A HISTORICAL LOOK AT NEVADA TEST SITE LOW-LEVEL WASTE DISPOSAL OPERATIONS

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ABSTRACT

The U.S. Department of Energy's National Nuclear Security Administration Nevada Site Office Environmental Management Program is charged with the responsibility to carry out the disposal of onsite and offsite defense-generated and research-related low-level radioactive waste at the Nevada Test Site. Core elements of this mission are ensuring that disposal take place in a manner that is safe and cost-effective while protecting workers, the public, and the environment.

The isolation protection and overall performance of the two low-level radioactive waste disposal facilities at the Nevada Test Site transcend those of any federal radioactive waste disposal site in the United States. The first of the two disposal sites is the Area 5 Radioactive Waste Management Site which is situated on alluvial fan deposits in the Frenchman Flat basin, approximately 770 feet (235 meters) above the water table. Area 5 utilizes a combination of engineered shallow land disposal cells and deep augured shafts for disposal of a variety of waste streams. These waste streams include high volume low-activity waste (3.2 million cubic feet [90,614 cubic meters] in fiscal year 2004), classified material, and high-specific-activity waste (including monoliths from Foster-Wheeler).

Fifteen miles (24 kilometers) north of Area 5 is the Area 3 Radioactive Waste Management Site located approximately 1,600 feet (488 meters) above the water table in Yucca Flat. Disposal activities in Area 3 center around the placement of bulk low-level radioactive waste in subsidence craters formed from underground testing of nuclear weapons. Native alluvium soil is used to cover waste placed in the disposal cells at both facilities.

This paper focuses on design of disposal units from historical slip trenches to present-day super-cells and the effects of radionuclide-activity on package selection and depth of disposal. In addition, technical attributes of the facilities established through the site characterization process will be further described. An update on current waste disposal volumes and capabilities will also be provided. This discussion leads to anticipated volume projections and disposal site requirements as the Nevada Test Site disposal operations look towards the future.

Historical Perspective

The first nuclear device was tested at the Nevada Test Site on January 27, 1951; effectively, the atmospheric test was the impetus for developing an onsite low-level radioactive waste disposal facility. Historical records indicate that as early as 1953, low-level radioactive waste generated by weapons testing activities was collected at a site in Area 5 of the Nevada Test Site. Further documentation identifies the cutting of the first trench, Sugar Bunker, into the alluvium at Area 5 in January 1961.

Following the construction of the Sugar Bunker trench, the Radiological Safety Division of Reynolds Electrical & Engineering Co., Inc. (REECo) published a proposal in July 1961 which recommended the consolidation of accumulated waste from around the Nevada Test Site into two locations; one of which is the Area 5 Radioactive Waste Management Site and the other in Area 12. Although no disposal site materialized in Area 12, the Area 5 Sugar Bunker trench became one of the major waste disposal locations for Nevada Test Site low-level radioactive waste.

Following the success of disposal operations in Area 5, an informal proposal prepared by REECo in January 1967 recommended the development and use of a large underground test subsidence crater in Area 3 (U3aus), as a "new below ground" site for consolidation of "abandoned radioactive waste in Areas 3, 6, and 11." A memorandum, dated March 27, 1968, approved the use of crater U3ax instead of the recommended crater U3aus (later used as a construction landfill) for the burial of non-classified radioactive waste, laying the foundation for the Area 3 Radioactive Waste Management Site, as it is known today. Records indicate that waste disposal began in cell U3ax on July 30, 1968. This disposal cell received relatively little waste volume until September 1976 when an increase in volume was experienced through November 1976 with bulk waste from cleanup of the Area 12, tunnels. Over 65,000 cubic feet (1,840.6 cubic meters) of waste was received during this period from one generator, nearly doubling the waste volume in that cell.

DISPOSAL FACILITIES ATTRIBUTES

Some of the same conditions that made the Nevada Test Site an ideal location for the testing of nuclear weapons also apply to the management of radioactive waste. The Area 5 and Area 3 Radioactive Management Sites are within the boundaries of the Nevada Test Site, an approximately 1,375 square mile (3,561 square kilometers) facility situated approximately 65 miles (104 kilometers) northwest of Las Vegas, Nevada. Access to the remotely located Nevada Test Site is restricted with additional protection provided by the buffer of U.S. Air Force and Bureau of Land Management property which surrounds it. In fact, the nearest population center

to the Area 5 Radioactive Waste Management Site is a rural community 24 miles (39 kilometers) to the southeast (Figure 1). The remoteness and the security of the radioactive waste management facilities provide protection to distant population centers and against unwanted intruders.

In addition to the favorable physical attributes, various environmental conditions add to the technical basis for the operation of disposal facilities. Both the Area 5 and Area 3 Radioactive Waste Management Sites are located in closed basins that are well above the water table at approximately 770 feet (235 meters) and 1,600 feet (488 meters), respectively. Recharge of the groundwater is not possible under current climate conditions since the average annual rainfall is four to six inches (10 to 15 centimeters) and evaporation exceeds rainfall by 12 times. This combination of extremely dry climate, deep groundwater, and thick alluvial soil with a high storage capacity for water severely limit the likelihood of any water migrating into the waste zone or groundwater.

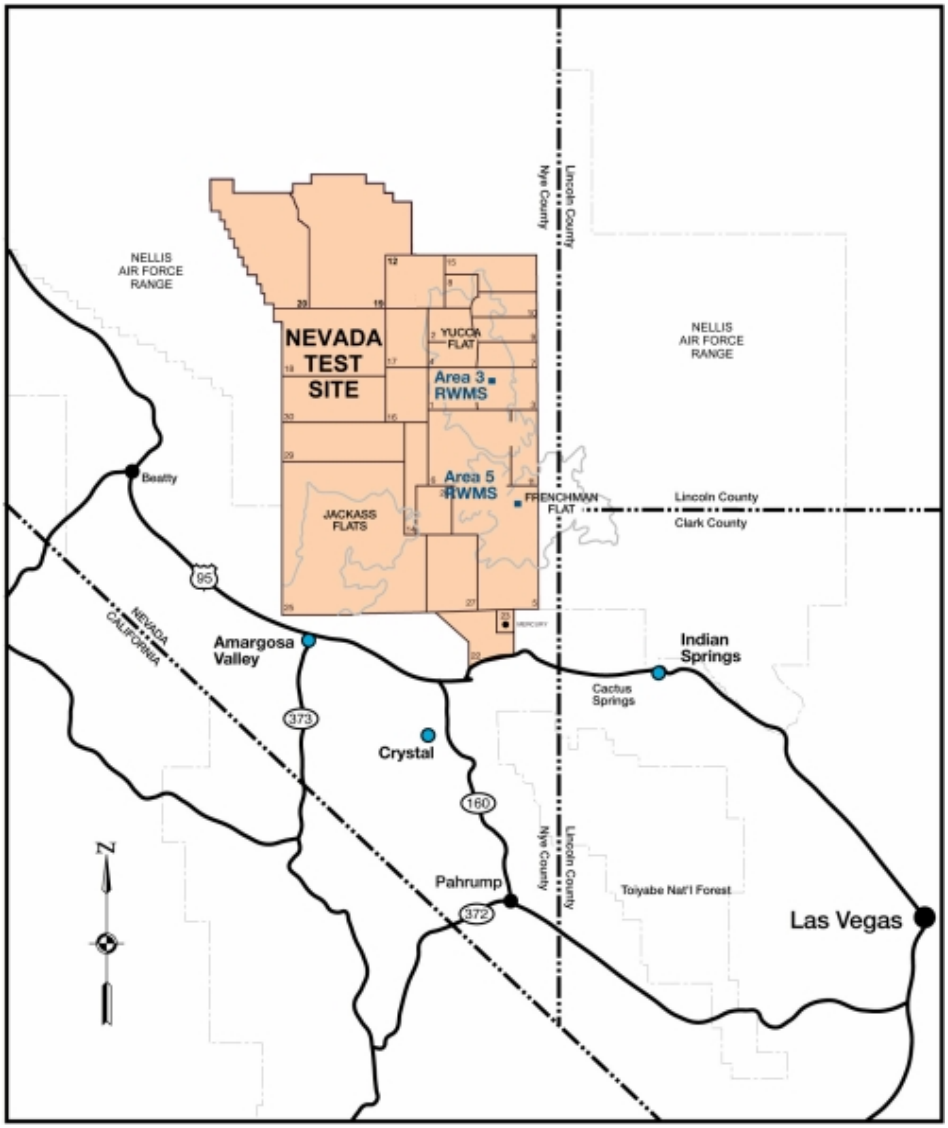

Fig. 1. Regional location of the Nevada Test Site and its disposal facilities

EARLY DISPOSAL PRACTICES

Waste disposed in Area 5 was recorded in a handwritten logbook and the records were typed and reported on a quarterly basis. Prior to 1963, these quarterly reports were the primary source of information on the waste received. Beginning in 1963, individual waste shipment records were used to document some of the key information from each shipment. This included the date received, origin of the waste, waste identification, type and number of each container, approximate volume, estimated activity in Curies, radiation levels at one foot, method of delivery, date of disposal, disposal location, and a section for remarks. A Radiation Monitor signed the waste shipment records. The form was changed again in the fall of 1963 to assist generators in estimating both the volume and the milli-Curies that the waste contained (by container), and provided a larger space for remarks. This "Radioactive Waste Disposal Record" was in use until 1978, when an electronic database replaced the paper records.

While early paper records were somewhat formalized, early waste emplacement practices were rudimentary; waste was simply unloaded into disposal cells. At the Area 5 disposal facility, it was common practice to unload the waste over the edge since early trenches were shallow excavations, usually no more than 15 feet (3 meters) deep. Once disposed in a cell, the exposed waste would be covered with soil.

Disposal practices at the Area 3 facility evolved differently since the 1967 proposal detailed the development of a spiral road into the crater; the placement, compaction, and covering of the waste; and the fencing and posting that are still used today.

The refining of disposal practices at Area 5 and Area 3 continue, particularly to accommodate the receipt of offsite-generated waste. In 1976, the first off-site generated low-level radioactive waste (from Mound Laboratories in Ohio) was disposed at the Nevada Test Site.

FORMAL PROGRAM

In 1978, the U.S. Department of Energy Nevada Operations Office (now the Nevada Site Office) formally established a managed low-level radioactive waste disposal project at the Nevada Test Site. The two sites already accepting waste for disposal were selected to house the Radioactive Waste Management Sites. The sites, located about 13 miles (21 kilometers) apart, afforded the Nevada Operations Office the opportunity to use at least two alternative technologies to effectively manage its disposal costs; engineered shallow-land disposal cells in Area 5 and converted subsidence craters created by the collapse of underground cavities caused by nuclear weapons testing in Area 3.

AREA 5 RADIOACTIVE WASTE MANAGEMENT SITE

There are 732 acres (296 hectares) available for low-level radioactive waste disposal in Area 5, of which approximately 140 acres (56 hectares) are currently used by Disposal Operations (Figure 2). The engineered disposal cells used for disposition of waste are excavated and, consequently, more expensive to develop than the subsidence craters used at Area 3. However,

Area 5 is the base of operations for disposal which makes it the preferred location for waste disposal.

Fig. 2. Area 5 Radioactive Waste Management Site at the Nevada Test Site.

Historically, the Area 5 disposal facility has been reserved for conventionally packaged waste in containers such as steel drums and 4 x 4 x 7 feet (1.2 x 1.2 x 2.1 meters) or 2 x 4 x 7 feet (0.6 x 0.6 x 2.1 meters) wooden and steel boxes. Other container sizes are accepted on a case-by-case basis, such as the regulated asbestos cell that accepts 8 x 8 x 20 feet (2.4 x 2.4 x 6.1 meters) cargo containers. In addition, a specialized cell (Pit 11) was constructed to accommodate the Foster-Wheeler monoliths (Figure 3) and deeper cells were excavated to accommodate high-thorium low-level radioactive waste from Fernald, and the Defense Logistics Agency.

The Foster-Wheeler monoliths (Figure 3) and high-thorium low-level radioactive waste are examples of the variety of waste managed at Area 5 which includes low-level radioactive waste, mixed low-level radioactive waste generated within the state of Nevada, radioactively contaminated regulated asbestos, and classified materials. High specific-activity low-level radioactive waste was disposed in Greater Confinement Disposal boreholes at one time; however, this disposal option is not currently used.

Fig. 3. High-activity low-level radioactive waste monolith from Foster-Wheeler is positioned for disposal in cell 11 at the Area 5 Radioactive Waste Management Site.

Nuclide-Specific Disposal

Tritium migration studies that were designed to evaluate disposal cell performance[1] were conducted and described four distinct areas where tritium transport from buried waste would be evaluated. The four areas were Trench T04U, where the 1976 tritium from Mound was buried; Pit P01U, the pit that received High-Specific Activity tritium in 1983; the Greater Confinement Disposal Test facility in 1984; and Greater Confinement Disposal boreholes from 1984 to 1987. These tests were designed to evaluate disposal techniques for highly mobile radionuclides. This was also the first attempt to develop waste stream specific low-level radioactive waste disposal options.

Greater Confinement Disposal

The Greater Confinement Disposal concept was conceived in 1980 when the "...National Low-Level Waste Management Program began to review alternatives to the shallow land burial of low-level radioactive wastes."[2] In 1981, this same national program and the U.S. Department of Energy Nevada Site Office began the Greater Confinement Disposal Test in the Area 5 Radioactive Waste Management Site. During the summer of 1984, 1,110.8 kilocuries of tritium, strontium-90, radium-226, and cesium-137 were emplaced in a 10-foot (3-meter) diameter hole at depths from 70 to 110 feet (21 to 34 meters) deep.[3] Twelve additional boreholes were excavated during the years following the Greater Confinement Disposal Test, and the concept was used for both classified and unclassified material. Disposal of radioactive waste in the Greater Confinement Disposal boreholes ceased in the late 1980's as a result of the state of Nevada classifying the boreholes as Class IV underground injection wells which are prohibited

under the U.S. Environmental Protection Agency's Safe Drinking Water Act. That classification remains controversial.

Alpha-Contaminated Low-Level Radioactive Waste

Between 1974 and 1989 the Nevada Test Site received transuranic waste from Lawrence Livermore National Laboratory which was placed into interim storage at the Area 5 Radioactive Waste Management Site. During this period, the definition of transuranic waste changed from 10 nano-curies per gram to 100 nano-curies per gram[4] resulting in a 1988 re-evaluation of transuranic waste in storage at the Nevada Test Site. At least eight boxes of waste were declared non-transuranic and disposed as alpha-contaminated low-level radioactive waste.

Mixed Low-Level Radioactive Waste

The Nevada Test Site began receiving mixed low-level radioactive waste in 1988 under Interim Status as authorized by the State of Nevada. All of the mixed low-level radioactive waste was placed in Pit 3 (P03U). The U.S. Department of Energy's Rocky Flats facility in Colorado shipped 283,105 cubic feet (8,016.64 cubic meters) of mixed low-level radioactive waste until 1990 when the State of Nevada imposed restrictions. Since then, small quantities of mixed low-level radioactive waste have been received only from U.S. Department of Energy waste generation activities within the state of Nevada. The total mixed low-level radioactive waste received, as of the end of fiscal year 2004, is 299,934 cubic feet (8,493 cubic meters).

Thorium Waste

Fernald shipped approximately 1,600 55-gallon (208-liter) drums of high-specific-activity thorium waste to the Nevada Test Site in 1992 which were disposed in T03U. Performance assessment calculations determined that the conventional burial depth (22 feet [6 meters])) was inadequate for this material. Based upon this determination, it was decided to relocate this thorium waste and dispose it at a greater depth (48 feet [14 meters]) in P06U. The waste was relocated with the new disposal location coordinates and the date of disposal was updated in the Low-Level Waste Information System database.

Asbestos Waste

As the result of a data call to all Nevada Test Site generators, it was determined there was a complex-wide need to dispose large volumes of radioactively contaminated asbestos. Since asbestos is a State of Nevada regulated material, a permit application was submitted to the State along with a cell design and operating plan. The State granted the permit and, in September 1997, the first shipments of asbestos were received from the U.S. Department of Energy's Fernald facility in Ohio and placed into P07U. Upon filling of P07U, the asbestiform waste permit was extended and asbestiform is currently disposed in P06U (above the thorium waste).

Remote-Handled Waste

As the clean up of the U.S. Department of Energy Complex continued, more difficult waste

streams were encountered, including high-activity wastes. Special handling techniques were developed to segregate these disposal activities from the contact-handled waste. New waste stream specific cells (such as Pit 11 in Area 5) were developed once the available space in larger cells was exhausted.

AREA 3 RADIOACTIVE WASTE MANAGEMENT SITE

Remote-Handled low-level radioactive waste was also disposed at the Area 3 Radioactive Waste Management Site (Figure 4) which covers 120 acres (49 hectares). This location is used primarily for the disposal of bulk low-level radioactive waste which is placed in subsidence craters formed by underground nuclear weapons testing. Of the approximately 800 subsidence craters on the Nevada Test Site, the seven (7) in Area 3 were selected to serve as disposal cells because the nuclear devices that created them were all emplaced above the water table. This criterion was chosen to ensure that no preferential pathway would be available to the underlying aquifers.

Fig. 4. Area 3 Radioactive Waste Management Site at the Nevada Test Site.

Between 1974 and 1992, the Area 3 facility evolved into the preferred location for bulk waste disposal. This resulted in the expansion of U3ax into an adjoining crater (U3bl) by excavating the "saddle" of soil separating the craters and using it as fill material between the tiers of waste. This process was repeated with craters U3ah and U3at, creating cell U3ah/at. Both disposal cells were used for the disposal of atmospheric test debris collected from fenced-off areas around Nevada Test Site between fiscal year 1983 through fiscal year 1990.

CURRENT DISPOSAL PRACTICES

When disposal operations became a managed project, the process at Area 5 changed to a stacked configuration that provided better utilization of the available space. Soon after, cell designs changed and the cells became deeper to accommodate a thicker operational cover. Today, waste containers are stacked one upon the other in a stair step configuration, until the stack is four feet below the top of the cell walls.

The disposal process at Area 3 also began to differ significantly in cell U3ah/at following the closure of U3ax/bl in 1988. Smaller packages were replaced with larger bulk-sized packages such as cargo containers, large pieces of equipment, super sacks or soils in lined dump trailers (referred to as "burrito wraps"). Instead of stacking the waste in a single monolith configuration, waste is disposed in layer-cake geometry with each layer of waste covered by a layer of compacted soil ranging from 1 to 3 feet (0.3 to 0.9 meters) in depth. This method of disposal continues today.

Disposal processes at both sites were factors in the development of waste acceptance criteria which required all packages accepted for disposal to meet the U. S. Department of Transportation performance based packaging requirements. With the exception of cargo containers, the Nevada Test Site Waste Acceptance Criteria currently requires all boxes to meet a 3,375-pound/square foot (16,478-kilograms/square meter) compressive strength test. This strength criterion in conjunction with the stacking configuration ensures integrity of the waste packages on the bottom which support in excess of 60,000 pounds (27,000 kilograms) of loading.

Waste emplacement processes and cell design are two of the several changes Disposal Operations made over time to accommodate specific waste streams. Some modifications were driven by needs of the U.S. Department of Energy complex. Other design changes reflected Performance Assessment requirements or changes to enhance worker protection, including package performance.

PERFORMANCE ASSESSMENT

Performance Assessment studies are used to demonstrate the U.S. Department of Energy's commitment to protect the public, workers, and the environment. The Nevada Site Office has been a leader in the development of probabilistic performance assessments to quantify uncertainty and aid in facility management. The Low-Level Waste Project at the Nevada Test Site enforces this protectiveness by meeting the disposal performance objectives outlined in U.S. Department of Energy Order 435.1 and Manual 435.1-1 for 1,000 years after closure and at 328 feet (100 meters) away. Table I shows that both the Area 5 and Area 3 Radioactive Waste Management Sites are well below these performance objectives.

Table I. Performance Assessment Results for the Area 5 and Area 3 Radioactive Waste Management Sites.

Performance Objective	25 millirem/year All Pathway	10 millirem/year Air Pathway	Radon Flux (20 pico-Curies per square meters/second)	Chronic Intruder <100 millirem/year	Groundwater Protection
Area 5	.09	8.0 E-5	0.6	4	No surface water resources and no ground water pathway
Area 3	4.0 E-5	3.0 E-5	1.0 E-2	4.0 E-2	
NOTE: Mean estimates for performance objectives; based on disposed inventory (through 2004) and projected to closure.					

DISPOSAL ACCESS

During the 1990's there were 15 U.S. Department of Energy sites across the United States who were approved to ship low-level radioactive waste to the Nevada Test Site. That number would eventually increase when the Waste Management Programmatic Environmental Impact Statement Record of Decision for Disposal of Low-Level Radioactive Waste and Mixed Low-Level Radioactive Waste was issued on February 25, 2000. The record of decision identified the Nevada Test Site as one of two regional disposal sites and made it possible to approve additional generator sites.

Today, the Nevada Test Site receives low-level radioactive waste from 29 generators consisting of: Aberdeen Proving Grounds; Argonne National Laboratory, East; Bechtel BWXT Idaho; Bechtel BWXT-Y12; Bechtel Jacobs, Oak Ridge Reservation; Bechtel Nevada; Boeing North American-Rocketdyne; British Nuclear Fuels Limited, Inc., Oak Ridge; Defense Logistics Agency; Fernald Environmental Management Project; Foster-Wheeler, Oak Ridge; General Atomics; Honeywell, Kansas City; Lawrence Livermore National Laboratory; Lovelace Respiratory Research Institute; Mound Plant; Nuclear Fuel Services; Paducah Gaseous Diffusion Plant; Pantex Plant; Portsmouth Gaseous Diffusion Plant; Princeton Plasma Physics Laboratory; Reactive Metals Incorporated; Rocky Flats Plant; Sandia National Laboratories/California; Sandia National Laboratories/New Mexico; Savannah River Site; Stoller-Navarro Joint Venture; U. T. Battelle, Oak Ridge; and the West Valley Demonstration Project. Approval for three additional generators, Perma-Fix, Brookhaven National Laboratory, and Los Alamos National Laboratory are pending at this time.

Generators obtain approval to ship to Nevada Test Site by undergoing a rigorous process to certify their compliance to Nevada Test Site Waste Acceptance Criteria (NTSWAC). This process includes developing a site-specific NTSWAC-compliant program and undergoing an on-site audit of the program by Nevada Test Site Radioactive Waste Acceptance Program personnel. Once a generator is approved, each low-level radioactive waste stream it intends to ship to the Nevada Test Site must be profiled and submitted for approval to the Radioactive Waste Acceptance Program. This ensures that the specific low-level radioactive waste stream meets the NTSWAC before it is shipped to the Nevada Test Site.

Although the Nevada Test Site was identified as a regional disposal site for low-level and mixed low-level radioactive waste, only Nevada Site Office mixed low-level radioactive waste generated within the state of Nevada is currently accepted.

PRESENT AND FUTURE CAPABILITIES FOR WASTE DISPOSAL

Currently, there are 31 disposal cells (8 active) located at the Area 5 Radioactive Waste Management Site, not including the Greater Confinement Disposal boreholes. The cells range in size from 83 to 1,133 feet (25 to 345 meters) long, 30 to 336 feet (9 to 102 meters) wide, and 8 to 48 feet (2.4 to 15 meters) deep. The total disposed volume of waste in these cells is approximately 12.0 million cubic feet (340,000 cubic meters). Available open capacity at Area 5, in existing cells, is approximately 5.6 million cubic feet (160,000 cubic meters). This includes

the 706,000 cubic feet (20,000 cubic meters) being proposed for offsite-generated mixed low-level radioactive waste disposal. One new cell with a capacity of 1.9 million cubic feet (54,375 cubic meters) will be constructed in fiscal year 2005. No master plan currently exists for the layout of future cells across the total 732 acres (296 hectares). However simple calculations based upon existing inventory for the 140 acres (56 hectares) show that the current capacity averages 161,000 cubic feet of waste per acre (4,572 cubic meters per 0.4 hectares) of available ground. Extrapolation of this calculation for the total 732 acres (296 hectares), taking no credit for future technology, such as deeper cells, shows the total capacity of Area 5 Radioactive Waste Management Site is about 116.5 million cubic feet (3.3 million cubic meters).

The current inventory of disposed waste in the five cells (seven craters) at the Area 3 Radioactive Waste Management Site is more than 19 million cubic feet (540,000 cubic meters). Open capacity available in the two developed cells is estimated to be approximately 4.5 million cubic feet (130,000 cubic meters). The two remaining craters, which at the present time are assumed to be individual cells, represent an estimated combined available future capacity of 7 million cubic feet (200,000 cubic meters).

In the five year period covering fiscal years 2000 through 2004, the Nevada Test Site has annually received on average 1,594 shipments of low-level radioactive waste representing 2,234,860 cubic feet (63,293 cubic meters) of waste from as many as 24 of the 29 approved waste generators. This volume of waste has been transported, received, and disposed safely with minimal risk to the general public, the workers, and the environment.

A conservative calculation of total remaining disposal capacity at the Nevada Test Site is about 128 million cubic feet (3.6 million cubic meters). This does not consider expansion into undesignated land surrounding the Area 5 Radioactive Waste Management Site or the inclusion of additional subsidence craters adjacent to the Area 3 Radioactive Waste Management Site.

The question of when Nevada Test Site may reach its disposal capacity is dependent on the volume of waste received. Using 1,607,110 cubic feet (45,514 cubic meters) of waste received per year it will take approximately 79 years for the Nevada Test Site Radioactive Waste Management Sites to reach capacity. Knowing that the waste volumes in the future will diminish as the U.S. Department of Energy completes cleanup of the weapons complex and that the 79-year estimate does not include expanding into undesignated areas or future technology, Nevada Test Site capacity is virtually unlimited.

CONCLUSION

The years of experience in waste management programmatic assessments and disposal operations, in conjunction with the remote location, superior physical attributes (depth to groundwater, arid environment) establish Nevada Test Site as one of the nation's premier low-level radioactive waste disposal facilities. The issuance of the Waste Management Programmatic Environmental Impact Statement for low-level radioactive waste, and an available capacity of over 128 million cubic feet (3.6 million cubic meters), make the Nevada Test Site low-level radioactive waste disposal facilities a keystone in the efforts to clean up and close U.S. Department of Energy sites across the complex. This is especially critical for those sites that are

unable to dispose of low-level radioactive waste at onsite facilities or unable to access a commercial facility. The continuing refinements and development of probabilistic performance assessment models for the facilities will further enhance the ability of the sites to provide the disposal needs required to accelerate cleanup across the complex.

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