rather than deferring to the details of the probabilistic analysis. It should be noted that Zach et al. (1996) subsequently studied the effect of specific alternative human characteristics and lifestyles on the predicted EIS doses. Based on the results of this study, it was concluded that the probabilistic postclosure assessment case study was "representative of the full spectrum of diets and lifestyles that might be encountered on the Shield including those of aboriginal peoples and northerners. …
7.03.05.04 .04	Postclosure – Biosphere – Parameters – Concentration Ratios	… The mean Bv values (plant/soil concentration ratio) adopted for the EIS are element dependent. Thus, the EIS does not ignore the fact that different radionuclides may behave quite differently in transfer from soil to plant. The Biosphere PRD states that the variations in the plant/soil concentration values have not been reported extensively and that the published results produced varied results. "Variation appears to be mainly a function of the number of samples and the range of conditions under which Bvi was measured rather than of the physical or chemical properties of the system studied." Zach and Sheppard (1992) reviewed the available information and concluded that there was insufficient data concerning the variation in Bv values to assign reliable but different GDSs for the different elements. They recommended a GSD of 10 for elements which was used in the EIS. The statement in Zach and Sheppard (1992) that the "variation appears to be mainly a function of the number of samples and the range of conditions under which Bvi was measured rather than of the physical or chemical properties of the system studied" does not imply that the "available information on ratios appears to be an artifact of the

		sampling" but rather that the observed variations in the Bv values in the available studies depend more on the number of Bv values measured and the range of conditions studied than on the properties of the element or soil used in the study. Perhaps, the text in the biosphere PRD should have been rephrased so as to avoid any possible confusion. …
7.03.05.04 .05	Postclosure – Biosphere – Parameters – Occupancy Factors	… The building occupancy factor (0.8) and ground occupancy (0.2) used in BIOTRAC (Davis et al. 1993) were obtained from the CSA N288.1 Standard (CSA 1987), which provides guidelines for calculating derived release limits normal operation of nuclear facilities. The water occupancy factor was conservatively selected to be equal to twice the value recommended in CSA (1987). The referenced report (AIHC 1994) was not available for comparison. However, occupancy factors can be found in U.S. EPA's Exposures Factors Handbook (U.S. EPA 1997). In this latter report the average water, building and ground occupancy factors are about 0.014, 0.87, and 0.13. These are not much different from those used in BIOTRAC. Since the EIS total doses are not very sensitive to the values of the occupancy factors, these difference will not affect the total doses predicted by BIOTRAC. …
7.03.05.04 .06	Postclosure – Biosphere – Parameters – Food Intake Rates	… CALDOS uses the following average feed ingestion rates for dairy cows, beef cattle, and chickens: 12, 10, and 0.08kg dry weight/day (assuming food water content 80%) and the following average drinking water ingestion rates for dairy cows, beef cattle and chickens: 60, 40 and 0.4 L/day. These are similar to the values used in the CSA N288.1 (1987) which provides guidelines for calculating derived release limits for normal operation of nuclear facilities: feed ingestion rates for dairy cows, beef cattle and chickens of 10,10,0.1 kg dry weight/day and water ingestion rates for dairy cows, beef cattle and chickens of 80, 50, 0.3L/d. Food and water ingestion rates can also be calculated from the allometric equations in U.S EPA (1993) assuming body weights for dairy cows, beef cattle and chickens of 500, 350 and 2.2 kg respectively (CSA 1987). Using these allometric equations, it is found that feed ingestion rates are about 30, 20 and 0.1 L/day, respectively. Thus, ingestion rates used in CALDOS are generally conservative compare to the values from the U.S. EPA (1993). …
7.03.05.04 .07	Postclosure – Biosphere – Parameters – Stable Iodine	… The stable iodine groundwater concentration is used to determine the upper groundwater limit to the internal I-129 dose. In the EIS, the stable iodine concentration was described using a uniform distribution ranging from 5E-3 to 2E-3 mg/L. This distribution was based on data from the WRA. Since the safety assessment calculations in the EIS were carried out on a hypothetical reference disposal system having geosphere characteristics similar to those at the WRA, it was appropriate to use groundwater data from the WRA to define the stable iodine background concentrations. Sheppard and Gascoyne (1997) have recently compiled a database of groundwater iodine, chlorine and carbon concentrations. For the WRA, the current recommended lognormal distribution function for the iodine concentration in groundwater has a geometric mean of 0.003mg/L and a geometric standard deviation of 4, with lower and upper bounds of 0.0002 mg/L and 0.05 mg/L, respectively. Both the median and lower bound of this distribution function are lower than the corresponding values used in the EIS. Consequently, because lower values of the stable

		iodine groundwater concentrations lead to larger I-129 doses, the new data indicate that the stable iodine groundwater concentrations used in the EIS were non-conservative. However, it should be noted that the sensitivity analyses carried out for the biosphere model did not find the stable iodine groundwater concentration to be an important parameter for the median value simulation. The above discussion indicates the importance of using site-specific data in the safety assessment. …
7.03.05.04 .08	Postclosure – Biosphere – Parameters – Plant-Soil Concentration Ratio	… Seasonal variations in the rate of nuclide uptake by plants do occur. However, what is important is the total nuclide uptake by the plant at the time the plant is harvested. This quantity, the plant/soil concentration factor, is determined from the experimental data obtained from plants grown in contaminated soil and harvested at the end of the plant growth period. For plants digested by animals, e.g., forage grass that can be eaten at any time during their own growth period, the annual mean value of the plant/soil concentration factor should be used, since animals ingest plants throughout the growing season and, hence any seasonal variations would tend to average out. It is true that the plant/soil concentration ratio or Bv factor can vary significantly among plant species and in differing environmental conditions. This could explain why measured Bv values show large variations. The plant soil concentration ratio was found to be an important biosphere parameter. Thus, plant/soil concentration factors appropriate for the repository site should be used if, such data are available. Furthermore, consideration should be given to using plant-specific plant/soil concentration ratios as was done in SR97 assessment, rather than generic values. This latter charge would tend to reduce the geometric standard deviation of the Bv value. The current OPG safety assessments code SCC404 differentiates between plants used for forage and garden plants. …
7.03.05.05	Postclosure – Biosphere – Research	… OPG recognizes that ERA may become a more important component of the safety assessment of used fuel disposal in a geological repository. ERAs of a single contaminant generally follow a relatively well-established methodology. However, the integration of the ecological effects of radioactive and chemical contaminants, and other stressors (e.g. habitat loss, temperature) within a single ERA framework is a new emerging science and is not currently routinely done by industry. However, the CNSC is starting to ask for ERAs of multi-stressor effects and this issue is receiving increasing attention. ERAs are site specific because they depend on the VECs (e.g., rare species or food species) present near the proposed facility. When the time comes for assessing the environmental impact of a geologic repository at a selected site, the most appropriate biosphere modelling methods for the conditions at the proposed repository site would be used both for ERA and the calculation of human exposure doses. Furthermore, there is ongoing significant international effort in this area already. It is well know that the radiation dose-response relationship cannot automatically be assumed to be the same for humans and other species. Radiological EA models like BIOTRAC, the EIS biosphere model, are difficult to validate because of the very low environmental nuclide concentrations and the very long time periods. For the present time, OPG intends to monitor the developments in the area of ERA, with emphasis on model improvements rather than on experimental data. …

7.03.05.06	Postclosure – Biosphere – Gaseous Radionuclides	… In the EIS, the local airborne concentrations from gaseous emissions from terrestrial and aquatic sources are calculated. Airborne transport of nuclides from one location to another is not modelled in BIOTRAC. Rather these effects are accounted for implicitly by calculating air concentrations in a conservative way. For shallow soils, losses of nuclides from the soil compartment due to gaseous evasion are neglected. This is conservative because soil concentrations would be lower if losses due to gaseous evasion were taken into account. However, the nuclides are concentrations calculated in the EIS include contributions from gaseous evasion from shallow soils. Except for radon, the infiltration of volatile nuclides into buildings (from soil) is not considered because estimates showed that the indoor air concentrations from this pathway would be much less than those predicted for release from domestic water for typical soil and water concentrations. …
7.03.05.07	Postclosure – Biosphere – Traits of the Critical Group	… Switches were used in the EIS postclosure assessment to determine the source of domestic water, to decide if the garden is irrigated, to determine the soil type and to determine the source of heating fuel. With this approach, critical groups having different characteristics could be investigated simultaneously in one probabilistic run. In the EIS, the dose rates received by these different critical groups were not reported. Rather those dose rates were averaged to obtain an average overall dose rate. This procedure is potentially non conservative because dose rates received by critical groups with potentially lower doses would be averaged with dose rates received by potentially more exposed critical groups. However, whether or not this is acceptable depends on the difference in the dose rates for the "different" critical groups. According to ICRP 60 (ICRP 1990), critical groups should be chosen to "be representative of individuals most highly exposed as a result of the source under review". In future, the sensitivity analyses can be used as a general test of whether any given switch should be used to define a different critical group. …
7.03.05.08	Postclosure – Biosphere – Doses Non-Human Biota	… The animal dose rates reported in the EIS Postclosure report were overestimated by a factor of 1000. However, since the original calculated dose rates were very low, this error does not affect the EIS conclusions that doses to non-human biota, resulting from used fuel disposal would be much smaller than the background doses. The error in the biosphere model was traced and has been corrected in the OPG safety assessment codes (SCC404 and later). The error affected the non-human doses from the water ingestion pathways and was due to a units conversion error. …
7.03.06	Postclosure – Software Quality Assurance	… The SYVAC-CC3/PR4 models developed and used by AECL were subjected to a fair amount of internal quality assurance processes, including change control and verification, since the late 1980's although this was not necessarily well documented at the time. Also, the formal CSA N286.7 standard for nuclear software was not issued until 1994, so there was no single reference standard. There was in practice little changes in the codes after 1996, but there was considerable effort to improve the documentation of the codes. Also, after codes were transferred to OPG, they were placed under OPG software QA procedures that are based on the CSA N286.7-99 standard. Therefore, there should be a well-established QA trail for the main codes by the time they are to be used in any future assessment. …

7.03.07	Postclosure – Input Data Quality Assurance	… The input data quality will be addressed by: • requiring that relevant measurements be carried out to appropriate standards, such as ISO 9000 (presently part of the OPG contract requirements); • control and documentation of the data once it is accepted into the OPG reference dataset; • on-going testing of the model using the datasets; • research, and data sharing with other organizations, to improve the database. The sensitivity study performed in the EIS and the SCS reports indicated which parameters have a larger influence on the results, and therefore provided priorities for the present work program – e.g., the in-situ diffusivity program at AECL URL which examined the tortuosity of sparsely-fractured rock, and the I-129 biosphere review. All the EIS/SCS parameters were recently internally reviewed as part of OPG preparation for a Third Case Study exercise. Further review of the data is planned, including comparison with the reference biosphere values recently accepted by CNSC for use in Derived Release Limit calculations. …
7.03.08	Postclosure – Uncertainty	… It is not expected that a meaningful quantitative measure of overall uncertainty in the results can be developed. However, there are some approaches that can be used to help assess the overall uncertainty and its importance. First, ongoing testing of the models will provide some quantification of the uncertainty with respect to specific processes or conditions. Second, confidence in the results will be approached in a future safety assessment by providing multiple lines of reasoning, use of simple bounding models, and explicit analysis of "what if scenarios". Thirdly, it is expected that future safety assessments will attempt to distinguish between and discuss better, the different types of uncertainties. Finally, some parameter uncertainties (e.g. soil type, rainfall rates), and possibly model uncertainty will decrease after a repository site has been selected. …
7.03.09	Postclosure – Verification and Validation	… The comments generally indicate that model verification was adequately achieved but question the extent of validation. With respect to verification, note that the AECL internal QA process for code development included a substantial degree of undocumented verification. Since the codes were transferred to OPG in 1996, there has been a fair amount of effort to document the models better, including further verification. With respect to validation, as noted in the EIS report, full validation of a used fuel disposal system model is not possible due to the long time scales involved. The AECB/CNSC R-104 Regulatory Policy Statement (AECB, 1987) also recognizes that the results of the predictive modelling will be approximate, and confidence in the modelling output must come from a combination of several complementary methods of examining the models and results. It is not expected that a firm quantitative criterion can be specified to judge whether the overall system model is valid or not. Rather, the planned process is to undertake a continuous program of testing the models. …
7.03.10	Postclosure – Probability Density	… In general, it is preferred to use best estimate PDFs rather than conservative PDFs. It is for those cases where data are particularly

	Functions	scarce, or values are likely unimportant, that OPG may use conservative PDF ranges. The database is presently archived and controlled as part of OPG's software QA system. As new information is developed, OPG's PDFs are updated. OPG is focussing on the more important parameters, which can be determined from the results of the sensitivity studies, from understanding of physical processes, and from review of other international studies. Some comments question whether a PDF can be used to adequately cover time-dependent effects. This is expected to be a reasonable approximation for processes that reach equilibrium quickly. The applicability of this approach in general is addressed in part through validation tests through results from the detailed supporting models and through selection of suitable range of scenarios in the safety assessment itself. The possibility of adding time-dependence to the model itself also is being considered. These need to be more explicitly considered in future safety assessments. …
7.03.11	Postclosure – Monte Carlo	… See the comments under 7.03.13.01. It is intended to review the basis for how the probabilistic results should be generated and analyzed. …
7.03.12	Postclosure –Median Value Simulations	… These comments essentially focus on the appropriateness of the median value simulation as a reference case, and in particular its usefulness with respect to sensitivity analysis. It seems doubtful that any single sensitivity analysis could provide all the information desired, and in fact, the EIS included both sensitivity analyses of the median value simulation and the probabilistic simulations. For future assessments, additional analysis of more "what if" scenarios or high-consequence scenarios, and of the sensitivity of the probabilistic results, should help put the Median Value Simulation results into perspective as simply another way of looking at the results to see if they make sense. …
7.03.13	Postclosure – Analysis of Results	
7.03.13.01	Postclosure – Analysis of Results – Statistical	… It is not clear that there is a single right way to statistically analyse the results of the probabilistic calculations. However, OPG will consult with relevant experts to determine a reasonable path forward for conducting and analyzing any future safety assessments. However, it is expected that future safety assessments will place less weight on the results of a single massive probabilistic analysis, and therefore will be less emphasis on statistical analyses. …
7.03.13.02	Postclosure – Analysis of Results – Sensitivity Analysis	… These comments reflect a range of concerns. In some cases, they could have been addressed in the EIS by a better explanation of the reported sensitivities; in one case the comment was addressed by the addition of the SCS, and in other cases additional studies would be required. A future safety assessment will need to include an explicit treatment of a number of "what if" scenarios that test the robustness of the concept to various assumptions. Ideally, there will be an opportunity for defining these scenarios with stakeholders during the safety assessment process, rather than waiting for the final report to see if the results of interest are included. …
7.03.13.03	Postclosure – Analysis of Results – Barrier Effectiveness	… It is agreed that a better way of presenting information on barrier effectiveness is desired. However, there is no single correct approach to do so. The reviewers have noted some general problems with the method used in the EIS (a different method was used in the SCS). OPG

		will observe what is used in other national studies, and likely try out some different approaches as part of future internal safety assessment exercises. One possibility is to separate out the treatment of barrier effectiveness and barrier redundancy. The former might be tested by including one barrier at a time. The latter would be tested by removing one barrier at a time. These two approaches have been used for example, in the EPRI analysis of the Yucca Mountain repository. …
7.03.13.04	Postclosure – Analysis of Results – Threshold Exceedence	… The EIS approach with arithmetic average was based on the AECB R-104 regulatory requirement. Nonetheless, it is acknowledged that the additional methods of presenting results as suggested here has merit, if there are enough probabilistic and PDF data to support the estimates of what are likely "low probability" results. However, the overall tone of the EIS/SCS panel review was that there was too much emphasis on probabilistic results, and therefore it is expected that probabilistic analysis will play a similar role in a future safety case. …
7.03.14	Postclosure – Presentation of Results	… Presentation of the results of a future safety assessment in order to meet the needs of all readers will require some iteration. OPG will incorporate lessons-learned from the EIS and SCS reports, and from other international safety assessments. OPG is planning to use more "what-if" scenarios in future assessments. …
7.03.15	Postclosure – Human Intrusion	… With respect to the EIS, the following specific points are made relative to the comments: • Risks from the human intrusion scenario presented in the EIS were incorrect (they were too low). The new calculations showed that risks were largest for the resident scenario and reached about 1.0E-9 at 10,000 years and 2E-7 at 100,000 years. • The revised calculations show that maximum risks for the human intrusion scenarios occur much later than 2000 years after closure. Thus, the maximum risk is not affected if it is assumed that active and passive institutional controls disappear at say 100 years rather than 500 years and 2000 years, respectively. • Only inadvertent human intrusion scenarios are investigated in the EIS. • The human intrusion scenario only describes those cases where a surface borehole intersects the vault itself. Intersection of the contaminant plume is already covered in the groundwater or SYVAC scenarios in which will is used as a drinking water source. • The probability of the human intrusion scenario was based on the area of the vault and the number of boreholes drilled (per unit area). In this calculation the estimates of future drilling rates were inflated by about two orders of magnitude over historical rates of drilling in the Canadian Shield. • There is no physical means by which the contents of a container can escape from the container, if the container does not fail. In the EIS for conservatism, it is assumed that if the container fails, then the container no longer hinders the transport of contaminants out of the container, regardless of the size of the defect in the container. More generally, the EIS indicated that the human intrusion scenario was important to consider in safety assessments. …
8	**Documentation**	… The comments relate to the presentation of information in AECL's EIS and primary references, and are not specifically technical comments.

		However, there are a number of points which may be noted for future inclusion in site-specific assessment: • Cross references to supporting information should be valid; • Provide site geological and hydrogeologic information; • Document the software; • Provide a list of model data and value used; • Discuss modelling considerations and potential software problems; • List key assumptions; • Provide intermediate results for key calculation to allow the reader to follow the calculations; • Define all terms; • Provide page numbers for references; • Translate material into aboriginal languages; • Use current definitions for risk terminology; • Provide and index; • Provide a summary of the safety assessment and key performance issues; • Provide an integrated description of what happens. …
9	**Options**	
9.01	Options – Requirements	
9.01.01	Options – Requirements – Risk Comparison	… In 2002, OPG and the other nuclear energy corporations in Canada formed the NWMO. The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. The NWMO must submit the study within 3 years (i.e. November 2005) and the federal government will then decide on the preferred approach for the long-term management of Canada's used nuclear fuel in Canada. These approaches include, but are not limited to, onsite storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. The NWMO will include an assessment of the risks and benefits associated with each approach. …
9.01.02	Options – Requirements – Control	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, onsite storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. However, it is worth noting that the reference plan for a deep geologic repository (used for cost estimating) purposes has approximately 30 years of preparation, 30 years of operation, and 70 years of monitoring before repository closure. Thus, even in this option there is a minimum of 100 years of underground access and monitoring. …
9.01.03	Options – Requirements – Elimination	… In the long-term, advanced reactors could reduce the amount of nuclear fuel waste produced for a given amount of power. For the present used fuel, the only option to reduce the actual radioactivity of the waste is transmutation following reprocessing and partitioning. Transmutation has been examined by most radioactive waste management organizations in the world. To date, the results of these studies suggest that transmutation would be difficult and expensive, and would not eliminate the need for a deep repository (e.g. SKB 1998). Although there is ongoing international research, there are fundamental

		physical reasons why transmutation will not be achieved easily. OPG will continue to monitor this research. …
9.01.04	Options – Requirements – Recycling	… Recycling of potentially useful materials in spent fuel requires chemical reprocessing. Currently, there is an adequate supply of natural uranium for the Canadian reactors and reprocessing of spent fuel in Canada is not economic. Even if used fuel is reprocessed, there will still be a need to manage the separated radioactive materials together with the secondary wastes generated. The deep geologic repository concept is suitable for both used fuel and for high-level waste from reprocessed fuel. …
9.01.05	Options – Requirements – Perfection	… Canada, and other nations have developed concepts for the long-term management of nuclear fuel wastes which include assessment of the safety of the concepts. It is recognized that the probability of accidents is not zero, and the deep geologic repository concept has therefore been developed based in part on consideration of possible accidents and other unlikely conditions. The current concept for the deep geologic repository is judged to be acceptably safe from a technical perspective (CEAA, 1998). …
9.01.06	Options – Requirements – Certainty	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. However, it is worth noting that the reference plan for a deep geologic repository (used for cost estimating) purposes has approximately 30 years of preparation, 30 years of operation, and 70 years of monitoring before repository closure. Thus, even in this option there is a minimum of 100 years of underground access and monitoring. Development of a deep geologic repository would take place in a stepwise fashion. Steps would include site identification, site investigations, detailed site characterization, EA with further opportunities for public input, construction license application, and operating licence application. At each approval stage, the safety assessment would be refined and updated for regulatory review. The waste owners' work to advance the repository concept subsequent to the Seaborn Panel hearings has been built upon recognition of the need for a complementary set of arguments to support the case for safety of a geologic repository (NEA, 1999). …
9.01.07	Options – Requirements – Sitability	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield, based on the AECL concept. Currently, the waste owners believe that there is the potential for suitable sites in Canada for either storage or disposal. The issue of specific siting for the government-selected approach will be addressed after the government decision. …
9.01.08	Options – Requirements – Canadian Location	… The government of Canada sets national policy on the management of radioactive wastes in Canada (NRCan 1996). …

9.01.09	Options – Requirements – Current Location	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. Continuation of the present situation – i.e. on-site storage at reactor sites – is explicitly being considered. …
9.01.10	Options – Requirements – Cost Comparison	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. The NWMO assessment of the options will consider cost estimates for these approaches. …
9.02	Options – Alternatives to Disposal	
9.02.01	Options – Alternatives to Disposal – Storage	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. These approaches include, but are not limited to, on-site storage at reactor sites, centralized storage either above or below ground, and disposal on the Canadian Shield. OPG and the other Canadian waste owners are presently moving fuel bundles from the on-site water storage into on-site surface dry storage containers. In support of the NWMO investigation, waste owners are conducting studies on the possible lifetime of surface dry storage facilities for used nuclear fuel. The present service lifetime estimate of a concrete/steel-based surface dry storage container housed in a building is approximately 100 to 300 years. …
9.02.02	Options – Alternatives to Disposal - Transmutation	… The NWMO was established in accordance with the federal Nuclear Fuel Waste Act to investigate approaches for long-term management of Canada's used nuclear fuel. Transmutation was discussed briefly in AECL's EIS, but is not seen as a currently-feasible concept. OPG has reviewed that status of transmutation, and its monitoring developments in other countries. Studies in the 1970s concluded there was no cost or safety incentive to pursue transmutation, however, major programmes of research on partitioning and transmutation (P&T) are now being pursued in several countries, notably the US program of R&D in Accelerator Transmutation of Waste, accompanied by programmes of international co-operation and technology exchange, fostered by the Nuclear Energy Agency of OECD (NEA) and the European Commission (EC). The transmutation cycles currently envisaged, involving destruction of the minor actinides and the very long fission products, would not eliminate the need for a geological repository for the remaining waste. The potential costs appear to be very large in comparison with estimated costs for permanent isolation of unprocessed used fuel. At present, both benefits and costs are uncertain. Advanced transmutation concepts require a breakthrough in technology development and a large research effort. …
9.02.03	Options – Alternatives to Disposal –	… Currently, there is an adequate supply of natural uranium for the Canadian reactors and reprocessing of spent fuel in Canada in not economic. Therefore, the present reference plan of OPG and the other

	Reprocessing	Canadian waste owners is to manage used fuel without reprocessing. The NWMO is considering the options for long-term management. A management method which included reprocessing would require an assessment of the implications. …
9.03	Options – Alternative Disposal Media	… Research conducted during the Canadian Nuclear fuel Waste Management program has provided technical and scientific evidence that long-term isolation of used fuel waste is achievable within an engineered repository at suitable depths within the rock of the Canadian Shield. Alternative geologic media, such as evaporates, clays and carbonates have not been as thoroughly assessed in Canada. However, it is known that Phanerozoic (570 million years ago to present) sedimentary sequences exist in Canada with thick, low permeability formations that may be suitable to host a used fuel repository. Internationally, efforts in the past 5 years have also begun to focus on sedimentary media, most commonly clays. …