



## ENVIRONMENTAL EVALUATION GROUP



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February 5, 2002



Dr. Barbara Pastina  
Study Director  
National Research Council, HA 456  
2101 Constitution Avenue, NW  
Washington, DC 20418

Dear Dr. Pastina:

Find enclosed "EEG Reflections on the WIPP Committee Interim Report  
'Characterization of Remote-Handled Transuranic Waste for the Waste Isolation Pilot  
Plant.'"

Thank you for the invitation to comment.

Sincerely,

  
Matthew Silva  
Director

MS:ss  
Enclosure

cc: Inés Triay, DOE  
Elisabeth Forinash, EPA  
Steve Zappe, NMED

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**EEG REFLECTIONS ON THE WIPP COMMITTEE INTERIM REPORT  
“CHARACTERIZATION OF REMOTE-HANDLED  
TRANSURANIC WASTE FOR THE  
WASTE ISOLATION PILOT PLANT”**

**Statement by  
Environmental Evaluation Group  
<http://www.eeg.org/>**

**NAS/NRC WIPP Committee**

**February 5, 2002  
Carlsbad, New Mexico**

## **INTRODUCTION**

The New Mexico Environmental Evaluation Group (EEG) conducts an independent technical evaluation of the operations of the Waste Isolation Pilot Plant (WIPP) to ensure the protection of public health and safety, and the environment of New Mexico. The EEG has been serving New Mexico in this capacity since 1978. Public Law 100-456 articulates EEG's role and responsibilities relating to WIPP. The EEG's impact on the design and operations of the project can be seen in its many publications on a variety of technical issues, including the characterization, transport and disposal of remote handled (RH) transuranic (TRU) waste. Moreover, the EEG continues to maintain, develop and improve its environmental monitoring program and radiological laboratory capabilities aimed at monitoring for radionuclides contained in both the contact handled (CH) TRU and the RH TRU waste inventory.

EEG activities over the past 23 years include:

- review of the planning, construction and operation of WIPP;
- review of the safety analysis report for the State of New Mexico;
- evaluation of WIPP compliance with regulatory standards;

all in consonance with its statutory obligations.

We appreciate the opportunity to present EEG's reflections on the NAS WIPP Committee Interim Report (hereafter referred to as the Report or Report). As previously stated and documented (Silva 2001; Neill 1999), the EEG supports the judicious identification and elimination of unnecessary requirements as long as such modification requests have supporting technical justification. The EEG's position on this has been consistent as

demonstrated in the EEG's extensive technical comments on a proposed modification by the DOE to the EPA certification (Allen et al. 2001) and the numerous permit modifications submitted by the DOE to the NMED (Walker and Silva 2002, p 9).

### **Charge of the Committee**

This Committee's focus "is to review and evaluate the U.S. Department of Energy's (DOE's) plans to characterize remote-handled (RH) transuranic waste to be disposed of at the WIPP." "The study will provide recommendations, as necessary, for improving the plan's technical soundness, protection of worker safety, and compliance with applicable regulatory requirements" (NAS 2002).

### **GENERAL OBSERVATIONS ON WIPP COMMITTEE INTERIM REPORT**

- The EEG understands that over 80% of the extant (circa 1995) RH TRU waste inventory will be either repackaged or treated and would be able to meet characterization requirements similar to those for CH TRU waste. Hence, much of this committee's effort will inherently focus on the remaining 20% of the anticipated RH TRU inventory.
- Overall, Chapters 1 and 2 are very well written and contain important background information.

- We agree with the Committee’s concern about the ambiguity and lack of supporting documentation for DOE’s “performance-based characterization plan.”
- It is important that the Report accurately reflect the history of waste characterization commitments by DOE and we are concerned about some inaccuracies, which we detail in our comments.
- The Committee would be remiss if it focused on waste characterization solely for meeting the long-term performance assessment calculations and ignored the requirements for safe transportation and handling during the operational phase.
- The EEG believes it important to view disposal of RH TRU as a system consisting of each of the major steps in leading to emplacement of RH TRU in the repository. The system consists of: (1) storage at a generator site; (2) characterization; (3) packaging; (4) transportation; and (5) receipt, handling, temporary storage, and emplacement at WIPP.

In view of the above information, we caution that any recommendation for a change based solely on RH TRU characterization and repository performance, could have a negative effect on another portion of the RH TRU disposal system. Indeed, we all might agree that several prohibited items such as pyrophoric materials; explosives, compressed gases may have no long-term effect on repository performance, but may have a major effect on employee and transportation safety. Transportation requirements prohibit explosives, corrosives, compressed gases, and non-radioactive

pyrophoric materials. Hence, transportation requirements and the technical basis for these requirements cannot be ignored when evaluating waste characterization needs. The EEG also notes that there is neither reference to, nor mention of, the WIPP Safety Analysis Report which is the primary document for controlling safety at the site and was the basis for many of the requirements in the first Waste Acceptance Criteria (DOE 1981).

## **REFLECTIONS AND COMMENTS**

The first section of our remarks focus upon the Recommendations contained in the Report and the Committee observations and issues for future consideration contained on pages 1 through 4 of the Report.

### **Interim Report Finding 1:**

Recommendation: DOE should not include in its characterization plan unnecessary requirements that do not affect the long-term performance of the repository and that do not have a safety, technical, or legal basis.

EEG Comment: The EEG found some statements in the rationale portion to be inconsistent with facts. In an effort to assist the Committee, a detailed discussion is provided herein.

With respect to the first sentence of the second paragraph of the rationale section on page 28 of the report, it is difficult to accept the statement “DOE failed to realize that the characterization requirements would become a burden for the generator sites.” Records indicate that for twenty years,

generator sites have commented on the various revisions of the Waste Acceptance Criteria (WAC), have participated as members in steering committees on waste characterization issues, and have long recognized the characterization requirements for RH TRU waste. For example, in 1994, Bild summarized the concerns of the DOE RH TRU Waste Interface Group. DOE clearly recognized that before RH TRU could go to WIPP, the waste must be characterized to meet the WAC disposal requirements and the NRC transportation requirements. Moreover, the DOE recognized that for RH TRU waste at the generator sites:

Characterization capabilities must include chemical (e.g., for Resource Conservation and Recovery Act [RCRA] hazardous materials and gas-generation potential), radiological (e.g., surface dose rates and radionuclide inventory), fissile content (e.g., for criticality safety and heat generation), and physical content (e.g., for free liquids and energy-storage devices).

Various oversight groups for the WIPP (e.g., the Blue Ribbon Panel) have recommended that non-destructive analysis (NDA) be performed on TRU waste for credibility. In preliminary discussions with the NRC regarding the certificate of compliance activities for the NuPac 72B cask, the NRC questioned how the radionuclide contents of an RH TRU waste container could be verified. Since the NRC had previously accepted NDA as a method of identifying radionuclide contents of CH TRU waste, NDA was identified as an acceptable technique for RH waste. NDA capability thus needs to be developed for RH TRU waste. Some development work has been done at the Los Alamos National Laboratory and a small system built to assay one-gallon cans, but there is no funding for further development. [Ref. 1] Other promising characterization techniques that need further development are non-destructive examination (NDE) and process knowledge. (Bild 1994, p 13)

As noted in our statement of October 4, 2001, the DOE has long recognized the need for waste characterization facilities at Oak Ridge and

Hanford. Progress reports for constructing the RH TRU waste characterization facilities for Hanford were presented by personnel from the generator sites including Louie in 1988, Roberts 1988, Guercia and Lipinski in 1991, and Peterson in 1993. In 1991, DOE's Carlsbad Area Office acknowledged the need for a facility to process, characterize and certify RH TRU waste at Oak Ridge (DOE 1991, p 4-2). At the annual National TRU Update meetings, there were progress reports by Stratton in 1988 and Mason in 1990 and 1991.

It is also difficult to accept the following Committee statement:

Also, DOE did not foresee that characterization requirements for CH-TRU waste would become a standard against which to evaluate the RH-TRU characterization plan. In fact, according to the information gathered by the committee, EPA and NMED intend to compare RH-TRU waste characterization requirements to those in the CH-TRU waste characterization plan as explained in Chapter 4.

Yet, in 1997, the DOE submitted the following statement to the NMED in the RCRA Part B Permit Application:

Since the DOE has determined that the waste analysis parameters (Section C-2a) are the same for CH and RH TRU mixed waste, RH TRU waste will be characterized using the same techniques as are used for CH TRU waste, with the exception of visual examination. Most RH TRU waste will be inspected using radiographic examination, but the DOE decided that visual examination will not be used to verify radiographic examination for RH TRU waste due to the added radiological exposure, cost, and waste generation associated with visual examination. The sampling and analytical methods that are used for CH waste characterization will not change except for that they will be performed remotely in shielded facilities for most RH waste characterization (DOE 1996a, p C-4).

Table C-7 to the application is entitled “Summary of Parameters, Characterization Methods, and Rationale for RH Transuranic Mixed Waste (Stored Waste)” (DOE 1996a, p C-113 through 116). This Table shows use of radiography, “100% gas sampling and analysis”, and for homogeneous solids, statistical sampling to analyze total metals, total VOCs, and total semi-VOCs for all three Summary Category Groups.

The DOE clearly knew that RH TRU characterization would be held to the standards for CH TRU characterization. Moreover, the DOE initiated the commitment. Hence, the regulatory agencies, quite justifiably, expected this level of characterization.

As to the next paragraph of the Interim Committee Report, it relegates the role of characterization to satisfy the long-term performance demonstration. Again, the condition is necessary, but not sufficient. Specifically, the paragraph on page 28 maintains:

DOE is failing to ask that most important question about the characterization of RH-TRU waste: what is the purpose of waste characterization for WIPP? The answer is the following: to evaluate the impact of waste components on the long-term performance of the repository.

The statement ignores the issue of safe transportation, temporary storage and handling of these containers that can have surface dose rates up to 1000 rem. Obviously, operational safety is paramount. In the hierarchy of programmatic documents, the Safety Analysis Report takes precedence over all other documents. The State of New Mexico relies on the Environmental Evaluation Group for its review of the Safety Analysis

Report (DOE and NM 1981). Any recommendation regarding waste characterization activities will require careful consideration in the evaluation of the SAR and the WAC. As noted by the DOE in 1992, the WAC was based on the need for operational safety (DOE 1992). The document was modified to consolidate other requirements including the requirements for safe transportation as determined by the NRC process.

Items that “do not have a safety, technical, or legal basis” for characterization, may have been the result of negotiation. As the committee has noted, “to facilitate the certification process, DOE imposed extra characterization requirements in the CH-TRU waste characterization plan, which was accepted by EPA and NMED.” The commitments may have provided the DOE with relief from more restrictive, costly and onerous requirements while allowing the EPA, the NRC, and the NMED to issue certificates and a permit, respectively. In proposing to eliminate such agreed upon requirements, the regulating agencies may find themselves compelled to revisit the certificates and the permit. The review could result in returning to other more costly and onerous requirements. It is also important to remember that the certification and permit process were subject to rulemakings which included workshops, public comment, and hearings, all of which are a matter of record.

The DOE has identified to this Committee three requirements for which it feels there are no safety, technical, or legal requirements. These include sampling and analysis of homogeneous waste, headspace gas sampling and analysis, and visual examination. (NRC 2001a, p 21; NRC 2001b, p 77-80). For CH TRU waste, the EEG notes that the RCRA Part B Permit

Application by the DOE clearly stated, "All waste containers (retrievably stored and newly generated) are sampled and analyzed for VOCs in the headspace gas. A statistically selected portion of each homogeneous solids and soil/gravel waste stream is sampled and analyzed for RCRA-regulated total VOCs, Semi-VOCs, and metals" (DOE 1996a) As noted in Chapter C (the proposed Waste Analysis Plan) "this WAP and the WAC, therefore, prohibit liquid waste, explosives, compressed gases, oxidizers, and pyrophorics. The absence of these wastes is confirmed by radiography, visual examination, and headspace gas analysis." (DOE 1996a). There have been some revisions to these requirements which were accomplished as permit modifications. If these three requirements are eliminated, and the negotiated requirements are more costly and restrictive, then the net effect would be a detriment to the WIPP.

It may be prudent to determine why the negotiations, rulemakings, workshops, public comment, and hearings, for CH TRU characterization took place and what requirements were negotiated away and replaced with requirements for sampling and analysis of homogeneous waste, headspace gas sampling and analysis, and visual examination. Nevertheless, CBFO-DOE may not have identified all the requirements that it believes do not affect the long-term performance of the repository and that do not have a safety, technical, regulatory or legal basis. In that case, the Committee may wish to request a list of the requirements that DOE believes do not effect the long-term performance of the repository and do not have a safety, technical, regulatory or legal basis.

In order to enhance the credibility of the assertion that the requirements are indeed unnecessary, the EEG would appreciate the opportunity to review the documented basis of the assertions that the requirements do not have a safety, technical, regulatory or legal basis, particularly the documentation associated with the negotiations that led to the DOE self imposing these requirements. Most organizations operating in a regulatory arena do not, voluntarily, self impose onerous or unnecessary conditions. Accordingly, it is important for this Committee, stakeholders, regulatory agencies and the EEG to understand why DOE believes it self imposed the requirements that were the result of negotiations.

If indeed there is no basis of these requirements, considering the entire RH TRU waste disposal system, not just waste characterization, then of course the requirements should be considered for elimination.

This Committee will recall that on October 4, 2001 the EEG raised the issue that DOE has deleted the technical justification for each criterion in the Waste Acceptance Criteria (WAC) making it difficult to revisit and understand the technical foundation of each requirement. The EEG is concerned if the requirements for sampling and analysis of homogeneous waste, headspace gas sampling and analysis, and visual examination procedures to characterize CH-TRU waste are deleted without understanding why these requirements were agreed upon, then the foundation and reasons for these requirements will be lost. The Committee may wish to consider restating its recommendation as follows:

The DOE should not include in its characterization plan unnecessary requirements that do not affect the long-term performance of the repository and that do not have a safety, technical, regulatory or legal basis and were not the subject of negotiation with regulatory agencies.

EEG Recommendation: Before any additional discussions regarding the deletion of waste characterization requirements that do not affect the long-term performance of the repository and that do not have a safety, technical, regulatory, or legal basis, this Committee should obtain from DOE its list of such requirements and obtain the reasons why DOE agreed to these requirements in the first place. The Committee should assure that operational safety concerns for the entire RH TRU waste disposal system are not compromised.

**Interim Report Finding 2:**

Recommendation: DOE should evaluate characterization requirements in the proposed plan against safety, their impact on performance of the repository, and regulatory compliance.

As a basis for this recommendation, the Committee uses information from a DOE-SANDIA Laboratory evaluation (Sandia National Laboratories, Carlsbad Programs Group, WIPP, RH-TRU Inventory Impact Assessment Report, June 1, 2001, as Attachment B to Sept. 2001 Notification of Proposed Change to the EPA 40 CFR 194 Certification of the Waste Isolation Pilot Plant, Rev. 0) (DOE 2001) which indicates that:

- 1) the detection of prohibited items
- 2) the determination of metal content, and
- 3) the attribution of waste summary category groups in the proposed RH-TRU waste characterization plan do not appear to affect the long term performance of the repository.

However, note that Sandia's (SNL) performance assessment was only concerned with the long-term performance of the repository, and as noted above, this is not the sole issue on which waste characterization requirements should be based. The WIPP Hazardous Waste Facility Permit (NMED 1999) was written with the understanding that the prohibition of specific items would be in place, so that additional mitigative processes would not have to be written into the Permit to accommodate them. Despite the SNL statement, the WIPP Compliance Application (DOE 1996c) does contain requirements for ferrous and non-ferrous metals for various purposes (ferrous metals to provide a reducing atmosphere, and non-ferrous metals to complex with ligands; see CCA Table 4-7). The "determination of metal content" is necessary in part to differentiate between these metals, and, of course, there are hazardous metals (cadmium and lead, for example) that are very likely to be found in mixed wastes. These hazardous metals must be reported in order to be in compliance with 40 CFR 261 requirements. Finally, the waste summary category groups are distinguished in order to determine the waste characterization methods to be applied to them. While these waste features may not affect the long-term repository performance, there are clear justifications for including them in the waste characterization process.

### **Interim Report Finding 3:**

Recommendation: In the supporting documents, DOE should clarify the objectives of the characterization plan and how to achieve the objectives.

The EEG agrees. We note that the committee also struggled to find a clear explanation of the concept of performance based characterization in DOE's supporting documentation. The EEG had similar difficulties when the DOE proposed a "performance-based waste acceptance criteria (PBWAC)" in the Draft Certification Compliance Application noting "PBWAC is not even defined in the Glossary." (Neill, et al., 1996). The EEG suggests that clear concise definitions, may help the Committee, the regulatory agencies, the EEG, and the generator sites understand "Performance-Based Measurement System" (PBMS). It should be noted that the EPA's consideration of a PBMS does not include elimination of the detailed chemical and physical analysis of a representative sample of the waste required by 40 CFR 264.13(a) (1). It should also be noted that the EPA's consideration of PBMS is a measurement system. PBMS would not seem to be applicable to the proposals of the DOE to characterize waste using AK with limited use of radiography and visual examination, none of which present methods for taking measurements.

### **Interim Report Finding 4:**

Recommendation: In the documents supporting its characterization plan, DOE should discuss the relative volumes of retrievably stored waste and newly generated waste in the context of the different qualities of AK. DOE

should also consider the impact of these volumes and AK differences on the characterization plan.

The EEG agrees. The characteristics and inventory of RH TRU waste in the DOE Complex are important in assessing the impact of the volumes of RH TRU waste. The inventory used by DOE is at least seven years old, and as is also noted in the EEG comments on the Recommendation to Interim Report Finding 6, was not considered reliable by the EPA in its certification decision. The EEG believes that an up to date inventory is necessary in order to critically assess the characterization plan. Without a clear understanding of the waste to be shipped to the WIPP there can be little justification of reducing the requirements. The poor knowledge of the waste—that is, the poor AK--was, after all, a major factor in the currently required waste characterization requirements for CH TRU. There has been no demonstration by the DOE that enough is known about the AK for RH TRU to require any less in the way of characterization. Since about 80% of the RH TRU is expected to be repackaged or treated, it should not be burdensome to provide a similar level of waste characterization (including NDA) as is provided for CH TRU.

**Interim Report Finding 5:**

Recommendation: The RH-TRU characterization plan should recognize the large variabilities from site to site and should ensure sufficient flexibility to accommodate them. However, characterization activities that share common elements across sites should be standardized.

The EEG agrees. However, if the actual (2002) inventory is substantially different than the 1995 inventory (both on a site by site basis and in total), it will be difficult to standardize common elements, unless DOE knows that it has inventoried all the RH TRU in the Complex and there is a low likelihood of significant changes. DOE really should tackle the problems of small quantity sites separately since there are practical problems in providing the same degree of waste characterization as appropriate for the larger sites. The EEG agrees that characterization activities that share common elements across sites should be standardized, notwithstanding the tendency for each site to go its own way in a number of areas. Lack of information or characterization facilities at the small quantity sites should not drive deletion of waste characterization throughout the Complex.

**Interim Report Finding 6:**

Recommendation: DOE should revise the supporting documents by adding clear and technically defensible data qualification requirements for its RH TRU waste characterization plan. Additionally, each data quality objective should have a safety, technical, or legal basis.

The EEG agrees. The Report states on page 33 that: The Committee observes that, just because DOE expects to emplace one fifth of the curies specified in the Land Withdrawal Act, this does not justify a requirement that the measured activity for a unit be within a factor of five of the “true value.” Moreover, the inventory that DOE used to arrive at the factor of five is from the 1995 WIPP Transuranic Baseline Inventory Report, which the EPA did not consider as reliable in making its certification decision. Note

that if the Savannah River Site decides not to send its RH TRU inventory to the high-level waste tanks (because of unforeseen reasons such as chemical incompatibility) the RH TRU inventory destined for WIPP may increase greatly. There may be other RH TRU waste created before the WIPP repository is filled, and the factor of five does not take this into account either. The EEG believes that DQOs for RH TRU should be developed in the same manner as was done for CH TRU; i.e., by what is found to be achievable for the gamma/neutron NDA systems and for radiochemistry.

#### **Interim Report Finding 7:**

Recommendation: To better develop and support its characterization plan, the DOE should provide more detailed and site-specific estimates of worker exposure and characterization costs for RH TRU wastes. The characterization plan should clearly demonstrate how it minimizes radiation exposure to workers and associated costs.

The EEG agrees. This should be done if the DOE still plans to use workers exposure and cost as a justification for reduced waste characterization. However, the EEG believes that the waste characterization requirements should be driven by the need for the data or information and not by ALARA and cost agreements.

## **Interim Report Finding 8:**

Recommendation: DOE should provide complete and defensible justification for the technologies proposed for obtaining confirmatory data and provide evidence of their effectiveness.

The EEG agrees.

The Report provides a number of observations and issues for future consideration. The EEG has addressed these as follows:

Observation/Issue: The information in the supporting documents for the RH TRU waste characterization plan is sometimes convoluted, difficult to understand, difficult to find, and repetitious.

Response: The EEG agrees.

Observation/Issue: There are also conflicting statements and discrepancies.

EEG Response: No comment.

Observation/Issue: It is not clear how visual examination and radiography can differentiate all prohibited items from non-prohibited items.

Response: The EEG agrees. This does not however mean that VE and radiography are not useful.

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## Appendix A

### NAS WIPP Committee Interim Report Suggestions on Details

A. On page 5, the Report indicates that “Document 1: Notification of proposed change to the EPA Title 40 CFR Part 194 certification of the WIPP (DOE-CBFO, 2001a)”;

on page 37 (DOE-CBFO, 2001a) refers to the Draft Class 3 Permit Mod. Request for RH-TRU Mixed Waste, Revision 1. July 17, 2001 and not the EPA certification.

B. On page 5, the Report indicates that “Document 2: Request for RCRA Class 3 permit modification to the NMED (DOE-CBFO, 2001b); on page 37 (DOE-CBFO, 2001b) refers to the Notification Of Proposed Changes to the EPA’s Waste Isolation Pilot Plant 40CFR Part 194 Certification. July 16, 2001 Draft. Revision 1 and not the RCRA request to NMED.

C. On page 9, the Report says: “Gamma radiation is due mainly to fission and activation products, principally from the progenies of cesium-137 and strontium-90, and from cobalt-60.”

Cesium-137 decays by an emission of a beta particle with an  $E_{\max}$  of 0.551 MeV about 95% of the time and with a beta particle with an  $E_{\max}$  of 1.17 MeV about 5% of the time. The progeny of cesium-137 is Ba-137m, which emits a series of gamma rays with the most energetic a 0.661 MeV gamma ray at about 90% of the time.

Strontium-90 decays with the emission of a beta particle with an  $E_{\max}$  of 0.546 MeV. The progeny of strontium-90 is yttrium-90, which emits a beta particle with an  $E_{\max}$  of 2.28 MeV about 99+% of the time and which emits a beta particle with an  $E_{\max}$  of 0.523 MeV well less than 1% of the time.

The progeny of strontium-90, yttrium-90, does not emit either gamma radiation or x-radiation. There might be some bremsstrahlung produced by the beta particles however.

Accordingly, the sentence should be modified to read as follows: Gamma radiation is due mainly to Ba-137m, a progeny of the fission product cesium-137, and from cobalt-60, an activation product.

D. Footnote 3 on page 10 says in part “In 1970, the Atomic Energy Commission (predecessor to DOE) first identified TRU waste as a ...”

In order to differentiate between the defense/promotion/development side of the USAEC and the regulatory side of the USAEC (civilian reactor licensing) it would appear reasonable to modify the sentence to read "In 1970, the portion of the US Atomic Energy Commission engaged in defense operations first identified TRU waste as a..." The defense portion of the USAEC became ERDA, which then became DOE. The regulatory portion of the USAEC became the US Nuclear Regulatory Commission.

E. The Interim Report (on page 14) uses as a reference "(DOE-CAO, 1996)". There is (DOE-CAO, 1996a) and (DOE-CAO, 1996b) but there is no (CAO-DOE, 1996) in the list of references.

F. The Interim Report (on page 21) uses as a reference "(DOE, 1998b)". There is no (DOE, 1998), no DOE, 1998a and no DOE, 1998b in the list of references.

G. The Interim Report (on page 30) uses as a reference (DOE, 1996a, Appendix WCL.2). There is no (DOE, 1996a) in the list of references.

H. On page 46 ALARA is defined as "As low as reasonably achievable. Radiation protection program for minimizing personnel exposure to radiation." The Committee may wish to substitute the following definition of ALARA: "ALARA means making every reasonable effort to maintain exposures to radiation as far below the dose limits in the DOE guidance as is practical consistent with the purpose for which the activity is undertaken."

I. On Page 47 the Gray is defined as "Gray (Gy): the standard unit of absorbed ionizing-radiation dose." A more useful definition is "Gray (Gy) is the SI unit of absorbed dose and represents one Joule of energy absorbed by one kilogram of absorbing material." However, we could not find where the Gray was used in the Report.

J. The Rad is not defined in the glossary. A reasonable definition would be "Rad is a unit of absorbed dose and represents one erg of energy absorbed by one gram of absorbing material. Rad and Rem are important units regarding WIPP because requirements are expressed in Rem, a derivative of Rad, and includes ionizing and indirectly ionizing (neutron) radiation."

K. The Rem is defined as “unit of radiation dose used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of eh radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose (rem) is determined by multiplying the absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation.” A more useful definition would be “Rem is a special unit of dose equivalent. One rem is the absorbed dose in rads multiplied by a quality factor (QF) to account for different biological effects caused by different radiations ( i.e.: X, gamma QF= 1; alpha particles QF = 20; etc.). Rem and Rad are important units regarding WIPP because requirements are expressed in Rem, a derivative of Rad, and includes ionizing and indirectly ionizing (neutron) radiation.”

L. On page 50 the Roentgen is defined as: “The unit used to measure a quantity called exposure. This can only be used to describe an amount of gamma and x rays, only in air. One roentgen is equal to depositing in air enough energy to cause  $2.58 \times 10^{-4}$  coulombs per kg. It is a measure of ionizations of the molecules in a mass of air. The main advantage of his unit is that it is easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x rays.”

The Committee may wish to substitute “The Roentgen is that quantity of x or gamma radiation less than 3 MeV in energy that produces 1 electrostatic unit of charge,  $2.58 \times 10^{-4}$  Coulombs, in one kilogram of dry air at 0 degrees Celsius and at an atmospheric pressure of 760 mm of Hg . Many radiation measuring instruments measure the Roentgen (ionization) directly.” However, we could not find where the Roentgen was used in the Report.

M. On page 50 the Sievert is defined as,” The unit of measurement of radiation dose equivalent. The Sievert is equal to the actual dose, in grays, multiplied by a quality factor for more dangerous forms of radiation.”

The Committee may wish to substitute: One Sievert is the absorbed dose in Gy multiplied by a quality factor (QF) to account for different biological effects caused by different radiations ( i.e.: X, gamma QF = 1; alpha particles QF = 20; etc.). However, we were unable to find where the Sievert was used in the Report.

N. The Curie is not defined in the glossary.  
A reasonable definition would be "Curie is that quantity of radioactive material that undergoes  $3.7 \times 10^{10}$  nuclear transformations per second."