UNDERTAKING No. U-21:

from the

Canadian Coalition for Nuclear Responsibility

to the

Joint Review Panel

Examples of Rolling Stewardship Beyond One or Two Generations.

by

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and

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All Photos and Graphics by Robert Del Tredici

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INTRODUCTION

Repository versus Dump

Ontario Power Generation (OPG) is seeking permission to construct a Deep Geologic Repository at Kincardine Ontario, less than a mile from Lake Huron, to store all of the nuclear wastes from all of Ontario's 20 nuclear power reactors, except for the irradiated nuclear fuel which is subject to a federal law called the Nuclear Fuel Waste Act.

The Canadian Coalition for Nuclear Responsibility (CCNR) is urging the Joint Review Panel to decouple two quite different aspects of this proposal: the first is OPG's plan to construct a Deep Geological Repository (DGR) where nuclear waste can be securely stored and monitored in a safe and retrievable fashion; the second is OPG's plan to abandon those wastes at some time in the future, closing and sealing the underground facility, thereby creating a Deep Underground Dump (DUD) which will forever after remain unmonitored, unmanned, unregulated – eternally beyond human control, right beside Lake Huron.

CCNR believes such a DUD should not be approved. CCNR believes it is both unethical and unscientific to abandon nuclear wastes – many of which will remain dangerous for hundreds of thousands, indeed even millions of years – based on the hope that radioactivity will never find a way to migrate out of the dump at some future date, entering the Great Lakes and thereby endangering the environment of living things.

Link for CCNR written submission: http://www.ccnr.org/CCNR_CEAA_DGR.pdf
Link for CCNR oral presentation: http://www.ccnr.org/DGR_GE_Transcript.pdf

The Concept of Rolling Stewardship

In both its written and oral submissions, CCNR has urged the Joint Review Panel to firmly reject the abandonment option in favour of Rolling Stewardship – an intergenerational waste management concept whereby each successive generation passes on the knowledge and provides the necessary resources to the next generation, so that nuclear wastes are never placed beyond human control and are never left unattended.

Rolling Stewardship is not intended as a mere caretaker operation, but as an active, fully involved effort to continually improve security by retrieving, recharacterizing and repackaging the waste in ever more protective ways, until such time as a genuine solution to the waste dilemma is found – perhaps in the form of a new technology that can destroy the waste, or render it harmless, or remove it permanently from the Earth.

The concept of Rolling Stewardship was first introduced in the 1995 U.S. National Research Council study, "Improving the Environment." In that report, the Regulatory Measures Subcommittee called direct attention to the concept of "Rolling Stewardship" as an important option for addressing contaminated sites that pose significant cleanup challenges. "Rolling stewardship" means planning for stewardship one generation ahead; by doing it one generation at a time, continuity of knowledge and effort is made possible.

This approach came to the attention of CCNR through the efforts of Jim Werner, who collaborated with Robert Del Tredici – under the auspices of the U.S. Department of Energy – to document the daunting multibillion dollar waste management and decontamination problems afflicting the US nuclear weapons complex. Their collaboration resulted in three important DOE publications: Closing the Circle on the Splitting of the Atom, Linking Legacies, and From Cleanup to Stewardship – all dealing with formidable nuclear waste management challenges.

Rolling Stewardship is discussed in a 1999 publication of the U.S. National Environmental Policy Institute entitled "Rolling Stewardship: Beyond Institutional Controls: Preparing Future Generations for Long-Term Environmental Cleanups", produced as part of the "How Clean is Clean?" project. It can be found on-line at: http://tinyurl.com/ljbwdv5

Examples of Rolling Stewardship

The Joint Review Panel has asked CCNR to provide examples of Rolling Stewardship. This document is a response to that request. Evidently, examples are not easy to come by. Never before has so much toxic material been created by any human enterprise, so the challenge of safely managing it over long time spans has never occurred. A new situation requires new and creative approaches. Like nuclear power itself, Rolling Stewardship is a relatively new concept.

Nevertheless CCNR has succeeded in identifying examples in the nuclear field where the failure of the "disposal" concept has led to a more responsible approach – in one way or another, some version of Rolling Stewardship. One might call this Rolling Stewardship by default – not planned ahead of time, but implemented as a fall-back position after misguided disposal efforts have backfired, causing extensive environmental impacts (e.g. Port Hope, Chalk River, Elliot Lake, Uranium City).

It is encouraging to note however that nuclear waste managers (and others) are increasingly adopting the philosophy of Rolling Stewardship – at least for a period of a few centuries at a time – although they do not refer to it as such.

CCNR has been pleased to respond to the Panel's request. However, the burden of proof regarding the safe management of nuclear waste should not be on us, the citizens, but on the nuclear corporations and their government owners who continue to mass produce this waste on a daily basis without having developed any proven reliable method to eliminate it or isolate it forever from the environment of living things.

CCNR calls on the Joint Review Panel to require OPG to provide examples of successful abandonment schemes involving long-lived persistent toxins – schemes that can be proven to have worked to protect humans and the environment for at least one or more centuries. CCNR believes that none exist. In the absence of such evidence, OPG's project for a DGR and a DUD at Kincardine, predicated on abandonment of the waste, ought to be rejected. Rolling Stewardship is the responsible course of action.

Gordon Edwards, Ph.D., President,
Canadian Coalition for Nuclear Responsibility.

Maids of Muslyumovo

Women from the village of Muslyumovo in Chelyabinsk watch Western scientists measure radiation in the Techa River by their town. The Chelyabinsk reactor, upstream, made plutonium for the first Soviet atomic bombs. From 1949 to1953 the plant dumped liquid high-level waste directly into the Techa – a crude attempt at radioactive waste disposal. Forty years later, these women are discovering that the illnesses all around them are related to the radioactive contamination that was dumpoed in their river.
Village of Muslyumovo, Chelyabinsk, Russia. 17 March 1991

CONTEXT

The Nature of the Waste

At first, OPG planned to put into its Deep Geologic Depository only radioactive wastes that are low-level and short-lived. Then OPG threw caution to the winds, announcing that it would include many more varieties of waste – objects that are far more radioactive and incredibly longer-lived – such as refurbishment wastes.

Refurbishment wastes include all the intensely radioactive metallic components that make up the primary cooling system – 7 to 9 kilometers of small-diameter pipes that conduct superheated water from the core of the reactor to several nuclear boilers.

The nuclear boilers, called steam generators, are the furthest away from the core. They are a lot less radioactive than the pipes in the core. Nevertheless, each steam generator has thousands of narrow tubes inside , and these tubes become heavily contaminated during decades of use. They are all part of the refurbishment wastes.

1) Many radioactive materials in refurbishment wastes are extremely long-lived.

The CNSC list of radionuclides contaminating the internal pipes of a used steam generator from the Bruce plant [See Appendix A] includes 8 substances with a half-life of over a million years, 13 with a half-life of over 100,000 years, 19 with a half-life of over 1000 years, and 21 with a half-life of over 100 years.

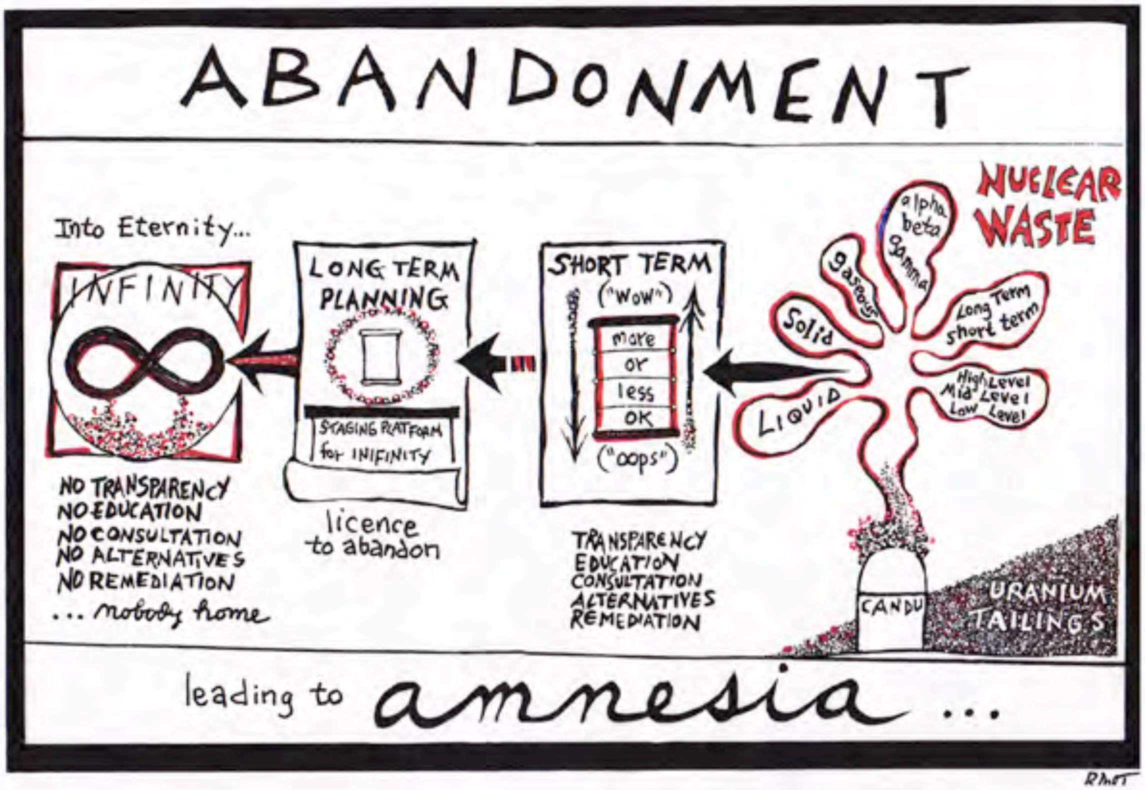
2) Many of these waste materials are extremely radiotoxic even in minute amounts.

The maximum permissible body burden of plutonium-239 for an atomic worker is 0.7 micrograms. Inside each used steam generator there are about 2.3 grams of plutonium-239. [See Appendix B.] Counting 128 steam generators from the Bruce NPP alone, there is enough plutonium-239 from the steam generators alone to overdose more than 420 million atomic workers. This is not counting the additional plutonium contamination from thousands of pressure tubes and feeder pipes. Since plutonium-239 has a 24,000 year half-life, the danger will not be significantly reduced by the time the steam generator tubes have completely disintegrated and released their inventories of plutonium.

3) NWMO acknowledges that dilution is not a solution to the nuclear waste problem.

Frank King of the Nuclear Waste Management Agency stated in his testimony to the Joint Review Panel, "Dilution simply doesn't work with nuclear material. It's out." Just as there is no safe level of cigarette smoking, and no safe level of asbestos, so too there is no safe level of exposure to atomic radiation. It is a characteristic of all carcinogenic and mutagenic substances, such as radionuclides, that even small exposures can cause deleterious health effects (i.e. cancers) if a large enough population is exposed. Since the Great Lakes provide drinking water for 40 million people, diluting long-lived radioactive poisons in Lake Huron will ensure that a very large number of people will be exposed for a very long time.

Since there is no practical method known to science that can destroy any of these radioactive wastes or render them harmless, sequestering them is essential.



Abandon (n) : to cease to support or look after; to desert.

Disposal (n): the process of throwing away or getting rid of something.

Management (n): the process of dealing with or controlling something.

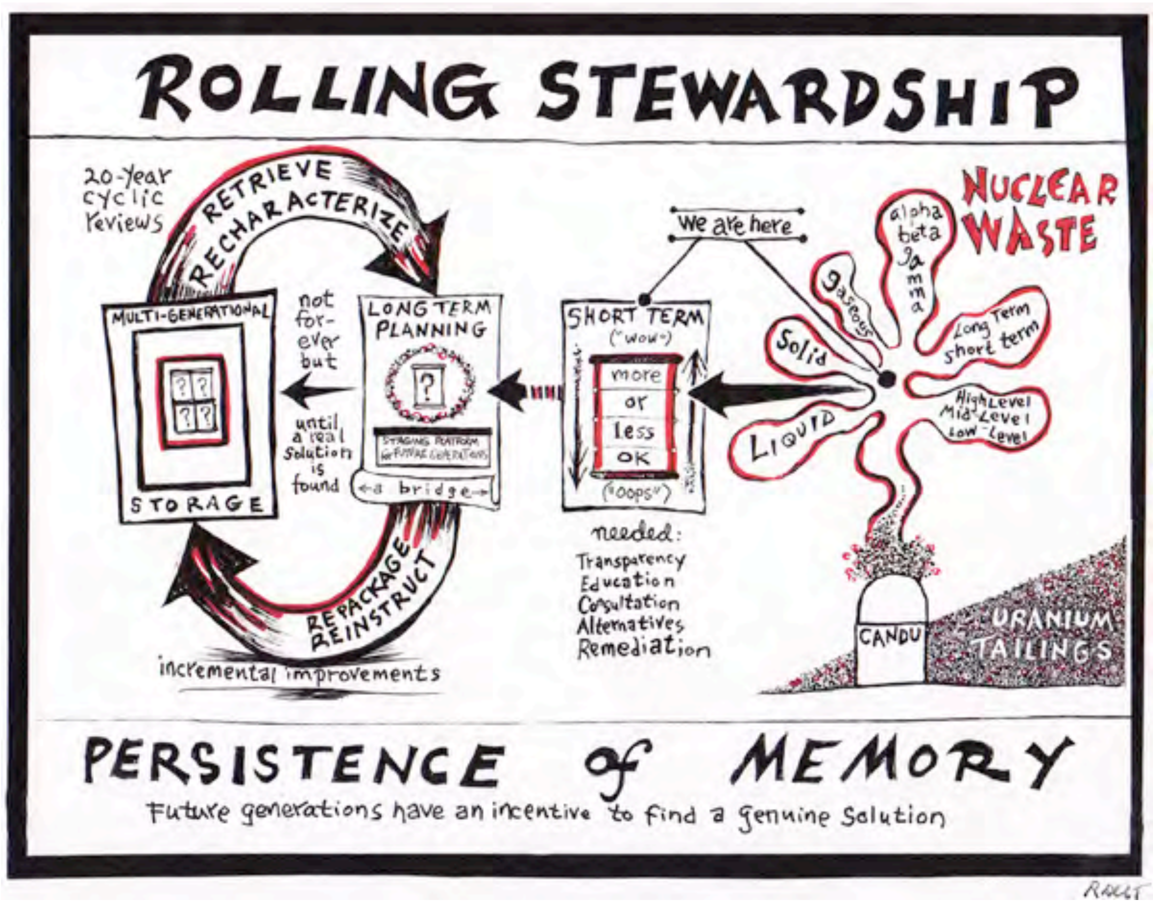
The nuclear industry and its government owners are responsible for the long-term management of nuclear waste. That means dealing with the waste and controlling it so that it does not endanger the health and safety of people or the environment.

To abandon nuclear waste, as proposed by OPG in its current proposal to build a Deep Geological Repository (DGR) beside Lake Huron, is to cease to look after it. As such it is a breach of governments' fundamental moral and legal obligations to society.

> *"The DGR Project includes the site preparation and construction, operations, decommissioning, and abandonment and long-term performance of the DGR."*
>
> *EIS Volume 1, second paragraph, Executive Summary*

Abandonment is intended to dispose of nuclear waste – to get rid of it by throwing it away. But no one knows how to truly get rid of long-lived nuclear waste or any other persistent toxic material in this manner. A corporation may rid itself of toxic waste but only at the risk of burdening others – present or future generations – with the obligation of coping with the waste or living with the harmful consequences.

Abandonment eventually leads to amnesia. Future generations have no adequate knowledge or resources to deal with leaks that may go undetected for long periods.



Realizing that there is as yet no genuine solution to the nuclear waste problem – we do not know how to destroy this waste or render it harmless – the only responsible alternative to abandonment is Rolling Stewardship. There is a growing awareness on the part of those who have struggled with this problem that this is the way to go.

> *"The word "disposal" has come to mean permanence and irretrievability in the minds of the public, and that raises questions about our stewardship of the waste. For that reason we do not use the word disposal."*
>
> *NWMO, Choosing A Way Forward, Final Study (2005), Page 21*

Nuclear waste remains harmful for unimaginably long periods of time. Until the waste can be eliminated, it must be managed on a multigenerational basis. This implies continual monitoring and periodic retrieval and repackaging (e.g. 50 – 100 years).

Rolling Stewardship implies persistence of memory : the accurate transmission of information and the transfer of responsibility from one generation to the next. For example, there could be a ceremonial "changing of the guard" every 20 years, accompanied by a thorough refamiliarization with & recharacterization of the waste.

Rolling Stewardship will ensure that leakages can be rapidly detected and corrected. It will also provide a constant incentive to improve containment and find a solution to the waste problem. But it requires meticulous planning and commitment to succeed.

The Concept of Abandonment	The Concept of Rolling Stewardship
1. Humans have never permanently disposed of anything.	1. Humans can contain waste securely for decades at a time.
2. Assumes a permanent solution to waste problem exists.	2. Recognizes a solution to the problem does not yet exist.
3. Monitoring the waste ceases after abandonment.	3. Continual monitoring of waste is essential.
4. Retrieval is difficult or impossible.	4. Retrieval is anticipated and actively planned for.
5. Containers will inevitably disintegrate.	5. Periodic repackaging is an integral part of the process.
6. If leakage occurs timely corrective action is not likely.	6. If leakage occurs timely corrective action will be taken.
7. Abandonment will eventually result in amnesia.	7. Rolling Stewardship is based on persistence of memory.
8. Difficulty in communicating to unknown future societies.	8. Information is readily transmitted to the next generation.
9. No intention to truly solve the problem of nuclear waste.	9. Ongoing reminder that the problem remains to be solved.

The concepts of abandonment and disposal are intimately related. According to the IAEA "disposal" means that there is no intention to retrieve the waste in the future – although such retrieval may, with difficulty, be possible; the waste is abandoned.

When disposal attempts fail – as in Port Hope Ontario, the Asse-II salt mine in Germany, the Love Canal in New York State, or the US DOE's "Pit 9" in Idaho – cleaning up and consolidating the waste is often exceedingly costly & difficult because of lack of documentation, failed packaging, and damage already done.

Ironically, the end result of failed disposal is usually some form of Rolling Stewardship – by default, not by intent. Had Rolling Stewardship been instituted from the start, the damage, difficulties and cost would have been greatly reduced.

When abandonment of a repository occurs, the repository becomes, de facto, a dump. Even if the repository has been well managed, the dump will not be. No matter how well designed a large nuclear power reactor might be, it would be foolish and irresponsible to licence it for operation, start it up and then abandon it. Yet that's what OPG hopes to do in the case of the Deep Underground Dump (DUD).

The pyramids of Egypt are 5,000 years old. The Great Lakes did not exist 15,000 years ago. But the half-life of plutonium-239 is 24,000 years, and in the DUD it gradually changes into uranium-235, with a half-life of 700 million years.

Science is unable to make reliable predictions over hundreds of thousands of years, since the mathematical predictions can't be verified against experience. As the rollout of ObamaCare has shown in the USA, computer bugs can often go undetected.

Geology is a descriptive science, not a predictive one. Besides, it is impossible to place wastes in an undisturbed geological formation without disturbing it.

Canadians have much expertise in mining – but a mine is for taking things out, not putting them in. And deserted mines always flood. No one knows how to put a rock formation back together again so that it returns to its original strength and integrity.

Example of Failed Abandonment:

AECL's "Geologic Disposal" Concept

In 1978 the Governments of Canada and Ontario signed an agreement to finance a 15-year research effort to "verify" the concept of geologic disposal of high-level nuclear waste (a.k.a. irradiated nuclear fuel) in a Deep Geologic Repository (DGR). This project was the grandfather of OPG's current proposal for a DGR at Kincardine.

The costly and ambitious AECL study – it involved constructing an Underground Research Laboratory in Manitoba – was precipitated by a flurry of reports that advocated a moratorium on new nuclear reactors unless a solution to the waste problem could be demonstrated. Evidently, the nuclear industry was under the gun.

Both levels of government had been assured by nuclear proponents in their employ that nuclear waste disposal is not a technical problem but merely a public relations problem. Abandoning the waste in a deep geological repository was portrayed as the solution before any ground was broken or evidence was collected. AECL's mission was to "verify", not to "explore" or "test", that hypothesis – not exactly objective.

The results of AECL's research was compiled in a multi-volume Environmental Impact Study (EIS) on the "Concept for Disposal of Canada's Nuclear Fuel Waste" (AECL-10711, COG-93-1). Then came a remarkable 10-year Environmental Review by the Seaborn Panel, with public hearings held in five different provinces.

In its final report, the Seaborn Panel stated that

> *"the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes." '*
>
> *Executive Summary, Seaborn Panel Report*

It appears that the sticking point for the Panel may have been the thorny question of abandonment, expressed by AECL through its use of the word "disposal". AECL carried out a detailed post-closure assessment to justify its thesis that abandoning the waste in the DGR, by closing, backfilling and sealing the underground chambers and shaft, would guarantee safety for at least 10,000 years.

But the Scientific Review Group set up to advise the Seaborn Panel on technical aspects of the EIS was unanimous in rejecting AECL's "post-closure assessment". [See Appendix C] There were just too many arbitrary assumptions at work.

In the Executive Summary of the Seaborn Panel's Report, the word "disposal" is never used – except to indicate that AECL uses that word and the government also. The section entitled "Future Steps" refers to the "management" of nuclear wastes, without a single mention of the word "disposal". [See Appendix D.]

And to top it all off, the Seaborn Panel recommends that "developing and comparing options for managing nuclear fuel wastes" should be an important next step. Then it concludes the Executive Summary by saying "If the AECL concept is chosen as the most acceptable option after implementation of the steps recommended above…." Twenty years of effort, $750 million spent – and the result is still uncertainty.

The Seaborn Panel simply could not bring itself to endorse AECL's concept of abandonment as an acceptable strategy for nuclear fuel waste management. When the Chrétien government responded to the Seaborn Panel's Report by passing the Nuclear Fuel Waste Act, a newly formed NWMO took the lesson of the Seaborn Report to heart and expunged the word "disposal" from its vocabularly.

This entire 20-year exercise – from 1978 to 1998 – cast serious doubts on the validity of the concept of abandonment as an acceptable strategy for nuclear waste.

Irretrievable High Level Waste Disposal Test Shaft

This granite chamber lies 500 meters beneath the surface of the Great Canadian Shield. It is a test shaft sunk by Atomic Energy of Canada Limited to investigate pre-Cambrian rock as a possible permanent repository for high-level nuclear waste.

Underground Research Laboratory, Lac du Bonnet, Manitoba. 15 September 1986.

An Example of Rolling Stewardship:

“Adaptive Phased Management”

The Nuclear Waste Management Organization (NWMO) has proposed a strategy for dealing with Canada’s nuclear fuel wastes called “Adaptive Phased Management”. The strategy was adopted by the Government of Canada in 2007 and is described in the 2005 NWMO Final Study entitled “Choosing A Way Forward” [Final Study].

NWMO’s Adaptive Phased Management includes a recipe for Rolling Stewardship for the next 100 to 300 years. If a single generation is counted as 20 years, then the NWMO strategy prescribes Rolling Stewardship for at least 5 to 15 generations.

In an illustrative implementation schedule [page 27] NWMO assigns 20 years to site a central storage facility, 10 more years to build a characterization facility, 30 years for transportation of used fuel to the central facility, another 30 years for emplacement of irradiated nuclear fuel in deep underground chambers, followed by extended monitoring for up to 300 years. That’s almost 20 generations.

The question arises: if Rolling Stewardship can work for 300 years, why not for another 300 years if need be? And then for another 300 years if the need contrinues? That’s close to a millennium.

In Choosing A Way Forward, NWMO explicitly refrains from using the word “disposal” except in the context of the specific AECL proposal for abandoning the nuclear fuel waste for eternity in a DGR specifically built for that purpose:

> *“For purposes of this report we have defined storage as a method of managing the waste in a manner that allows access under controlled conditions for retrieval or future activities -- while disposal is conclusive without any intention of retrieval or further use…. Note that the only time we refer to disposal as a possible Canadian approach is in reference to [the] specific AECL proposal.” Final Study, page 21*

NWMO clearly envisages the eventual closure and sealing (“decommissioning”) of its underground facility at some future date, but it is clearly conditional:

> *“Once a societal decision was made and the necessary approvals were obtained, decommissioning would commence and all underground access tunnels and shafts would be backfilled and sealed.” Final Study, page 27.*

NWMO does not presuppose that such permission has been granted already. Nor does NWMO assert that abandonment will be regarded as acceptable. It is for future generations to judge the matter, based on knowledge gained and technological advances made, whether to abandon the waste, or to implement a more satisfactory containment strategy, or to continue searching for a genuinely permanent solution.

Rolling Stewardship by Default:

The Port Hope Saga

In the early years of Canada's uranium / radium history, large volumes of radioactive wastes from the Eldorado refinery in Port Hope Ontario were dumped into the harbor and into several of the beautiful ravines around town. These were crude efforts at disposal, for there was certainly no intention to retrieve these wastes at the time.

During the World War II Atomic Bomb Project, many of these wastes were processed to extract the leftover uranium, the key element needed for all nuclear weapons. Before the war there had been no market for uranium, so the refinery was built to extract radium – a naturally occurring radioactive byproduct of uranium that was the most valuable substance on Earth during the first half of the twentieth century.

But in the mid-1970s it became clear that hundreds of thousands of tonnes of dangerous radioactive material had been carelessly dumped in ways that were completely irresponsible. Hundreds of homes and some schools had been built using radioactive material that posed serious long-term health risks for the inhabitants.

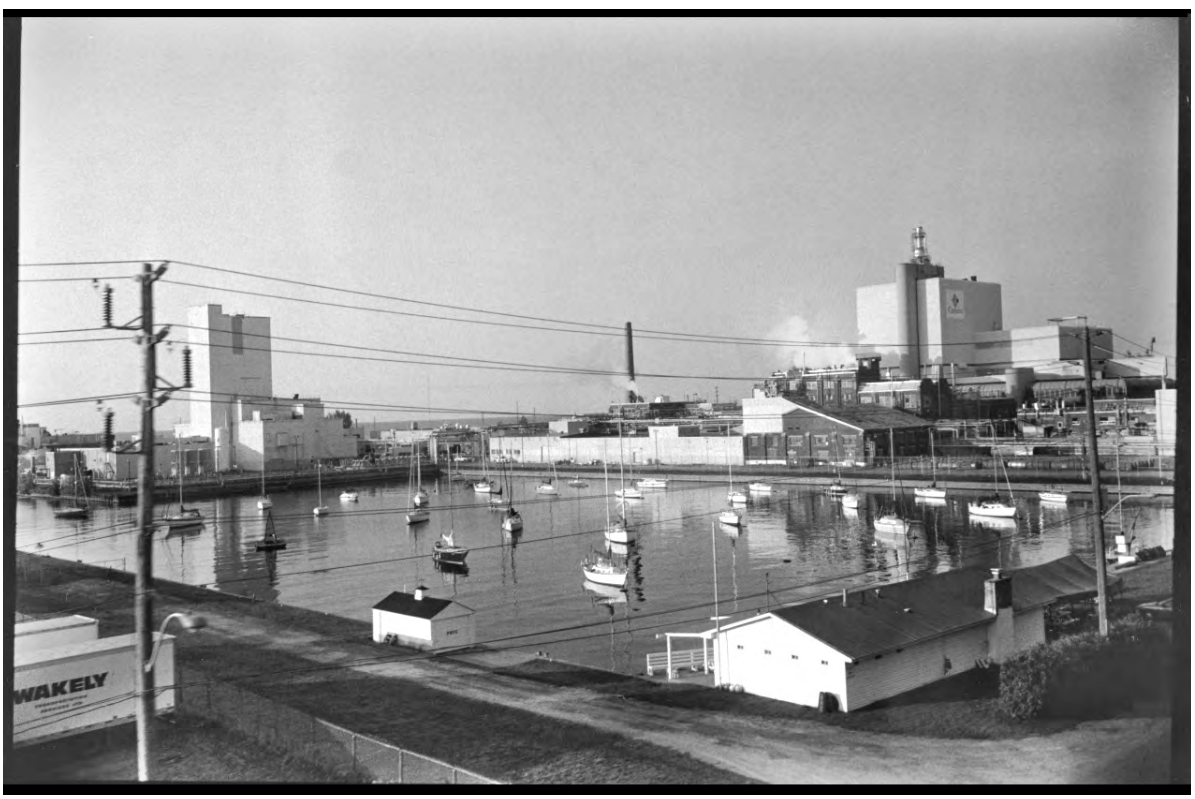
In the 1980s a federal agency was formed, the Siting Task Force, with a specific mandate to find a home for some 800,000 tonnes of long-lived low-level radioactive wastes from Port Hope. The Task Force spent three years trying to find a willing host community somewhere in Ontario to accept these radioactive wastes in exchange for economic benefits, but they came up empty-handed.

Radiation Warning Sign, Welcome Dump, Port Hope, Ontario

In the 1990s, AECL's Low-Level Radioactive Waste Management Organization was formed, and a few years later plans were made to remediate the Town of Port Hope by excavating and consolidating all of the radioactive waste material that had been carelessly strewn around town. Since no other Ontario community is willing to accept these wastes, plans have been made to construct a long-term waste facility at the Welcome dump site, located on Marsh Road just north of the town of Port Hope.

The new Welcome facility is designed to last for 500 years. But the radium-bearing wastes will continue to generate radon gas for thirty times as long, since radium-226 has a half-life of 1600 years. Evidently, Port Hope should be embarking on a long-term exercise in Rolling Stewardship. The only question is, will it be planned and executed smoothly on an intergenerational basis? Or will it be characterized by neglect and degenerate into yet another radioactive fiasco in the future?

The cleanup of the Town of Port Hope is currently underway. The cost has spiraled upwards from \$800 million to \$1,800 million. To extract radioactive sediments from the Port Hope harbor, vertical steel plates will be used to line the sides and then the harbour will be dredged. In other parts of town large volumes of contaminated soil must be dug up and packaged as radioactive waste. Had the principle of Rolling Stewardship been applied from the beginning, the damage would never have got out of hand – the environmental impacts, the social distress, the runaway costs, all of these factors would have been minimized by Rolling Stewardship.



Port Hope Harbour, with the largest uranium conversion facility in the world

Conclusion

The Canadian Coalition for Nuclear Responsibility encourages the Joint Review Panel to make it clear that it cannot approve OPG's proposal to abandon Ontario's inventory of low and intermediate level nuclear waste close to Lake Huron.

Since OPG is determined to make the abandonment of nuclear waste an integral part of its DGR project, CCNR urges the Panel to reject the proposal in its entirety.

The nuclear industry worldwide is beginning to realize it needs not only a regulatory licence to manage its wastes; it also needs a social licence. OPG's plan to abandon nuclear wastes by the Great Lakes is, for millions of people on both sides of the border, unacceptable. No social licence is forthcoming for this scheme.

There are so many uncertainties associated with the long term future that the Seaborn Panel's *Scientific Review Group* could not endorse abandonment of nuclear waste in a DGR. This Panel should do likewise for similar reasons.

The NWMO has carefully avoided forcing a decision today on the future prospect of abandoning nuclear waste. CCNR believes this Panel should do the same.

OPG has made it clear that current waste storage practices can be extended for decades. Let them do so. With continual monitoring and dramatic improvements in technology, greater security can be provided at less cost than the proposed DGR.

Hanford Plutonium Finishing Plant, Hanford, Washington. 11 July 1994.

Appendix A : Radioactive contaminants in used nuclear steam generators

*Here is a **partial** list of radioactive contaminants inside a used steam generator from one of the Bruce reactors. The amount of radioactivity is expressed in becquerels per cubic metre; one becquerel corresponds to one radioactive disintegration every second. (Source: OPG)*
http://www.nwmo.ca/uploads_managed/MediaFiles/539_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf (p. 50)

For Scientists/Engineers			*For Citizens/ Decision Makers*		
Symbol	Half-Life	Amount	Name	Half-Life	Amount
Ag 108	1.3E+02	2.3E+02	Silver-108	130 y	230
Am-241	4.3E+02	5.9E+07	Americium-241	430 y	59 000 000
Am-243	7.4E+03	3.8E+04	Americium-243	7 400 y	38 000
C-14	5.7E+03	7.6E+07	Carbon-14	5 700 y	76 000 000
Cl-36	3.0E+05	1.4E+04	Chlorine-36	300 000 y	14 000
Cm-244	1.8E+01	1.4E+07	Curium-244	18 y	14 000 000
Co-60	5.3E+00	1.2E+09	Cobalt-60	5.3 y	1 200 000 000
Cs-134	2.1E+00	1.9E+06	Cesium-134	2.1 y	1 900 000
Cs-135	2.3E+06	2.2E+01	Cesium-135	2 300 000 y	22
Cs-137	3.0E+01	2.2E+07	Cesium-137	30 y	22 000 000
Eu-152	1.3E+01	1.8E+06	Europium-152	13 y	1 800 000
Eu-154	8.8E+00	1.6E+07	Europium-154	8.8 y	16 000 000
Eu-155	5.0E+00	3.0E+07	Europium-156	5 y	30 000 000
Fe-55	2.7E+00	5.8E+09	Iron-55	2.7 y	5 800 000 000
I-129	1.6E+07	6.3E+00	Iodine-129	16 000 000 y	6.3
Nb-94	2.0E+04	2.9E+05	Niobium-94	20 000 y	290 000
Ni-59	7.5E+04	2.0E+05	Nickel-59	75 000 y	200 000
Ni-63	9.6E+01	2.9E+07	Nickel-63	96 y	29 000 000
Np-237	2.1E+06	1.8E+03	Neptunium-237	2 100 000 y	1 800
Pu-238	8.8E+01	1.0E+07	Plutonium-238	88 y	10 000 000
Pu-239	2.4E+04	1.2E+07	Plutonium-239	24 000 y	12 000 000
Pu-240	6.5E+03	1.7E+07	Plutonium-240	6 500 y	17 000 000
Pu-241	1.4E+01	5.5E+08	Plutonium-241	14 y	550 000 000
Pu-242	3.8E+05	1.7E+04	Plutonium-242	380 000 y	17 000
Ru-106	1.0E+00	8.4E+08	Ruthenium-106	1 y	840 000 000
Sb-125	2.8E+00	2.1E+07	Antimony-125	2.8 y	21 000 000
Se-79	1.1E+06	7.6E+01	Selenium-79	1 100 000 y	76
Sm-151	1 9E+01	7.6E+01	Samarium-151	19 y	76
Sn-126	2.1E+05	1.2E+02	Tin-126	210 000 y	120
Sr-90	2.9E+01	1.8E+07	Strontium-90	29 y	18 000 000
Tc-99	2.1E+05	2.8E+03	Technetium-99	210 000 y	2 800
U-234	2.5E+05	1.9E+04	Uranium-234	250 000 y	19 000
U-235	7.0E+08	3.2E+02	Uranium-235	700 000 000 y	320
U-236	2.3E+07	3.6E+03	Uranium-236	23 000 000 y	24 000
U-238	4.5E+09	2.4E+04	Uranium-238	4 500 000 000 y	24 000
Zr-93	1.5E+06	3.8E+02	Zirconium-93	1 500 000 y	380
TOTALS					
Long half-lives only		**8.7E+09**		**(long-lived)**	**8 700 000 000**
Including short half-lives		**1.6E+10**		**(all radionuclides)**	**16 000 000 000**

According to this OPG document (see the last 2 lines), there are over eight BILLION radioactive disintegrations taking place every second in each cubic metre, if we consider only the long-lived radioactive contaminants. Each disintegration releases an alpha particle, a beta particle, or a gamma ray; so there are more than eight billion of these subatomic projectiles emitted every second. That's more than 28 trillion per hour, and over 245 quintillion per year. *[OPG = Ontario Power Generation]*

In particular, there are five plutonium isotopes found in the steam generators. There are about 580 million alpha rays given off each second, in each cubic metre, from these five plutonium isotopes alone. If the steam generators are just stored on-site as radioactive waste for one thousand years, these plutonium isotopes will still be giving off about 30 million alpha particles per second, per cubic metre.

Gordon Edwards, Ph.D

Appendix B. Plutonium in Bruce "A" nuclear steam generators

*Here is a **partial** list of radioactive contaminants inside a **single** used steam generator from each one of the two reactors (Units 1 and 2 of Bruce A), according to CNSC (document CMD-10-H19B). The mass (in grams) of each radioactive material listed is estimated by CNSC staff.*

RADIONUCLIDE		***MASS***	
Name of Isotope (with Atomic Mass)	Half-Life (years)	Unit 1 (grams radioactive material)	Unit 2
Americium-241	430 y	0.103412	0.102412
Americium-243	7 400 y	0.002162	0.002432
Carbon-14	5 700 y	0.009065	0.072501
Curium-244	18 y	0.002644	0/000347
Cobalt-60	5.3 y	0.001781	0/000881
Cesium-137	30 y	0/000249	0.000238
Europium-154	8.8 y	0.000027	0.000290
Iron-55	2.7 y	0.000272	0.000290
Hydrogen-3 (Tritium)	13.0 y	0.000057	0.000051
Hafnium-181	2.7 y	0.000001	0.000001
Iodine-129	17 000 000 y	0.000060	0.000060
Niobium-94	20 000 y	0.002159	0.002158
Nickel-59	75 000 y	0.173601	0.036723
Nickel-63	96 y	0.030194	0.006526
Neptunium-237	2 100 000 y	0.028703	0.033295
Plutonium-238	*88 y*	*0.007507*	*0.004703*
Plutonium-239	*24 000 y*	*2.124977*	*2.471769*
Plutonium-240	*6 500 y*	*0.827304*	*0.957105*
Plutonium-241	*14 y*	*0.021309*	*0.030809*
Plutonium-242	*380 000 y*	*0.048762*	*0.056317*
Antimony-125	2.8 y	0.000001	0.000001
Strontium-90	29 y	0.009097	0.007581
Technetium-99	210 000 y	0.000143	0.000092
TOTALS			
Long-lived (> one year half-life)		**3.416108**	**3.787315**
Mass of plutonium isotopes only		**3.029859**	**3.520703**
Percent plutonium		**88.7%**	**93.0%**
TOTAL MASS			
(Source: CNSC document		*CMD-10-H19B)*	

There are 5 plutonium isotopes present in the steam generators.
In addition there are 18 other long-lived isotopes listed.

In the 16 Bruce A steam generators from Units 1 and 2 (8 from each) the total mass of radioactive material is estimated to be about 57.6 grams, of which 52.4 grams is plutonium. So the 5 isoptopes of plutonium make up 91.0 percent of the mass of radioactive material in all 16 vessels.

Plutonium is extremely dangerous even in minute quantities. For example, the maximum permissible "body burden" of plutonium-239 for an atomic worker (e.g. someone working in the U.S. nuclear weapons industry) is 0.7 micrograms. Inside the steam generators there are 36.8 grams of this one particular isotope – enough, in principle, to give over 52 million atomic workers their maximum permissible body burden of plutonium-239 . If we include all five isotopes of plutonium, the number of atomic workers who could be overdosed, in principle, is about doubled.

Plutonium isotopes also have very long half-lives, ranging from decades to hundreds of thousands of years. This means that anyleakage of these materials can pose long-lasting dangers.

- Gordon Edwards, Ph.D., November 8, 2010

An Evaluation of Atomic Energy of Canada Limited's "Environmental Impact Statement on the Concept for Disposal of Canada's Nuclear Fuel Waste"

(AECL-10711, COG-93-1)

by the *Scientific Review Group (SRG)*

Advisory to the Federal Environmental Assessment Review Panel

Taken from the Executive Summary

Summary and Conclusions

The AECL postclosure reference case study raises problems. In addition to the fact that it is site specific and has not been demonstrated to be applicable to various other potential fuel waste repository sites in the Canadian Shield**, there are problems with unclear objectives, with methods of analysis, and with the validity of the results of the postclosure reference case study itself.**

The assessment is based on predictions from numerical models. The SRG notes with concern that reliance on SYVAC has inhibited the introduction or use of more modern and flexible software and up-to-date data and has, to a degree, undermined the effectiveness of the assessments.

The SRG concludes that the results of the postclosure performance assessment are not reliable because:

- the reference case is too narrow a representative of the disposal concept;
- the conceptual framework for the reference case model is flawed;
- the choice of input parameteres, initial and boundary conditions, and source terms for the model are not satisfactory;
- the uncertainty analysis is not convincing; and
- the modelling of the exposure of humans and other living organisms to contaminants passing through the biosphere does not accomodate the likelihood of environmental or ecological changes over a 10,000 year period.

On the basis of these shortcomings, and its review of the detailed descriptions of the concept presented in the EIS and the supporting primary reference documents, **the SRG disagrees with AECL's conclusion** that:

> *"The methodology to evaluate the safety of a disposal system against established safety criteria, guidelines and standards has been developed and demonstrated to the extent reasonably achievable in a generic research program."*

Environmental Assessment Report on High Level Waste Disposal Concept

EXECUTIVE SUMMARY

In a 1978 joint statement, the governments of Canada and Ontario directed Atomic Energy of Canada Limited (AECL) to develop the concept of deep geological disposal of nuclear fuel wastes. A subsequent joint statement in 1981 established that disposal site selection would not begin until after a full federal public hearing and approval of the concept by both governments.

In September 1988, the federal Minister of Energy, Mines and Resources referred the concept, along with a broad range of nuclear fuel waste management issues, for public review. He made this referral under the federal Environmental Assessment and Review Process Guidelines Order. On October 4, 1989, the federal Minister of the Environment appointed an independent environmental assessment panel to conduct the review. A copy of the Terms of Reference for the review is included in Appendix A, and biographies of the eight panel members are included in Appendix B.

The panel's mandate was unusual compared to that of any other federal environmental assessment panel in that it was asked

- to review a concept rather than a specific project at a specific site;
- to review a proposal for which the implementing agency was not identified;
- to establish a scientific review group of distinguished independent experts to examine the safety and scientific acceptability of the proposal;
- to review a broad range of policy issues; and
- to conduct the review in five provinces.

AECL describes its concept as a method for geological disposal of nuclear fuel wastes in which

- the waste form is either used Canada Deuterium Uranium (CANDU) fuel or the solidified high-level wastes from reprocessing;
- the waste form is sealed in a container designed to last at least 500 years and possibly much longer;
- the containers of waste are emplaced in rooms in a disposal vault or in boreholes drilled from the rooms;
- the disposal rooms are between 500 and 1000 metres below the surface;
- the geological medium is plutonic rock of the Canadian Shield;
- each container of waste is surrounded by a buffer;
- each room is sealed with backfill and other vault seals; and
- all tunnels, shafts and exploration boreholes are ultimately sealed in such a way that a disposal facility would be passively safe – that is, long-term safety would not depend on institutional controls.

Such a facility would cost an estimated $8.7 billion to $13.3 billion in 1991 dollars, depending on the amount of waste to be disposed of.

The Panel conducted its review in Saskatchewan, Manitoba, Ontario, Quebec and New Brunswick. To develop guidelines to help AECL prepare an environmental impact statement (EIS), the Panel held scoping meetings in autumn 1990 in 14 communities. It also held a workshop on Aboriginal issues and met with members of Canadian Student Pugwash. The Panel then prepared draft guidelines, released them for public comment in June 1991, and issued them in final form on March 18, 1992. On October 26, 1994, AECL submitted an EIS, supported by nine primary reference documents. The period for public review of the EIS began on November 8, 1994, and ended on August 8, 1995.

Public hearings were held in 16 communities over three phases beginning March 11, 1996 and ending March 27, 1997. Phase I focused on broad societal issues related to managing nuclear fuel wastes; Phase II focused on the safety of the AECL concept from a technical viewpoint; and Phase III focused on the public's opinions of the safety and acceptability of the concept. During all three phases, the Panel heard from a total of 531 registered speakers and received 536 written submissions, as listed in Appendix F. Participants were also allowed to submit brief closing statements in writing by April 18, 1997. The Panel considered all written and oral information received in the period from its appointment to the end of the hearings, as well as the closing statements, in preparing this report. A detailed chronology of the panel's activities can be found in Appendix E.

Among other activities, the Terms of Reference directed the Panel

- to examine the criteria by which the safety and acceptability of a concept for long-term waste management and disposal should be evaluated; and
- to prepare a final report addressing whether AECL's concept is safe and acceptable or should be modified, and the future steps to be taken in managing nuclear fuel wastes in Canada.

CRITERIA FOR SAFETY AND ACCEPTABILITY

The Panel examined the criteria by which the safety and acceptability of any concept for long-term waste management should be evaluated (Chapter 4 of this report). In doing so, it came to the following key conclusions.

Key Panel Conclusions

- Broad public support is necessary in Canada to ensure the acceptability of a concept for managing nuclear fuel wastes.
- Safety is a key part, but only one part, of acceptability. Safety must be viewed from two complementary perspectives: technical and social.

On this basis, the Panel defined the safety and acceptability criteria as follows:

To be considered acceptable, a concept for managing nuclear fuel wastes must

- a) have broad public support;
- b) be safe from both a technical and a social perspective;
- c) have been developed within a sound ethical and social assessment framework;

- d) have the support of Aboriginal people;
- e) be selected after comparison with the risks, costs and benefits of other options; and
- f) be advanced by a stable and trustworthy proponent and overseen by a trustworthy regulator.

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.

Safety and Acceptability of the AECL Concept

After applying these criteria to the AECL disposal concept, the Panel arrived at the key conclusions listed below. The rationale for them, and an elaboration on the technical and social perspectives of safety, are documented in Chapter 5.

Key Panel Conclusions:

- From a technical perspective, safety of the AECL concept has been on balance adequately demonstrated for a conceptual stage of development, but from a social perspective, it has not.
- As it stands, the AECL concept for deep geological disposal has not been demonstrated to have broad public support. The concept in its current form does not have the required level of acceptability to be adopted as Canada's approach for managing nuclear fuel wastes.

Future Steps

The Panel considered the steps that must be taken to ensure the safe and acceptable long-term management of nuclear fuel wastes in Canada (in Chapter 6 of this report). It arrived at the following key recommendations.

Key Panel Recommendations

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;
- initiating an Aboriginal participation process;
- creating a nuclear fuel waste management agency (NFWMA);
- conducting a public review of AECB regulatory documents using a more effective consultation process;

- developing a comprehensive public participation plan;
- developing an ethical and social assessment framework; and
- developing and comparing options for managing nuclear fuel wastes.

Taking into account the views of participants in our public hearings and our own analysis, we have developed the following basic recommendations to governments with respect to a management agency:

- that an NFWMA as described in Chapter 6 be established quickly, at arm's length from the utilities and AECL, with the sole purpose of managing and coordinating 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;
- that its board of directors, appointed by the federal government, be representative of key stakeholders;
- that it have a strong and active advisory council representative of a wide variety of interested parties;
- 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
- that it be subject to multiple oversight mechanisms, including federal regulatory control 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.

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.

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 shortcomings identified by the Scientific Review Group and other review participants; establish their priority; and generate a plan to address them. The NFWMA should make this plan publicly available, invite public input, then implement the plan.

Additional and detailed recommendations on future steps are outlined in Chapter 6. Other aspects of the panel's mandate are dealt with in chapters 2 and 3 and in the appendices.