EVALUATION OF LOW-LEVEL RADIOACTIVE WASTE
CHARACTERIZATION AND CLASSIFICATION PROGRAMS
OF THE WEST VALLEY DEMONSTRATION PROJECT

ORISE--97052306

BY

KARREN R. TAIE

B.S., COLLEGE OF CHARLESTON, 1988

SUBMITTED TO THE FACULTY OF THE
GRADUATE SCHOOL OF PUBLIC HEALTH
IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

UNIVERSITY OF PITTSBURGH

1994

dg

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ABSTRACT

The West Valley Demonstration Project (WVDP) is preparing to upgrade their low-level radioactive waste (LLW) characterization and classification program. This thesis describes a survey study of three other DOE sites conducted in support of this effort. The LLW characterization/classification programs of Oak Ridge National Laboratory, Savannah River Site, and Idaho National Engineering Laboratory were critically evaluated. The evaluation was accomplished through tours of each site facility and personnel interviews.

Comparative evaluation of the individual characterization/classification programs suggests the WVDP should purchase a real-time radiography unit and a passive/active neutron detection system, make additional mechanical modifications to the segmented gamma spectroscopy assay system, provide a separate building to house characterization equipment and perform assays away from waste storage, develop and document a new LLW characterization/classification methodology, and make use of the supercompactor owned by WVDP.

ACKNOWLEDGEMENTS

I wish to thank Peter Bourgeois for his guidance as my supervisor at West Valley Demonstration Project, Daniel F. Burke, Thomas F. Kazmierczak, and John J. Hollinden for their assistance in Site operations, James P. Griffin for his advice in the field of health physics, and Dr. Michael J. Tobin for his assistance as my advisor.

I also wish to thank Dr. H. Gregg Claycamp and Jerry C. Rosen for serving on my thesis examination committee.

This work was performed under appointment to the Applied Health Physics Fellowship program administered by Oak Ridge Institute for Science and Education (ORISE) for the U.S. Department of Energy.

I want to thank DOE-ORISE for the Applied Health Physics Fellowship that made my research at WVDP possible and to thank H. Gregg Claycamp for his work as Fellowship Coordinator.

TABLE OF CONTENTS

Abstract.....	iii
Acknowledgements.....	iv
List of Tables.....	vi
List of Figures.....	v
I. Introduction.....	1
A. WVDP Site History.....	1
B. WVDP Operations.....	4
C. WVDP LLW Generation.....	12
II. Theory.....	15
A. LLW Management Strategies.....	15
B. LLW Characterization and Classification.....	16
C. WVDP Characterization and Classification Methodology.....	24
III. Evaluation of WVDP LLW Classification Strategies.....	30
A. LLW Characterization/Classification Problem Areas at WVDP....	30
B. Efforts of Waste Management Engineering Department.....	32
C. Methodology of Survey Study.....	36
D. Intercomparison of Three DOE Sites.....	38
1. Brief Site Histories.....	38
2. Origin of LLW Management Activities.....	39
3. Similarities of Programs.....	40
a. Characterization Methods.....	40
b. Characterization Instrumentation.....	41
c. Waste Streams.....	48
d. Origins of WAC.....	49
4. Differences of Classification Programs.....	49
a. Stage of Development.....	49
b. Waste Categories.....	49
c. WAC Requirements.....	51
d. Major Radionuclides Present.....	54
5. Health Physics Issues.....	54
IV. Recommendations.....	55
Bibliography.....	58

LIST OF TABLES

TABLE 1: 10CFR61.55, Long-lived radionuclides.....	21
TABLE 2: 10CFR61.55, Short-lived radionuclides.....	21
TABLE 3: WVDP Isotopes of Concern and Isotopes Measured to Determine the Value by the Assay.....	25
TABLE 4: WVDP LLW in Storage.....	33

LIST OF FIGURES

FIGURE 1:	Site location of WNYNSC.....	2
FIGURE 2:	High-Level Waste Tank Contents.....	7
FIGURE 3:	Process Overview.....	8
FIGURE 4:	STS Process Flow Diagram.....	9
FIGURE 5:	CSS Process Flow Diagram.....	11
FIGURE 6:	Block Diagram of Segmented Gamma Scanner.....	28

I. Introduction

A. WVDP Site History

The West Valley Demonstration Project (WVDP) is located in the Western New York Nuclear Service Center (WNYNSC) in Cattaraugus County, New York, 30 miles south of Buffalo (Figure 1). The communities of West Valley, Riceville, Ashford Hollow, and Springville are located within 5 miles of the Center. Population density in Cattaraugus County is sparse, averaging 64 persons per square mile. The closest population center is Springville, 3.7 miles to the north, with approximately 4,300 people. The WNYNSC lies within the northern hardwood forest region. The adjoining land is used primarily for agriculture and arboriculture. Cattaraugus Creek to the north serves as a water recreation area. No public water supplies are drawn from the creek downstream of the Center.

Within the 3345 acre site of the WNYNSC, the WVDP site includes a decommissioned commercial nuclear fuel reprocessing plant, a spent nuclear fuel receiving and storage facility, disposal areas for solid radioactive wastes, underground tanks containing liquid high-level radioactive wastes (HLW), and facilities for storing low-level radioactive wastes (LLW), radioactive mixed wastes (RMW), and transuranic (TRU) wastes.

In 1963, the Atomic Energy Commission (AEC), predecessor of the Nuclear Regulatory Commission (NRC), issued a permit allowing Nuclear Fuel Services, Inc. (NFS), a subsidiary of Getty Oil Company, to construct and operate the commercial fuel reprocessing facility. Construction was completed in early 1966. With NFS as operator and New York State as owner, the plant began to reprocess fuel from both commercial and federally-owned reactors later that year.

Two licensed disposal areas are also part of the Center: the NRC Licensed Disposal Area (NDA) and the State Licensed Disposal Area (SDA). Approximately 4,300 m³ of lower activity solid waste generated during the NFS reprocessing activities

Figure 1. Site location of WNYNSC. Drawing is taken from AWMP, 1992.

were disposed of by shallow land burial (AWMP, 1992). From 1982 through 1986, the DOE used the NDA to dispose of NFS waste when they began preparations for HLW processing. By 1987, LLW was no longer buried at the NDA. The SDA, located in the vicinity of the NDA, was operated by the state of New York. Approximately 67,000 m³ of waste from colleges, hospitals, state institutions, power plants, and NFS was disposed of by shallow land burial (AWMP, 1992). The SDA closed in 1975.

The reprocessing plant closed in 1972 for modifications and expansion. In order to reopen by the mid 1970's, the site would have had to meet the more rigorous federal and state safety regulations in effect. These new regulations focused on the disposal of HLW and the requirement of earthquake resistant structures. NFS decided that compliance was not economically feasible and withdrew from the reprocessing business in 1976. At this time, New York State requested that the Federal government take over operation and maintenance of the Center.

In 1980, Congress passed Public Law 96-368, the West Valley Demonstration Project Act (PL 96-368, 1980). This Act directed the DOE to conduct a waste management demonstration project to solidify 2.1 million liters of high-level radioactive waste created by spent fuel reprocessing activities. The Act also mandated that containers suitable for transport and disposal of the HLW be developed along with provisions to dispose of the LLW and TRU wastes resulting from solidification and vitrification of the HLW. Finally, the Act required the cleaning of tanks, facilities, materials, and hardware used in connection with the project.

While the DOE administered the WVDP Act, the NRC provided review, consultation, and monitoring to identify potential radiological danger to public health and safety. The Act required DOE to consult with the NRC concerning all substantive aspects of the project. NRC approval was also required for the final site decontamination and decommissioning plan.

Since New York State owns the site, it is required by the Act to participate in funding the Project. The State's interests in this Project are represented by New York State Environmental, Research and Development Agency (NYSERDA), under a Cooperative Agreement between DOE and NYSERDA (AWMP, 1992). In the current stage of the Project, DOE is contributing 90% of the operating costs with NYSERDA responsible for the balance.

Westinghouse Electric Corporation is the prime contractor and site operator. All daily operational activities and waste generation are controlled by the contractor. Many daily operations, such as environmental services, are completed by subcontractors.

B. WVDP Operations

The WVDP project schedule is divided into two phases. Phase I activities currently underway include the processing and solidification of the high-level liquid waste and sludge, development of the containers for the solidified HLW, and decontamination of existing facilities required to support solidification activities. Transuranic and low-level waste management, facility operation, and maintenance are also included in Phase I. The focus of operations is to support the processing and solidification of the HLW from NFS fuel reprocessing. Vitrification is the solidification technique to be employed. This process will blend and solidify the waste into borosilicate glass enclosed in stainless steel canisters.

Completion of the Vitrification Facility is the present focus of Site operations. Vitrification is scheduled to begin in 1996 and when completed, the facility will undergo decontamination and decommissioning. This will initiate Phase II of the Project that will include the transportation of the HLW canisters to a federal repository, disposal of LLW and TRU waste, decontamination and decommissioning of equipment, tanks, hardware, and facilities used in connection with HLW treatment process. At this point, the decision will be made concerning the fate of the Center as a disposal area.

By December 1, 1992, the amount of HLW had increased to 2.48 million liters. The HLW is stored in three underground tanks (8D-1, 8D-2, 8D-4) in the Waste Tank Farm area. The additional volume of waste came from plant decontamination efforts, addition of caustic (NaOH) solution, and demineralized water. Tank 8D-1 contains spent ion-exchanger (zeolite) from the separation of radioactive cesium from the HLW supernatant and sludge wash solution removed from 8D-2. The cesium-loaded zeolite is covered with water for cooling and shielding purposes while in storage. The zeolite will ultimately be transferred to 8D-2 and blended with the other waste streams. Tank 8D-2 contains sludge and an alkaline supernatant from PUREX fuel reprocessing activities (DOE/NE/44139-47, 1988). PUREX, or Plutonium-Uranium Extraction Process, refers to a series of separations that remove the plutonium and uranium from spent fuel (DOE/NE/44139-63, 1990). The addition of NaOH and demineralized water is a sludge washing process that removes nonradioactive metal ions by precipitation. Washing the sludge removed approximately 82% of the salts, ultimately reducing the quantity of high-level waste solids (AWMP, 1992). Tank 8D-4 contains THOREX acid waste. THOREX, or Thorium Extraction, refers to a reprocessing technique that removes the thorium from spent nuclear fuel (DOE/NE/44139-63, 1990). Testing and analysis is underway to prepare for future neutralization and transfer of THOREX waste to 8D-2. This tank is full and excluded from additional storage use.

The washed sludge from 8D-2, the zeolite, and the THOREX waste will be blended, and the total volume (approx. 170,000 liters) will be slurry-fed underground from the Waste Tank Farm to the Vitrification Facility. The mixture will be concentrated, blended with glass-forming chemicals, and transferred to a Slurry-Fed Ceramic Melter. The machine will operate between 2,000 and 2,200 degrees Fahrenheit, producing molten glass. The molten glass will be poured into stainless steel canisters that will be sealed by welding, decontaminated, and stored in the former Chemical Process

Cell (CPC) of the plant. It will remain in storage until eventual shipment to a Federal waste repository (AWMP, 1992).

The vitrified waste will be classified and stored as high-level waste. However, much of the HLW in the underground tanks will be able to be disposed of as LLW (Figure 2). This is made possible by the Integrated Radioactive Waste Treatment System (IRTS), described below. This facility, also located in the former process plant, has completed the supernatant processing and is currently processing the sludge wash solution from Tank 8D-2. By the end of 1992, processing of the supernatant had been completed (approx. 2.32 million liters) and approx. 0.23 million liters of sludge wash solution had been processed (AWMP, 1992). The IRTS consists of four parts: the Supernatant Treatment System (STS), the Liquid Waste Treatment System (LWTS), the Cement Solidification System (CSS), and the Radioactive Waste Treatment System (RTS) Drum Cell (Figure 3).

The supernatant and sludge wash solutions are processed through the STS (Figure 4). It is an ion-exchange process using zeolite coated with TiO_2 as the exchange medium that removes ^{137}Cs and residual Pu from the liquids. The ion-exchange process was proven to be the most reliable method for remote operation. This process removes more than 99.9% of the radioactivity contained in the solutions and reduces the cesium concentration from 2,000 mCi/mL to less than 1.5 mCi/mL for transfer to the LWTS (DOE/NE/44139-47, 1988).

The decontaminated liquid is then transferred to the evaporator in the Liquid Waste Treatment System (LWTS). The LWTS consists of two parallel process streams, one for processing decontaminated supernatant and other liquid waste streams with high total dissolved solids (TDS), and the second one for processing low TDS waste (AWMP, 1992).

Figure 2. High-Level Waste Tank Contents. Drawing taken from DOE/NE/44139-63.

Figure 3. Process Overview. Drawing taken from AWMP, 1992.

Figure 4. STS Process Flow Diagram. Drawing taken from DOE/NE/44139-47.

The evaporator bottoms from the LWTS are processed through the CSS. There, the waste is concentrated, mixed with cement and solidified in 71 gallon square drums. This reduction in radionuclide concentration permits reclassification of HLW to LLW. The solidified material is stored in the RTS Drum Cell.

The CSS (Figure 5) is an automated batch process system that provides the optimum mixing time and waste-to-cement ratio for the particular liquid waste to be processed (AWMP, 1992). The solidification mix includes calcium nitrate blended with Portland Type V cement, antifoam agents, and sodium silicate to control gel time. This system features a high-shear mixer that blends waste, cement and additives into a homogeneous slurry (WVNS-PCP-004, 1993). This method ensures thorough and homogeneous blending of all components.

The RTS Drum Cell building is a shielded, temperature-controlled facility constructed for storage and as a potential disposal site for solidified LLW. The facility is constructed with 20-inch thick concrete walls. A computerized crane allows remote handling of the drums. It has a capacity of 19,325 square, 71 gallon drums. Approximately 11,700 have been produced and stored through 1992 (AWMP, 1992).

The LAG (or Surge) Storage Building and associated LAG Storage Areas (LSAs) were constructed to provide weather protection for packaged LLW generated from decontamination, maintenance, and construction activities. The LAG Storage building has metal siding while the two additional LSAs are engineered fabric structures.

Wastes packaged and stored in the LAG storage facilities include some compacted wastes, liquid and wet wastes partially immobilized in cement, equipment and hardware, and contaminated soil and concrete. The dose rate at the surface of unshielded packages in the LAG Storage Building and LSAs must be less than 100 mrem/hr (SOP 9-2, 1991). If the dose rate of a package exceeds this level, it must be covered with a shield overpack sufficient to reduce the dose rate to the acceptable level. The LAG storage buildings also have certain packaging criteria that must be met. These criteria are

Figure 5. CSS Process Flow Diagram. Drawing taken from DOE/NE/44139-50.

listed in the document, SOP 9-2, Solid Radioactive Waste Handling (SOP 9-2, 1991). The radiometric equipment used for classifying packaged LLW is also located in LAG Storage building. Drums of LLW are assayed here. A partial wall of lead panels provides shielding from the waste drums in storage.

Another fabric structure, the Waste Storage Area (WSA), contains highly radioactive items resulting from decontamination operations in the CPC. These items are waiting further conditioning and volume reduction. There are boxes and concrete overpacks of dense, packaged waste placed around the high radiation items to provide shielding. Outdoor gravel pads are used for the storage of large or heavy items.

C. WVDP LLW Generation

During NFS operations, both commercial and defense spent nuclear fuel was reprocessed. As a result, the WVDP site has measurable amounts of virtually every fission, activation, and transuranic isotope. Furthermore, WVDP produces a broad range of radioactive wastes from plant operations such as high-level waste, transuranic waste, low-level waste, and mixed waste. There are also the hazardous (RCRA) wastes and sanitary wastes generated during Site operations. However, the LLW generated by WVDP activities is rapidly accumulating and becoming one of the Site's greatest concerns.

LLW generating activities at West Valley are primarily associated with the treatment of supernatant and sludge wash solutions processed through the STS and CSS. However, other LLW streams generated at the WVDP arise from plant operations and consist of compactible trash, construction materials and equipment (AWMP,1992). The LLW is divided into four categories based upon physical properties (AWMP,1992): trash and miscellaneous dry solids, liquid and wet solid wastes immobilized in cement, equipment and hardware, and soil.

Trash and miscellaneous dry solids consist of contaminated protective clothing, paper, plastic, and other dry solid material. Density of a drum packed with such materials will vary. In an effort to provide more storage space, these items are usually compacted. This procedure does not alter the activity content of the waste, but it does change the form. Bulk density after compaction is assumed to be 0.53 g/cm^3 (AWMP, 1992).

Liquid and wet solid wastes immobilized in cement include uranyl nitrate solution, decontaminated supernatant, and sludge wash solution. These wastes are solidified in cement and packaged in either round 55 gallon or square 71 gallon drums to an average density of approximately 1.7 g/cm^3 (AWMP, 1992).

Waste-water sources from the laundry, plant drains, surface runoff, cooling tower blowdown, and leachate from the SDA and NDA are treated by the existing Low-Level Waste Treatment Facility (LLWTF). Evaporator distillate from the LWTS is also processed through the LLWTF. The facility employs a scavenging-precipitation, ion-exchange process. The processed waste water is transferred to a lagoon until sampling determines it is suitable for release.

Equipment and hardware include metal objects such as tools contaminated in a "hot" job or scrap metal. This material is segregated whenever possible and can be compacted. After compaction, the bulk density of this material is assumed to be 2.0 g/cm^3 .

Contaminated dirt and clay generated from site excavations creates large volumes of LLW. The contaminated soil is stored in 70 ft^3 steel boxes and rolloff containers. Cost-effective soil decontamination methods are currently under development.

Other types of waste become intertwined with low-level waste generation and cause their own problems and issues. Issues involving transuranic and mixed waste often appear along side those of LLW.

Transuranic, or TRU, waste as defined by the NRC is contaminated with alpha-emitting radionuclides of atomic number greater than 92 and half-life greater than twenty

years at concentrations greater than 100 nCi/g (40CFR191, 1991). The WVDP Act includes concentrations greater than 10 nCi/g (PL 96-368, 1980). This issue of definition must be resolved before decommissioning of the Site. TRU waste at WVDP was generated primarily by NFS reprocessing activities and decontamination efforts. This is referred to as "legacy waste." At present, TRU waste generation is minimal, but future decontamination and decommissioning efforts are expected to generate significant amounts.

Another problem facing WVDP is that it appears their TRU waste does not have a destination. The Waste Isolation Pilot Plant (WIPP), a designated federal repository for TRU waste, will accept only TRU waste categorized as Defense waste, and NFS processed both commercial and defense spent fuel. The WVDP currently follows the guidelines established by WIPP in their waste acceptance criteria. This allows the TRU waste to be characterized and classified with consistency while the ultimate disposal location is determined. TRU waste is stored in LAG storage building, but is kept segregated from the remaining LLW.

The most recent addition to the list of regulated radioactive wastes is radioactive mixed waste (RMW). Mixed wastes are RCRA hazardous materials that are radioactively contaminated. RCRA hazardous materials at WVDP include mostly lead and organic solvents. Mixed wastes pose an interesting and rather frustrating challenge. There are no codified regulations for treatment, storage, or disposal of this type of waste. This and the lack of treatment facilities allowed to accept mixed waste translate into long-term interim storage and maintenance for generators.

II. Theory

A. LLW Management Strategies

Initially, straightforward LLW management strategies were considered to be safe, secure, and convenient. Once a radioactive material had reached the end of its usefulness, it was prepared and packaged as waste and either stored on-site or buried in shallow trenches (Stelluto, 1993). Storing the waste on-site avoided the risks associated with transportation. The other option, burial in shallow land trenches, was also considered to be a viable solution. Burial could be accomplished quickly and easily with conventional equipment. It was a modification of the already common practice of sanitary landfill disposal. The retention properties of soil and the shielding it provided were thought to be sufficient to alleviate immediate concerns.

Six commercial disposal facilities were opened in the early 1960's. There are only two disposal facilities that currently accept radioactive waste: Hanford, WA and Barnwell, SC. After 1993, access to the two remaining facilities will be restricted. Hanford will only accept waste from states within the Northwest and Rocky Mountain Compacts. The Barnwell facility will remain open within its region, the Southeast Compact, and will only accept out-of-region waste subject to the approval of the Southeast Compact Commission (Bremen et al., 1993).

The Low-Level Radioactive Waste Policy Act of 1980 gave each state responsibility for disposing LLW generated within its borders. Out of this Act, states formed compact agreements in which regional disposal facilities would be built. The original Act was to take effect in 1986. However, this deadline has been postponed twice. The earliest projected opening of a regional disposal facility (the North Carolina site in Wake County) is 1996. By 2006, a total of 45 states, representing approximately 92% of the nation's waste, are predicted to be served by 13 regional compacts (Bremen et al., 1993).

The delayed availability of permanent disposal facilities forced the development of alternative LLW management strategies. In addition, the increased costs of disposal under the LLW Policy Act of 1980 provided strong incentives to develop more cost-effective management procedures. Since disposal costs were determined by volume, waste management strategies introduced methods of volume reduction. Steps were added such as LLW sorting and segregation, material reclamation, recycling, and physical reduction by compaction or incineration to achieve less volume (Stelluto, 1993).

The next form of action taken was waste minimization. Administrative controls were enacted in an attempt to reduce the quantity of waste generated. This meant less waste requiring treatment and/or disposal. Finally, with increasing projected costs, greater efforts were put into disposal avoidance. A lucrative subcontracting industry evolved from the necessity of volume reduction (Stelluto, 1993). Generators were able to ship their waste for supercompaction or incineration before shipping for disposal. In some cases, final disposal of the waste was included in the contract.

While the aforementioned disposal strategies are now common practice among generators, on-site storage remains the most popular form of disposal avoidance. It appears that on-site storage will continue to substitute for permanent disposal for the next five to fifteen years. Low-level waste will either remain on-site or, if it is shipped for volume reduction, will be returned to the point of origin. For generators who use short-lived radioisotopes, such as hospitals, on-site storage has been common practice. Others, such as power plants, are now allotting space to accommodate on-site storage.

B. LLW Characterization and Classification

Perhaps the most cost-effective solution to the problem of radioactive waste management can be found in its early stages. The initial radioactive waste characterization and classification are crucial parts of the proper disposal process. A universal policy for characterization and classification would help to stabilize the

transition phase from on site storage to permanent disposal facility after the regional disposal sites are completed.

Briefly, characterization consists of taking samples from each source of waste (waste stream) and determining the radioactive constituents (Cline, 1986). Classification uses the results of characterization to determine how the waste will be treated. In the United States, the U.S. Department of Transportation (DOT), U.S. Environmental Protection Agency (EPA), U.S. Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), individual states, and other regulatory bodies have established standards for radiation and environmental protection (Amir, 1993). The waste must be completely characterized before classification. Such properties as isotope half-lives, activity levels, and types of radiation serve as characterization parameters. Physical and chemical properties of the waste material are also determined (Amir, 1993).

All generators of LLW are required to characterize the waste in order to meet criteria established by storage or disposal facilities. There are four general waste characterization methods that are widely used by generators. Most generators employ more than one of these methods to ensure reliable data:

- (1) process knowledge
- (2) materials accountability
- (3) nondestructive assay (NDA) techniques
- (4) sample analysis

Process Knowledge The principal characterization method is process knowledge, based on documented evaluation of the waste stream. Process knowledge can be used when the waste stream is characterized by source. For example, process knowledge can characterize solid waste from an experimental hood produced in a laboratory experiment where the materials are controlled as part of the experimental process. Another example is the solid waste generated from the maintenance of processing equipment for which the radionuclides and chemicals are known and controlled. It should be noted that these are

idealized examples. In practice, it is very difficult to maintain a controlled environment where there is total accountability of radioactive materials and their waste products.

Materials Accountability Another method for establishing the isotopic content of the waste stream is materials accountability. The quantity of radionuclides is determined as the difference between the quantity of material entering and exiting the waste generating process. For example, an operation that introduces a known amount of an isotope into a glove box could use this method to determine the radionuclide concentration in the material taken out of the glove box. This strategy is best used when only a limited number of easily identified isotopes are used.

NDA Assay Techniques Nondestructive assay (NDA) techniques for the identification and quantification of radionuclides provide characterization data without disturbing the waste packaging by sampling. This is usually accomplished through direct gross gamma measurements of the waste packaging. Another NDA technique measures spontaneous or induced neutron emissions. Gross radiation measurements are well-suited for the routine analysis of limited quantity, low to medium density, and low specific activity types of waste streams (Amir, 1993).

A radionuclide distribution can be indirectly obtained by assaying a known gamma emitter spectroscopically and employing that measurement to infer other radionuclide concentrations in the waste stream using *scaling factors*. This is known as an indirect measurement. Nuclides that do not emit neutrons or gammas are estimated by recourse to process knowledge and scaling factors. NDA measurements alone are not sufficient to characterize low-level waste. In general, process knowledge is used along with NDA techniques in the characterization process.

Sample Analysis The most accurate description of a waste stream would be obtained through direct sample analysis. This is also known as specific radiation measurement. This involves sampling the waste and laboratory analysis. Determining the radiological and chemical composition of radioactive waste is rarely straightforward.

Obtaining a representative sample from a waste stream can be difficult. Often, a representative sample cannot be obtained or would result in significant dose to the worker. Some radionuclides (e.g., ^{90}Sr) must be analyzed through complicated radiochemical procedures, adding both time and expense.

The three methods of nuclide determination currently employed at the WVDP are sample analysis, scaling factors (or ratios) used in NDA determinations, and dose rate to activity conversions. The scaling factors are based on isotopic distribution data developed by radiochemical analysis, plant operating history and HLW tank isotopic composition (DOE/NE/44139-16, 1987). The dose rate to activity conversion is a result of ion-chamber readings converted to an activity content based on scaling factors of gamma and beta emitters.

The classification of LLW at the WVDP is based on the criteria for radionuclide concentrations defined in the NRC's 10CFR61.55 and 61.56 for Class A, B, and C low-level waste suitable for near surface disposal. This regulation specifies that classification can be based on direct analysis, material accountability, or scaling factors to measured nuclides (10CFR61.55(8)).

Although WVDP is funded mainly by DOE, the site began as a commercial facility and so continues to use 10CFR61. In utilizing 10CFR61, the WVDP is unique among DOE sites, where waste programs are operated in accordance with DOE guidelines. The current DOE Order 5820.2A, "Radioactive Waste Management" is the document that outlines how DOE sites manage radioactive and mixed waste and contaminated facilities (Duggan et al., 1993). There is no conflict, however, since the NRC regulations in 10CFR61 meet the DOE requirements. Private industry and the federal government have concordant definitions of low-level radioactive waste. The NRC and the DOE refer to the Low-Level Waste Policy Act for their definition of LLW, "radioactive waste not classified as high-level radioactive waste, transuranic waste, spent

nuclear fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act (e.g., uranium or thorium tailing and waste)" (PL 96-573, 1985).

The NRC recognizes three classes of low-level radioactive waste suitable for near surface disposal termed Class A, B, and C. To determine classification, consideration is given to concentration of both long-lived and short-lived radionuclides. The concentrations of long-lived and short-lived radionuclides that determine the category are summarized in Tables 1 and 2 (10CFR61.55(3)-(4)). The NRC cites long-lived radionuclides as a concern because of their potential hazard after the engineered barriers are no longer effective. The concentrations of short-lived radionuclides are regulated because they can be effectively managed through controls, waste form and disposal methods (e.g., decay in storage).

Section 61.56 entitled "Waste Characteristics" describes the requirements that must be met in order for the waste to be suitable for near surface disposal. This section covers items such as packaging, liquid waste, solid waste containing liquid, potential explosivity, and flammability. It also states that packaged waste must have structural stability. That is, the waste should maintain its physical dimensions and its form, under expected disposal conditions. The intent of Section 61.56 is to ensure that waste will not structurally degrade and thereby allow water infiltration. It is commonly accepted that the primary risk to the public from the disposal site would be from radionuclide migration into drinking water supplies.

The three classes of LLW are separated by concentration of long-lived and/or short-lived radionuclides present in the packaged waste and requirements on waste characteristics. However, the physical matrix of the waste can be anything from anti-C clothing to metal to solidified sludge. Any of these forms can be either Class A, B, C, or even be unsuitable for near surface disposal due to radionuclide concentration or inappropriate characteristics.

Table 1. Long-lived radionuclides, from 10CFR61.55

RADIONUCLIDES	CONCENTRATION LIMITS IN Ci/m ³		
	Class A	Class B	Class C
¹⁴ C	≤ 0.8	-	≤ 8.0
¹⁴ C in activated metal	≤ 8.0	-	≤ 80.0
⁵⁹ Ni in activated metal	≤ 22.0	-	≤ 220.0
⁹⁴ Nb in activated metal	≤ 0.02	-	≤ 0.2
⁹⁹ Tc	≤ 0.3	-	≤ 3.0
¹²⁹ I	≤ 0.008	-	≤ 0.08
CONCENTRATION IN nCi/g			
Alpha emitting transuranics with half-lives > 5 years	≤ 10.0	-	≤ 100.0
²⁴¹ Pu	≤ 350.0	-	≤ 3500.0
²⁴² Cm	≤ 2000.0	-	≤ 20000.0

Table 2. Short-lived radionuclides, from 10CFR61.55

RADIONUCLIDES	CONCENTRATION LIMITS IN Ci/m ³		
	Class A	Class B	Class C
Total of all with half-life < 5 years	≤ 700.0	≥ 700.0	*
³ H	≤ 40.0	≥ 40.0	*
⁶⁰ Co	≤ 700.0	≥ 700.0	*
⁶³ Ni	≤ 3.5	≤ 70.0	≤ 700.0
⁶³ Ni in activated metal	≤ 35.0	≤ 700.0	≤ 7000.0
⁹⁰ Sr	≤ 0.04	≤ 150.0	≤ 7000.0
¹³⁷ Cs	≤ 1.0	≤ 44.0	≤ 4600.00

*These will be Class B unless concentrations of other nuclides in Table 2 determine waste to be Class C independent of those nuclides.

Class A waste is generally considered to have a low hazard potential. It must meet the packaging and stability requirements of Section 61.56. It is often segregated from other waste classes at the disposal site due to the waste not meeting the stability requirements of Section 61.56 (10CFR61.55(2)(i)). Class B waste must meet more stringent requirements on waste form to ensure stability after disposal (10CFR61.55(2)(ii)). Class C, including the most hazardous forms, requires that greater measures be taken to ensure a stable waste form. Also, it is necessary to take additional measures at the disposal facility to secure against inadvertent intruders (10CFR61.55(2)(iii)). An inadvertent intruder is an individual who may occupy the disposal site after closure and engage in normal activities such as agriculture or dwelling (10CFR61.2).

A waste may be determined to be unsuitable for near-surface disposal if it exceeds the concentrations given in Tables 1 and 2. This waste is generally referred to as "greater than Class C" waste. In this case, disposal methods must be different and more stringent. In the absence of disposal requirements in 10CFR61.55, such waste must be disposed of in a geologic repository as defined in 10CFR60 (10CFR61.55(2)(iv)).

DOE 5820.2A was issued in September 1988 and allows the individual site to develop and implement programs on general waste reduction, segregation, minimization and characterization of radioactive waste as long as the following performance objectives and dose limits are met:

- (1) a limit on annual effective dose from all exposure pathways of 25 mrem for members of the public beyond the boundary of the disposal site and at any time after disposal;
- (2) limits on annual effective dose from all exposure pathways of 100 mrem for continuous exposure scenarios and 500 mrem for a single acute exposure scenario for inadvertent intruders into disposal sites following the loss of institutional control, which is assumed to occur at 100 years after disposal;
- (3) protection of ground water resources consistent with Federal, State, and Local requirements.

The chapter covering LLW describes a management program that is assessed based on ability to meet criteria given in performance objectives. The performance objectives for management of LLW basically coincide with those mentioned previously. It is the policy of the DOE that whenever practical, its LLW be disposed of on the site where it was generated. Only if this is not possible should LLW be shipped off site for disposal. Essentially all DOE sites generate LLW. Subsequently, they must undergo the performance assessment process. This process is set up to determine whether or not the performance objectives are being met.

The DOE Order also requires that waste acceptance criteria (WAC) be established for each LLW disposal facility. In general, the WAC provide the limits on quantities and/or concentrations of specific radionuclides that are acceptable for disposal in order to comply with the performance objectives for the protection of public health and the environment. The limits on the quantities and concentrations of radionuclides are intended to ensure that the aforementioned dose limits for the public or inadvertent intruders would not be exceeded. In support of the WAC, each generator must implement a low-level waste certification program. The generator and the facility receiving the waste are both responsible for making sure the WAC are met. Furthermore, generators are financially responsible for nonconformance. The certification programs are subject to periodic audit.

DOE 5820.2A requires that low-level waste be characterized with sufficient accuracy to permit proper segregation, treatment, storage, and disposal. This is an attempt to know and record radiological content, physical and chemical properties at all stages of the waste management process. The concentration of a radionuclide may be determined by direct methods, such as sample analysis, or indirect methods such as use of scaling factors, or radionuclide material accountability (DOE 5820.2A, 1988).

The Order does not specify separate classes based on radionuclide content and concentration. However, it does list the waste characterization data to be recorded on a

waste manifest. This list includes physical and chemical characteristics, volume and weight (total waste and any solidification or absorbent media), major radionuclides ($\geq 5\%$ of total curie content of a waste mixture by mass) and their concentrations, packaging date, package weight, and external volume.

C. WVDP Characterization and Classification Methodology

In 1987, WVDP issued DOE/NE/44139-16, the document that outlined their waste classification policies and procedures. At that time, the Site was required to meet the classification criteria of 10CFR61.55-56 and DOE Order 5820.2 (precursor to DOE 5820.2A). 10CFR61 was the more conservative of the two, so the program was set up to meet these requirements. The document DOE/NE/44139-16, West Valley Demonstration Project Low-Level and Transuranic Waste Assay Methodology, was published in 1987. It was estimated that the total cost of the waste characterization system was 1.3 million dollars and required approximately 28 man-months of effort to develop.

WVDP developed a four component system for characterization and classification that employed the following techniques and analytical equipment (DOE/NE/44139-16, 1987):

- Curie content from gross gamma analysis
- High-resolution segmented gamma spectroscopy
- 4π passive neutron assay system
- Estimating curie content of waste by sampling and radiochemical analysis

This system design was based on information gathered from a comprehensive survey of the former Center. Waste disposal areas and streams were characterized based upon existing surveys and plant operating history (DOE/NE/44139-16, 1987). These efforts focused on areas and systems that were likely to be contaminated by TRU waste. Isotopic data was obtained through basic radiochemical assay techniques such as high-

resolution gamma spectroscopy, radiochemical separations followed by alpha spectrometry or beta analysis. This isotopic data was used to develop methodology to characterize and ultimately classify LLW and TRU waste.

This system was integrated using a computerized network that performed functions such as data reduction, a curie estimate program, classification, inventories, record keeping, and manifesting. Software was developed to determine the classification from a list of nuclides present and their concentration. The counting systems were designed to detect radionuclides specified in the 10CFR61.55 tables either directly or indirectly by recourse to scaling factors. The radioisotopes typical to WVDP at that time are listed in Table 3 along with the isotope used to measure the level.

TABLE 3: WVDP Isotopes of Concern and Isotopes Measured to Determine the Value by the Assay. Taken from DOE/NE/44139-16.

<u>Radionuclide</u>	<u>Nuclide Measured</u>
^{241}Am	^{241}Am
TRU	^{241}Am
^{241}Pu	^{241}Am
^{137}Cs	^{137}Cs
^{99}Tc	^{137}Cs
^{129}I	^{137}Cs or ^{129}I
^{63}Ni	^{137}Cs
^{90}Sr	^{90}Sr or ^{137}Cs
^{60}Co	^{60}Co
^{14}C	^{137}Cs
^{134}Cs	^{134}Cs or ^{137}Cs
^{147}Pm	^{137}Cs
^{151}Sm	^{137}Cs
^{154}Eu	^{137}Cs
^{125}Sb	^{137}Cs or ^{125}Sb
^3H	^3H

According to Table 3, ^{241}Am is used to obtain TRU and ^{241}Pu content (DOE/NE/44139-16, 1987). This is accomplished by using scaling factors specific to the Site. These scaling factors were developed by radiochemical analysis, plant operating history, and high-level waste tank isotopic composition. ^{137}Cs activity is used to determine activity of ^{129}I , ^{99}Tc , ^{14}C , and ^{63}Ni using scaling factors based on isotopic composition of the high-level waste tank. The author of DOE/NE/44139-16 justified the use of scaling factors by the fact that the reprocessing plant had not been operating for 15 years. The claim was made that the existing waste streams had reached a stable state and isotopic distribution could be predicted on nuclear decay chains.

DOE/NE/44139-16 describes how the different assay systems are used based on the type of container. LLW that is packaged in 55 gallon drums may be assayed by the segmented gamma scanner (SGS) system or the "dose rate to curie" conversion program. Waste that is packaged in 90 ft³ boxes is generally assayed using dose rate to curie conversion. LLW suspected to be contaminated with transuranics was to be assayed by the neutron counting system.

"Dose Rate to Curie" Conversion

The principal method used by WVDP to characterize LLW is to estimate curie content from dose rate. As explained in DOE/NE/44139-16, this method was developed from plotted curves that converted exposure rate (in mrem/hr) to activity (in Ci) in the waste package. The curves and models take into account changes in package dimensions, waste density and average gamma energy. These conversion factors were coded into a software routine that produces the classification.

The rationale for this method is as follows. The principal gamma emitting nuclide (percentage-wise) on the Site is $^{137\text{m}}\text{Ba}$, progeny of ^{137}Cs . Dose rate measurements are based on this radioisotope. A waste package is surveyed and the measured gamma dose rate is converted to curies of ^{137}Cs . Once the ^{137}Cs curie value is determined, the activity values for other isotopes are calculated through the scaling factors developed by

isotopic distribution data on the composite high level waste material. The other radioisotopes include: ^{90}Sr , ^{99}Tc , ^{129}I , ^{63}Ni , ^{134}Cs , ^{147}Pm , ^{151}Sm , ^{154}Eu , ^{155}Eu , ^{125}Sb , ^{60}Co , ^{14}C , and ^3H .

High-Resolution Segmented Gamma Spectroscopy

The SGS employs a nondestructive radiometric assay technique. The SGS was purchased from Canberra Industries in 1982. The system used a high resolution, high purity germanium gamma detector with 20% efficiency. The detector was selected for maximum performance at the energies of ^{241}Am , ^{137}Cs , and ^{60}Co nuclides, radioisotopes most commonly found on site. It was also equipped with a transmission source for corrections due to the density of the waste package, a rotating table that moves in a horizontal direction to seven different locations, and a mini-computer to control and automate the system (Figure 6).

The SGS also corrects for matrix absorption, dead time and pulse pile-up. The transmission source, ^{152}Eu , emits multiple gamma ray energies that are used to correct for absorption of ^{241}Am , ^{137}Cs , and ^{60}Co . High counting rates can cause errors due to system dead time and/or pulse pile-up. The chance of this occurring was minimized by installing a live time correction/pulse pile-up rejecter and a proprietary WVNS dead time correction device. The correction device uses ^{54}Mn , a gamma emitting source.

The SGS was required to be calibrated daily before each use. NIST-traceable standards of ^{241}Am , ^{137}Cs , and ^{60}Co were used. Known amounts are placed in various configurations in calibration drums and measured. The results are recorded and permanently stored.

Passive Neutron Assay System

A passive neutron assay system, which was never operational, was designed and built for \$90,000 to measure potential TRU contamination of a waste package too large for the SGS. It was designed to detect as little as 10 nCi/g of transuranic nuclides in a waste package up to 90 ft³. A 4 π geometry was chosen so that the contents could be

Figure 6. Block Diagram of Segmented Gamma Scanner. Drawing taken from DOE/NE/44139-16.

detected on all four sides in a single measurement (DOE/NE/44139-16, 1987). The system used an array of 78 BF₃ neutron proportional counting tubes. The 4 π configuration consisted of four identical sides and two identical end modules. There were fifteen counters on each of the four sides and nine counters on each of the two end models.

A thirty minute count was determined to be required to yield a statistically significant net neutron signal. The neutron count from each section would be recorded in a separate scaler. This arrangement would make it possible to determine the inhomogeneity of the TRU distribution, commonly referred to as "hot spots."

Radiochemical Sample Analysis

The final characterization method described in DOE/NE/44139-16 is radiochemical sample analysis. When this document was published in 1987, the radiochemical laboratory was equipped with instrumentation and methods for alpha spectroscopy, high resolution gamma spectroscopy, beta analysis, gross alpha and beta analysis, uranium fluorescence, and elemental analysis by Inductively Coupled Plasma (ICP) spectrometry.

Alpha spectroscopy is used to determine ²³⁸Pu, ²³⁹Pu, and ²⁴⁰Pu, content in sampled waste streams. High resolution gamma spectroscopy is employed to detect gamma emitting isotopes. Beta analysis is performed primarily to determine ⁹⁰Sr content in the waste material. Gross alpha and beta analyses are performed on all waste samples to verify the accuracy and to account for all activity in the waste sample. The radiochemical laboratory is verified by independent quality assurance audits by WVNS personnel, periodic DOE reviews, and periodic NRC audits.

III. Evaluation of WVDP LLW Classification Strategies

A. LLW Characterization and Classification Problem Areas at WVDP

Upon discovering many inconsistencies in its LLW classification methodology, the WVDP discontinued waste classification operations in March, 1991. Since that time, WVDP has accumulated over 100,000 ft³ of undetermined/unclassified LLW. In addition, there is approximately 180,000 ft³ of LLW to be reclassified. In association with on-going WVDP activities, volume projections for future generation and shipment of low-level waste are approximately 20,000 ft³ per year until the completion of vitrification, expected in four to six years.

Problems typical to the waste classification system at the WVDP stem from the methods of nuclide determination. These methods are described in the report, DOE/NE/44139-16, West Valley Demonstration Project Low-Level and Transuranic Waste Assay and Methodology. These problem areas have been researched and acknowledged by the Waste Management Engineering Department at WVDP. In order to have an effective classification program, these issues must be resolved:

- (1) The scaling factors used for classification of solidified supernatant and sludge wash are determined on 8D-2 supernatant. These numbers should be measured on 5D-15A and 5D-15B, the holding tanks for material ready to be made into cement.
- (2) Scaling factors for ⁵⁹Ni, ⁶³Ni, and ¹⁴C are in question. For example, ⁶³Ni is ten times higher than the correct value. ⁵⁹Ni and ¹⁴C still need to be measured.
- (3) From past assumptions, it was assumed there was no Np, Am, or Cm present in 8D-2 supernatant. Since then, traces of ²³⁷Np have been found.
- (4) No reference or documentation for scaling factors in computer programs.
- (5) There are typographical errors in the numerical data in DOE/NE/44139-16. The data must be recalculated.

The basis of LLW classification at the WVDP is found in 10CFR61.55 and 61.56. According to these regulations, the concentration of several isotopes must be known in

order to classify radioactive wastes. The classification is divided into two parts, long-lived radioisotopes and short-lived radioisotopes (refer to Tables 1 and 2).

It follows, then, that in order to classify waste, the Analytical and Process Chemistry (A&PC) Department at WVDP must be capable of determining the concentration of the following isotopes: ^3H , ^{14}C , ^{59}Ni , ^{63}Ni , ^{60}Co , ^{90}Sr , ^{94}Nb , ^{99}Tc , ^{129}I , ^{137}Cs , ^{241}Pu , ^{242}Cm , alpha-emitting transuranics with half-lives greater than five years, and all radioisotopes with half-lives less than five years.

The alpha-emitting transuranics with half-lives greater than five years that are present in HLW at the WVDP site are ^{237}Np , ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{242}Pu , ^{241}Am , ^{243}Am , ^{243}Cm , ^{244}Cm , ^{245}Cm , and ^{246}Cm . Their presence has been shown by or predicted from ORIGEN2 code calculations, NFS data, and/or prior analyses of tanks 8D-2 and 8D-4. The bulk of TRU isotopes were predicted to be found in tank 8D-2 sludge.

DOE/NE/44139-16, West Valley Demonstration Project Low-Level and Transuranic Waste Assay and Methodology, is the basis of LLW and TRU Waste Classification at WVDP. Unfortunately, it contains numerous typographical errors, especially in the numerical data. For example, Table 5.2, "High Level Waste Tank Radionuclide Content," is a list of isotopes and their respective curie content. It does not specify tank 8D-2 or 8D-4. Some values are the sum of the activity in 8D-2 supernatant and 8D-2 sludge while others are the sum of the activity in 8D-2 supernatant, 8D-2 sludge, and 8D-4. Many numbers were incorrectly copied from the original reference, "Radionuclide Content of Vitrification Feed" (HK:86:0096, 1986).

In order to make accurate TRU waste calculations, the data will have to be corrected. Neutron contributions to the waste activity will have to be obtained by analytical measurements and must take into account the chemical path from 8D-2/8D-4 to waste container. It is probable that the complex actinide chemical behavior will change the scaling factors as the HLW is processed into cement and glass.

The cement end product of the CSS is characterized by direct sample analysis. While the holding tank, 5D-15A, has been routinely analyzed for many elements required by 10CFR61, it was assumed that no neptunium, americium or curium were soluble in 8D-2 supernatant. There are indications that ^{237}Np is present in 8D-2. Further analyses are required to verify assumptions made about these radionuclides.

Other scaling factors are also in question. ^{59}Ni , ^{63}Ni , and ^{14}C are all calculated by scaling factors. The factor for ^{63}Ni is about 10 times higher than the correct value. ^{59}Ni and ^{14}C still need to be measured. The scaling factors are also determined on 8D-2 supernatant. These numbers should be measured on 5D-15A and 5D-15B material, since this is the liquid that is to be made into cement. 8D-2 supernatant is chemically processed and it has not been verified that the scaling factors do not change during the chemical treatment.

No reference or documentation are available for the scaling factors used in the computer programs. The source code needs to be audited to document the computational assumptions. Likewise, the scaling factors used in the computer programs need to be verified. No reference or documentation to the factors used to convert beta, gamma dose readings into ^{137}Cs activity have been found. These numbers need to be defined and referenced.

B. Efforts of Waste Management Engineering Department

Table 4 describes the status of WVDP low-level waste in storage as of November 30, 1992:

TABLE 4: WVDP LLW in Storage

<u>TYPE</u>	<u>VOLUME(m³)</u>
IRTS Drum Cell:	
Class C stabilized supernatant	2,701
Class C stabilized sludge wash	70
Class A stabilized sludge wash	266
Other Low-Level Waste A	4,507
B	513
C	104
TRU Waste (includes suspect TRU)	250
Undetermined/Unclassified Status	2,632

During 1992, significant efforts were initiated in an attempt to resolve the low-level waste issues (refer to Section III(A)) since limited space for LLW storage was available. Construction of more LAG storage buildings, either the type of building enclosed by metal siding or the engineered fabric structure, is very costly and may provide only temporary relief to the shortage. Also, this solution would not address the cost of future disposal of the waste.

The more aggressive approaches to solving the storage problem involved volume reduction and off-site treatment at a commercial facility. In 1992, approximately 31,000 ft³ of pipes, equipment, vessels, and miscellaneous plant wastes were compacted (AWMP, 1992). Also, the WVDP proposes to prepare Class A low-level radioactive and mixed waste for transportation off-site to a commercial volume reduction facility and to receive and store the volume-reduced residues. The inventory of eligible wastes types

includes: anti-C clothing, gloves, plastic, herculite, paper, oil, wood, metals, concrete rubble, soil, and tubing.

A large percentage of the Class A waste consists of soil slightly contaminated with radioactivity. Investigations were conducted by WME into the most economical method of treating the soil. Two options that were presented were soil washing that would be done off-site or stockpiling the soil on-site. Stockpiling was chosen as the best alternative as it avoids off-site transportation and is safe and economical (AWMP, 1992).

A Segmented Gamma Scanner (SGS) is a vital part of a complete low-level and TRU waste characterization program. NDA techniques should be actively employed whenever possible. When designed for a specific site or use, these techniques can provide characterization results with reasonable margins of error while achieving ALARA.

Since 1984, the SGS at West Valley for NDA included a Canberra Model 2220B Segmented Gamma Scan System for the waste classification of low-density, 55 gallon drums containing radioactive waste. This model SGS was designed for use at reactor sites and meant to detect very low levels (sub- μ Ci range) of gamma emitters. Since replacement parts were no longer available for some subsystems and many of the SGS mechanical components had exceeded their useful life, a decision was made to upgrade the existing system at a cost of approximately \$100,000.

Canberra Industries, Inc., Nuclear Products Group performed the upgrade of the SGS to a Model 2440 in approximately ten months. The advantages of the upgraded system included identification and quantification of activities for all gamma emitting isotopes instead of the three (^{241}Am , ^{137}Cs , and ^{60}Co) with the old system. A low-Z pedestal that allows more accurate scanning of contents at the bottom of the drum was installed, along with a heavy duty vertical lift mechanism to accommodate drum masses up to 1000 pounds.

The SGS was enhanced with the capability of determining the maximum and average dose rates of waste containers and the ability to process spectroscopy data faster and more efficiently. Computer hardware and software were improved to facilitate gamma analysis, the incorporation of scaling factors for non-gamma isotopes for different waste streams, and waste classification per 10CFR61.55. Finally, worker safety features were added such as frame bolt-down, warning lights for motion indication of mechanical components and open shutter conditions for transmission source, and a locking cover over the source shield and shutter.

Ideally, the SGS system would be able to analyze 55 gallon drums of radioactive waste for all gamma-emitting isotopes with the completion of the upgrade. However, performance also depends on waste density, density and activity distribution uniformity, attenuation of low-energy gammas, and data collection time. As mentioned in Section I(C), the density of the waste matrix will vary.

The process of upgrading the SGS began in November 1992 with a purchase order for equipment and installation. It was scheduled to be operational in April, 1993 (AWMP,1992). In adjusting the system to meet the specifications of the West Valley site, several mechanical and system difficulties arose. These problems took approximately 7 months to resolve. The SGS system was operational in November 1993.

Efficiency and energy calibrations were conducted to prepare attenuation data and the required charts. Difficulties were encountered with the calibration of ^{241}Am . It was attributed to attenuation of the low energy gamma and was corrected. Three LLW drums were selected for the preparation of attenuation data. At this point, the SGS system is able to scan light weight, uniform density drums for potential waste classification purposes.

Much more work is required to make the SGS fully operational such that it scans all types of waste drums of nonuniform density and energy level. Items suggested to extend the range of waste weight and density as well as general improvements to make

the system safer and easier to use are expected to take approximately 1.5 years with no complications.

The 4π Passive Neutron Assay System was dismantled in November of 1992. When LLW classification ceased in 1991, it was determined that this particular model did not meet the needs of the WVDP. Replacement alternatives are being considered. This piece of equipment is also an integral part of the nondestructive characterization of drums and boxes, particularly in identifying TRU waste. Along with data obtained from the SGS, one can determine with reasonable certainty the type, quantity, and sometimes position of the TRU material.

A waste classification task force was formed in May 1992 to develop and implement a LLW characterization and classification program (AWMP, 1992). The task force was given the assignments of identifying waste streams unique to WVDP, regulatory requirements, and methodologies for upgrading the existing 10CFR61 waste classification system. The task force will prepare a report that will provide a list of radionuclides at WVDP necessary to properly characterize the waste streams. A flow chart will be developed showing the sequence of steps in LLW classification and accompanying responsibilities. A document will support this flow chart by explaining the underlying logic and listing activities required in implementing LLW classification. Also during 1992, conceptual plans for a Waste Remediation and Treatment Facility (WRTF) were refined. It will be designed for inspection, characterization, repackaging, and treatment of LLW and TRU waste.

C. Methodology of Survey Study

The purpose of this study is to critically evaluate the waste classification systems Oak Ridge National Laboratory (ORNL), Savannah River Site (SRS), and Idaho National Engineering Laboratory (INEL) in order to improve the LLW classification system at the WVDP.

The objective of this survey study was to enhance the waste classification efforts of the WVDP. A strong argument for this effort may come from this intercomparison study of the waste classification processes of other selected DOE sites. Several facets of each classification program were used to give an overall comparison:

- (1) site history
- (2) major radionuclides present
- (3) types and number of major waste streams
- (4) characterization methods used
- (5) types of equipment (assets, limitations)
- (6) detection limits (of equipment)
- (7) QA programs for characterization systems
- (8) waste acceptance criteria that determines waste classification program
- (9) LLW classification categories and terminology
- (10) health physics issues

This study was accomplished through site visits. These visits consisted of tours of the waste characterization/classification systems, disposal areas, and interviews with site personnel. Each site program was thoroughly studied. The results of the study were summarized in written reports covering the aforementioned areas relevant to each site. This information, along with informed recommendations from this paper for redeveloping WVDP's LLW characterization and classification program was presented to the Waste Management Engineering Department. It is hoped that this survey study of the characterization/classification programs of three DOE laboratories will provide valuable information on what is necessary to have a successful program. This information could also provide support in acquiring funds to build a successful program (i.e., purchase necessary equipment and hardware, provide appropriate housing for equipment, manpower, etc.).

D. Intercomparison of Three DOE Sites

1. Brief Site Histories

The Department of Energy strongly encourages information sharing among its laboratories and remediation sites. DOE 5820.2A requires all DOE facilities to have a LLW characterization/classification program in place that meets its objectives. This is more important than ever with the advent of the LLW Policy Act. Each LLW repository will have its own set of criteria for LLW disposal. The first repository is scheduled to open in 1996 (refer to Section II(A)). The closer the agreement on LLW disposal criteria, the easier the transition from on-site storage to regional (permanent) disposal facilities will be.

The three DOE laboratories that were included in this survey study were Oak Ridge National Laboratory (ORNL), Savannah River Site (SRS), and Idaho National Engineering Laboratory (INEL). All three laboratories originated in support of national defense. They have all since diversified their efforts and research.

ORNL ORNL is managed by Martin Marietta Energy Systems for the DOE. The laboratory is located on a site occupying approximately 4.5 square miles 10 miles southwest of Oak Ridge, Tennessee. Originally Clinton Laboratories, the laboratory was built in 1943 as part of the WWII Manhattan Project. ORNL is recognized as one of the nation's most diversified federal research and development centers. The principal elements of ORNL's missions in support of DOE include activities in areas such as energy production and conservation technologies, physical and life sciences, scientific and technological user facilities, environmental protection and waste management, science and technology transfer, and education.

SRS The SRS occupies approximately 325 square miles along the Savannah River in central South Carolina. The Site was established in 1950 by the United States Atomic Energy Commission to produce material for nuclear defense. The SRS is currently managed by the Westinghouse Savannah River Company (WSRC). The SRS

includes fuel and target fabrication facilities, low temperature/low pressure reactors, chemical separations facilities, tritium extraction, loading and recovery facilities, high-level radioactive waste facilities, and low-level radioactive waste facilities.

INEL The INEL was officially established in 1949 as the National Reactor Testing Station. The federal government selected the INEL site when the Atomic Energy Commission needed a location for conducting nuclear research and development and nuclear-related defense work. The Site is located on 890 square miles in the southeastern Idaho desert. Within this perimeter are nine nuclear research and development facilities. EG&G Idaho is a prime management and operations contractor at the INEL.

2. Origin of LLW Management Activities

Each of these laboratories has always managed their low-level radioactive waste. However, LLW did not become the focus of much attention until about ten years ago. Radioactive wastes contaminated with transuranics were a primary concern due to the dangers of internal contamination. When the government decided to construct a federal repository, the Waste Isolation Pilot Plant (WIPP), to safely dispose of TRU waste, it was necessary to establish acceptance criteria for waste shipped to the disposal site. Government sites began to manage and characterize TRU waste. Based on this, the passage of the LLW Policy Act, and the DOE Order 5820.2A, LLW management became a very important operation.

ORNL Prior to 1986, ORNL Waste Management had a TRU waste certification program that met the waste acceptance criteria for WIPP. The program consisted of a small number of Generator Certification Officials (GCO) who supervised waste packaging. TRU waste drums were then stored on-site for future disposal at WIPP.

There was no separate program at ORNL for LLW because there were no regulations in place for such a program. The GCO's for TRU waste were considered to be informal GCO's for LLW. There were no plans to send LLW off-site to a disposal

facility. Waste Management planned to continue burying on-site. Once one burial site closed, another would open to take more waste. Solid Waste Storage Area (SWSA) -6 was the last one to be used.

In 1986, SWSA-6 was closed due to concerns over RCRA materials. At this point, interest turned to the LLW that was being generated. ORNL had to prove they could meet the objectives of DOE 5820.2A before they could reopen the storage area.

INEL In 1952, INEL established the Radioactive Waste Management Complex (RWMC) as a 13-acre location for storage and disposal of solid radioactive waste. At first only beta-gamma waste was accepted for disposal. Then in 1954, Rocky Flats (CO) began shipping waste containing TRU elements. Today the RWMC is a 144-acre area used to manage transuranic contaminated, solid, and low-level radioactive waste. Located on the RWMC is the Stored Waste Experimental Pilot Plant (SWEPP) that certifies TRU waste destined for WIPP. The SWEPP facility also certifies LLW.

SRS With the advent of DOE 5820.2A, the SRS upgraded their LLW management programs. They designed and constructed below grade vaults for low-level solid radioactive waste (<200 mR at 3 inches) and intermediate-level solid radioactive waste (≥ 200 mR at 3 inches) to meet the performance objectives in the Order. Approximately 195 acres in the center of the Site are used for the storage and disposal of solid radioactive waste.

3. Similarities of Classification Programs

a. Characterization Methods

In general, all three of the sites surveyed relied upon the same characterization methods. All sites base characterization of solid radioactive waste on three areas: physical form and content, chemical form and content, and radiological content. Process knowledge and NDA analysis are the principal characterization methods along with sample analysis performed whenever possible. Knowledge of waste content, how it is

layered and packaged, and what chemical separations process generated the waste stream is essential to correctly interpret the data. In all cases, responsibility for proper characterization lies with the generator.

At SRS, all methods must be documented and approved and are subject to internal audit. At ORNL, the GCO develops a Waste Management Plan that includes characterization of waste. This plan must be approved by the Laboratory Certification Official (LCO), the highest authority. The INEL relies primarily on process knowledge as the main source of characterization. Part of the characterization process for a drum includes analysis of headspace gases. The SWEPP facility, which contains equipment to perform nondestructive examinations of waste packages, is responsible for back-up checks of the generator's characterization techniques.

b. Characterization Instrumentation

Three basic NDA survey instruments were found at all three sites surveyed: a segmented gamma scanner, a 4π neutron assay system, and a real-time radiography unit. However, each program also had additional equipment and aspects that made it unique.

ORNL The Waste Examination and Assay Facility (WEAF) of ORNL was established in 1982 as the central certification facility for nondestructive assay and examination of low dose rate TRU waste packages. Solid low-level waste was subsequently included in compliance examinations done by WEAFF.

All waste drums and some "B25" (4x4x6 ft) boxes are examined in the Drum Real-Time Radiography (DRTR) Unit. The DRTR is basically an X-ray room that allows the examiner to view the contents of the drum or box for noncompliant items such as RCRA materials, pressurized aerosol cans, or free standing liquid.

Features of the DRTR include a variable 420 kV-max constant potential X-ray tube head that generates the X-rays in the examination. A rare-earth phosphor screen converts the X-ray energy to light energy, which in turn, is converted to electrical pulses

viewed by the instrument operator on a CRT screen. This TV monitor is located in its own control room. The drum loader can hold three drums at a time or one B25 box. The drums (scanned one at a time) are rotated and scanned vertically, while the X-ray generator and image system remain stationary. Each scan is videotaped for archival storage and compliance with applicable quality assurance requirements.

The WEAFF team has created their own version of the segmented gamma scanner that they call the Gamma Assay Segmented Passive (GASP) System. The GASP is very similar mechanically to the model owned by West Valley. It was also originally purchased from Canberra, Inc. and subsequently modified to meet the needs of ORNL. The GASP is equipped with a high-purity germanium detector and a ^{152}Eu transmission source. The WEAFF team is currently establishing detection limits for gamma emitting nuclides for the GASP.

The GASP handles only 55 gallon drums. It is used primarily for the examination of suspect TRU drums. WEAFF does not scan every low-level or TRU solid waste drum. If there is reasonable cause to believe that a drum contains TRU waste, it is scanned. This measurement is then added to the generators inventory of that drum. This instrument identifies the transuranic isotopes in the drum.

The GASP has no moving trolleys to minimize vibrations to the detector. The trolley that holds the detector and the trolley that holds the transmission source are secured in positions closest to the drum turn-table. The drums are loaded and unloaded by fork-lift. Also, a pad has been placed underneath the detector housing. The software for the GASP system, referred to as TRIFID, was developed at the Rocky Flats site. The WEAFF team adopted this software that took approximately ten years to develop.

The Active-Passive Neutron Examination and Assay (APNEA) System was designed and built by the WEAFF team. It replaced the Passive-Active Neutron (PAN) system developed at Los Alamos National Laboratory that is available commercially. This NDA technique uses thermal neutrons as its probe and fission neutrons as its signal.

The APNEA utilizes a 4π neutron detection system incorporating shielded (cadmium-wrapped) and bare ^3He detector tubes positioned both inside and outside the assay chamber walls. The system is capable of both active and passive scans. The active scan uses a deuterium-tritium neutron generator that emits approximately one million 14-MeV neutrons per pulse and can be pulsed up to a maximum rate of 100 times per second. After thermalization, the pulsed neutrons are then absorbed by any fissile nuclides (e.g., ^{235}U and ^{239}Pu) contained in the drum. The resulting fast-fission neutrons are detected by the cadmium-wrapped ^3He detector tubes. The passive scan detects any spontaneous fission and (α, n) neutrons. The combined assay yields the total TRU content of the waste drum. This system has proven to be sensitive to less than a milligram of ^{239}Pu in a 55 gallon drum.

In the APNEA, this technique was extended to address the difficult problem of determining the sizable and usually unpredictable effect the waste matrix has on the measurement of the waste material in the drum. The waste matrix modifies the effective thermal neutron flux and attenuates the signal neutrons. Commonly encountered examples are elements such as hydrogen (in water or plastics) or iron that drastically reduce the effective thermal flux. Consequently, the data acquisition, the neutron generator, and the detector configurations for the APNEA unit were specifically designed to supplement the traditional differential dieaway measurement with special imaging information that can be used to correct for the distorting effects of the waste matrix.

The APNEA unit technique supplies one other form of imaging that is essential for the final determination of the total amount of TRU material. The neutron generator-based imaging provides the basis for determining the spatial disposition of TRU material within a drum. In addition, the passive measurement of neutron activity from the drum yields a crude but confirmatory measure of the position of any material that spontaneously generates neutrons.

The GASP unit, together with the APNEA can give the type, quantity, and position of the TRU material in a drum. These two systems are used primarily to assay TRU waste drums. Presently, a drum goes through a GASP examination to determine the isotopics, then the APNEA passive scan gives the amount of ^{240}Pu , (or another even-numbered Pu isotope). The isotopic ratios that result from the gamma scan are applied to the ^{240}Pu , to get the remaining amounts of plutonium. The order of examination is the DRTR, then if necessary, the GASP and the APNEA.

INEL The NDA equipment housed at the SWEPP facility, which supports INEL, includes a real-time radiography (RTR) unit, a drum assay chamber, and an ultrasonic unit that measures drum integrity. A segmented gamma scanning system is being developed to be incorporated into the examination of TRU waste. There is a SGS that currently assays low-level waste. Detection limits for gamma emitting nuclides were not available.

When a 55 gallon drum of TRU waste is brought into the SWEPP facility, it is weighed and smears are taken to check for external contamination. A bar code is fixed to the drum for identification. The drum is then moved into the RTR by transfer cart. Here, a nonintrusive exam of the physical contents of the drum is performed. All RTR inspections are recorded on video cassette and placed in archival storage. This system consists of an X-ray head, an imaging system, a video cassette recorder, and three TV monitors. The maximum operating voltage of the tube is 420 kV. The transport cart can hold three drums or a box.

SWEPP contains two high sensitivity, NDA units used in measuring TRU packages. Both were designed and constructed by Los Alamos National Laboratory. Both units operate on the combined active/passive neutron measurement principle and provide information that is useful in making corrections for the effects of waste matrix materials on the measurement. One unit is designed to accommodate standard 55 gallon drums while the second unit accommodates metal or wooden crates as large as 84 x 54 x

54 inches. The drum and crate NDA units operate independently. However, they share some electronic equipment and use a common data acquisition system and operating software. The drum/box assay chamber is designed to detect 100 nCi/g of a transuranium radionuclide.

The methodology behind the operation of the active and passive neutron measurements is essentially the same as that described for the APNEA system. The active portion uses pulses of thermalized neutrons to interrogate the waste packages and to produce fissions in ^{239}Pu and other fissile TRU isotopes. The passive detection measures spontaneously generated neutrons, using electronic processing that separates neutrons detected in clusters of two, three, or more at a time from neutrons that are singly detected. The cluster events can be related to spontaneous fission of ^{240}Pu .

Since most of the TRU waste processed at SWEPP has a constant isotopic fraction of ^{240}Pu in it, the ^{240}Pu measurement is used to estimate the total Pu mass in a waste package. The single events are related to (α, n) reactions in the waste matrix, which for most of the SWEPP wastes, are produced by ^{241}Am . After processing, this data can be used to estimate the total ^{241}Am .

The Container Integrity System ultrasonically examines the wall thickness of 55 gallon steel drums to determine if the drums have acceptable wall thickness to meet the DOT Type A container requirements. These measurements are made using an eight channel multiplexed ultrasonic instrument and fixed bubbler type search unit assemblies. The drum is placed in a fixture that rotates the drum and positions the search units on the drum to scan over eight selected paths. The thickness measurement information from the ultrasonic instrument is transmitted to a microcomputer for on-line data processing.

The segmented gamma system and drum assay chamber are also used to examine LLW. All drums are assayed in the drum assay chamber first. Then, if significant gamma emissions are detected, the drum is assayed with the segmented gamma system. All drums are examined in the RTR and ultrasonic unit.

SRS Located on the Savannah River Site is the Experimental Transuranic Waste Assay Facility (ETWAF). It is part of the ETWAF/Waste Certification Facility (WCF), which was built to certify and package waste for transport to WIPP. ETWAF houses the nondestructive assay and examination equipment.

A Toledo Scale System obtains the mass of drummed waste. A total mass is obtained and then the approximate weight of the drum, liner, etc. is automatically subtracted, leaving the net mass of the drum contents. This measurement is then carried over to the assay systems manually to be used in determining concentrations for the isotopic inventory.

An X-ray analysis system is part of ETWAF. It is a Gemini II #505-0154 model built by TFI Corporation. This system is capable of scanning only 55 gallon drums. It operates under the same principles as the previously described radiography units. However, this system operates at 160 kV and only gives satisfactory results when imaging relatively homogeneous low density waste. Also, the imaging chain consists of a fluorescent screen and video camera and is susceptible to a washing out of high density areas due to screen saturation from low density areas.

The second-generation Passive-Active Neutron (PAN) system installed in ETWAF in 1989 was developed and built by Los Alamos national Laboratories. It is capable of scanning 55 gallon drums. Both the active and passive measurements are made utilizing a large number of ^3He proportional detectors. Some of the detectors have a cadmium sheet cover to capture thermal neutrons and measure fast neutrons. Others are left bare to measure both thermal and fast neutrons. This gives some neutron energy data based on the ratios of counts received by the various detectors.

The passive mode records the number of spontaneous fission neutrons, both single and coincident counts, produced by the radionuclides within the drum. The active measurement involves pulsing the drum with a burst of over one million 14 MeV neutrons from a Zetatron neutron generator and measuring prompt neutrons from the

activation process. The PAN data, when properly interpreted, provides an estimate of the mass of TRU radionuclides contained in the drum. The precision of the technique depends heavily on the method used to generate the calibration curve in the analysis software and depends on the mix of isotopes present in the waste drum. The PAN system has a lower limit of detection of approximately 1 mg of ^{239}Pu or ^{235}U and 10 mg for ^{240}Pu (and other spontaneous fission neutron emitting nuclides).

The Segmented Gamma Scanner (SGS) was purchased in 1989 from Canberra Industries and was installed in December, 1992. The equipment was developed at Los Alamos National Laboratory and the technology transferred to Canberra for production and sale. The SGS uses a single high purity germanium-lithium detector.

A transmission gamma source corrects for absorption and attenuation of gamma events in the waste matrix. A reference source is also incorporated to lock the energy spectrum obtained to a known energy peak to prevent drift. The gamma events detected are correlated in time and space and linked to the rotation of the drum.

The SGS method assumes that the waste is more homogeneous in the radial plane than in the vertical direction. The equipment performs discrete measurements on approximately 20 slices of a drum and sums them to obtain a total for the drum. The Ge(Li) detector has an energy resolution capability of better than 1.80 KeV. The system can measure all gamma energies. Detection limits were not available for this system.

The combination of the PAN data (provides mass data) and the SGS data (provides relative abundance data) allows the absolute mass of most radionuclides contained in the TRU drum to be determined to within 25%. Process knowledge as to what waste is in the drum, how it is layered and packaged, and what chemical separations process generated the waste stream is essential to correctly interpret the data and cannot be neglected.

Each of the three facilities had similar quality assurance (QA)/quality control (QC) programs for their characterization equipment. Primarily, the QA programs

consisted of calibrating the instruments either daily or before each use, then placing this data in archival storage. Procedures also involved in the QA/QC process include inspections, audits, control of nonconforming items, as well as corrective action.

c. Waste Streams

Waste streams, or the origin of the LLW, unique to each particular site were difficult to obtain. However, the Integrated Data Base/1992: US Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics gives waste forms commonly found on DOE sites. The following list is based on information provided by the Waste Management Information System:

- biological
- contaminated equipment
- decontaminated debris
- dry solids
- solidified sludge

The waste streams found on INEL were available in a document that detailed their coding system used in characterizing LLW and TRU waste. This system assigns an item description code to each waste stream and is entered into computer prior to characterization process (RWMC-421, 1993). The following list gives the major waste streams on the INEL site:

- absorbed liquid
- benelex, plexiglas
- cemented sludges
- combustibles
- concrete, brick
- filters
- glass
- glovebox gloves
- metals
- mixed waste - paper, metal, glass, etc.
- nonmetal molds and crucibles
- other - mercury, fuel samples, etc.
- particulate waste
- precertified waste
- radioactive sources
- resins
- salts
- uncemented sludges

Each of these specific categories can be grouped under one of the broad categories found in the list published in the IDB, 1992.

d. Origins of WAC

The three DOE Sites surveyed are required to have documented waste acceptance criteria, according to DOE 5820.2A. These criteria specify what is acceptable and what is not acceptable in low-level and TRU waste that has been submitted for storage or disposal at a certified storage/disposal facility.

Waste acceptance criteria for these three sites, as well as the characterization facilities and equipment, were begun in support of the TRU waste permanent disposal facility, WIPP. The WAC requirements for each site were essentially those of WIPP. When DOE began requiring LLW to be managed according to DOE 5820.2A, the WIPP WAC were adapted to form WAC for LLW.

4. Differences of Classification Programs

a. Stage of Development (of Programs)

The three DOE sites, ORNL, SRS, and INEL, have very young LLW characterization/classification programs. ORNL developed and implemented a LLW certification plan in January of 1993. The development of this plan started in 1988 when DOE Order 5820.2A was issued. As of October of 1993, SRS had not yet implemented their program. The SRS WAC document had just been submitted for review. INEL supplemented their WAC for TRU waste to develop a WAC document for LLW.

b. Waste Categories

Waste acceptance criteria will define waste categories for a particular site. This is important in the classification process as this labeling will determine how and where the waste will be stored or disposed. This can be compared to the Class A, B, and C categories of 10CFR61.55. However, since there are no specified categories in DOE

5820.2A, each DOE site may name and define their own waste categories. While the categories are often close in definition, there are subtle differences in some instances that make waste management at each site unique. It is essentially a difference in semantics.

SRS On the Savannah River Site, LLW is segregated into a higher activity fraction, intermediate-level waste onsite, and a lower activity fraction, low-level waste onsite. Intermediate-level waste is low-level waste that has a dose rate of greater than or equal to 200 mR/hr at 3 inches from the surface of an unshielded container. Low-level waste is anything below intermediate-level.

Low-level waste is further divided for purposes of vault storage. The three types consider tritium contamination. The intermediate-level waste is separated into tritium and nontritium fractions. The low-level waste onsite must not contain tritium waste. A separate concrete vault has been designed for disposal of each of the waste types.

The SRS deviates from the definition given in the Order for TRU waste. Any waste package on the Site containing greater than or equal to 10 nCi/g (the Order gives 100 nCi/g) of transuranics is defined as TRU waste. So, waste containing less than 10 nCi/g of transuranics is packaged and disposed of as low-level waste.

ORNL ORNL recognizes eight categories:

Contact-handled (CH) SLLW (compactible and noncompactible) - ≤ 200 mrem/hr at the surface of an unshielded container

Remote-handled (RH) SLLW - > 200 mrem/hr at the surface of an unshielded container

Fissile Waste Material - solid waste that contains the isotopes ^{233}U , ^{235}U , ^{238}Pu , ^{239}Pu , ^{241}Pu , and/or the elements Np, Am, Cm, Bk, Ca

Asbestos Waste - LLW that contains commercial asbestos or asbestos material

Very Low Activity Waste - waste that contains no measurable contamination by radiation survey, but judged by ORNL because of its past history and inaccessible areas, to be possibly radioactively contaminated above free release limits

Naturally Occurring and Accelerator Produced Radioactive Material (NARM)

TRU Waste - containing transuranic radionuclides ($Z > 92$) with half-lives greater than 20 years and concentrations > 100 nCi/g at time of assay

INEL INEL recognizes the following categories of radioactive waste:

TRU waste - radioactive waste containing transuranic elements with half-lives greater than 20 years and at concentration of 100 nCi/g

Mixed TRU waste - TRU waste combined with hazardous materials as defined in RCRA

Alpha-low level waste (LLW) - radioactive waste containing alpha emitting radionuclides at a concentration less than or equal to 100 nCi/g

Mixed alpha-LLW - alpha-LLW combined with hazardous materials as defined in RCRA

Contact-handled (CH) waste - LLW that has a dose rate measurement of 200 mrem/hr or less on the surface of an unshielded container

Remote-handled (RH) waste - LLW that has a dose rate measurement of greater than 200 mrem/hr on the surface of an unshielded container

c. WAC Requirements

Documented waste acceptance criteria (WAC) are required for all DOE sites. The three sites surveyed all had similar areas of concern, such as acceptable waste characteristics, excluded waste materials, waste categories, and documentation requirements. However, each program studied was organized differently and definitions often varied.

ORNL At Oak Ridge National Laboratory the Waste Minimization, Planning, and Certification Department (WMPC) is responsible for developing the WAC for the disposal/storage facilities at ORNL to ensure that the radioactive solid waste is disposed of in a manner that meets DOE, State of Tennessee, Martin Marietta Energy Systems, Inc., and ORNL requirements. Since the implementation of the plan, WMPC provides the planning, organizing, and controlling activities relating to the certification of solid radioactive waste packages against the requirements set forth in the WAC documents.

The organization of responsibilities within the plan are divided among a Laboratory Certification Official (LCO), Generator Certification Officials (GCO), and Waste Generators. The LCO oversees the entire certification program for the Laboratory

and assesses the programs of the individual generators through inspections, audits, etc. The GCO must be appointed by all facilities or operations that generate SLLW. There are 103 GCO's at ORNL. The GCO must be present when waste is being packaged and certifies by signature that the waste is properly classified and packaged. A Waste Generator is any individual, program, or organization whose activities result in the production of SLLW. The waste generator's organization has the responsibility to develop and implement specific waste certification plans for their individual waste streams that are consistent with and complementary to this WAC. These plans are reviewed and approved by the LCO.

Waste acceptance criteria at ORNL are written for disposal sites as well as by types of radioactive waste. The WAC presently in use is written for Solid Waste Storage Area Number 6 (SWSA-6). SWSA-6 is the LLW storage site with remaining space. The WAC for SWSA-6 provides general WAC for the disposal site and then gives the WAC for each waste form.

Waste characterization information is used in the waste acceptance process to evaluate the waste characteristics against the WAC. Identifying the characteristics and constituents of a waste also identifies handling, treatment, storage, and storage requirements, options or restrictions. Generators are required, as part of ORNL's certification program, to ensure that wastes are segregated to avoid contamination across waste streams (WMRA-WMPC-203, 1993). Waste segregation and security of the waste containers after the characterization process is paramount to ensure that the integrity of the characterized waste is maintained.

ORNL also requires recharacterization of LLW after treatment by compaction, evaporation, or incineration. This is because certain waste characteristics will change as a result of treatment. The organization that treated the waste or contracted the treatment of the waste would become the generator of the "new" waste and would be responsible

for identifying in a WMPC approved waste management plan how the waste would be characterized to meet the WAC requirements.

SRS The Savannah River Site has recently developed and documented their waste acceptance criteria in the document, "Savannah River Waste Acceptance Criteria Manual" (WSRC-1S). WSRC-1S is a manual which is subdivided into procedures. These procedures consist of general requirements, responsibilities, and individual WAC's for disposal facilities on the Site. To comply with WSRC-1S, each hazardous and radioactive waste generator that delivers waste to SRS Treatment, Storage, and Disposal facilities is required to implement a quality assurance program plan, to be named a Waste Certification Program (WCP) (WSRC-1S, 1993). Each waste generator is required to establish waste acceptance criteria based on their own performance objectives. However, the generator must also account for the anticipated disposal facility waste acceptance criteria.

The Savannah River Site has also created the Waste Acceptance Criteria Certification (WACC) Department. This department is responsible for reviewing, assessing, and certifying, through a documented and approved method, each generator's waste. The SRS has generator certification officials (GCO) who are appointed to oversee compliance to the Waste Acceptance Criteria Program. A GCO is assigned to each waste generator, whether that be a single waste stream or a specified area of the Site. The GCO signs the disposal manifest stating that a waste package meets all applicable requirements of the disposal facility. If the WAC are not met, the GCO withholds waste shipment approval.

INEL INEL uses the Waste Isolation Pilot Plant waste acceptance criteria (WIPP-DOE-069, rev. 4) as the primary WAC document.

d. Major Radionuclides Present

From the perspective of curie amount, the most prevalent nuclides present on all three sites are fission products (i.e., Cs and Sr). However, at SRS and INEL there are operations unique to those particular sites that significantly impact each site's entire LLW management program. Due to tritium recycling and reloading activities at SRS, tritium is typical to the Site and affects LLW classification, categorization, and storage. For example, SRS has recently completed construction of below-ground vaults for tritium and nontritium LLW. Since INEL houses a large amount of TRU waste originally from Rocky Flats, much of their LLW is contaminated with alpha-emitting radionuclides. While INEL's SWEPP facility also supports LLW classification activities, it was built to characterize and classify TRU waste for WIPP. The ORNL is similar to West Valley in that it has a broad range of radioisotopes present in measurable amounts on-site.

5. Health Physics Issues

The health physics issues pertinent to LLW characterization and classification are primarily in the area of handling the LLW drums/packages. Interviews with radiological personnel from each site revealed that drum handlers do not receive a significant dose from the drums. ALARA practices were maintained to keep the radiation exposure to a minimum. For example, a LLW package labeled as contact-handled (CH) has a dose rate of ≤ 200 mrem/hr at the surface of the container. Packages exceeding that limit must be handled remotely. NDA assays are favorable from an ALARA standpoint. The RTR unit allows viewing and the SGS and PAN allow LLW assays without worker exposure to radioactive waste package contents.

IV. Recommendations

In order to have a complete, reliable LLW characterization and classification program, certain equipment and conditions are necessary. At present, West Valley is lacking in both of these areas. The department of Waste Management Engineering recognizes these deficits and has made attempts to correct the situation. However, operations at the Site are focused on completion of vitrification. So, funding and manpower are allocated for this operation. Recommendations for the upgrade of the WVDP LLW characterization/classification program come from conclusions drawn from this study.

Purchase two other necessary characterization instruments

The three essential pieces of equipment are the real-time radiography unit, the segmented gamma scanner, and the passive-active neutron detector. The RTR saves time and dose to workers. Therefore, it saves money. This instrument allows the individual to view the contents of drum or box without having to open the drum/box for examination. At ORNL, the RTR was often the only instrument used to verify classification. Due to a strict classification program that held generators accountable, documentation of process knowledge provided radiological and chemical analysis. The SGS and PAN will also allow characterization without disturbing the packaged waste. Currently, the TRU content (nCi/g) of a waste package at WVDP is estimated from the ^{241}Am value taken from the SGS. The ^{241}Am gamma energy is very low. The PAN would provide more reliable data.

House the instruments and perform NDA's in a separate building

At West Valley, the SGS is located in LAG storage with hundreds of LLW drums. This creates an environment with extremely high background, and the hpGe detector is a very sensitive instrument. Before West Valley ceased classification efforts, drums were assayed using the SGS in this building. The reliability of this data is questionable.

It is essential to house the characterization equipment and assay the drums in a separate facility or building. The three DOE facilities surveyed each had separate facilities that housed their characterization equipment. For example, at ORNL the GASP is located in the ETWAF building. This building is specifically for housing the waste characterization equipment. It is located on the perimeter of a disposal area and occasionally will hold up to ten LLW drums waiting to be assayed. These factors contribute to a slightly elevated background. However, the separate facility creates a more favorable environment for more accurate assay results. The WVDP LLW assay methodology should also include an intercomparison of the waste characterization methods. This would provide a cross check to verify that the characterization methods were providing consistent results.

Many of the problems that occurred with the PAN could be attributed to the same thing. When the machine was purchased, it was assembled in LAG storage. It was at this time that a large number of LLW drums were being moved into the building. Once the instrument was assembled, it was not able to be calibrated. It was taken apart and reassembled with more (polyethylene) shielding. However, this effort was also unsuccessful. The PAN was never operational.

Additional modifications to SGS

There are additional modifications that should be made to the SGS. The trolleys should be welded in place in the "closed" position. This would reduce almost completely the vibrations to the detector. The drums are loaded by forklift onto the platform. Padding should also be placed underneath the detector. The "control booth" should be arranged so that the operator can view the assaying procedures.

Develop a LLW classification program that includes GCO's and WAC

WVDP needs to develop and document waste acceptance criteria for each waste category and storage area. They should assign GCO's for each LLW generator that would be held accountable for characterization of that specific waste stream.

Start using supercompactor again

Finally, WVDP owns a supercompactor. It has not been used since 1990. This is an excellent means of volume reduction and should be utilized.

BIBLIOGRAPHY

10CFR §§61.50-61.59 (1992).

40CFR §191.02 (1991).

Public Law No. 96-368, "The WVDP Act of 1980" (1990).

Public Law No. 96-573, "Low-Level Radioactive Waste Policy Act of 1980" (1980).

DOE Order 5820.2A, Radioactive Waste Management (1988).

DOE/NE/44139-16, West Valley Demonstration Project Low-Level and Transuranic Waste Assay and Methodology, Charles W. McVay, March 1987.

DOE/NE/44139-30, Decontamination and Decommissioning of the West Valley Reprocessing Plant, H. F. Daugherty, R. Keel, November, 1986.

DOE/NE/44139-47, Supernatant Treatment System Design Through Testing, D. K. Ploetz, I. M. Leonard, December, 1988.

DOE/NE/44139-50, Low-Level Waste Cement Solidification Design, Installation, and Start-Up, G. R. Jezek, August, 1988.

DOE/NE/44139-62, Functional Description of the West Valley Demonstration Project Vitrification Facility, Ronald R. Borisch, Carol L. McMahon, July, 1990.

DOE/NE/44139-63, Design Characteristics of the Sludge Mobilization System, Carol L. MacMahon, September, 1990.

DOE/RW-0006, Rev. 8, Integrated Data Base for 1992: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics (IDB), October, 1992.

HK:86:0096, Radionuclide Content of Vitrification Feed, L. E. Rykken, July, 1986, unpublished.

SOP 9-2, Rev. 16, Solid Radioactive Waste Handling, W. A. Bridenbaker, September, 1991.

WVDP-019, Rev. 11, Annual Waste Management Plan, Daniel F. Burke, December, 1992.

WMRA-WMPC-203, Waste Acceptance Criteria for Radioactive Solid Waste Disposal at SWSA-6, January, 1993.

WSRC-1S, Savannah River Site Waste Acceptance Criteria Manual, February, 1993, unpublished.

WVNS-PCP-004, Rev. 2, Process Control Plan for Cement Solidification of Decontaminated Sludge Wash Liquid Using Portland Type V Cement, M. N. Baker, August, 1993.

RWMC-421, Rev. 2, EPA Hazardous Waste Codes Found in INEL Stored TRU Waste Content Codes, R. D. Falconer, June, 1993, unpublished.

Amir, Syed J., "Radioactive Waste Characterization," Proceedings: Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference, CONF-921137-PROC, March, 1993.

Bremen, Sherol, Buckner, Ted, Visocki, Kathryn, "1993: Where is the Low-Level Waste Going?," Proceedings: Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference, CONF-921137-PROC, March, 1993.

Cline, J. E., "Determination of Composition of Low-Level Radioactive Waste," Radioactive Waste Technology, eds. Herschel W. Godbee, Sue A. Hobart, A. Alan Moghissi, American Society of Mechanical Engineers: New York, 1986.

Duggan, Gregory J., Williams, R. Eric, Kudera, Don E., Bailey, David E., "Planned Revision to DOE Order 5820.2A, 'Radioactive Waste Management'," Proceedings: Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference, CONF-921137-PROC, March, 1993.

Jacobi, Lawrence R., LeMone, David V., "Radioactive Waste Reclassification," Waste Management '93: Technology and Programs for Radioactive Waste Management and Environmental Restoration, ed. Roy G. Post, vol. 1, WM Symposia, Inc., 1993.

Stelluto, Janis D., "Current and Future Economic Impacts of Onsite Storage: A National Perspective," Proceedings: Fourteenth Annual U.S. Department of Energy Low-Level Radioactive Waste Management Conference, CONF-921137-PROC, March, 1993.