Commentary by Jaro Franta
on NWMO's "Asking the Right Questions?"

I have written this commentary after prompting by the Toronto Star's science writer Peter Calamai, in an e-mail dated Friday, January 09, 2004, which followed an earlier discussion about his Dec. 6 2003 article "Already enough to fill five hockey rinks."

Calamai referred me to NWMO's "Asking the Right Questions?" in support of his statements about nuclear waste that I considered misleading or plain wrong. Similar statements were indeed found in the NWMO document, as were other deficiencies. Thus the answer to NWMO's "key question" asking, "Has the problem been described correctly?" is "no."

In this commentary I limit my expression of concern to three sections:

1. "The Context," a six-page section in chapter 1;
2. "What is used nuclear fuel," a three-page section in chapter 2 and
3. "Why is used nuclear fuel hazardous," a two-page section also in chapter 2.

One reason I have not written comments about NWMO's documents previously is because I was unaware of the fact that NWMO was inviting submissions through its web site, or that it was posting Submitted Comments. Having found these items, I must say that they certainly do not stand out on the web site. Instead, spotlight is given to Background Papers, many of which espouse highly debatable points of view, but are presented as "contextual information about the state of our knowledge on important topics… to contribute to an informed dialogue."

Commentary on "The Context"

By limiting the "story of nuclear energy in Canada" to human science and technology, NWMO's document perpetuates the myth of the uniqueness of radioactive nuclear waste, which is responsible for much of the public's fear of all things nuclear, be they energy, medicine, sterilization, pest control, or whatever.

Such myopic presentations of "the context" have not gone unchallenged in the past. The description of Earth as "a planet-sized lump of fallout from a star-sized nuclear explosion, a supernova that synthesized the elements that go to make our planet and ourselves" is one example of an appropriate context, in this case provided by Professor James Lovelock, one of the founders of the development of environmental awareness since the 1960s. The late American popular astronomer Carl Sagan said, similarly, that "we are made of star stuff," another reference to the nuclear waste of fusion reactions in giant stars and stellar explosions.

Some reference to natural radioactivity left over from the decay of the nuclear waste that formed the earth nearly five billion years ago is made in the section "Why is used nuclear fuel hazardous" on page 28, but the casual reader has no clue where this radioactivity comes from, because it was left out of the context section. Not knowing the natural origin of these radioactive leftovers of the

nuclear waste of which the earth and we are made, of course perpetuates the myth of the uniqueness of man-made radioactive nuclear waste in the public's mind.

According to Dr. Philippe Duport, Director of the International Center for Low Dose Radiation Research at the University of Ottawa[1],

> The Earth's crust contains some seventy chemical elements that are naturally radioactive. They irradiate us from the outside and from inside the body. The bulk of radioactive materials contained in rocks and soil are from uranium and thorium. They emit gamma radiation and release a radioactive gas (radon), which is present everywhere in varying quantities. There are heavily populated areas in the world where natural levels of radiation exceed several times the maximum Canadian dose limits for radiation workers. *If such levels were observed in Canadian a nuclear facility, their operator would be required to drastically reduce radiation exposures and, failing this, a shutdown of the facility*.
> Typically, the first top meter of a 15 by 25-metre house lot contains, on average, three kilograms of uranium and ten kilograms of thorium. One of the elements borne from the decay of uranium is a gas called radon. Radon escapes continuously to the air from the surface of the earth. In average, every square meter of land releases about 10 thousand atoms of radon every second, that is, a source of 10,000 Becquerels. Radon, which is also radioactive, decays into a series of radioactive atoms, one of them being polonium 210. Rain, fog, snow, and dust bring polonium 210 back to the ground, where it accumulates. Since the source of radon never stops, the quantity, and the activity (quantity) of polonium on the ground remains constant at about 10,000 Becquerels per square meter. The International Commission on Radiological Protection calculates that polonium-210 is five to ten times more harmful than plutonium 239. Therefore, in terms of theoretical risk of cancer due to radioactivity, 10,000 Becquerels of polonium 210 are equivalent 50,000 to 100,000 Becquerels of plutonium 239. If one converts the quantity of polonium 210 on the ground into a mass of plutonium that presents the same theoretical danger to health, there is the equivalent of 0.044 mg of plutonium per square meter of land. This does not look like much, but for the Province of Quebec alone – an area of 1.5 million square kilometers - this is equivalent to some 60 tons of plutonium 239. One may object that this in an unfair comparison because the very dispersion of radioactive materials reduces its risk, but this is exactly the point: the risk may be zero when exposures are low enough.

The fact that uranium is used – and consumed – in modern nuclear power reactors - Canadian nuclear power reactors - is reason enough why its origin should be described in the context section of any document attempting to address nuclear waste management issues in a public forum.

By omitting any mention of the origin ("nucleosynthesis") of the earth's reserves of uranium, NWMO's document not only fails to provide proper perspective. It unwittingly covers up the fact that the long-term effect of large-scale nuclear energy use is a significant depletion of natural uranium and its radioactive decay "daughters," and consequently the long-term net effect of reducing radioactivity in the global environment. The public only reads about the intense radioactivity of man-made nuclear waste, but remains ignorant of the fact that this intensity is

[1] Comments on Dr. Rosalie Bertell's presentation before the Senate Standing Committee on Energy, Environment and Natural Resources, September 21, 2000.

inversely proportional to the material's chronological decay rate and hence its rapid change from radioactive to non-radioactive, relative to long-lived materials like uranium, thorium, potassium-40, etc.

As explained in other Submitted Comments on the NWMO web site, this is but one example of NWMO's tendency to provide only negative aspects of the issues.

Commentary on "What is used nuclear fuel?"

To the casual reader, this section probably appears to provide a concise introduction to the technical aspects of used nuclear fuel. In fact, it leaves out so much that it actually presents a misleading picture. Nor is it stated whether Canadians are supposed to get those missing details elsewhere, and if so, where.

After reading this section, the casual reader certainly won't know the answer to "What is used nuclear fuel?" even though he/she might think they do. The implantation of false perceptions is responsible for the problem with people's lack of understanding of reality. The result is perception that is not reality, and opinions (fears) that are based on fiction.

For instance, the statement that "it is important to note that the radioactivity of newly irradiated fuel is great and long-lived" is nonsense: as already mentioned above, radioactivity is inversely proportional to lifetime (or half-life), thus radioactivity is either great or it is long-lived, but not both. While newly irradiated fuel has both short-lived and long-lived types of radioisotopes, the "greatly radioactive" ones are short-lived and the long-lived radioisotopes are "feebly radioactive." It is for this reason that "the radioactivity of newly irradiated fuel is great," while that of irradiated fuel a few hundred years old is feeble and no longer requires remote handling. The last point is never made in the document. That's simply unacceptable.

Equally nonsensical is NWMO's claim that "The most significant fission products…. are listed in Table 2.1." Most significant by what measure ? In fact the list in table 2.1 appears completely arbitrary, with no selection criterion stated. If one looks at "greatly radioactive" newly irradiated fuel, then the most significant fission products – measured by the amount of heat and radioactivity (the latter giving rise to the former) – are radioisotopes such as iodine-138, antimony-124, niobium-100 and iodine-134, all of which have a half-life shorter than a few hours, and therefore are gone in a day or two. These radioisotopes do not appear in the "most significant fission products" list table 2.1. The table provided here (next page) lists the radioisotopes that emit nearly 100% of the radioactivity of newly irradiated fuel, but it includes none of those in NWMO's table 2.1, because their contribution to the total radioactivity (and heat) is too tiny to be of significance at this stage. In fact their contribution only becomes somewhat significant many years in the future, when the overall radioactivity of used nuclear fuel is but a tiny fraction of newly irradiated fuel.

If one looks very far into the future, the radioactivity of used nuclear fuel is that of the un-burnt uranium fuel and its decay products, due to the formers' long life, 4.5 billion years for uranium-238 and 710 million years for uranium-235. None of the "significant fission products" listed in table 2.1 will be present in the distant future, when the un-burnt uranium is still nearly all there. Moreover, that uranium would still be there regardless of whether it's in the ground as a mineral, or in an old

used nuclear fuel bundle. The difference is that some of that uranium will have been destroyed by fission and converted to much shorter-lived fission products. As stated previously, the net effect is an overall reduction in terrestrial radioactivity. In fact, according to University of Pittsburgh physics professor Bernard L Cohen, “If radon effects are taken into account, mining uranium out of the ground [for nuclear fuel production] is a great life saving activity, saving hundreds of lives per gigawatt-year of electricity generated, whereas buried waste kills far less than one [life per gigawatt-year of electricity generated]. All of this is based on linear-no threshold theory and probabilistic risk assessment.”

So what is it about the fission products in table 2.1 that’s “most significant”? Not much. One can only speculate that the radioisotopes selected for the list were thought by the author(s) to be “significant” from the point of view of appearing scary to the casual reader, on account of their half-life of many years. But as Einstein said long ago, “everything is relative.” The natural potassium-40 in our bodies, with a half-life of 1.3 billion years, will still be around long after we’re all dead and after all the “most significant” fission products in NWMO’s table 2.1 are all gone.

The introduction to table 2.2, the “main actinides in used fuel,” doesn’t say that those with the longest half-lives are the same ones as those in the fresh fuel, prior to irradiation. Table 2.4 provides the numerical comparison that illustrates the point very well, but an unreasonable level of reliance is put upon the reader’s patience, scientific knowledge and ability to discern the fact that close to 100% of used fuel is the same material as that which was in the fresh fuel, and indeed in the ground prior to mining, refining, and fabrication into fuel. Confirmation is provided on p. 27, with the statement, “a relatively small amount of material changes inside the fuel – only about 1.3 per cent of the fuel is modified.” But casual readers are again left guessing about “modified relative to what?” Also, the introduction to table 2.2 omits any mention of the fact that americium-241, with a half-life of 460 years, is a very useful product of nuclear reactors, used in life-saving smoke detectors in millions of Canadian homes. It could be argued that at least this nuclear waste component has broad public support and that it makes everyone part of a “stakeholder group,” whether they know it or not. There are also stakeholders among us today who owe their very survival to plutonium, another used fuel actinide: people whose cardiac pacemakers are powered by plutonium-238. Nobody is proposing to store nuclear waste inside people’s bodies, but its clear that that’s exactly where some of its components may find use. Many radioactive fission products are useful in modern nuclear medicine. An estimated 18.4 million nuclear medicine procedures were performed in the U.S. alone in 2002, up 9.8% compared with the 2001 volume of 16.8 million procedures, according to a report from research firm IMV Medical Information Division.

On page 27, the captions of the two graphs are mixed up -- figure 2.2 has the linear scale and figure 2.3 the logarithmic one.

More importantly, the statement that "Activity [of used fuel] declines to that of natural uranium and its associated radioactive decay products after about one million years" leaves out so much that it actually presents a misleading picture. Instead of its figure 2.3, it would have been better if NWMO had reproduced the decay graph from one of its own references, the NWMO Health and Safety Background Paper no. 3-2, *Human Health Aspects of High-level Radioactive Waste*, by John Sutherland, Edutech Enterprises. Sutherland’s graph shows the total activity of high-level waste declining to below the level of “uranium ore equivalent to one tonne of fuel” in a few thousand

years, and he underscores that fact with the statement that "The general and widely publicized belief about such spent fuel is that it is dangerously radioactive for millions of years….[but] this

TABLE 1

Megawatts of heat (in parentheses) produced at shutdown by fission products
(Grouped according to half-life; 3,000 thermal megawatt reactor after shutdown)

Half-Life, $T_{½}$						
<7 s	7 to 70 s	70 s to 12 min	12 min to 2 h	2 to 19 h	19 h to 8 days	>8 days
^{138}I(**4.2**)	^{140}Cs(2.8)	^{100}Nb(**3.6**)	^{134}I(**3.4**)	^{132}I(2.1)	^{140}La(2.6)	^{144}Ce ^{144}Pr }(0.9)
^{124}Sb(**3.6**)	^{135}Te(2.2)	^{98m}Nb(2.7)	^{138}Cs(2.9)	^{135}I(1.8)	^{133}I(1.1)	
^{92}Rb(2.4)	^{139}Xe(2.0)	^{96}Y(2.6)	^{104}Tc(2.8)	^{97}Zr(1.3)	^{143}Ce(0.6)	^{106}Ru ^{106}Rh }(0.8)
^{93}Rb(1.8)	^{143}Ba(1.6)	^{132}Sb(2.4)	^{134}Te(2.7)	^{92}Y(1.0)	^{131}I(0.3)	
^{97}Y(1.8)	^{95}Sr(1.5)	^{95}Y(2.2)	^{142}La(2.6)	^{93}Y(0.8)	^{132}Te(0.3)	^{95}Zr(0.7)
^{144}La(1.7)	^{90}Kr(1.4)	^{90}Rb(2.0)	^{133m}Te(2.3)	^{141}La(0.8)	^{133}Xe(0.3)	^{95}Nb(0.7)
^{142}Cs(1.4)	^{105}Mo(1.2)	^{137}Xe(1.9)	^{141}Ba(1.9)	^{88}Kr(0.7)	^{99}Mo(0.2)	^{104}Ba(0.5)
^{139}I(1.4)	^{141}Cs(1.2)	^{139}Cs(1.8)	^{101}Mo(1.7)	^{91}Sr(0.6)		^{91}Y(0.4)
^{94}Rb(1.3)	^{87}Br(1.1)	^{93}Sr(1.7)	^{94}Y(1.6)	^{105}Ru(0.6)		^{103}Ru(0.4)
^{89}Br(1.2)	^{101}Nb(0.9)	^{133}Sb(1.6)	^{143}La(1.5)	^{145}Pr(0.4)		^{89}Sr(0.3)
^{95}Rb(0.8)	^{103}Mo(0.9)	^{136}I(1.5)	^{138}Xe(1.3)			^{134}Cs(0.3)
^{102}Tc(0.8)	^{106}Tc(0.9)	^{94}Sr(1.4)	^{89}Rb(1.2)			^{141}Ce(0.3)
^{143}Cs(0.7)	^{140}Xe(0.9)	^{102}Mo(1.4)	^{141}Pr(1.1)			^{143}Pr(0.3)
^{141}Xe(0.5)	^{103}Tc(0.8)	^{132}Sn(1.4)	^{97}Nb(1.0)			^{156}Eu(0.2)
^{92}Kr(0.4)	^{105}Tc(0.8)	^{99}Nb(1.3)	^{89}Rb(0.8)			
^{93}Kr(0.3)	^{97m}Nb(0.6)	^{91}Rb(1.2)	^{131}Sb(0.8)			
	^{108}Rh(0.6)	^{89}Kr(1.2)	^{139}Ba(0.8)			
	^{147}Ce(0.6)	^{130}Sn(1.2)	^{101}Tc(0.7)			
	^{86}Br(0.5)	^{142}Ba(1.1)	^{133}Te(0.7)			
	^{91}Kr(0.5)	^{130m}Sb(1.0)	^{87}Kr(0.6)			
	^{98}Zr(0.5)	^{131}Sn(1.0)	^{131}Te(0.6)			
	^{104}Rh(0.5)	^{145}Ce(0.8)	^{129m}Sn(0.4)			
	^{148}Ce(0.5)	^{102m}Tc(0.5)	^{107}Rh(0.3)			
	^{85}Se(0.3)	^{107}Ru(0.5)	^{84}Br(0.2)			
		^{147}Pr(0.5)	^{146}Ce(0.2)			
		^{148}Pr(0.5)				
		^{128m}Sb(0.3)				
		^{149}Pr(0.3)				
Group Totals (MW)						
24.3	**24.8**	**39.6**	**34.1**	**10.1**	**5.4**	**5.8**
∑ = 144						
Smaller contributors = 8						
Total 152 MW						

perception is incorrect."

Even if one takes into account the much larger amount of uranium ore equivalent to one tonne of *enriched* uranium fuel used in PWRs, relative to the natural uranium fuel used in our CANDU reactors, the picture presented by NWMO's figure 2.3 and associated text is misleading.

"Activity" is a very specific term, which implies all radioactive decay, including that which doesn't leave the spent fuel or the uranium ore rock sample. However, as concerns radioactivity that will hit a person's body or its internal organs when approaching an old spent fuel bundle or a pile of uranium ore (ie. external exposure), additional facts need to be taken into account: Gamma rays will get out into the space surrounding the material and penetrate the body, but alpha particles will not. Alpha-emitting isotopes are more active in spent fuel than in uranium ore, for some time. But that hardly matters, unless we grind them up and start eating or snorting them, just to get a good alpha dose. People generally don't consume rocks or shoe polish, so there is little reason to believe they would behave differently with used fuel. Dr. Bernard Cohen stated that "In fact, one can calculate that after 600 years a person would have to ingest approximately half a pound of the buried waste [not including uranium] to incur a 50 percent chance of suffering a lethal cancer." But, he cautioned, "One good scare story in the news appears to have a far greater impact on public opinion than many well conceived scientific risk assessments." NWMO's presentation unfortunately appears to cater to supporting the former rather than understanding of the latter.

According to Canadian Nuclear Society President, Dr. Jeremy Whitlock, "Unshielded, the radiation dose measured at a distance of 30 cm from a used CANDU fuel bundle, one year following discharge, would be about 50 - 60 Sv/h (5000 - 6000 rem/h), which is lethal after a few minutes' exposure. The radiation level drops to about 1 Sv/h after 50 years, 0.3 Sv/h after 100 years, and less than 0.001 Sv/h (100 mrem/h) after 500 years. At this time the major hazard from the used fuel is no longer one of external exposure" (see http://www.nuclearfaq.ca/cnf_sectionE.htm#v).

Various analyses predict corrosion and leaching of used fuel bundles after many thousands of years of storage deep underground. But the quantities are tiny and the leaching rates extremely slow, compared to the huge volume of rock above, all of which combine to yield very large dilution factors. Uncertainties in the properties assumed for the rock formation in which the repository would be located are allowed for in the SYVAC analysis used in AECL's Environment Impact Statement (EIS) to estimate releases from a deep geological repository.

Using radiotoxicity figures provided by the ICRP (the International Commission on Radiological Protection), a more accurate picture of the long-term health risk of the fission products and actinides in spent fuel – relative to uranium ore in the ground – is obtained, as shown on the following page.

Clearly, on the basis of radiotoxicity, the decay of gamma-emitting used fuel radioisotopes (pink curves) to the level of radioactivity of natural uranium ore occurs within about three centuries, while that of the total high-level waste (HLW) including actinides (purple curves) other than the remaining natural uranium, occurs within about 7,000 years, not millions of years.

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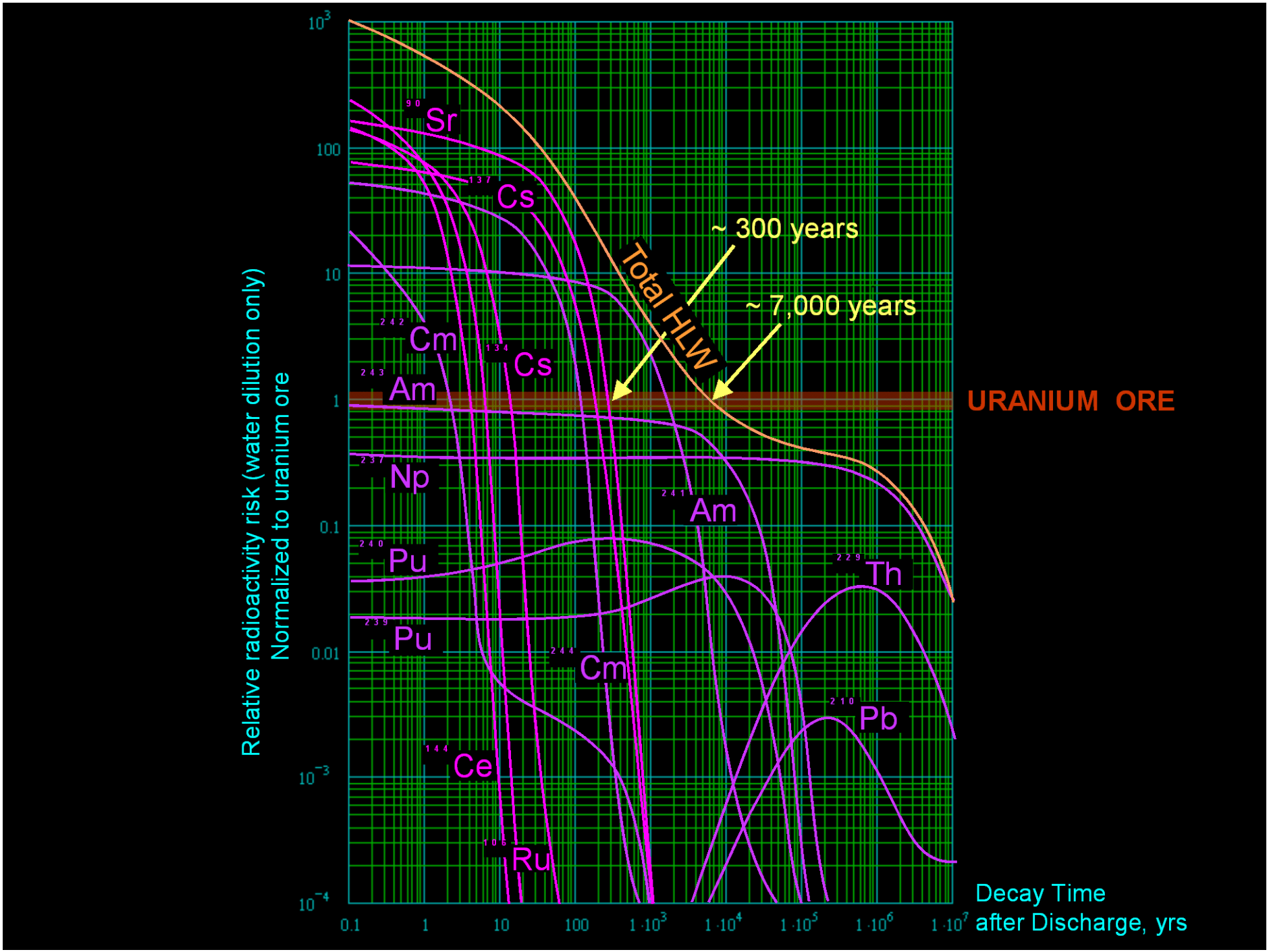
Relative radioactivity risk (water dilution only)
Normalized to uranium ore
10^{3}
100
10
1
0.1
0.01
10^{-3}
10^{-4}
0.1
1
10
100
$1 \cdot 10^{3}$
$1 \cdot 10^{4}$
$1 \cdot 10^{5}$
$1 \cdot 10^{6}$
$1 \cdot 10^{7}$
Decay Time
after Discharge, yrs
Total HLW
~ 300 years
~ 7,000 years
URANIUM ORE
90 Sr
137 Cs
242 Cm
134 Cs
243 Am
237 Np
241 Am
240 Pu
229 Th
239 Pu
244 Cm
210 Pb
144 Ce
106 Ru