Presentation to the Rocky Mountain Low-Level Radioactive Waste Board on Disposal of Depleted Uranium from the National Enrichment Facility

Mr. Chairman and members of the Board, thank you very much for this opportunity to present my analysis of the issues relating to disposal of large amounts of depleted uranium generated by uranium enrichment plants in general, and, in particular, the disposal of the DU that the National Enrichment Facility (NEF) is expected to generate over its operating life.

In the proceeding relating to the application of Louisiana Energy Services (LES) to build and operate the National Enrichment Facility in New Mexico, the Nuclear Regulatory Commission issued an order on October 19, 2005 (CLI-05-20) that raised fundamental issues regarding the classification and disposal of DU. (I was an expert witness for the interveners in the proceeding. [1]) Those issues are still outstanding, despite the fact the Atomic Safety Licensing Board granted a license to LES to construct and operate the NEF. This process has led to a situation where the DU from the NEF is without a clear categorization in the waste classification scheme of 10 CFR 61.55, and without a clear path to disposal. This is because during the LES license proceeding neither the NRC Staff nor LES made an assessment of the environmental impact of the disposal of DU from the NEF in a low-level waste facility. At the same time DU from the NEF was not located within the classification scheme of 10 CFR 61.55 so as to clarify the type of low level waste facility (Class A, B, C, or Greater-than-Class-C) it would require for its disposal.

This raises the possibility that there may be no suitable low-level waste facility in which to dispose of the DU from the NEF – and indeed, our analysis shows that shallow land burial is an unsuitable way to dispose it of. Hence, the export of this waste for disposal outside New Mexico – the operating assumption throughout the LES license proceeding – faces significant hurdles that cry out for your attention and more generally the attention of the people of New Mexico and potentially the other two members of the Rocky Mountain Compact. That is why I particularly appreciate that you decided to hear the results of our research on this issue.

Let me explain. Prior to the October 19, 2005 Order, the Commission had already determined that DU was low-level waste. This definition simply follows upon the residual catch all definition of low-level waste in regulations; it corresponds to paragraph J of the Rules of the Rocky Mountain Low-Level Radioactive Waste Board. But the category of waste within that definition and the manner of its disposal remained to be decided. Specifically, its place within the scheme developed under the low-level waste disposal rule, 10 CFR 61.55 remains to be decided.

In its October 19, 2005 ruling, the Commission stated the DU was Class A low-level waste under 10 CFR 61.55(a)(6), but attached caveats to that conclusion that are central to the issue of classification of DU from enrichment plants in general and to the question of the environmental impacts of disposal of DU from LES in particular.

The Commission's Order noted that in issuing the final 10 CFR 61.55 rule, DU from enrichment plants had been explicitly excluded. Specifically, the environmental impacts of disposal of the large amounts of DU generated by enrichment plants were not examined in the Final EIS for that rule and therefore

currently have no coverage under the National Environmental Policy Act (NEPA). Hence, the Commission ordered the NRC staff to conduct a separate proceeding, apart from the LES license proceeding, to determine the class to which large amounts of DU from enrichment plants belong:

> The Commission is aware that in creating the § 61.55 waste classification tables, the NRC considered depleted uranium, but apparently examined only specific kinds of depleted uranium waste streams – "the types of uranium-bearing waste being typically disposed of by NRC licensees" at the time. The NRC concluded that those waste streams posed an insufficient hazard to warrant establishing a concentration limit for depleted uranium in the waste classification tables. Perhaps the same conclusion would have been drawn had the Part 61 rulemaking explicitly analyzed the uranium enrichment waste stream. But as Part 61?s FEIS indicates, no such analysis was done. Therefore, the Commission directs the NRC staff, outside of this adjudication, to consider whether the quantities of depleted uranium at issue in the waste stream from uranium enrichment facilities warrant amending section 61.55(a)(6) or the section 61.55(a) waste classification tables. [2]

It is plain that an a priori assumption that DU from enrichment plants is Class A low-level waste under 10 CFR 61.55(a)(6) is contrary to the Commission's order until the NRC staff considers the issue separately from the LES license. That proceeding has not yet been conducted. Hence DU from enrichment plants, including the DU that will be generated by LES, has no classification within the scheme of 10 CFR 61.55, even though it is in the broad category of low-level waste.

This lack of a classification for DU from enrichment plants is no mere technical formality. Throughout the licensing proceeding, LES based its technical strategy and its cost estimate of disposal on shallow land burial. Specifically, LES suggested that it could dispose of its DU at one of two sites – the Waste Control Specialists site in Texas, just east of the NEF site in New Mexico, and the Envirocare site [3] near Clive, Utah. However, neither LES nor the NRC staff did any calculation of the environmental impact of disposing of more than 100 million kilograms of DU from the NEF at either site. This is the second aspect of the LES license proceeding that is problematic because it was in contravention of the Commission's October 19, 2005 Order, cited above. While rejecting the idea that the classification of DU from enrichment be decided in the LES proceeding ("The NRC has long prohibited the use of adjudicatory proceedings to challenge the terms of regulations.") it went on to require the estimation of the environmental impact of DU disposal by shallow land burial in the LES proceeding, independent of how the generic classification issue might be decided:

> Despite section 61.55(a), we are permitting the NIRS/PC waste impacts contention to go forward because a formal waste classification finding is not necessary to resolve the disposal impacts contention, which at bottom goes to whether the impacts of near-surface disposal have been adequately estimated or assessed for NEPA purposes.
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> We close with a word of caution. An NRC "impacts" analysis does not require a fullscale site-specific review, an inquiry in the purview of the responsible licensing agency, such as an Agreement State. NEPA also does not call for certainty or precision, but an estimate of anticipated (not unduly speculative) impacts. An assessment of the estimated impacts at one or more representative or reference sites can be sufficient. In this type of analysis, the impacts for a range

> of potential facilities or locations having common site or design features can be bounded. The LES facility will generate large new quantities of depleted uranium for disposal, and therefore it is appropriate for the NRC in its impacts analysis to assess whether the impacts of disposing of the LES depleted uranium are expected to be small, moderate, or otherwise. [4]

Neither the NRC staff nor LES conducted an actual assessment of any kind to estimate the environmental impacts of shallow land disposal of DU to be generated by the NEF. In fact, the Institute for Energy and Environmental Research was the only party to the LES proceeding to have conducted such an analysis. Before describing the results of our analysis, which was officially presented to the Licensing Board during the proceedings, in which I was an expert witness for the interveners (the Nuclear Information and Resource Service and Public Citizen), let me describe what the LES and the NRC Staff did rely on.

First, the NRC Staff rejected the Waste Control Specialists (WCS) site in Texas as providing a plausible disposal option, since WCS did not (and, to date, still does not) possess a license to dispose of low-level radioactive waste. Further, our analysis of the WCS license application turned up errors that indicated that the company appears unqualified even to receive uranium waste, much less manage it and dispose of it. [5]

There were two critical elements to the argument that DU from the NEF could be disposed of at the Envirocare site. The first, relied on by both LES and the NRC Staff, was that the Division of Radiation Control (DRC) in Utah had assured them that DU could be disposed of safely at Envirocare site based on the existing license for that site. Thus both the NRC Staff and LES relied on the word of the Utah DRC rather than their own estimates, which were required by the Commission's October 19, 2005 Order, as quoted above. The basis for this reliance was that Utah is an agreement state and therefore is responsible for assuring the safety of the disposal at sites under its purview.

There are several problems with this argument. First, the Envirocare site is licensed only to dispose of Class A low-level radioactive waste. However, as noted above, in its October 19, 2005 Order, the Commission explicitly excluded matters relating to the general classification of DU from enrichment plants from the LES licensing proceeding. It required that calculations of environmental impact be done for the LES proceeding. The Utah DRC has done no calculations or estimates specific to large amounts of depleted uranium from enrichment plants. Hence, in effect, the NRC Staff and the Atomic Safety and Licensing Board (ASLB) of the NRC chose to rely on pre-existing estimates of disposal of waste that did not include explicit consideration of DU from enrichment plants. This is, in my view, in contravention of the explicit requirement of CLI-05-20, quoted above.

In regard to the specific question of the environmental impacts of disposal of DU from the NEF at the Envirocare site, the NRC staff stated that they were going to rely on environmental assessments done as part of the licensing of that site for low-level waste disposal. Specifically, the NRC Staff stated that they were relying on the following 1990 report: D. Baird, M.K. Bollenbacher, E.S. Murphy, R. Shuman, and P.B. Klein, Evaluation of the Potential Public Health Impacts Associated with Radioactive Waste Disposal at a Site Near Clive, Utah, Rogers and Associates Engineering Corporation, June 1990 (RAE-9004/2-1), which I will call the "Baird et al. report" for brevity. In response to a question from interveners' counsel, Lindsay Lovejoy, an NRC expert testified that he considered this report scientifically sound.

It is far from that. As I testified then, and as I will show here, this report contains many scientifically absurd results in its estimates of the allowable concentrations of some radionuclides in Utah soil. My testimony stands unrefuted in the record; that silence on the part of LES and the NRC Staff speaks very loudly indeed. Table 1 shows why. For one scenario, the report estimated that the allowable concentration per gram of soil of U-238 and of Th-232 would be greater than the weight of the Earth. Similar problem results were obtained for plutonium239 and plutonium-242.

1.5E+27 Much more than than 100,000 trillion times the Pu-239 ever made

Table 1: Some of the Scientifically Absurd Results in the Baird et al. report [6]

	"Allowabl pCi/gm. (Intruder/e scenario)
Uranium-238	5.2E+37
Thorium-232	5.1E+37
Plutonium-239	9.5E+37
Plutonium-242	7.1E+37

Evidently, soil concentration per gram of any substance cannot exceed more than one gram of that substance. That is physically impossible. In the above examples (which are not the only ones of this kind in the report), the "allowable" soil concentration exceeds one gram by large margins. It exceeds the weight of the Earth for U-238 and Th-232 and exceeds by huge margins the amounts of the two plutonium isotopes ever created on Earth. Despite the evidence I offered about that, the Baird et al. report contained physically impossible results, the NRC Staff did not withdraw its reliance on it.

There was evidently a problem of quality in producing and publishing the Baird et al. report. It is astonishing that a report with such egregious errors was used in the licensing of the Envirocare site. That is not to say that all the calculations or results in the report are wrong. Some may not be. But it is evident that many of them are wrong and even impossible. This report is clearly an unsuitable basis for establishing the environmental impact of disposal of DU, which, after all, consists primarily of U-238, one of the radionuclides in Table 1 above.

In summary, the record of the licensing proceeding as well as the license for the Envirocare site in Utah clearly shows that:

- There is currently no NEPA analysis that covers disposal of the large amounts of DU generated by enrichment plants in facilities permitted to dispose of low-level waste.
- Neither the NRC Staff nor LES did any radiation dose estimates for shallow land disposal of DU in this case.

- The proceeding that is needed to determine whether or not the default classification of DU as Class A waste under 10 CFR 61.55(a)(6) applies to DU from enrichment plants, and if not where in the scheme of 61.55 it belongs, has not yet been conducted. This means that DU from the NEF is not covered by the Class A classification under any part of 10 CFR 61.55, which only applies to the much smaller amounts of DU that were considered when it was finalized.
- The Envirocare site only has a license for disposing of Class A low-level waste.
- The Utah DRC did not do any calculations specific to the disposal of DU from the NEF.
- The basic technical document that the NRC Staff relied on for determining the suitability of the Envirocare site for disposal of DU from the NEF contains egregious errors regarding allowable concentrations in soil of some radionuclides, including for uranium-238, the main constituent of DU. It has evidently not been well checked for the quality of its analysis and results.

Might one anticipate that, were the NRC Staff to conduct the process asked of it by the Commission that DU from enrichment plants would be determined to be Class A waste? I cannot say what the NRC Staff will conclude, but I can assert that no reasonable analysis could come to such a conclusion, provided the waste disposal rules for LLW in 10 CFR 61 Part C are not greatly altered. As you know, those rules require that the maximum dose from low-level waste disposal be limited to 25 millirem, without a time limit. In effect the dose limit must be met at the time of peak dose. The lack of a time limit in the rule was reaffirmed by one of the members of the ASLB during the LES proceeding. This is a critical public safeguard for future generations when it concerns long-lived radionuclides like uranium-238, thorium-232, thorium-230, and plutonium-239.

DU disposal impacts

Let me now present our analysis of the impacts of shallow land DU disposal. We used the ResRad model developed by Argonne National Laboratory to perform the computations. The Institute for Energy and Environmental Research reports contain the details of the parameters we used, to enable independent verification of our results. Their correctness was not challenged during the LES license proceeding.

Table 2 is taken from IEER's February 2005 report. It contains a number of analyses of disposal of the DU from the NEF at various types of sites – ranging from wet with high radionuclide mobility and moderate erosion to dry with low radionuclide mobility and low erosion.

In all cases, the maximum dose was estimated to be well over 100 rem at peak times between about 9,800 years and 17,400 years. The reason for this result is that for wet sites and high radionuclide mobility, groundwater becomes contaminated; for dry sites with low radionuclide mobility, the cover erodes away and the external gamma radiation from radium-226 becomes very high. This range of calculations covers the types of conditions that would occur at the Envirocare site. The uncovering of the waste would take longer if the disposal were deeper, but even in the case of disposal at significantly larger depths than the 7.6 meters assumed in our calculations, such as the 12.3 meters proposed for the WCS site, erosion and exposure of the waste would ultimately prevail at all shallow burial sites.

The fact that the peak doses are three to four orders of magnitude higher (leaving aside the question of organ dose, in which case the exceedances would be even higher in some scenarios) means that it is highly unlikely that any shallow land burial could meet the dose criteria of 10 CFR 61 Part C. Hence, our conclusion that DU in the quantities produced by enrichment plants should be disposed of in deep

geologic disposal in a manner similar to the disposal of transuranic waste at the Waste Isolation Pilot Plant near Carlsbad, New Mexico. Further scientific foundation for this conclusion lies in the fact that the DU consists of alpha-emitting, long lived actinides, whose dosimetric characteristics per unit radioactivity are broadly similar to the main constituents of TRU waste. This is readily seen in Table 3.

All of the above points indicate a classification of Greater than Class C waste for DU from enrichment plants, including that from NEF.

The Utah DRC has dealt with the problem of high peak doses by assuming it away. It assumes that no one will intrude upon the site or live there at any time in the future. While it is reasonable to assume that the scarce and saline groundwater at the site poses hurdles for human settlement, these have not been insuperable in other dry areas, as witness the development of Las Vegas. Further, the external doses at a dry site where radionuclides migrate only slowly are so large, that the 10 CFR 61 dose limit would be violated in a few hours. The Baird et al. report notes that prior to the construction and operation of the low-level waste facility there, the environs of the site were used for "grazing of sheep, jackrabbit hunting, and occasional recreation vehicle driving." [7] Such activities would be sufficient to violate the dose limits around the time of peak dose. Thus, NRC Staff ignored parts of the very document it relied on for its determination that the use of the Envirocare was a plausible strategy for disposal of DU from the NEF.

The general results that we obtained for shallow land burial of DU have also been obtained by others. The NRC itself considered shallow land burial unsuitable for DU in the 1994 LES license proceeding. In that case the NRC calculation was for a wet site. The DOE has also come to the same general conclusion in its own environmental analysis. More details are provided in the two IEER reports I have given you, where we analyzed dry as well as wet sites. [8]

DU from the NEF is low-level waste within the scheme of waste classification under present law, but it has no place as yet within the scheme of 10 CFR 61.55. It is well within the realm of possibility that DU in the large amounts to be generated by the NEF will be officially determined to be unsuitable for shallow land burial.

Table 2: Summary of our ResRad dose calculations for shallow earth disposal of DU_3O_8 powder under a variety of assumptions for an arid climate. [9] (All numbers have been rounded) [10]

Scenario [11]	U-238 Dose
higher Kd (clay) low effective moisture low erosion	88
higher Kd (clay) moderate effective moisture low erosion	78
higher Kd (clay) low effective	72

moisture
moderate erosion
higher Kd (clay) 67
moderate
effective
moisture
moderate erosion
lower Kd (sand) 32
low effective
moisture
low erosion
lower Kd (sand) 658
moderate
effective
moisture
low erosion
lower Kd (sand) 38.4
low effective
moisture
moderate erosion
lower Kd (sand) 658
moderate
effective
moisture
moderate erosion

Table 3: Comparison of mortality per Bq and mortality per gm of depleted uranium oxide at secular equilibrium to that of plutonium-239 contained in TRU waste at 100 nCi per gram [12]

Mortality per Bq for tap water	Mortality per Bq for Dietary	Ratio of mortality per Bq to Pu, tap water	Ratio of mortality per Bq to Pu, food	Mortality ratio, adjusted for specific activity per gm,	Mortality ratio, adjusted for specific activity per gm, fo

					tap od wa ter [13]	
Ur ani um -23 8	1.13E -09	1.51E -09	0.40	0.42	1.34	1.41
Ur ani um -23 4	1.24E -09	1.66E -09	0.44	0.46	1.48	1.55
Th ori um -23 0	1.67E -09	2.16E -09	0.59	0.60	1.99	2.05
Ra diu m- 22 6	7.19E -09	9.56E -09	2.52	2.63	8.53	8.93
tot al mo rtal ity rati o at sec ula r e qui lib riu m			3.93	4.11	13.34	13.94
Plu ton iu m- 23 9	2.85E -09	3.63E -09				

The issue of DU classification is likely to get more complex as time goes on. Investigations done at the Armed Forces Radiobiology Research Institute after the 1991 Gulf War indicate that uranium may be toxic in a number of ways in addition to its carcinogenicity. Animal experiments at relatively high doses indicate that uranium may be

Mutagenic
Cytotoxic
Tumorigenic
Teratogenic
and Neurotoxic, including in a manner analogous to exposure to lead. [14]

Further, the research indicates that the alpha particles emitted by uranium may act synergistically with the heavy metal toxicity. Some effects increase with increasing uranium enrichment. This makes uranium rather like a radioactive form of lead and rather different than, say, plutonium-239. The much higher specific activity of plutonium means that the radiation damage becomes very high before there is appreciable heavy metal toxicity. With uranium (especially depleted, natural, and low enriched uranium), the specific activity is low enough that appreciable radiation damage and heavy metal toxicity seem to be in the same general range of exposure. The implications of the animal research for human beings are unclear. This is because it is difficult to extrapolate the animal experiment results of non-cancer effects at high doses to low-dose human exposure.

I would like to note that the ASLB excluded all of my testimony regarding possible future stricter regulation of DU, even though it was linked to the question of whether the costs of DU disposal might go up in the future.

The research at Institute for Energy and Environmental Research has shown that it would be unsafe to dispose of DU in shallow land burial and that deep geologic disposal in ceramic form (after deconversion to uranium dioxide) is the most appropriate method of waste management. Such management and disposal applied to the DU from the NEF would likely cost about $3 billion or more – that is about four times more than the decommissioning financial guarantee given to the State of New Mexico by LES.

In its ruling granting the license, the ASLB found fault with fundamental aspects of the LES cost estimate for private DU deconversion and disposal. The Commission review of the matter affirmed those findings. LES had stated that its primary strategy would be to rely on private deconversion and disposal. It still insists that it will go that route, although there is no approved cost basis for it.

In granting the license, the ASLB proceeded on the assumption that the DOE cost estimate provided to LES would suffice because the DOE was obligated to assume charge of the waste under the USEC Privatization Act. That has settled none of the issues relating to the classification and environmental impact of disposal of large amounts of DU from the NEF. It has not settled the issue of how reliably DOE actually has executed its legal commitments for spent fuel under the Nuclear Waste Policy Act. My testimony in that regard was also excluded.

As a final problem, the license granted to LES allows possession of transuranic radionuclides (like plutonium-239) as well as fission products like technetium-99 in trace amounts present in recycled uranium “as a consequence of the historical feed” of such uranium “at other facilities.” The “other

facilities" are not defined; no upper limit is set on the trace amounts. The problem of the environmental impacts of disposing of DU contaminated with transuranic radionuclides and fission products was not examined at all during the license proceedings.

You are faced with an unprecedented challenge created by the precipitous issuance of the license to LES. No compact Board has so far been forced to deal with issues of disposal or export in the face of fundamental unresolved waste classification issues. This will be considerably complicated if the NEF actually receives recycled uranium contaminated with plutonium, neptunium-237 and/or fission products.

Notes:

1. The Institute for Energy and Environmental Research produced two reports in that case: Arjun Makhijani and Brice Smith, Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES, Institute for Energy and Environmental Research, Takoma Park, Maryland, November 24, 2004, redacted version published in February 2005 (hereafter Makhijani and Smith 2005) and Arjun Makhijani and Brice Smith, Update to Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES, Institute for Energy and Environmental Research, Takoma Park, Maryland, July 5, 2005, redacted version published August 10, 2005 (hereafter Makhijani and Smith 2005a). ? Return
2. NRC Memorandum and Order, CLI-05-20, October 19, 2005, p. 17. ? Return
3. Envirocare is now named EnergySolutions. The old name is retained here for convenience, since it is referred to that way in the reports prepared by IEER on the NEF. ? Return
4. NRC Memorandum and Order, CLI-05-20, October 19, 2005, p. 18. Emphasis in the original. ? Return
5. Makhijani and Smith 2005a. ? Return
6. Columns 1 and 2 are from Baird et al. 1990, op. cit., p. 5-13. Column 3 is calculated from column 2 using the specific activities of the radionuclides in question (about 0.34 microcuries per gram for U-238, 0.11 microcuries per gram for Th-232, 0.063 Ci/gram for Pu-239, and 4 millicuries per gram for Pu-242). ? Return
7. Baird et al. 1990, pp. 4-4 and 4-5. ? Return
8. Makhijani and Smith 2005 and Makhijani and Smith 2005 a. ? Return
9. The annual doses for the uranium isotopes as shown include the contribution from their respective decay products as well. It is important to note that the doses are given in rem per year as opposed to mrem per year. ? Return
10. Source for Table 2: Makhijani and Smith 2005. ? Return
11. Notes:
    - The Kd values used for the uranium and its decay products were taken from the ResRad data collection manual for the indicated soil type. All other soil parameters not set to default values remained at the values appropriate to clay. (ResRad data collection manual p. 110-111)
    - low effective moisture = rain of 0.178 m/yr and an evaotransportation coefficient of 0.9
    - moderate effective moisture = rain of 0.356 m/yr and an evaotransportation coefficient of 0.7
    - low erosion = 0.0005 m/yr
    moderate erosion = 0.001 m/yr ? Return
12. Source for the Table 3: Makhijani and Smith 2005. ? Return
13. The source for the drinking water and dietary mortality ratios is EPA Federal Guidance Report

13.(FGR 13 1997 p. 102-103) The two right most columns show the ratio of the mortality coefficients for uranium and its daughter products versus plutonium-239 after adjusting by 340/100 to account for the greater specific activity of bulk DU3O8 relative to that of the transuranic elements at the threshold of TRU waste. ? Return

14. This research is summarized in Makhijani and Smith 2005, from which this list is taken. ? Return