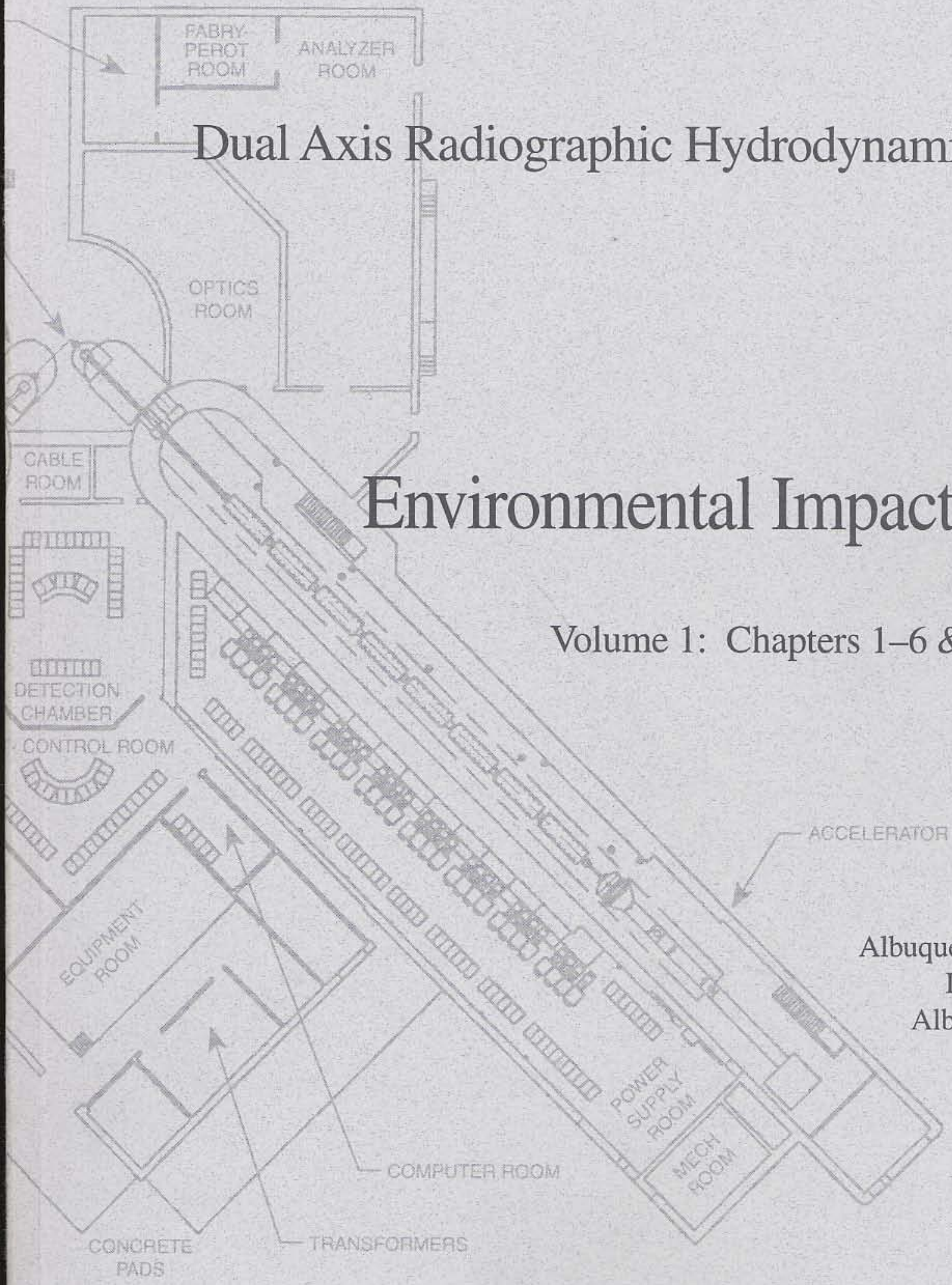
DOE/EIS-0228



Dual Axis Radiographic Hydrodynamic Test Facility

Final
Environmental Impact Statement

Volume 1: Chapters 1–6 & Appendixes A–K

Department of Energy
Albuquerque Operations Office
Los Alamos Area Office
Albuquerque, New Mexico

August 1995

Figur List First

Final Environmental Impact Statement (EIS), Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility (DOE/EIS-0228)

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Dear Reader:

This is your copy of the final Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility Environmental Impact Statement (EIS). The EIS analyzes the environmental impacts that might occur if the Department of Energy (DOE) were to complete and operate the proposed DARHT facility at the Department's Los Alamos National Laboratory (LANL) in northern New Mexico. The DOE has identified as its preferred approach for this project two concurrent courses of action: (1) completing and operating the proposed DARHT facility; and (2) implementing an enhanced containment strategy for testing at the DARHT facility so that most tests would be conducted inside of steel vessels, to be phased in over ten years. This would involve constructing and operating a vessel cleanout facility in addition to the DARHT facility.

The impacts that might occur from this proposal are weighed against the impacts of continuing to operate the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) hydrodynamic testing facility at LANL. The hydrodynamic testing facility at the Lawrence Livermore National Laboratory in California is also discussed. The EIS analyzes four other alternative means to operate the DARHT or PHERMEX facilities.

This EIS takes into account the Department's consideration of comments on the May 1995 draft EIS received from the State of New Mexico, American Indian Tribal governments, local governments, other federal agencies, and the general public. Additional mitigation measures have been developed to protect cultural resources of importance to local tribes, and federally-listed threatened species habitat. A complete set of the comments received, and our responses to them, are included in Volume II of the EIS.

We appreciate the time and assistance of everyone who reviewed the draft EIS and look forward to your continued interest as we reach our final decision on this proposal. For additional copies of this document or for more information on this environmental review, please contact Diana Webb, DARHT EIS Project Manager, DOE, Los Alamos Area Office, 528 35th Street, Los Alamos NM 87544, telephone (505) 665-6353, facsimile (505) 665-4872.

Sincerely,

Victor H. Reis

Assistant Secretary for Defense Program

Enclosure

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COVER SHEET

RESPONSIBLE AGENCY:

U.S. Department of Energy (DOE)

TITLE:

Final Environmental Impact Statement (EIS), Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility (DOE/EIS-0228)

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ABSTRACT:

DOE proposes to provide enhanced high-resolution radiographic capability for hydrodynamic tests and dynamic experiments to help meet its mission to ensure the safety and reliability of the Nation's nuclear weapons. The DARHT Facility would include two electron accelerators to produce x-ray beams that intersect at a firing point to produce radiographs of exploding or imploding material. This EIS evaluates the potential environmental impacts of six alternatives: **No Action** (continue to operate the 30-year old Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility at the Los Alamos National Laboratory (LANL) and the Flash X-Ray (FXR) Facility at the Lawrence Livermore National Laboratory; **DARHT Baseline** (complete and operate the DARHT Facility at LANL); **Upgrade PHERMEX** (upgrade PHERMEX with enhanced radiography technology instead of completing the DARHT Facility); **Enhanced Containment** (in addition to containing all experiments involving plutonium, enclose most or all experiments under one of three options: **vessel containment**, **building containment**, or **phased containment**, which is the preferred alternative); **Plutonium Exclusion** (exclude any applications involving experiments with plutonium at the DARHT Facility); and **Single Axis** (complete and operate only a single axis of the DARHT Facility). The affected environment is primarily within LANL. Analyses indicate very little difference in the environmental impacts among the alternatives. The major discriminator would be contamination of soils near the firing points, health effects to workers, and amount of construction materials.

DOE issued a draft EIS on May 12, 1995, and held a formal public comment period on the draft through June 26, 1995. Two public meetings were held during the comment period. Comments received and DOE's response to those comments, are found in the second volume of this EIS. The final EIS reflects DOE's consideration of public comments.

This EIS includes a classified supplement. The draft classified supplement was made available for review by appropriately cleared parties with a need to know the classified information.

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EXECUTIVE SUMMARY

On August 11, 1995, announcing his decision to seek a zero-yield Comprehensive Test Ban Treaty (CTBT), President Clinton stated:

_ "I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States."

_ "I am assured by the Secretary of Energy and the Directors of our nuclear weapons laboratories that we can meet the challenge of maintaining our nuclear deterrent through a science-based stockpile stewardship program without nuclear testing. I directed the implementation of such a program almost two years ago."

_ "The nuclear weapons in the United States arsenal are safe and reliable, and I am determined that our stockpile stewardship program will ensure they remain so in the absence of nuclear testing."

_ "While I am optimistic that the stockpile stewardship program will be successful, as President I cannot dismiss the possibility, however unlikely, that the program will fall short of its objectives. Therefore, in addition to the new annual certification procedure for the nuclear weapons stockpile, I am also establishing concrete, specific safeguards that define the conditions under which the United States can enter into a CTBT."

One of the safeguards which condition U.S. entry into a CTBT is:

_ "The conduct of a science-based stockpile stewardship program to ensure a high level of confidence in the safety and reliability of nuclear weapons in the active stockpile, including the conduct of a broad range of effective and continuing experimental programs."

(From Fact Sheet released by Office of the Press Secretary along with text of President Clinton's announcement)

The U.S. Department of Energy (DOE) proposes to provide enhanced high-resolution radiography capability for the purpose of performing hydrodynamic tests and dynamic experiments in support of the Department's historical mission and near-term stewardship of the nuclear weapons stockpile. This environmental impact statement (EIS) analyzes the environmental consequences of alternative ways to accomplish the proposed action. The DOE's preferred alternative for accomplishing the proposed action would be to complete and operate the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility at Los Alamos National Laboratory (LANL) in New Mexico and implement an enhanced approach to containing test materials in steel vessels, phased in over 10 years. In May 1995, DOE issued the draft EIS for review and invited comments from the State of New Mexico, affected American Indian tribes, county governments, other Federal agencies, and the general public. DOE has issued this final EIS to document the environmental consequences associated with the proposed action and alternatives and to respond to comments received on the draft EIS.

PURPOSE AND NEED

DOE is responsible for ensuring that U.S. nuclear weapons remain safe, secure, and reliable. The DOE program that responds to Presidential and Congressional direction to ensure confidence in the nuclear weapons stockpile is called the Stockpile Stewardship and Management (SS&M) Program (DOE 1995). This is an ongoing program that has evolved over time and whose goals are redirected from two former DOE programs: weapons research, development, and testing and stockpile support. Today's SS&M Program has moved away from DOE's past reliance on direct observations of nuclear tests toward ensuring weapons safety and reliability through a more challenging "science-based" approach to develop a greater scientific understanding of nuclear weapons phenomena and better predictive models of performance.

Historically, hydrodynamic tests and dynamic experiments have been a requirement to support the DOE's (and its predecessor agencies') mission; they remain essential elements of the SS&M Program and assist in the understanding and evaluation of nuclear weapons performance. Dynamic experiments are used to gain information on the physical properties and dynamic behavior of materials used in nuclear weapons, including changes due to aging. Hydrodynamic tests are used to obtain diagnostic information on the behavior of a nuclear weapons primary (using simulant materials for the fissile materials in an actual weapon) and to evaluate the effects of aging on the nuclear weapons remaining in the greatly reduced stockpile. The information that comes from these types of tests and experiments cannot be obtained in any other way.

DOE's existing capability to obtain diagnostic information was designed and implemented at a time when the Agency could rely on direct observations of the results of underground nuclear tests to provide definitive answers to questions regarding nuclear weapons performance. Without the ability to verify weapons performance through nuclear tests, some remaining diagnostic tools are inadequate by themselves to provide sufficient information. Accordingly, as the Nation moves away from nuclear testing DOE must enhance its capability to use other tools to predict weapons safety, performance, and reliability. In particular, DOE must enhance its capability to perform hydrodynamic tests and dynamic experiments to assess the condition and behavior of nuclear weapons primaries.

Although the current U.S. stockpile is considered to be safe and reliable, the existing weapons are aging beyond their initial design lifetimes and, by the turn of the century, the average age of the stockpile will be older than at any time in the past. To ensure continued confidence in the safety and reliability of the U.S. nuclear weapons stockpile, DOE needs to improve its radiographic hydrodynamic testing capability as soon as possible. Uncertainty in the behavior of the aging weapons in the enduring stockpile will continue to increase with the passage of time because existing testing techniques, by themselves, are not adequate to assess the safety, performance, and reliability of the weapons primaries. Should DOE need to repair or replace any age-affected components, retrofit existing weapons, or apply new technologies to existing weapons, existing techniques are not adequate to assure weapons safety and reliability. In an era without nuclear testing DOE believes that it is probable that the existing weapons will require these types of repairs or retrofits in the foreseeable future. DOE has determined that no other currently available advanced techniques exist that could provide a level of information regarding nuclear weapons primaries comparable to that which could be obtained from enhanced radiographic hydrodynamic testing.

In addition to weapons work, DOE uses its radiographic testing facilities to support many other science missions and needs to maintain or improve its radiographic testing capability for this purpose. Hydrodynamic tests and dynamic experiments are important tools for evaluating conventional munitions; for studying hydrodynamics, materials physics, and high-speed impact phenomena; and for assessing and developing techniques for disabling weapons produced by outside interests.

Along with other stockpile stewardship responsibilities, DOE has assigned a hydrodynamic testing mission to its two nuclear weapons physics laboratories, LANL and Lawrence Livermore National Laboratory (LLNL). The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) is the existing radiographic hydrodynamic testing facility at LANL and the Flash X-Ray (FXR) is the existing radiographic hydrodynamic testing facility at Site 300 at LLNL.

PHERMEX has been in continuous operation since 1963. In addition to major, full-scale hydrodynamic tests, PHERMEX is used for smaller types of experiments, such as high-explosive tests or tests requiring static radiographs. Although PHERMEX was state of the art in the 1950s when it was designed, it is no longer adequate. It cannot provide the degree of resolution, intensity, rapid time sequencing, or three-dimensional views that are needed to provide answers to current questions regarding weapons condition or performance. Even if this type of diagnostic information were not needed, PHERMEX might not remain a viable test facility over an extended time because of anticipated increasing difficulty in maintaining the facility.

FXR has been in continuous operation since 1983; it is DOE's most advanced radiographic hydrodynamic testing facility. Although FXR uses linear induction accelerator technology for high-speed radiography, it cannot provide the degree of resolution, intensity, or three-dimensional views needed to address current questions. Additionally, DOE does not perform dynamic experiments with plutonium at LLNL because the necessary infrastructure is not in place. Neither PHERMEX nor FXR is adequate to provide the enhanced radiographic hydrodynamic testing capability that DOE now needs in the absence of nuclear weapons testing.

EIS	Notice of Intent	Draft EIS	Final EIS	Record of Decision
DARHT EIS	Nov 94	May 95	Aug 95	Oct 95
LANL SWEIS	May 95	Apr 96	Dec 96	Mar 97
SS&M PEIS	Jun 95	Feb 96	Jul 96	Sep 96

Note: Dates are subject to change.

The Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility is proposed by DOE to acquire enhanced radiographic hydrodynamic testing capability. The DARHT Facility would consist of a new accelerator building with two accelerator halls, a firing point, and the associated support and diagnostic facilities. The firing point would be at the juncture of the x-ray beams produced by two electron beam accelerators oriented at right angles to each other to provide dual-axis, line-of-site radiographs. Construction of the DARHT Facility is about 34 percent complete, having been started under earlier environmental documentation. Construction is currently stopped under a U.S. District Court preliminary injunction issued on January 27, 1995, pending completion of this EIS and issuance of the Record of Decision.

DOE plans two other National Environmental Policy Act (NEPA) reviews regarding proposed actions at LANL related to the *Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility EIS* _ the *LANL Sitewide Environmental Impact Statement* (SWEIS) and the *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (PEIS).

PROPOSED ACTION AND ALTERNATIVES

DOE is proposing to provide enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of the Department's historical mission and near-term stewardship of the nuclear weapons stockpile. This EIS analyzes the following alternatives:

_ **No Action Alternative:** DOE would continue to use PHERMEX at LANL and the FXR at LLNL in support of its stockpile stewardship mission. Construction of the DARHT Facility would not be completed although the building would be completed for other uses. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

_ **DARHT Baseline Alternative:** DOE would complete and operate the DARHT Facility and phase out operations at PHERMEX. DOE may delay operation of the second axis of DARHT until the accele-rator equipment in the first axis is tested and proven. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

_ **Upgrade PHERMEX Alternative:** Construction of the DARHT Facility would not be completed although the building would be completed and put to other uses. Major upgrades would be constructed at PHERMEX, and the high-resolution radiographic technology planned for DARHT would be installed at

PHERMEX, including a second accelerator for two-axis imaging. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

_ **Enhanced Containment Alternative:** Three options are considered under this alternative: 1) the Vessel Containment Option, 2) the Building Containment Option, and 3) the Phased Containment Option (preferred alternative). This alternative is similar to the DARHT Baseline Alternative except that most or all tests would be conducted in a containment vessel or containment structure. All tests would be contained if a containment structure were used. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

_ **Plutonium Exclusion Alternative:** This alternative is similar to the DARHT Baseline Alternative except that plutonium would not be used in any of the experiments at DARHT. In the future, DOE may perform some dynamic experiments with plutonium. Those involving radiography would be conducted at PHERMEX and would be conducted in double-walled containment vessels.

_ **Single Axis Alternative:** This alternative is similar to the DARHT Baseline Alternative except that only one accelerator hall at DARHT would be completed and operated for hydrodynamic tests and dynamic experiments. The other hall would be completed for other uses. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

AFFECTED ENVIRONMENT

LANL occupies an area of approximately 28,000 ac (11,300 ha) on the Pajarito Plateau, in Los Alamos County in north central New Mexico. The alternatives analyzed (including no action) would all occur within Area III of Technical Area 15 situated in the south central portion of LANL, an area that has been dedicated to high explosives testing for over 50 years. The PHERMEX site and the DARHT site are about 1/2 mi apart and are ecologically similar, set in a ponderosa pine plant community. The only discriminators between the two sites are resources that are point-specific, such as specific archeological sites or specific existing facilities.

ENVIRONMENTAL CONSEQUENCES

The analyses in this EIS indicate that there would be very little difference in the environmental impacts among the alternatives analyzed. The major discriminator among alternatives would be potential impacts from depleted uranium contamination to soils and surface waters, which would be substantially less under the Enhanced Containment Alternative, and commitments of construction materials, which would be substantially greater under the Upgrade PHERMEX Alternative. Also, there is a projected increase in the estimated worker dose from radioactive materials under all options of the Enhanced Containment Alternative. This is a result of a potential increase in worker exposure to radiation as a result of vessel or building cleanout operations. Potential impacts from the use of plutonium would be essentially identical under all alternatives, with an extremely unlikely or incredible accident having consequences of up to 12 latent cancer fatalities in the exposed population. All tests using plutonium would be conducted using double-walled steel containment vessels. Likewise, impacts from the three options examined under the Enhanced Containment Alternative are similar to one another and often similar to the other alternatives. The Phased Containment (preferred alternative) and Vessel Containment options contain elements of both of the uncontained alternatives and elements of the Building Containment Option (representing full containment). Typically, the Phased Containment and Vessel Containment options have impacts that are more like the Building Containment Option than the uncontained alternatives. In general, the impacts from accidents involving single-walled containment vessels would be higher than those for uncontained tests, because the releases are more concentrated and are closer to the ground. Table S-1 presents a comparison of the environmental consequences for all alternatives analyzed in this EIS based on the assessments contained in chapter 5 of this EIS. The table provides direct comparisons of expected consequences for each environmental factor for the alternatives.

REGULATORY REQUIREMENTS

DOE has obtained operating permits for PHERMEX. The DARHT Facility (DARHT Baseline Alternative) has received septic tank permits, and cooling tower blowdown has been incorporated into the LANL Sitewide National Pollutant Discharge Elimination system permit. DOE has also received approval to construct from the Environmental Protection Agency under 40 CFR Part 61, Subpart A, regarding emissions of radionuclides from DOE facilities. Nonradioactive air emissions from DARHT would be covered by a LANL sitewide operating permit to be submitted to the New Mexico Environment Department (NMED) in late 1995. Emission of toxic air pollutants may require a permit from NMED. This is currently being evaluated. Permit modifications may be needed depending on the course of action selected in the Record of Decision.

DOE has consulted Federal, State, and Tribal agencies regarding wildlife habitat, threatened and endangered species, cultural resources protection, and other laws pertaining to Native American traditional use of land and resources. The U.S. Fish and Wildlife Service concurred with DOE that the construction and operation of DARHT would not be likely to adversely affect the Mexican spotted owl, a federally listed threatened species. DOE has committed to take appropriate mitigation measures to minimize impacts to cultural and natural resources; no adverse effects to cultural resources are expected.

Table S-1._*Summary of the Potential Environmental Impacts of the Alternatives*

Factor, Measure	**No Action**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative Single Axis Alternative**
				Vessel	**Building**	**Phased**		
Land Resources Acreage committed PHERMEX (ac) DARHT (including RSL) (ac)	11 8	11 8	11 8	11 9[a]	11 8	11 9[a]	11 8	11 8
Air Quality **Construction** Maximum percent of standard[b] NO$_2$ PM$_{10}$ SO$_2$ **Operations** Maximum percent of standard[b] NO$_2$ PM$_{10}$ SO$_2$ Be Heavy Metal Lead	1.6 5 1 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 0.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 2.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001
Noise (qualitative)	Possible nuisance	Possible nuisance	Possible nuisance	75% reduction	Nuisance unlikely	Possible nuisance, phasing to 75% reduction	Possible nuisance	Possible nuisance

Water Resources Depleted uranium contamination, % drinking water standard (after millennia)	<1	<1	<1	<0.1	<0.1	<0.1	<1	<1

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table S-1._*Summary of the Potential Environmental Impacts of the Alternatives _ Continued*

Factor, Measure	**No Action**	**DARHT Baseline** **Alternative**	**Upgrade** **PHERMEX** **Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion** **Alternative** **Single Axis** **Alternative**
				Vessel	**Building**	**Phased**		
Soils Depleted uranium contamination area (ac) Max. concentration (approx.) (ppm)	15 9,000	15 5,000	15 9,000	15 2,000	15 1,000	15 3,000	15 5,000	15 5,000

Biotic Resources Habitat reduction[c] (ac) Threatened, endangered and sensitive species Disturbance by noise	None None Some	None When mitigated, none Some	None None Some	1 When mitigated, none 75% reduction	1 None Near zero	1 When mitigated, none Some, phasing to 75% reduction	None When mitigated, none Some	None When mitigated, none Some
Cultural Resources (qualitative)	None	When mitigated, none	None	When mitigated, none	None	When mitigated, none	When mitigated, none	When mitigated, none
Socioeconomics (Annual impacts, 1996 to 2002) Employment (FTE) Regional labor income (millions) Regional goods & services (millions)	–[d] –[d] –[d]	191 $ 4.1 $ 6.8	199 $ 4.3 $ 6.9	321 $ 6.8 $ 12.0	238 $ 5.1 $ 8.4	253 $ 5.4 $ 9.0	273 $ 4.9 $ 8.6	104 $ 2.2 $ 3.8

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table S-1._***Summary of the Potential Environmental Impacts of the Alternatives _ Continued***

Factor, Measure	**No Action**	**DARHT Baseline** **Alternative**	**Upgrade** **PHERMEX** **Alternative**	**Enhanced Containment Alternative**		**Plutonium Exclusion** **Alternative** **Single Axis** **Alternative**

				Vessel	**Building**	**Phased**		
Human Health	7 x 10^{-4}	7 x 10^{-4}	7 x 10^{-4}	5 x 10^{-4}	5 x 10^{-4}	6 x 10^{-4}	7 x 10^{-4}	7 x 10^{-4}
Depleted Uranium	30	30	30	13	8	17	30	30
Public, 30-yr life of project	None	None	None	None	None	None	None	None
MEI dose (rem)	0.3	0.3	0.3	0.6	0.6	0.6	0.3	0.3
Population dose (person-rem)	9	9	9	60	60	60	9	9
Latent cancer fatalities	None	None	None	None	None	None	None	None
Workers, 30-yr life of project	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}	3 x 10^{-10}
Average dose (rem)	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}	3 x 10^{-7}
Collective dose (person-rem)	None	None	None	None	None	None	None	None
Latent cancer fatalities	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}	9 x 10^{-9}
Plutonium	None	None	None	None	None	None	None	None
Public, 30-yr life of project	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
MEI dose (rem)								
Population dose (person-rem)								
Latent cancer fatalities								
Noninvolved Workers, 30-yr life of project								
Collective dose (person-rem)								
Latent cancer fatalities								
Workers								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table S-1._*Summary of the Potential Environmental Impacts of the Alternatives _ Continued*

Factor, Measure	**No Action**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative** **Single Axis Alternative**
				Vessel	**Building**	**Phased**		
Facility Accidents	15	15	15	15	15	15	15	15
Involved workers, worst case	6 x 10^{-4}	6 x 10^{-4}	6 x 10^{-4}	1 x 10^{-2}	1 x 10^{-3}	1 x 10^{-2}	6 x 10^{-4}	6 x 10^{-4}
explosion related fatalities	1.9	1.9	1.9	17	1.7	17	1.9	1.9
Depleted Uranium	None	None	None	None	None	None	None	None
Public	7 x 10^{-4}	7 x 10^{-4}	7 x 10^{-4}	5 x 10^{-2}	5 x 10^{-3}	5 x 10^{-2}	7 x 10^{-4}	7 x 10^{-4}
MEI dose (rem)	76	76	76	76	76	76	76	76
Population dose (person-rem)	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Latent cancer fatalities	12	12	12	12	12	12	12	12
Noninvolved worker dose (rem)	160	160	160	160	160	160	160	160
Plutonium								
Public (95th percentile								
meteorology)								
MEI dose (rem)								
Population dose (person-rem)								
Latent cancer fatalities								
Noninvolved worker dose (rem)								
Transportation	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Workers, 30-yr life of project	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}
Dose (rem)	None	None	None	None	None	None	None	None
Public, 30-yr life of project								
Population dose, (person-rem)								
Latent cancer fatalities								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table S-1._*Summary of the Potential Environmental Impacts of the Alternatives _ Continued*

Factor, Measure	**No Action**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative Single Axis Alternative**
				Vessel	**Building**	**Phased**		
Waste Generated, Annual	9,400	9,400	9,400	9,400	9,400	9,400	9,400	9,400
Solid Sanitary Waste (ft^3)	310	310	310	310	310	310	310	310
(non-hazardous, non-radioactive)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Hazardous (lb)	1	1	1	1	1	1	1	1
Solid	12,500	12,500	12,500	3,600	360	5,700[e, f]	12,500	12,500
Liquid	2	2	2	2	2	2	2	2
Mixed Waste (55-gal drums)								
Low-Level Waste (ft^3)								
TRU Waste (tons) (steel vessels)								
Unavoidable Adverse Impacts	See soils	See soils	See soils	See soils	See soils	See soils	See soils	See soils

Irreversible and/or Irretrievable	15,000	15,000	28,000	16,000	22,000	16,000	15,000	15,000
Commitment of Resources	9,500	11,500	17,000	12,500	18,200	12,500	11,500	11,500
Construction	365	365	750	365	450	365	365	365
Concrete (yd^3)	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540
Diesel fuel (gal)	8,700	10,400	13,000	13,300	14,800	12,600[e, g]	10,400	10,400
Electricity (MWh)	550	2,250	2,500	2,600	2,900	2,500[e, g]	2,250	1,350
Operations	None	None	None	None	None	None	None	None
Depleted uranium (lb/yr)								
Natural gas (ft^3/yr)								
Electricity (MWh/yr)								
Long-term Productivity								
(qualitative)								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

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ACRONYMS AND ABBREVIATIONS

ac acre

ACO Access Control Office

ADM action description memorandum

AHF Advanced Hydrotest Facility

AIANAFP American Indian and Alaska Native Area

AIRFA American Indian Religious Freedom Act

Am americium

AMAD activity median aerodynamic diameter

AQCR Air Quality Control Regulation

As arsenic

Ba barium

Be beryllium

BEA Bureau of Economic Analysis

CCNS Concerned Citizens for Nuclear Safety

CEQ Council on Environmental Quality

CETC Contained Explosives Test Complex

CFR Code of Federal Regulations

CHIEF Clearinghouse Inventory of Emission Factors

Ci curie

Ci/g curie per gram

cm centimeter

cm^2 square centimeter

Co cobalt

CO carbon monoxide

CO_2 carbon dioxide

CPS current population survey

Cr chromium

Cs cesium

CTBT Comprehensive Test Ban Treaty

Cu copper

CX categorical exclusion

D&D decontamination and decommissioning

DAC derived air concentrations

DARHT Dual Axis Radiographic Hydrodynamic Test Facility, proposed to be operated at LANL

dB decibel

dBA A-weighted decibel

DCG derived concentration guides

DFAIC DARHT Feasibility Assessment Independent Consultants

DNAA delayed neutron activation analysis

DOD U.S. Department of Defense

DOE U.S. Department of Energy

DOE/AL DOE/Albuquerque Operations Office

DOI U.S. Department of the Interior

DOL U.S. Department of Labor

dose unless otherwise specified, means effective dose equivalent

DOT U.S. Department of Transportation

DU depleted uranium

DX dynamic experimentation

EDE effective dose equivalent

EES earth and environmental science

EIS environmental impact statement

EM environmental management

EPA U.S. Environmental Protection Agency

ES economic sectors

ESA Endangered Species Act

F fluorine

Fe iron

ft foot

ft^2 square foot

ft^3/min cubic feet per minute

ft^3 cubic foot

ft^3/s cubic feet per second

FIPS Federal Information Procedures System

FR *Federal Register*

FTE full time equivalent personnel

FXR Flash X-Ray Facility (located at LLNL)

FY fiscal year

g gram

G acceleration due to gravity (seismology)

g/L grams per liter

gal gallon

gal/mo gallon per month

gal/d-ft^2 gallons per day per square foot

gal/d-ft gallons per day per foot

gal/min gallons per minute

gal/min-ft gallons per minute per foot

h hour

H-3 tritium

ha hectare

HE high explosive

He-Ne laser helium-neon laser

HEPA high-efficiency particulate air (filter)

HFS hydrotest firing site

HI hazard index

HMX cyclotetramethylenetetranitramine

HNO_3 nitric acid

HPAIC Hydrotest Program Assessment Independent Consultants

HTO tritiated water

HVAC heating, ventilation, and air conditioning

I iodine

ICRP International Commission on Radiological Protection

IDLH immediately dangerous to life or health

in inch

in^2 square inch

in^3 cubic inch

INAA instrument neutron activation analysis

ITS Integrated Test Stand

kg/m^2 kilograms per square meter

kg kilogram

kg/yr kilograms per year

kJ kilo Joule

km/h kilometers per hour

km kilometer

km^2 square kilometers

kPa kilopascal

kV kilovolt

kW kilowatt

kWh kilowatthour

kWh/gross ft^2 kilowatthour per gross square foot

kWh/gross m^2 kilowatthour per gross square meter

L liter

LAAO Los Alamos Area Office

LAMPF Los Alamos Meson Physics Facility

LANSCE Los Alamos Neutron Science Center

lb pound

lb/yr pounds per year

lb/in^2 pounds per square inch

LCF latent cancer fatalities

LiH lithium hydride

LiOH lithium hydroxide

LLNL Lawrence Livermore National Laboratory

LLW low-level radioactive waste

m meter

m^2 square meter

m^3/s cubic meters per second

m^3 cubic meter

MCL maximum contaminant level

MCLG maximum containment level guideline

MEI maximally exposed individual

MEPAS Multi-media Environmental Pollution Assessment System

MeV million electron volt

mg milligram

mg/L milligram per liter

mi mile

mi/h miles per hour

mi^2 square mile

micron micrometer (10^{-6} meter)

mL milliliter

mrem millirem (1/1000 rem)

mrem/yr millirem per year

MSDS material safety data sheets

MTF memorandum to file

mV millivolt

NA not applicable

NAAQS National Ambient Air Quality Standards

nCi/L nanocurie per liter

NCRP National Council on Radiation Protection and Measurements

NEPA National Environmental Policy Act

NESHAP National Emission Standards for Hazardous Air Pollutants

ng/dry g nanograms per gram of dry sample weight

ng/m^3 nanograms per cubic meter

Ni nickel

NIPA national income and product accounts

NMDGF New Mexico Department of Game and Fish

NMED New Mexico Environment Department

NO_2 nitrogen dioxide

NOI Notice of Intent

NPDES National Pollutant Discharge Elimination System

NRHP National Register of Historic Places

NSC National Security Council

nsec nanosecond

NTS Nevada Test Site

NTU nominal turbidity units

ODS ozone depleting substances

OSHA Occupational Safety and Health Act or Occupational Safety and Health Administration

OU operable unit

P phosphorus

Pb lead

PCB polychlorinated biphenyls

pCi/dry g picocuries per gram of dry sample

pCi/L picocuries per liter

pCi/mL picocuries per milliliter

PDL public dose limit

PEIS programmatic environmental impact statement

person-rem unit collective population dose

PETN pentaerythritoltetranitrate

PFS PHERMEX Firing Site

pg/m^3 picograms per cubic meter

PHERMEX Pulsed High Energy Radiation Machine Emitting X-Rays Facility (located at LANL)

PM particulate matter

ppb parts per billion

PPE personal protective equipment

ppm parts per million

PSD prevention of significant deterioration

Pu plutonium

R/pulse roentgen per pulse

R roentgen

rad unit of absorbed dose

RCRA Resource Conservation and Recovery Act

RDX cyclotrimethylenetrinitramine

rem/yr common unit of effective dose equivalent rate

RF radio frequency

ROD Record of Decision

ROI region-of-interest

RPC regional purchasing coefficient

RSL Radiographic Support Laboratory, located at LANL

Se selenium

SF_6 sulfur hexafluoride

SIC Standard Industrial Classification

SO_2 sulfur dioxide

Sr strontium

SS&M stockpile stewardship and management

SST safe secure transport

SVOC semivolatile organic compound

SVR standard visual range

SWEIS site-wide environmental impact statement

T_2 two chemically bound tritium atoms

Ta tantalum

TA technical area

TATB triaminotrinitrobenzene

TCLP Toxicity Characteristics Leaching Procedure

TES threatened, endangered, and sensitive (species)

Th thorium

Tl thallium

TLD thermoluminescent dosimeters

TLV threshold limit value

TNT trinitrotoluene

TRU transuranic

TU tritium units

U uranium

USFWS United States Fish and Wildlife Service

V vanadium

W tungsten

WCFS Woodward-Clyde Federal Services

WIPP Waste Isolation Pilot Plant

WSS weapons stockpile stewardship

yd^3 cubic yard

yr year

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CHAPTER 1

INTRODUCTION

This chapter outlines the environmental review for the *Dual Axis Radiographic Hydrodynamic Test Facility Environmental Impact Statement*.

Important Terminology

Stockpile Stewardship and Management Program _ DOE's single, highly integrated technical program for maintaining the safety and reliability of the U.S. nuclear stockpile in an era without nuclear testing and without new weapons development and production. To meet these requirements, a "science-based" program is being developed to increase understanding of the basic scientific phenomena associated with nuclear weapons.

Dynamic Experiment _ An experiment to provide information regarding changes in materials under conditions caused by the detonation of high explosives.

Hydrodynamic Test _ A dynamic, integrated systems test of a mock-up nuclear package (figure 1-2) during which the high explosives are detonated and the resulting motions and reactions of materials and components are observed and measured. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid).

Hydrodynamic Testing Facility _ A facility in which to conduct dynamic and hydrodynamic testing for nuclear and conventional weapons research and assessment. Fast diagnostic systems that are available include radiographic, electrical, optical, laser, and microwave. The testing can provide both two- and three-dimensional information for performance evaluation.

Enhanced Radiography _ A capability for producing extremely high-resolution, time-phased, photographic images of an opaque object by transmitting a beam of x-rays (or gamma rays) through it onto an adjacent photographic film; the image(s) results from variations in thickness, density, and chemical composition of the object.

1.1 OVERVIEW

The U. S. Department of Energy (DOE) proposes to provide enhanced high-resolution radiography capability to perform hydrodynamic tests and dynamic experiments in support of its historical mission and near-term stewardship of the nuclear weapons stockpile. This environmental impact statement (EIS) analyzes the environmental impacts of alternative ways to accomplish the proposed action. The DOE's preferred alternative would be to complete and operate the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility under the Phased Containment Option (a new option since the draft DARHT EIS) of the Enhanced Containment Alternative at its Los Alamos National Laboratory (LANL) in northern New Mexico. An artists' concept of the DARHT Facility is shown in figure 1-1.

This EIS has a classified supplement that provides additional information and analysis. Although the details of a nuclear weapon are classified, figure 1-2 provides an unclassified summary of a nuclear weapon.

DOE began the preliminary design for DARHT in the early 1980s and conducted a series of environmental reviews for the project between 1982 and 1989. DOE concluded that no significant environmental impact should result from constructing and operating the facility. Funding for DARHT was authorized and appropriated by Congress in 1988. Construction of the DARHT Radiographic Support Laboratory began in 1988 and was completed in 1990. In 1993, DOE decided to fund the accelerator and x-ray equipment for the second axis of DARHT under a separate budget line item. Construction of the actual DARHT Facility began in April 1994.

In October 1994, three citizen groups wrote to the Secretary of Energy requesting, among other things, that DOE prepare an EIS on the DARHT Facility. They also requested that further construction of the facility be halted until an EIS was completed. On November 16, 1994, two of these groups (the Los Alamos Study Group and the Concerned Citizens for Nuclear Safety) filed a lawsuit in U.S. District Court, Albuquerque, New Mexico, to enjoin DOE from proceeding with the DARHT project until completion of the EIS and issuance of the Record of Decision (ROD). On November 22, 1994, DOE published a *Federal Register* notice of its intent to prepare this DARHT EIS [59 FR 60134]; see appendix A. On January 27, 1995, the court issued a preliminary injunction enjoining DOE from further construction of the DARHT Facility and related activities, such as procuring special facility equipment, pending completion of this EIS and the related ROD. The court entered a final judgment on May 5, 1995. Figure 1-3 is a photograph of the DARHT site, taken in May 1995, showing the condition of the DARHT Facility at the time of construction shutdown and when the site was secured in a standby condition. No construction has taken place since January 27, 1995.

Preparing an EIS at this time responds to public concern and allows for a full dialogue between DOE and the State, Tribal, county, and municipal governments; other Federal agencies; and the general public. The EIS will also provide the basis for appropriate mitigation measures, if needed, for the course of action selected.

1.2 ORGANIZATION OF THIS EIS

This EIS consists of six chapters.

_ **Chapter 1 _ Introduction**: DARHT background and the environmental analysis process.

_ **Chapter 2 _ Purpose and Need**: reasons why DOE needs to take action at this time.

_ **Chapter 3 _ Proposed Action and Alternatives**: the way DOE proposes to meet the specified need and alternative ways the specified need could be met. This chapter includes a summary of expected environmental impacts if any of the alternatives analyzed in this EIS were to be implemented.

_ **Chapter 4 _ Affected Environment**: aspects of the human environment (natural, built, and social) that might be affected by any of the alternatives analyzed in this EIS.

_ **Chapter 5 _ Environmental Consequences**: comparative analyses of the changes or impacts that any alternative would be expected to have on the affected elements of the human environment. Impacts are compared to the human environment that would be expected to exist if no action were taken (the No Action Alternative).

_ **Chapter 6 _ Regulatory Requirements**: agencies and individuals consulted, and environmental regulations that would apply if any of the alternatives analyzed in this EIS were to be implemented.

The Proposed Action

Provide enhanced high-resolution radiography capability to perform hydrodynamic tests and dynamic experiments.

DARHT EIS Alternatives

_ **No Action:** Continue to operate PHERMEX at LANL and FXR at LLNL.

_ **DARHT Baseline Alternative:** Complete and operate the DARHT Facility at LANL.

_ **Upgrade PHERMEX:** Upgrade PHERMEX with the enhanced radiography technology instead of completing the DARHT Facility.

_ **Enhanced Containment:** In addition to containing all experiments involving plutonium, enclose most or all experiments. Three containment options are considered under this alternative: 1) the Vessel Containment Option, 2) the Building Containment Option, and 3) the Phased Containment Option. The Phased Containment Option is the DOE's preferred alternative.

_ **Plutonium Exclusion:** Exclude any applications involving experiments with plutonium at the DARHT Facility.

_ **Single Axis:** Complete and operate only a single axis of the DARHT Facility.

1.3 ALTERNATIVES ANALYZED

This EIS analyzes the environmental impacts associated with constructing and operating a facility that would provide the needed enhanced capability for hydrodynamic testing and dynamic experiments. Radiographic hydrodynamic testing is now conducted at two existing facilities within the DOE complex _ the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility at LANL and the Flash X-Ray (FXR) Facility at Lawrence Livermore National Laboratory (LLNL) in California. The potential impacts of five operational alternatives also are analyzed in the EIS and compared to the expected impacts of the No Action Alternative (see box). DOE considered, but did not analyze, several other alternatives (see section 3.10).

1.4 LAWS AND REGULATIONS

This EIS is being prepared pursuant to the National Environmental Policy Act of 1969 (NEPA) [42 U. S.C. 4321 *et seq.*], the Council on Environmental Quality NEPA regulations [40 CFR 1500_1508], and DOE NEPA regulations [10 CFR 1021].

1.5 PUBLIC REVIEW OF DRAFT EIS

In May 1995, DOE made the draft DARHT EIS available for review and comment. Over 500 copies of the draft EIS were distributed. The draft was distributed to Congressional members and committees; the State of New Mexico; the Tribal governments of Cochiti, Jemez, Santa Clara, and San Ildefonso Pueblos; other tribal governments and American Indian Organizations; Los Alamos, Rio Arriba, and Santa Fe County governments; other Federal agencies; private consultants; public interest groups; and the general public.

DOE held public hearings on May 31 and June 1, 1995, in Los Alamos and Santa Fe, New Mexico, to afford the public and other parties an opportunity to provide spoken and written comments on the draft EIS. In addition, DOE extended invitations to the State of New Mexico; Cochiti, Jemez, Santa Clara, and San Ildefonso Pueblos; Los Alamos, Rio Arriba, and Santa Fe counties; certain other Federal agencies, [in particular the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the U.S. Department of the Interior, and the Department of Defense]; and New Mexico congressional members to participate in briefings regarding the DARHT EIS or specific issues related to the environmental analyses. During the public comment period on the draft EIS, DOE and LANL hosted several tours of the DARHT and PHERMEX sites for State personnel, Tribal officials, local government officials, other Federal agencies, and other interested parties.

The public comments received are included in their entirety in chapter 2 of volume 2; DOE responses to these comments are presented in chapter 3 of volume 2. DOE received written comments from 40 parties and oral comments from 48 individuals at its public hearing.

In addition to the unclassified portion of the draft DARHT EIS, DOE provided the draft classified supplement to the draft EIS for review by appropriately cleared parties with a need to know the classified material. These included the Department of Defense, the EPA, the State of New Mexico, and certain Tribal governments. The final classified supplement reflects the external reviews.

Major Changes _ Draft to Final DARHT EIS

_ DOE has added a Phased Containment Option to the Enhanced Containment Alternative.

_ DOE's preferred alternative has changed from the DARHT Baseline Alternative to the Phased Containment Option of the Enhanced Containment Alternative.

_ Two alternative sites within LANL have been identified as potential locations for the proposed vessel cleanout facility.

_ Recent field surveys have confirmed the presence of a federally listed threatened species, the Mexican spotted owl, in the vicinity of the DARHT site. In consultation with the USFWS, measures have been identified to mitigate any adverse effect to the spotted owl.

_ DOE has decided to propose to incorporate upgraded accelerator equipment within both the first and second axis of the proposed DARHT Facility.

_ DOE has started preparation of the *Stockpile Steward-ship and Management PEIS*.

_ The final EIS includes unclassified aspects of the analysis contained in the classified supplement.

1.6 MAJOR CHANGES, DRAFT TO FINAL DARHT EIS

DOE has revised the draft EIS in response to public comments received, provided additional environmental baseline information, and discussed additional technical considerations. The major changes in this final EIS are noted in the box.

The final DARHT EIS also reflects the commitment made by the President on August 11, 1995, to seek a "zero-yield" Comprehensive Test Ban Treaty. A "zero-yield" treaty would ban any nuclear weapon test explosion or any other nuclear explosion. In committing the United States to this policy, the President stated that maintaining a safe and reliable nuclear weapons stockpile is a supreme interest of this country and that the Nation's Stockpile Stewardship and Management Program will ensure the safety and reliability of weapons in the enduring stockpile. The type of capability proposed for the DARHT Facility is essential to assuring the continued safety and reliability of the stockpile under a "zero-yield" test ban.

1.6.1 Phased Containment Option

(Preferred Alternative)

The draft DARHT EIS indicated that DOE's preferred alternative for meeting its need for enhanced radiographic hydrodynamic testing was to complete and operate the DARHT Facility. Under this alternative, most tests and experiments would be uncontained tests _ that is, the test assembly would be placed in the open air at the firing point, the high explosives would be detonated, and the DARHT Facility would be used to radiograph and measure the resulting explosion or implosion. The draft EIS also analyzed an Enhanced Containment Alternative with two options. Under the Vessel Containment Option, most tests and experiments would be conducted inside modular steel containers. Under the Building Containment Option, all tests and experiments would be conducted inside a concrete building that would enclose the firing point.

After reviewing the environmental impacts identified in the draft EIS, DOE reconsidered the advisability of conducting the majority of the future hydrodynamic testing program as uncontained tests. DOE noted that, over the past 50 years, the ongoing program of uncontained testing had contaminated the soil in the vicinity of the existing firing sites at TA-15, particularly as a result of tests with depleted uranium. DOE re-examined an earlier LANL suggestion to explore the use of modular steel containment vessels, which would require DOE to build a separate vessel cleanout facility to recycle the containers for repeated use.

At the same time, in response to DOE's invitation to comment on the draft DARHT EIS, many commenters indicated that they would prefer that more tests be contained. Many of the comments received agreed that further contamination from depleted uranium and other hazardous materials could be lessened if DOE would conduct most or all tests and experiments following one or the other of the Enhanced Containment Alternative options discussed in the draft EIS. Both the New Mexico Environment Department and the EPA expressed this point of view (see volume 2 of this EIS). In addition to public comments received, during consultations with American Indian Tribes and the USFWS, DOE agreed that containment would provide additional mitigation from flying shrapnel, which in turn could mitigate possible adverse impacts to cultural resource sites or wildlife.

The Enhanced Containment Alternative options analyzed in the draft EIS posed hypothetical "bounding" situations, where DOE based its analysis of environmental impacts on somewhat infeasible operating conditions. From a programmatic standpoint, however, either of these options would have serious design or operating limitations. For example, under the Building Containment Option the concrete containment structure would have to be very large in comparison to the firing site to contain the overpressure from an explosive test; DOE would forego the capability for experiments or tests using larger amounts of high explosives or some other specific types of large tests because of the structural limitations of the building. This option places limits on DOE's ability to conduct dynamic experiments with plutonium because of the difficulty in moving the large, double-walled steel containment vessels needed for plutonium experiments in and out of the containment building.

Under the Vessel Containment Option, the EIS analysis assumes that the DARHT Facility would begin operation with 75 percent of the tests and experiments conducted inside modular, single-walled steel containment vessels. However, the number of tests that could be conducted early in the operating life of the facility would be significantly reduced if this limitation were imposed. Although some conceptual work has been done, DOE has not yet designed the vessels. DOE would have to perfect a prototype vessel before fabricating all the vessels required. Also, the Vessel Containment Option depends on construction of a vessel cleanout facility; the design for this building could not be finalized until after the prototype vessels were perfected to determine the specific details of cleanout equipment, interface to the vessel, and other operational techniques. DOE estimates that it would take approximately 10 years beyond the availability date for the DARHT Facility to complete these activities and be able to conduct a full schedule of contained tests.

After considering the benefits of mitigation afforded by enhanced containment weighed against the programmatic constraints that would result from implementing either of the two Enhanced Containment Alternative options and in response to public comment on the draft EIS, DOE decided to analyze a third option, Phased Containment, and to designate this as the Agency's preferred course of action. Accordingly, in this final EIS the preferred alternative identified in the draft EIS (to complete and operate the DARHT Facility) has been renamed the DARHT Baseline Alternative; this alternative still serves as a starting point for other alternatives and provides a basis of comparison. The Phased Containment Option of the Enhanced Containment Alternative, now the DOE's preferred alternative, is essentially like the Vessel Containment Option except that implementation would be phased in over 10 years to reach the level of containment analyzed under the Vessel Containment Option. This would be accomplished in two 5-year increments over 10 years; the third phase would extend for the remainder of the operating life of the facility.

Implementing the Phased Containment Option would bring containment to the levels described in the Vessel Containment Option of the Enhanced Containment Alternative in the draft EIS for the last 20 years of the expected operating lifetime. This option would also allow DOE to proceed in the near-term to complete the DARHT Facility instead of waiting to design prototype vessels and the vessel cleanout facility, but would also allow DOE to take advantage of the additional environmental protection benefits of containing most tests and experiments in the future. DOE and LANL would develop operating procedures so that, if programmatic requirements so indicated, any given test or experiment could be performed uncontained (except for dynamic experiments with plutonium, which would always be contained in double-walled steel vessels). However, in the aggregate over the lifetime of the facility, most tests and experiments could be contained in vessels. The preferred alternative includes construction and operation of the vessel cleanout facility as part of DOE's proposal.

Because this EIS includes the proposed vessel cleanout facility as part of both the Vessel Containment Option and the Phased Containment Option (preferred alternative) of the Enhanced Containment Alternative, DOE has added site-specific details to this final EIS pertaining to the proposed cleanout facility. In the draft EIS, DOE mentioned generally that the facility would occupy about 1 ac (0.4 ha); in the final EIS, DOE identifies two specific 1-ac (0.4-ha) parcels and an access road location. DOE and LANL have conducted site-specific field surveys of the two parcels and the access road location to obtain additional environmental baseline data concerning cultural resources and biologic resources, specifically threatened and endangered species habitat. The two alternative sites and potential access road location are identified in section 3.7; environmental baseline information is identified in chapter 4 and analyzed in chapter 5.

1.6.2 Mexican Spotted Owl

The draft DARHT EIS included a discussion of federally listed threatened and endangered species, but did not mention the Mexican spotted owl, a species that was federally listed as threatened in November 1994. Just after the draft EIS was issued in May 1995, LANL biologists conducted their first field survey for the Mexican spotted owl and identified that suitable habitat existed in the vicinity of the DARHT site. Later in May, they documented field observations of two spotted owls and in June and July confirmed that the owls had successfully nested and fledged two owlets. The final EIS has been revised to include this information and the results of consultations between DOE and the USFWS.

The draft DARHT EIS stated that DOE had not yet started consultation with the USFWS under the requirements of Section 7 of the Endangered Species Act (ESA). Like NEPA, the ESA includes certain procedural provisions that a Federal agency must take to ensure that the habitat for threatened or endangered species is not jeopardized. Although NEPA regulations provide that a NEPA review should discuss the status of any consultations with the USFWS under the ESA, the NEPA review and the ESA process are independent regulatory requirements. The ESA review is initiated when an agency submits a completed biological assessment to the USFWS. DOE and LANL revised the draft biological assessment in May 1995 and included the new information on the Mexican spotted owls and the mitigation measures developed in consultation with the USFWS. DOE submitted the revised assessment to the USFWS in July 1995, and in August the USFWS concurred with DOE's finding that the DARHT Facility is not likely to adversely affect the Mexican spotted owl.

The final DARHT EIS includes updated information pertaining to the discovery of the Mexican spotted owls in the vicinity of the DARHT site (see section 4.5.4, chapter 5, and appendix K). It also includes a discussion of the process and results of the informal consultation between DOE and the USFWS (section 6.8 and appendix K). Mitigation measures agreed to between DOE, LANL, and the USFWS to protect the Mexican spotted owl and other wildlife and plant species are discussed in section 5.11.2 and appendix K.

1.6.3 Upgraded Accelerator Equipment

As part of the ongoing process for the development of technology for enhanced, high-resolution radiography capability, DOE has decided that it would be useful, cost-effective, and feasible to plan for upgraded accelerator and x-ray diagnostic equipment to be incorporated into all alternatives that propose to use accelerators as described in the DARHT Baseline. By extending the accelerators using existing designs to increase the minimum electron-beam energy, about 25 percent from a nominal 16 MeV to a nominal 20 MeV using new x-ray detection equipment, and by enhancing existing equipment to generate a higher current beam, DOE proposes to increase the output x-ray intensity by about 2 to 4 times while still maintaining the small x-ray spot size. The facilities proposed in the various alternatives in this EIS support the upgraded accelerator equipment without modifications in facility footprint or service. For the purposes of this EIS, DOE has decided to bound the impact analysis by considering electron beam energies of up to 30 MeV and output x-ray dose of up to 2,000 R. No additional environmental impacts have been identified between the draft EIS and the final EIS as a result of the proposed accelerator upgrade; however, project costs would be higher as shown in table 3-4.

1.6.4 Stockpile Stewardship and Management PEIS

The draft DARHT EIS was issued in May 1995, and although it referenced DOE's plans to prepare a *Stockpile Stewardship and Management Programmatic EIS* (PEIS), DOE did not formally issue its Notice of Intent to prepare the PEIS until June 1995. The text of the final EIS has been modified to reflect DOE's May 1995 report, *The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapons Stockpile*, and the PEIS Notice of Intent (see section 2.6).

1.6.5 Unclassified Impacts for the Classified Supplement

DOE prepared a classified supplement as part of the DARHT EIS. The draft classified supplement was completed concurrently with the unclassified portion of the draft DARHT EIS in May 1995, and the final classified supplement was completed concurrently with this unclassified portion of the final EIS. After the draft EIS was issued and as part of its ongoing declassification efforts and normal classification reviews, DOE determined that most of the environmental impacts identified were not classified, although they depend on classified information. Accordingly, in May 1995, DOE issued an unclassified summary of the environmental impacts from the classified supplement. This was released after the draft EIS had already been distributed, but it was made available to the general public and was announced in the *Federal Register* and at the public hearings on the draft DARHT EIS. For the most part, this information discusses the potential for adverse impacts to workers and the public under routine and accident conditions during dynamic experiments with plutonium. Many people commented on the information contained in the unclassified summary (see volume 2). One commenter asked that DOE incorporate the results of the unclassified summary into this final EIS.

To provide the public with as full a disclosure as possible of the environmental impacts that will be considered by the DOE in deciding whether or not to proceed with the DARHT proposal, DOE has incorporated the results of the environmental impact analysis contained in the classified supplement into this unclassified portion of the final DARHT EIS. The human health impacts and accident scenarios analyzed are included in chapter 5 and appendixes H and I.

1.6.6 Other Changes

The final DARHT EIS reflects other changes made to update information, correct errors, and incorporate the suggestions and comments made by the state, tribes, other local governments and Federal agencies, the general public, and DOE and laboratory reviewers. Of note is information from two sources released just before this final EIS was issued: information from the President's statement of August 11, 1995, regarding this Nation's commitment to a Comprehensive Test Ban Treaty and moratorium on small-scale nuclear tests, and information from a report, *Stockpile Surveillance: Past and Future*, released August 7, 1995, by the three DOE weapons laboratories _ LANL, LLNL, and

Sandia National Laboratory (SNL) _ that discusses the expected lifetimes of weapons systems in the enduring nuclear weapons stockpile and the potential for safety, reliability, or aging concerns based on past surveillance results.

1.7 NEXT STEPS

The ROD may be issued no sooner than 30 days after the final EIS. The ROD will explain all factors, including environmental impacts, that DOE considered in reaching its decision (see inside back cover). The ROD will specify the alternative or alternatives that are considered to be environmentally preferable. If the selected alternative is different from the environmentally preferred alternative, the ROD will present the rationale for its selection. DOE anticipates that, in addition to environmental impacts, the decision will be based on cost, technology, national security, and infrastructure considerations. If mitigation measures, monitoring, or other conditions are adopted as part of the Agency's decision, these will be summarized in the ROD as applicable, and included in a Mitigation Action Plan. The Mitigation Action Plan would explain how and when mitigation measures would be implemented, and how DOE would monitor the mitigation measures over time to judge their effectiveness. The Mitigation Action Plan must be in place prior to taking action that causes the impact. The ROD and Mitigation Action Plan also will be placed in the LANL Community Reading Room and will be available to interested parties upon request.

1.8 REFERENCE CITED IN CHAPTER 1

Johnson, K., et al., 1995, *Stockpile Surveillance: Past and Future*, August, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratory.

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CHAPTER 2

PURPOSE AND NEED FOR DOE ACTION

This chapter specifies the underlying purpose and need for the Proposed Action.

Date Event/Policy Change

September 1991 The President made the first of three announcements on significant reductions in the nuclear weapons stockpile.

September 1992 The DOE performed the last underground nuclear test.

October 1992 The President signed a nine-month moratorium stopping all nuclear testing until July 1993.

July 1993 The President announced an extension of the moratorium on underground nuclear testing. The President directed DOE to develop alternative means for a stockpile stewardship program.

November 1993 A Presidential Decision Directive established the scope of the stockpile stewardship program and emphasized increased importance of hydrodynamic testing in the absence of nuclear testing. This was reaffirmed by the Secretary of Defense.

November 1993 In the National Defense Authorization Act [P.L. 103-160], Congress instructed the Secretary of Energy to "establish a stewardship program to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons."

July 1994 In the National Security Strategy, the President stated that the Nation would retain nuclear forces sufficient to deter foreign hostility and would also stem proliferation of nuclear weapons.

September 1994 The Secretary of Defense completed the Nuclear Posture Review and reaffirmed that nuclear weapons remain essential even though stockpiles will be reduced.

May 1995 Nonproliferation Treaty indefinitely extended.

August 1995 The President announces decision to seek zero-yield Comprehensive Test Ban Treaty and establishes conduct of science-based stockpile stewardship program as condition of U.S. Entry. Maintenance of a safe and reliable stockpile is considered "a supreme national interest of the United States."

2.1 OVERVIEW

One of the core responsibilities of the U.S. Department of Energy (DOE) is its role as steward of the Nation's nuclear weapons stockpile. The purpose and need for the proposed course of action analyzed in this EIS is part of that responsibility. The discussion in this chapter is augmented by the classified supplement to this EIS.

The President and Congress have directed that DOE ensure the safety, security, and reliability of the Nation's nuclear weapons stockpile. DOE and its predecessor agencies have held this responsibility for over 50 years, and DOE's custody of the nuclear weapons stockpile will continue for the foreseeable future. In response to the end of the cold war and changes in the world political regime, the emphasis of the U.S. nuclear weapons program has shifted dramatically over the past few years and the weapons stockpile is being greatly reduced.

For instance, the United States has halted the development and production of new nuclear weapons systems and has begun closing much of the former weapons production complex and consolidating the remaining elements. In addition, the Nation is observing a moratorium on underground testing of nuclear weapons (aboveground testing has been prohibited by treaty since 1963) and is pursuing a "zero-yield" international comprehensive test ban. Recent events and changes in U.S. policy that have affected the nuclear weapons program are summarized in the box on page 2-1.

The DOE program that responds to Presidential and Congressional direction to ensure confidence in the nuclear weapons stockpile is called the Stockpile Stewardship and Management (SS&M) Program (DOE 1995). This is an ongoing program that has evolved over time and whose goals are redirected from two former DOE programs: weapons research, development, and testing and stockpile support. Today's SS&M Program has moved away from DOE's past reliance on direct observations of nuclear tests toward ensuring weapons safety and reliability through a more challenging "science-based" approach to develop a greater scientific understanding of nuclear weapons phenomena and better predictive models of performance.

With the moratorium on nuclear testing, DOE now relies on advanced computational modeling and other types of experimental techniques, instead of direct observations of nuclear tests, to arrive at predictions of the safety and reliability over time for the weapons remaining in the nuclear weapons stockpile (LLNL 1994). DOE must use these tools to evaluate many issues regarding nuclear weapons, including:

- Age-related material changes discovered through routine stockpile surveillance
- Unexpected effects discovered with improved computer models
- Retrofits to existing weapons or components to improve safety or reliability
- New technologies applied to existing weapons or components to improve safety or reliability

Since the late 1940s, DOE and its predecessor agencies have used hydrodynamic tests and dynamic experiments in conjunction with nuclear tests to study and assess the performance and reliability of nuclear weapons primaries. In these types of experiments, test assemblies that mock the conditions of an actual nuclear weapon are detonated using high explosives. Radiographs (x-ray photographs) are used to obtain information on the resulting implosion; computer calculations based on these test results are used to predict how a nuclear weapon would perform.

Hydrodynamic tests and dynamic experiments have been an historical requirement to support the DOE's mission and remain essential elements of the SS&M Program, and they assist in the understanding and evaluation of nuclear weapons performance. Dynamic experiments are used to gain information on the physical properties and dynamic behavior of materials used in nuclear weapons, including changes due to aging. Hydrodynamic tests are used to obtain diagnostic information on the behavior of a nuclear weapons primary (using simulant materials for the fissile materials in an actual weapon) and to evaluate the effects of aging on the nuclear weapons remaining in the greatly reduced stockpile. The information that comes from these types of tests and experiments cannot be obtained in any other way.

On August 11, 1995, announcing his decision to seek a zero-yield Comprehensive Test Ban Treaty (CTBT), President Clinton stated:

- "I consider the maintenance of a safe and reliable nuclear stockpile to be a supreme national interest of the United States."

- "I am assured by the Secretary of Energy and the Directors of our nuclear weapons laboratories that we can meet the challenge of maintaining our nuclear deterrent through a science-based stockpile stewardship program without nuclear testing. I directed the implementation of such a program almost two years ago."

- "The nuclear weapons in the United States arsenal are safe and reliable, and I am determined that our stockpile stewardship program will ensure they remain so in the absence of nuclear testing."

- "While I am optimistic that the stockpile stewardship program will be successful, as President I cannot dismiss the possibility, however unlikely, that the program will fall short of its objectives. Therefore, in addition to the new annual certification procedure for the nuclear weapons stockpile, I am also establishing concrete, specific safeguards that define the conditions under which the United States can enter into a CTBT."

One of the safeguards which condition U.S. entry into a CTBT is:

- "The conduct of a science-based stockpile stewardship program to ensure a high level of confidence in the safety and reliability of nuclear weapons in the active stockpile, including the conduct of a broad range of effective and continuing experimental programs." *(From Fact Sheet released by Office of the Press Secretary along with text of President Clinton's announcement)*

DOE's existing capability to obtain diagnostic information was designed and implemented at a time when the agency could rely on direct observations of the results of underground nuclear tests to provide definitive answers to questions regarding nuclear weapons performance. Without the ability to verify weapons performance through nuclear tests, some remaining diagnostic tools are inadequate by themselves to provide sufficient information. Accordingly, as the Nation moves away from nuclear testing DOE must enhance its capability to use other tools to predict weapons safety, performance, and reliability. In particular, DOE must enhance its capability to perform hydrodynamic tests and dynamic experiments to assess the condition and behavior of nuclear weapons primaries.

Although the current U.S. stockpile is considered to be safe and reliable, the existing weapons are aging beyond their initial design lifetimes and, by the turn of the century, the average age of the stockpile will be older than at any time in the past. To ensure continued confidence in the safety and reliability of the U.S. nuclear weapons stockpile, DOE needs to improve its radiographic hydrodynamic testing capability as soon as possible. Uncertainty in the behavior of the aging weapons in the enduring stockpile will continue to increase with the passage of time because existing testing techniques, by themselves, are not adequate to assess the safety, performance, and reliability of the weapons primaries. Should DOE need to repair or replace any age-affected components, retrofit existing weapons, or apply new technologies to existing weapons, existing techniques are not adequate to assure weapons safety and reliability in an era without nuclear testing; DOE believes that it is probable that the existing weapons will require these types of repairs or retrofits in the foreseeable future. DOE has determined that no other currently available advanced techniques exist that could provide a level of information regarding nuclear weapons primaries comparable to that which could be obtained from enhanced radiographic hydrodynamic testing.

In addition to weapons work, DOE uses its radiographic testing facilities to support many other science missions and needs to maintain or improve its radiographic testing capability for this purpose. Hydrodynamic tests and dynamic experiments are important tools for evaluating conventional munitions; for studying hydrodynamics, materials physics, and high-speed impact phenomena; and for assessing and developing techniques for disabling weapons produced by outside interests.

Secretary of Energy O'Leary, in April, 1995, stated to the U.S. Senate Committee on Armed Services:

- "In the past, our confidence in the stockpile was ensured through weapon research and development in the laboratories and underground nuclear testing at the Nevada Test Site. In July 1993, the President announced a moratorium on underground nuclear testing that he recently extended until September 1996..."

- "The current stockpile is safe, secure, and reliable. However, the history of the stockpile has shown that continuous surveillance, repair, and replacement of components and subsystems is commonplace. In fact, the seven weapons that will be in the enduring START II stockpile have already been retrofitted to varying degrees and some have had major components of the nuclear system replaced. We cannot predict with any certainty whether or when such problems will arise in the future, but we must be equipped to respond effectively should they materialize."

2.2 POLICY CONSIDERATIONS

The Nuclear Posture Review, completed by the Secretary of Defense in September 1994, reaffirmed that in today's security environment nuclear weapons remain essential even though nuclear weapons stockpiles will be reduced. The Review outlined:

- A future nuclear posture with a focus on maintaining good stewardship of the weapons remaining in the national stockpile

- A continuing relationship between DOE and the Department of Defense under the aegis of the SS&M Program to maintain a reliable, safe, and secure nuclear stockpile

- Actions to ensure a stockpile stewardship program within the bounds of a future comprehensive test ban treaty

- The Department of Defense requirements for DOE to, among other things, maintain nuclear weapons capability (without underground nuclear testing or fissile material production), while emphasizing that there is no foreseeable need for new-design nuclear warhead production

In responding to the Nation's need to ensure safety, security, and reliability of the nuclear weapons stockpile, DOE must consider national policy regarding nuclear deterrence and stockpile stewardship.

2.2.1 Nuclear Deterrence

Nuclear deterrence remains a cornerstone of U.S. policy, and this Nation will continue to rely on DOE to maintain a safe, secure, and a reliable nuclear weapons stockpile. In the past, DOE has been able to accomplish that mission by retiring weapons before the end of their design life and by upgrading or redesigning weapons, if potential problems were detected, through nuclear testing and hydrodynamic tests and dynamic experiments (see figure 2-1). However, the President has discontinued underground nuclear testing and has decided that the United States will not build new nuclear weapons for the foreseeable future (even to replace those removed when past their useful life). Thus, under current U.S. policy, DOE would not produce new-design nuclear weapons.

Now DOE must rely more than ever on the data from hydrodynamic tests and dynamic experiments to ensure the safety and reliability of the weapons. The level of information received from underground nuclear testing cannot be fully replaced by current or upgraded hydrodynamic testing facilities. However, information that would be obtained from enhanced hydrodynamic capability would provide a higher level of confidence in maintaining the nuclear weapons stockpile in the absence of underground nuclear testing.

2.2.2 Stockpile Stewardship and Management

Since the 1940s, DOE and its predecessor agencies have been responsible for ensuring the safety, security, and reliability of the nuclear weapons in the stockpile. This stockpile stewardship assignment has always required hydro-dynamic testing and was included in the Atomic Energy Act [42 U.S. C. 2011 et seq.], along with the responsibility to design, manufacture, and certify nuclear weapons. DOE now intends to accomplish this mission through the SS&M Program. The SS&M Program is a single, highly integrated technical program for maintaining the safety and reliability of the U.S. nuclear stockpile in an era without nuclear testing and without new weapons development and production. This new approach must rely on scientific understanding and judge-ment, not on nuclear testing and the development of new weapons to pre-dict, identify, and correct prob-lems affecting the safety and relia-bility of the stockpile (DOE 1995).

Stockpile Stewardship & Management

Stockpile Stewardship – Includes activities required to maintain a high level of confidence in the safety, reliability, and performance of nuclear weapons in the absence of underground nuclear testing.

Stockpile Management – Includes activities required to dismantle, maintain, evaluate, and repair or replace nuclear weapons in the existing stockpile.

President Clinton, in the National Security Strategy, July 1994, stated:

- "Even with the Cold War over, our nation must ... deter diverse threats."

- "We will retain strategic nuclear forces sufficient to deter any future hostile foreign leadership ... Therefore we will continue to maintain nuclear forces of sufficient size and capability to hold at risk a broad range of assets valued by such political and military leaders."

- "A critical priority for the United States is to stem the proliferation of nuclear weapons and other weapons of mass destruction and their missile delivery systems."

President Clinton, in the Presidential Decision Directive of November 1993, stated:

- Stockpile stewardship will use past nuclear test data in combination with future nonnuclear test data, along with computational modeling, experimental facilities, and simulators to further comprehensive understanding of nuclear weapons.

- Stockpile stewardship will include stockpile surveillance, experimental research, development and engineering programs, and maintaining a production capability to support stockpile requirements.

- Achieving stockpile stewardship objectives will require continued use of current facilities and programs, a limited set of new experimental facilities and computational facilities and programs, and periodic review and evaluation of program elements.

- In the absence of nuclear testing, hydrodynamic testing programs have increased in importance.

These programs include developing baseline hydrodynamic experimental data for the enduring stockpile and increasing the number of hydrodynamic experiments as part of the stockpile sampling and aging evaluation programs.

- Hydrodynamic testing is also needed to support a development program necessary to help retain and exercise weapon design engineering skills and to examine safety modifications in existing nuclear warhead designs that could be introduced into the stockpile without nuclear testing in case they are needed in the future.

- The future hydrodynamic testing program requires ongoing support from the DOE and Department of Defense for research, development and testing activities; the program requires increased funding for constructing upgraded experimental facilities as well.

DOE's three weapons laboratories [Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia National Laboratories (SNL)] perform the stockpile stewardship mission. These laboratories are asked to identify, develop, and implement selected tools – programs and facilities – needed to achieve their assigned responsibilities. Through the directors of the weapons laboratories, DOE must certify that nuclear weapons will not accidentally detonate during storage and handling (safety), that the weapons would thwart any attempts for unauthorized use (security), and that they would function as designed in the event of authorized use (performance and reliability).

For almost 50 years, nuclear tests were key to gathering data used for developing nuclear weapons and certifying their safety, reliability, and performance. Nuclear tests were also used to evaluate the effectiveness and certify performance of weapons that were redesigned. Since the 1992 moratorium on nuclear tests, DOE has recognized that a new approach, based on scientific understanding and expert judgment, is needed to ensure confidence in a nuclear deterrent and the U.S. stockpile. Given the moratorium on nuclear testing, the termination of new weapons development, and closure of weapons manufacturing and production facilities, this confidence will depend on the competence of the people who must make the scientific and technical judgments related to the safety and reliability of U.S. nuclear weapons. Those people must have a fundamental understanding of the basic scientific phenomena associated with nuclear weapons.

DOE's SS&M Program has been developed to meet three particular challenges (DOE 1995).

- Fully support the Nation's nuclear deterrent while transitioning to a more appropriate nuclear weapons complex.

- Preserve the core intellectual and technical competencies of the weapons laboratories.

- Ensure that stewardship and management activities are compatible with the Nation's arms-control and nonproliferation objectives.

DOE identified five critical issues and strategies to address them (DOE 1995). Two of the strategies speak directly to DOE's continuing need for enhanced radiographic hydrodynamic testing capability.

- **Enhanced experimental and computational capabilities:** These include aboveground experimental capabilities to study technical issues regarding weapons primaries, specifically high-resolution, multiple-time, multiple-view hydrodynamic experiments using simulant materials.

- **Enhanced weapons and materials surveillance technologies:** These include hydrodynamic testing on test units built, when possible, with aged stockpile components (with modified pits using simulant materials) to provide important data on the effects of aging on weapons safety and performance.

DOE must be able to preserve the current high confidence in the safety and performance of the U.S. stockpile. Confidence is subjective; rests on the judgement of people; and is based on information, experience, and trust. In some cases, the Nation might be willing to forego the means to ensure a higher degree of confidence in the condition of its nuclear weapons in favor of some other value, as was the case when the Nation decided to accept a moratorium on underground nuclear testing. Preserving high confidence in the enduring stockpile without nuclear testing will require an improved, more complete, and more accurate understanding of the underlying physical principles involved in nuclear weapons and new or enhanced experimental capabilities (DOE 1995). DOE has determined that to ensure the continued confidence in the safety and reliability of the enduring stockpile, its hydrodynamic testing programs have increased in importance. They are an essential means to develop baseline experimental data, to determine the effects of aging, and to use as a tool for stockpile sampling; therefore, an enhanced radiographic hydrodynamic capability is needed as soon as possible.

Purpose of SS&M Program

Critical Issues and Strategies

- Maintaining stockpile confidence without nuclear testing – enhanced experimental and computational capability

- Reducing the vulnerability of a smaller stockpile – enhanced weapon and materials surveillance

- Providing an effective and efficient production complex – consolidated/downsized and new manufacturing approaches

- Providing long-range stockpile support – greater emphasis on preventive versus corrective maintenance

- Ensuring an adequate tritium supply

2.3 NEED FOR ENHANCED RADIOGRAPHIC CAPABILITY

DOE has determined that it needs to obtain an enhanced capability to conduct radiographic hydrodynamic tests and dynamic experiments. The capability to obtain high-resolution, multiple-time, multiple-view information is needed to assess safety, performance, and reliability of weapons; evaluate aging weapons; obtain information about plutonium through dynamic experiments; and for other uses.

The DOE's determination has been independently confirmed by a panel of technical experts who studied the requirements for the DOE SS&M Program (JASON 1994). DOE has determined that aboveground, radiographic diagnostics are the best means – and for some parameters, the only known means – to obtain the needed information, and that linear induction accelerators (the technology proposed for DARHT) represent the best available technology to produce the high-speed, high-resolution, deeply penetrating radiographs that are needed. In addition, DOE has determined that no other advanced technology is currently available that could provide a comparable level of information. DOE's conclusions have been independently verified by panels of consultants convened to consider these issues (JASON 1994; HPAIC 1992; DFAIC 1992; and DOE 1993). The major points considered in these reviews included the ability of x-rays to penetrate ultra-dense materials at the late stages of an implosion, temporal resolution of the rapidly moving materials, spatial resolutions in the resulting image, and the need for an additional axis (or axes) to provide three-dimensional information. The capabilities and limitations of current facilities are described in section 2.4.

2.3.1 Assessing Weapons Safety, Performance, and Reliability

To ensure the continued viability of the smaller stockpile, DOE must improve its scientific understanding of the physics of a nuclear weapon beyond its design life, and develop a better understanding of how a nuclear weapon behaves during the complex interactions that occur in the brief interval between high-explosive detonation and nuclear explosion. This information is needed to assure the continued safety, performance, and reliability of existing weapons. Two examples of specific problems that involve both a fundamental understanding of weapons reliability and potential issues concerning stockpile aging are the process and efficiency with which boosting occurs (see figure 1-2), and the critical configurations required for materials at late stages of implosion. Both of these examples are best studied with the high-energy, high-dose, short-pulse capabilities planned for DARHT.

DOE has not yet determined how to predict with sufficient accuracy, from computer calculations alone, the rapidly changing shape of a weapons primary during the last stages of implosion. However, this information is essential to predict the safety, performance, and reliability of a nuclear weapon. At this time, the highest priority issues for stockpiled primaries are those that affect the successful ignition of the deuterium-tritium boost gas. DOE needs to be able to predict the implosion movement of the three-dimensional weapons assembly to provide an integral measure of the expected performance of the fission drive, to assess nuclear safety in accidents, and for render-safe and disablement effectiveness. Current diagnostic capabilities are insufficient to make all of the necessary types of measurements of an imploding primary or to make refined measurements at the high level of detail needed. Therefore, DOE needs to establish an enhanced diagnostic capability to make the necessary types of measurements at the desired level of detail. These kinds of technology issues would also arise in weapons design; but, under current U.S. policy, DOE does not develop or produce new-design weapons systems.

The safety aspect of DOE's stockpile mission arises from concerns about how a primary would behave if the high explosives were unexpectedly detonated in scenarios such as a transportation accident, damage from a projectile, or a nearby fire or explosion. In these instances, the high explosive would not be detonated in the manner required to trigger a nuclear explosion; but such an explosion could affect the primary. Even if nuclear yield did not result, an accidental detonation of the high explosives within a nuclear weapon could result in vaporizing or scattering plutonium metal or other hazardous materials. Assuring safety requires knowing how the primary materials might be affected by these explosion conditions.

Changes Can Affect Primaries

A nuclear weapons primary is part of the weapons' nuclear package (see figure 1-2). The primary is where the nuclear fission process starts. Many complex physical and chemical interactions occur during the split second that the primary operates. If the primary does not work properly, the secondary will not work properly. The interactions in a weapons primary are extremely complex. Changes as small as thousandths of an inch, or less than millionths of a second, can affect its margin of safety or performance.

High Explosives (HE). The primary contains HE which surrounds a metal pit. When a weapon is detonated a series of steps occur very rapidly in a controlled sequence. First the HE is detonated. After the detonators are triggered, a wave of detonation passes through the main HE charge. The HE burn and the detonation wave can be affected by the type of explosive and its chemistry, the grain size, impurities, manufacturing method, and gaps in the HE assembly, among other things. If the HE does not detonate as designed, the pit may not implode properly but may still blow apart, scattering plutonium metal or other materials.

Pit Implosion. The pressure caused by the detonating HE causes a shock wave to travel through the pit material. The pit responds in a complex set of interactions as it implodes radially to a compact shape. As the shock wave crosses the pit, small amounts of material may be ejected from each interface, which may or may not affect the implosion. The response of the pit _ how the metal moves, flows, or melts, for example _ is complex and depends on dynamic materials properties which can be affected by factors associated with component fabrication as well as by the intrinsic properties of specific materials (particularly plutonium). DOE has limited data on some aspects of the properties of plutonium and other pit materials, especially at the high strain rates associated with pit implosion. If the pit does not implode properly, the boosting process may be affected.

Boosting. The tritium-deuterium boost gas is heated by the pit implosion and the onset of the fissioning process. The heated boost gas undergoes nuclear fusion and generates large numbers of high-energy neutrons. These enter the fissile pit material and cause subsequent fissioning. These boost-induced nuclear interactions generate additional fission yield, "boosting" the nuclear yield of the primary. If boosting does not occur properly or is inadequate, weapons performance may be dramatically decreased.

Prior to the President's moratorium on nuclear testing, the United States used both hydrodynamic and nuclear testing to obtain information needed to assess nuclear weapons safety, performance, and reliability. Nuclear testing at appropriate nuclear yields allowed DOE to maintain the stockpile and its nuclear expertise with very high confidence; the performance and safety of the enduring stockpile was validated by such tests. Because of the moratorium on nuclear testing, DOE did not complete all of the underground nuclear tests that had been planned. Certain types of data gaps, which the design laboratories expected to be partially filled by analyzing the results of nuclear tests, remain unfilled.

Without nuclear testing, mathematical calculations based on experimental data would be the only way to obtain needed information on weapons performance and reliability. However, theoretical mathematical calculations alone cannot be relied on to predict the behavior of a nuclear weapons primary; the calculations must be verified against actual experimental data. DOE considers enhanced radiographic hydrodynamic testing to be the best (and in some areas, the only known) tool to obtain certain types of information regarding weapons primaries. These data are needed to verify and refine predictive analytical models.

In an era during which nuclear testing will not be performed, DOE will have to assess weapons safety, performance, and reliability in other ways. Enhanced radiographic hydrodynamic testing would provide a powerful tool for implementing the SS&M Program. Whether or not this approach will fully satisfy the need for stockpile assurance without nuclear testing is not completely known; and, it will not be known for several years after an enhanced hydrodynamic capability, among other tools, is put into place and test results are analyzed. The possibility exists that, without nuclear testing, the Nation cannot ensure the continued viability of a nuclear deterrent based on the existing weapons in the nuclear weapons stockpile. The sooner DOE can obtain better diagnostic information, the sooner the Nation can determine if its existing nuclear deterrent is sufficient. Conversely, the longer the Nation waits before an enhanced capability is achieved, the greater the chance that a problem will arise that cannot be addressed with the current capability, in a manner that is sufficient to ensure the necessary level of confidence in the nuclear weapons stockpile. Such circumstances could lead, pursuant to a Presidential announcement in August 1995, to U.S. withdrawal from a Comprehensive Test Ban Treaty (CTBT) under a "supreme national interest" clause to conduct necessary nuclear tests.

Baseline research is expected to take several years and will involve many different types of calculations, tests, and experiments performed at different DOE weapons facilities, primarily LANL, LLNL, and SNL. Baselining to document the correct physical status of the weapons systems will involve a broad range of observations, measurements, and tests. Hydrodynamic testing is one activity that would support baseline research and supply specific information needed to answer particular questions about the safety and performance of nuclear weapons. The extent and duration of these activities will depend on the nature of the results, but several years is the best early estimate.

2.3.2 Evaluating Aging Weapons

In August, 1995, an independent panel of experts, the JASONS, stated:

To maintain high confidence in the safety, reliability, and performance of the individual types of weapons in the enduring stockpile for several decades under a Comprehensive Test Ban Treaty (CTBT), the United States must provide continuing and steady support for a focused, multifaceted program to increase understanding of the enduring stockpile; to detect, anticipate and evaluate potential aging problems; and to plan for refurbishment and remanufacture, as required. In addition the U.S. must maintain a significant industrial infrastructure in the nuclear program to do the required replenishing, refurbishing, or remanufacturing, of age-affected components, and to evaluate the resulting product; for example, the high explosive, the boost gas system, the tritium loading, etc.

Stewardship of Nuclear Weapons Primaries

Confidence in the weapons in the enduring stockpile is based to a large extent on ensuring the safety and reliability of the weapons' primary. The boost, yield and implosion of the primary are key concerns regarding reliability. The primary contains the main high explosive (HE) charge and plutonium that would be the focus of safety concerns.

Age Related Changes

Material degradation and imperfections caused by aging can profoundly affect the performance of the primary. Every component in a nuclear weapon may exhibit changes as the weapon grows older. It is relatively easy to replace many of the weapons' electrical parts or other components. However, nuclear components can not be readily repaired or exchanged without taking the entire weapon apart, replacing the nuclear components with remanufactured or retrofitted parts, and reassembling the weapon. This could require that DOE recertify that the weapon is safe and reliable. Replacing nuclear components and recertifying a weapon is expensive.

Age-related changes that can affect a nuclear weapons primary include:

_ Structural or chemical degradation of the HE leading to a change in explosives performance, or migration of HE.

_ Changes in plutonium properties as impurities build up inside the material due to radioactive decay.

_ Corrosion along interfaces, joints and welds.

_ Chemical or physical degradation of other materials or components.

Weapons Safety and Reliability

The effects of aging on weapons components can affect their long-term safety and reliability. Safety may be affected by chemical or structural changes in the HE or detonators, which may lead to altered response to impact or fire. Corrosion or cracking may compromise fire-resistant layers in an accident. The reliability of the primary could be affected by changes that might perturb the primary implosion, and their effect on boosting.

If the effect of aging on the weapons' components is serious enough to require that the part be replaced, it is possible that the steps that would need to be taken to correct the problem could introduce additional changes that could affect the weapons' performance or safety. DOE must be able to ensure that the safety or reliability of the primary would not be compromised if the components were replaced. This requires the same special skills and expert judgment needed for a new design. Even very small changes in a weapons primary could dramatically affect the weapons performance, and remanufacturing or replacing the primary components could introduce these types of changes.

Although the U.S. nuclear weapons stockpile is presently safe and reliable, the nuclear weapons in today's U.S. stockpile are aging. Existing weapons, on the average, are about 15 years old, and in about 5 years, many weapons will begin exceeding their original design lifetime. In the past, individual weapons in the stockpile were replaced by new-design, upgraded, or replacement weapons before they approached the end of their design life. However, because the United States is not currently producing new nuclear weapons, DOE does not anticipate replacing the weapons now in the stockpile before the end of their original design life. This creates uncertainty about the safety and performance capability of the remaining weapons as they continue to age because DOE does not know how the weapons will behave over the long term.

DOE believes that inventorying or benchmarking the condition of weapons and their expected performance characteristics is needed as soon as possible. This would provide a baseline for comparing future surveillance observations and performance tests over the period of time that the weapons will eventually be called upon to serve in the stockpile. DOE would use many diagnostic tools at several of its sites to assist with benchmarking the inventory, which is expected to take several years. DOE would use enhanced radiographic hydrodynamic testing capability to accurately benchmark weapons primaries. The sooner that benchmarking takes place, the sooner DOE would have more reliable data and could be more certain about the condition of the weapons remaining in the stockpile. DOE would expect that aging or other types of problems would be discovered through surveillance activities, including "static" radiographs of weapons and components. These "static" radiographs can use long x-ray exposure times and, therefore, can be obtained without using DARHT facilities. Static radiographs, are also taken in preparation for dynamic experiment or hydrodynamic tests, before the high explosive charge is detonated and aligned. The static radiograph provides a picture of the initial condition of the test assembly and hence, defines the initial condition of an experiment.

Why Retrofit Existing Weapons?

A nuclear weapon may contain over 6,000 parts; the nuclear package, which contains the weapons primary and secondary assemblies, has about 300 parts (see figure 1-2). DOE continually monitors the condition of nuclear weapons through its surveillance program, where weapons are returned from the stockpile, taken apart, and examined. Some parts are tested and damaged or destroyed in the testing process. Through the surveillance program, DOE may find that any one of the thousands of parts in a weapon is defective. There may have been a miscalculation in the original design, a manufacturing error, or a part may have expanded, cracked, shifted, or deteriorated over time. In addition to observations through the surveillance program, new or improved computer codes may disclose that a weapon component may be defective or may not function as intended. Sometimes defective parts may be limited to a small number of warheads, and sometimes the defect may extend through an entire series of weapons ("common mode failure").

DOE must be able to replace parts that are destroyed through the surveillance process; and, if the examination reveals that a weapons part is defective or has changed, DOE must be able to decide whether to replace the part, redesign the part, or leave the part in place if the safety or performance of the weapon is still acceptable.

When the weapons were built, DOE manufactured some spare parts to replace those expected to be used up in surveillance testing. DOE did not manufacture spare parts for all components and could not foresee which components might need to be replaced.

Based on past experience, DOE expects that in the future some replacement parts will need to be manufactured, particularly as the existing weapons get older and the original parts degrade or change over time. In some cases, replacement parts will have to be redesigned or reengineered to solve defects or other problems uncovered by the surveillance program. In addition, DOE expects that as new technologies are developed, some parts will be replaced to take advantage of these improvements. DOE must be able to ensure that repaired, replaced, or newly developed parts will perform as expected and will not cause an unexpected problem within the entire weapons system. Hydrodynamic tests and dynamic experiments would continue to be one tool that DOE would use to ensure the safety, performance, and reliability of weapons in the enduring stockpile.

At first, it might seem that further testing of weapons systems would be unnecessary if DOE would remanufacture replacement parts to the original design specifications. However, this process would be impractical and would not avoid the need for future tests. Many weapons components were manufactured using machinery, such as large metal presses or milling equipment, that were cost-effective only for large production runs at facilities that now have been shut down, such as the DOE Rocky Flats Plant. In some cases the process lines, materials, tools, and equipment that were used for the original parts are no longer available. Manufacturing processes that were state-of-the-art when the original weapons were manufactured are now obsolete. Manufacturing specifications are never all-inclusive and some details of practice that were employed or manufacturing conditions (such as temperature or humidity) may not have been fully documented or would be difficult to reconstruct. DOE could not realistically expect the exact duplication of all production processes and practices and could not expect an exact replication of certain components. Therefore, the parts would still need to be tested.

Remanufacturing is, of course, only of interest for those cases when the original design specifications were correct. In those instances when the original design or manufacturing processes were faulty, there would be little incentive to duplicate them.

Based on these considerations, DOE has concluded that remanufacturing alone is not sufficient to maintain the enduring nuclear weapons stockpile and that remanufacturing would not offer an alternative approach to stockpile maintenance that would avoid future weapons testing.

As materials age, particularly those used in nuclear weapons, they tend to change. DOE weapons personnel can predict some types of changes that would be expected to occur over time in the materials that make up the weapons. However, other effects, which aging may bring about on the performance and reliability of these weapons and on their behavior under certain postulated accident conditions, are largely unknown. DOE needs to ensure that aging weapons remain safe and reliable.

Should systems in aging weapons need to be reengineered or replaced, DOE needs a capability to validate that the replacement systems would not compromise weapons safety, reliability, or performance. Sophisti-cated manufacturing processes are not always easy to replicate once they have been dismantled. If weapons components are to be remanufactured, testing (nonnuclear) the products from this process is an important tool for reducing uncertainty about any significant differences from the original product. DOE also must be able to predict the physics behavior that would be expected from an aging weapon under abnormal conditions, such as those that might occur in an accident or those that might lead to changes in the material properties.

Many complex systems, including some weapons systems, experience a history of early problems, but their number and frequency decrease with time. This downward trend is a result of experience. Later, these same systems will show the effects of aging and the trend for problems may increase. Currently, most existing stockpile systems are believed to benefit from the experience factor, but are not yet suffering the increased problems due to aging. The potential for an eventual increase in problems is normal and expected.

DOE has considerable evidence to indicate that, as weapons age, problems related to the deterioration of weapons components can and do occur. Before the recent changes in policy, most weapons were replaced by newer systems before their design life had been exceeded. Therefore, most of the historical information on safety, reliability, or performance of stockpiled weapons was related to issues that arose unexpectedly before the end of their design lifetime. DOE has 50 years of experience in solving a wide diversity of issues (e.g., the large number of ways that materials can crack, corrode, or otherwise degrade) and in increasing its understanding of plausible accident scenarios. This experience helps prevent exact recurrences of past problems, but it does not prevent new issues from arising.

DOE operates direct surveillance programs that have been ongoing for more than 40 years. Under one of these programs, every system in the stockpile is examined each year; a given number of weapons for each system are taken as a representative sample and examined. The direct surveillance program may detect types of failures that could affect the dynamic performance of either the high explosives or other primary materials during the implosion process.

By itself, weapons surveillance is not adequate to predict and resolve performance or reliability problems. To certify a weapons system, prototype systems were tested extensively, using both nuclear testing and hydrodynamic tests, before any production of stockpile weapons was authorized. DOE relies on its stockpile surveillance program to observe post-production problems for weapons in the stockpile. Once a problem is discovered, DOE must determine the impact that the problem might have on weapons safety or performance and reliability. The probable impact of an observed change is calculated based on known computer codes and then corroborated with experimental testing.

Although certain limited-life components were designed to be replaced (such as batteries) or replenished (such as tritium gas reservoirs), other essential components of weapons were presumed to last the life of the weapon. High explosives, primaries, secondaries, and radiation cases were not designed to be replaced unless testing programs indicated that a problem existed with a given component. However, the metals, plastic explosives, and other materials that make up the weapons in the existing stockpile are known to have the possibility of becoming brittle, cracked, or otherwise show changes in their material properties over extended periods of time. The question faced by weapons personnel is whether these changes, if they occur, would affect the safe handling characteristics or performance reliability of the weapons.

The three weapons laboratories (LLNL, LANL, and SNL) conducted a study, *Stockpile Surveillance: Past and Future* (Johnson et al. 1995), to review the results of past surveillance and make recommendations for future actions needed to ensure the safety and reliability of the stockpile. The report notes that, in the past, significant problems have been found in the stockpile and that changes to stockpiled weapons have been made to assure safety, performance, and reliability; it also notes that problems have been found in each of the weapons types expected to be in the stockpile in the year 2000. The study concludes that it is reasonable to expect that problems will continue to arise in the stockpile at the rate of one or two defects per year that would require action as the stockpile ages beyond the original design expectations.

The nuclear weapons stockpile, projected for the year 2003 and beyond, would be smaller than the U. S. has had at any time since 1959. The newest weapons in the future stockpile would have been built in 1990, the average age of the stockpile in 2005 would be 20 years, and the oldest weapons would be about 28 years old. Under the present plans for continued downsizing, some weapons will remain in the stockpile for more than 40 years. Until the past few years, there has been no expectation that weapons would remain in the stockpile longer than they have in the past (about 20 years or less). Continuous modernization to improve the safety, reliability, and performance kept the stockpile relatively young as new weapons types replace old ones. With no new weapons entering the stockpile, the existing nuclear deterrent is steadily aging (Johnson et al. 1995).

The three weapons laboratories have updated their "Defects Database," which now contains more than 2,400 entries. Although specific details are classified, more than 370 cases have resulted in some kind of action due to safety or reliability concerns; 46 of the 50 weapons-types studied have had at least one problem; and problems not requiring actions to the nuclear components affected 39 weapons types (Johnson et al. 1995).

Until 1992, the U.S. used underground nuclear tests to test the full operation of a weapons system and to assure that the nuclear package would operate as intended. These tests contributed to a broad range of weapons research and design activities, from development of new weapons to stockpile confidence tests (tests to verify performance of already-manufactured weapons that have entered the stockpile). In the past, nuclear tests identified certain classes of problems not observed through the surveillance program, such as the lack of one-point safety for several weapons types previously deployed in the stockpile. In addition, nuclear tests were used to resolve issues raised by the surveillance program such as whether a particular corrosion problem would affect nuclear yield. They have been used to verify the efficiency of design changes, such as the adequacy of certain mechanical safing techniques. Nuclear testing also was used to prove that a potential problem that could have been expensive or difficult to fix did not exist (Johnson et al. 1995).

There have been 17 stockpile confidence tests since 1972, including a test of each of the weapons types expected to remain in the stockpile well into the next century. In addition, there have been at least 51 additional underground nuclear tests since 1972 involving nuclear components from the stockpile, weapons production lines, or specification builds. Five of these tests revealed or confirmed a problem that required corrective action. Six tests confirmed a fix to an identified problem; and five tests investigated safety concerns affecting three warhead types and confirmed that a problem did not exist (Johnson et al. 1995).

In a future without nuclear testing, DOE's ability to assess nuclear components will be more difficult and DOE must rely on other testing means to compensate for having set aside nuclear testing. This comes at the same time that the Nation has accepted reliance on a smaller, older, stockpile to serve as a nuclear deterrent for the foreseeable future. At this juncture of fewer diagnostic tools, and when confidence in the long-term capability of the stockpile becomes more uncertain, DOE needs to enhance its capability to make the best use of proven techniques.

DOE cannot predict with certainty when safety or reliability concerns will arise in the future, but DOE anticipates that problems will be discovered more frequently as weapons become older and exceed their original design lifetime. Because the weapons will become older than any weapons with which DOE has had experience, there will be a need to address and correct problems not previously encountered. Of the weapons types introduced since 1970, nearly one-half required nuclear testing following their development (either while they were deployed or still being produced) to verify, resolve, or certify that problems relating to safety or reliability were resolved. A majority of these problems involved the primary stage of the weapon. Since 1970, several thousand weapons have been removed from the active stockpile for major modification or have been accelerated on their path to retirement, to fully resolve such safety or performance reliability concerns.

One example of unanticipated problems is the now-retired W68 warhead for a submarine-launched ballistic missile. Routine surveillance disclosed a premature degradation of the warhead's high explosive. Without modification, the problem ultimately would have rendered the weapon inoperable. Consequently, the weapons were disassembled and the high explosive replaced with a more chemically stable formulation. In addition, because some of the materials used in the original production were no longer available commercially, some additional changes were made in the rebuilt weapon. Nuclear test data were used to assure that the high explosive and other changes would not compromise adequate performance of the weapons. DOE performed a nuclear test to verify that the rebuilt weapons would perform as designed and was surprised to find that the weapon yield was degraded. However, DOE decided that the lower yield was acceptable. This example and others have been summarized in a 1987 unclassified report to Congress by Drs. George Miller, Carol Alonso, and Paul Brown (Miller et al. 1987).

The Miller report describes a number of weapons systems that have been in the Nations's stockpile. This report documents several examples of unanticipated problems that arose following deployment of a weapons system to the stockpile. This report is valuable because it provides historical examples of some problems with systems in the stockpile. However, the Miller report and several similar reports in the open literature have some important limitations. They cannot present classified information, which is especially important for the more recent systems in the enduring stockpile. As a result, these reports do not provide good bases for statistical conclusions about the rates or types of problems encountered. Still, the examples given will portray the existence of unanticipated problems in post-deployment systems.

Following publication of the Miller report, a one-point safety problem was identified in the W79 systems by way of nuclear testing. One-point safety implies that a device will not produce nuclear yield if its high explosive is detonated at any single place. This one-point safety greatly limits the impacts from a broad range of accident scenarios.

In the absence of nuclear testing, DOE must rely more heavily on hydrodynamic testing to provide the same assurance of safety, performance, and reliability – particularly to verify, resolve, or validate fixes to problems in existing systems. DOE considers enhanced radiographic hydrodynamic testing to be a crucial tool for producing information on the effects of aging within weapons primaries.

2.3.3 Dynamic Experiments with Plutonium

Some components of nuclear weapons contain plutonium, which is a material with unique behavioral characteristics. As part of its effort to better understand the materials science aspect of nuclear weapons aging and performance, DOE needs to develop a better understanding of the physical properties of plutonium. In metal form, plutonium is an extremely heavy, dense silvery metal; it is sometimes stored as an oxide or in solution. Any form of plutonium may react with water, plastics, metals, or other materials with which it comes into contact. It is important that the DOE weapons laboratories have the tools to study the various forms of plutonium and its physical properties and have an ability to evaluate and predict plutonium behavior under dynamic conditions (conditions involving very rapid motion).

Currently, the body of knowledge regarding the behavior of plutonium is inadequate for assuring weapons reliability and safety of weapons within the stockpile as they age beyond their design life. DOE needs:

- A better understanding of the properties of plutonium

- More accurate equations-of-state to predict the behavior of plutonium, especially at high pressures and temperatures

- More information regarding the behavior of the plutonium surface following a physical shock

Since radiographic dynamic experiments are the best tool to obtain this information, DOE must have the capability to conduct dynamic experiments with plutonium using enhanced high-resolution radiography. As a matter of policy, dynamic experiments involving plutonium, would always be conducted in double-walled containment vessels. Accordingly, DOE also needs the capability to stage, maintain, and clean out the plutonium containment vessels.

2.3.4 Other Needs

DOE also needs more information on other issues related to nuclear deterrence and nuclear weapons materials science.

- The United States must be able to continue to assist other nations, under nuclear cooperation agreements, in evaluating the condition, safety, and expected performance of their weapons and weapons designs under current international agreements.

- The United States must be able to assess the condition, safety, and performance reliability of other nuclear weapons, such as those designed by a nonfriendly nation or a terrorist. The Emergency Response Program is used to assess threats of foreign systems well in advance of an emergency.

- DOE must be able to continue to assist the U.S. Department of Defense with evaluation of conventional weapons and other military equipment.

- DOE must be able to study explosives-driven materials and high-velocity impact phenomena for nonweapon applications and other uses of interest to industry.

- The accelerator technology developed for high-resolution radiography may have other science and industry applications.

In 1991, the President stated that the United States would not design new nuclear weapons in the foreseeable future. However, in the event that this Nation decides, as a matter of policy, that new nuclear weapons should again be developed, DOE would use all appropriate means at its disposal to accomplish this. Hydrodynamic testing, along with many other tools, could be used to assist in weapons development. However, any decision to develop new nuclear weapons would be made by the President and be subject to Congressional review and approval.

2.4 LIMITATIONS OF EXISTING FACILITIES

Along with other stockpile stewardship responsibilities, DOE has assigned a hydrodynamic testing mission to its two nuclear weapons physics laboratories, LANL and LLNL. The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) is the existing radiographic hydrodynamic testing facility at LANL and the Flash X-Ray (FXR) is the existing radiographic hydrodynamic testing facility at site 300 at LLNL.

PHERMEX has been in continuous operation since 1963. In addition to major, full-scale hydrodynamic tests, PHERMEX is used for smaller types of experiments, such as high-explosive tests or tests requiring static radiographs. Although PHERMEX was state of the art in the 1950s when it was designed, it is no longer adequate. It cannot provide the degree of resolution, intensity, rapid time sequencing, or three-dimensional views that are needed to provide answers to current questions regarding weapons condition or performance. Even if this type of diagnostic information were not needed, PHERMEX might not remain a viable test facility over an extended time because of anticipated increasing difficulty in maintaining the facility.

A set of upgrades recently have been started at PHERMEX. These upgrades comprise a modification to safety systems in compliance with 10 CFR 835, Occupational Radiation Protection; a modification to the PHERMEX accelerator that required removal of large amounts of depleted uranium [176 lb (80 kg)] from shield; and a final modification, scheduled for completion in 1996, will provide for two reduced-intensity pulses and, hence, two radiographs, although at greatly reduced x-ray intensity. The removal of the uranium had an additional effect of reducing interference with the beam that increased the penetrating ability. These upgrades, still in progress, will have served to increase some of the capability of PHERMEX; however, enhanced radiographic capability, sufficient to meet DOE's purpose and need as described by the proposed action, is not attained. For example, the PHERMEX spot size and, therefore, degree of resolution will remain approximately the same as it has been.

FXR has been in continuous operation since 1983; it is DOE's most advanced radiographic hydrodynamic testing facility. Although FXR uses linear induction accelerator technology for high-speed radiography, it cannot provide the degree of resolution, intensity, or three-dimensional views needed to address current questions. Additionally, DOE does not perform dynamic experiments with plutonium at LLNL because the necessary infrastructure is not in place at site 300.

Nation's Commitment to Nonproliferation

- On May 11, 1995, 178 nations agreed to permanently extend the expiring nuclear Nonproliferation Treaty and accept a set of "principles and objectives" that include specific steps to turn back the nuclear arms race. The five nuclear states also agreed to work toward a comprehensive test ban by 1996 and rapid negotiation of a treaty to end production of nuclear bomb material.

- On August 11, 1995 President Clinton announced that the United States would seek a "zero-yield" Comprehensive Test Ban Treaty:

"One of my Administration's highest priorities is to negotiate a Comprehensive Test Ban Treaty (CTBT) to reduce the danger posed by nuclear weapons proliferation. To advance that goal and secure the strongest possible treaty, I am announcing today my decision to seek a "zero" yield CTBT. A zero yield CTBT would ban any nuclear weapon test explosion or any other nuclear explosion immediately upon entry into force. I hope it will lead to an early consensus among all states at the negotiating table."

- The United States has entered the START I treaty into force, and the Administration is working closely with the Senate and the Russian government to ratify START II.

Neither PHERMEX nor FXR is adequate to provide the enhanced radiographic hydrodynamic testing capability that DOE now needs in the absence of nuclear weapons testing. At present, both PHERMEX and FXR can take only one image at a time. If planned upgrades are completed, PHERMEX and FXR may soon have the capability to make sequential radiographs up to 100 –s apart (referred to as double-pulse capability), but without improvement in x-ray dose or spot size. In fact, in producing the sequential radiograph, there is a noticeable reduction in x-ray dose, thus reducing the degree of penetration of the x-ray beam. While this capability allows DOE to obtain more information than the original PHERMEX or FXR design, the level of information obtained from these radiographs does not satisfy DOE's need for enhanced radiography. These machines are not capable of producing a high x-ray dose coupled with a small beam spot size to provide the diagnostic capability that DOE now needs. Neither machine is capable of taking very high-resolution radiographs, which is dependent on the accelerator beam spot size, nor are they capable of producing x-ray beams with the intensity required, which is principally dependent on x-ray dose strength. They do not have the capability to obtain three-dimensional information for one test event, which requires the ability to take pictures from more than one point of view. To obtain three-dimensional data at PHERMEX or FXR, laboratory personnel must make up more than one test assembly, explode them one at a time, and rotate each subsequent device to obtain an additional point of view. Besides increasing cost – a full-scale hydrodynamic test costs $1.5 to $2 million, with the cost multiplied by the number of views tested – it is difficult to reproduce precise dimensions and alignments (within hundredths of an inch) to replicate test results for components in a series of tests. The confidence in the resulting data is also limited because of the uncertainties of using sequential tests. DOE's observations regarding the limitations of PHERMEX and FXR, even after planned upgrades have been incorporated, have also been reflected by independent researchers (JASON 1994).

2.5 NONPROLIFERATION

DOE has determined that enhanced hydrodynamic testing capability in support of its SS&M Program would be consistent with the U.S. policy on nonproliferation.

The President is committed to curbing the proliferation of nuclear weapons. The DOE SS&M Program is a key component of the U.S. nonproliferation strategy. This Nation's commitment to nonproliferation is evident by our support for an indefinite extension of the Nonproliferation Treaty in force since 1970; [21 UST 483] (see box). In support of these goals, the SS&M Program provides a means to assure the safety and reliability of the Nation's remaining stockpile of nuclear weapons under a continuing testing moratorium and a future comprehensive test ban.

On August 11, 1995 the President announced his commitment to seek a "zero-yield" CTBT (see box). The President also established several safeguards that condition the United States entry into a CTBT. One of these safeguards is the conduct of a science-based Stockpile Stewardship and Management Program, including the conduct of experimental programs. This safeguard enables the Nation to enter into such a treaty while maintaining a safe and reliable nuclear stockpile consistent with National security strategy (see box section 2.2).

One global benefit of science-based stockpile stewardship is to demonstrate the U.S. commitment to Nonproliferation Treaty goals; however, the U.S. nuclear posture is not the only factor that might affect whether or not other nations might develop nuclear weapons of their own. Some nations that are not declared nuclear states have the ability to develop nuclear weapons. Many of these nations rely on the U.S. nuclear deterrent for security assurance. The loss of confidence in the safety or reliability of the weapons in the U.S. stockpile could result in a corresponding loss of credibility of the Nation's ability to provide a nuclear deterrent and could provide an incentive to other nations to develop their own nuclear weapons program.

The United States has halted the development of new nuclear weapons systems. The Nuclear Posture Review commits the United States to maintaining a safe and reliable nuclear deterrent. The hydrodynamic testing program, when used to assess the safety and reliability of the nuclear weapons primaries in the remaining stockpile, does not constitute proliferation. The results of such testing are classified and could not lead to proliferation without a breach of security. Nonproliferation verification would not be affected by a choice to perform hydrodynamic testing in open-air shots or containment. The levels of energy release from high explosives in hydrodynamic testing is far from adequate for clandestine nuclear testing of weapons, even very-low-yield nuclear testing. Because the United States is already a nuclear weapons state and has had a hydrodynamic testing program for several decades, continuing to maintain a hydrodynamic testing capability does not change our Nation's status regarding proliferation. Lack of hydrodynamic testing capability, while seriously impacting our ability to ensure the continued safety and reliability of the stockpile, also would not change the status of the United States in terms of proliferation – we would remain a nuclear weapons state. Proliferation drivers for other states, such as international competition or the desire to deter conventional armed forces, would remain unchanged regardless of whether DOE implemented the proposed action analyzed in this EIS.

Most of the component technology used for hydrodynamic testing is unclassified and is available in the open literature; many other nations have developed a considerable accelerator technology capability. Accelerator-based radiographic technology is currently used by other weapons states for many of the same reasons it is used by the United States. In the NPT the parties agree to not transfer nuclear weapons, other devices, or control over them, and to not assist, encourage, or induce nonnuclear states to acquire them. However, the treaty does not invoke stockpile reductions by nuclear states, and it does not address actions of nuclear states in maintaining their stockpiles. Article VI obligates each of the parties to negotiate in good faith on the "cessation of the nuclear arms race at an early date and to nuclear disarmament..." The concept of hydrodynamic testing is known to all the signatories, and the capability exists with several of the nuclear states. Such capability is said to have been an important factor for the nuclear states to have entered into the treaty and to agree to further negotiate for a CTBT.

EIS	**NOI**	**Draft EIS**	**Final EIS**	**ROD**
DARHT EIS	Nov 94	May 95	Aug 95	Oct 95
LANL SWEIS	May 95	Apr 96	Dec 96	Mar 97

SS&M PEIS	Jun 95	Jan 96	Jul 96	Aug 96

Note: Dates are subject to change.

2.6 RELATIONSHIP OF THE DARHT EIS TO OTHER DOE EISs

DOE plans two other National Environmental Policy Act (NEPA) reviews regarding proposed actions at LANL related to the *Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility Environmental Impact Statement* (EIS) – the *LANL Sitewide Environ-mental Impact Statement* (SWEIS) and the *Stockpile Stewardship and Management Program-matic Environmental Impact Statement* (PEIS).

DOE is in the process of preparing the SWEIS for LANL [Notice of Intent, 60 FR 25697]; the public comment period on the scope of the SWEIS ended on June 30, 1995. The purpose of the SWEIS is to provide DOE and its stakeholders a comprehensive look at the cumulative environmental impacts of ongoing and reasonably foreseeable future operations at LANL. The SWEIS will focus on impacts of current LANL activities and activities proposed or anticipated to occur 5 to 10 years into the future. It will replace the prior SWEIS that was completed in 1979. The SWEIS will include all activities at LANL and will incorporate the results of any related environmental impact analyses in any current NEPA documents, which will be combined with impact analyses performed specifically for the SWEIS. Under current schedules, the DOE plans to issue the Record of Decision (ROD) on the DARHT EIS prior to issuing the draft SWEIS. Information on the environmental impacts of the course of action selected in the DARHT ROD will be included in the analysis of cumulative impacts for the SWEIS.

DOE gave preliminary notice of its intent to prepare the *Stockpile Stewardship and Management PEIS* in October 1994 [59 FR 54175]. DOE's report, *The Stockpile Stewardship and Management Program: Maintaining Confidence in the Safety and Reliability of the Enduring U.S. Nuclear Weapons Stockpile,* (DOE 1995), provides a framework for the issues to be considered in the PEIS. DOE started the PEIS in June 1995 [Notice of Intent, 60 FR 31291]; the public comment period on the scope of the PEIS ended August 11, 1995. The PEIS will assess the environmental impacts of alternatives for conducting the SS&M Program, will assist with decisions to identify specific capabilities and facilities for conducting the program, and will help determine the configuration (sites for facilities) of the nuclear weapons complex that would most efficiently implement the SS&M Program. The environmental impact analysis of the course of action selected in the DARHT ROD will be incorporated into the PEIS.

Proceeding with the DARHT EIS in advance of the completion of either the SWEIS or the PEIS is necessary because a decision on whether to proceed with the DOE's preferred alternative to implement DARHT, or pursue another alternative course of action, is needed as soon as possible to help ensure the continued safety and reliability of the nuclear weapons stockpile. As a matter of policy and in response to Presidential and Congressional direction, DOE will continue to maintain and improve its hydrodynamic testing capability regardless of the outcome of either the SWEIS or the PEIS. Thus, the alternatives analyzed in this DARHT EIS are not dependent on the decisions expected to flow from either the SWEIS or PEIS.

Under NEPA regulations, while work on a required program environmental impact statement is in progress, a Federal agency may not undertake in the interim any major action covered by the program unless the action:

- Is justified independently of the program

- Is itself accompanied by an EIS

- Will not prejudice the ultimate decision on the program, including determining subsequent development of the program or limiting programmatic alternatives [40 CFR 1506.1 (c)]

DOE believes that any course of action selected after completion of the DARHT EIS would meet this standard. Chapter 2 of the EIS provides the technical justification for providing enhanced hydrodynamic testing capability. This conclusion has been supported by the President and Congress who have directed DOE to rely on hydrodynamic testing to ensure the safety, performance, and reliability of the stockpile in the absence of underground nuclear testing. This determination is unrelated to, and would not depend on, any other stockpile stewardship actions which may be proposed as part of the SS&M program. Under any course of action to be analyzed in the SS&M PEIS, DOE would still need to continue hydrodynamic testing and would still need to acquire enhanced radiographic capability.

Similarly, because enhanced hydrodynamic capability is needed in the near term regardless of the alternatives to be analyzed in the SS&M PEIS or the decisions that will result from the SS&M ROD, DOE believes that a decision to implement any of the alternatives analyzed in this DARHT EIS would not prejudice any ultimate decisions regarding the SS&M program. Hydrodynamic testing and dynamic experiments at LANL as an ongoing mission will continue in support of stockpile stewardship, and this fact will be one of the baseline assumptions for the SS&M PEIS. The proposal contained in the DARHT EIS would not render more or less reasonable any of the alternative courses of action to be considered in the SS&M PEIS, nor would it affect any decisions expected from the SS&M ROD. DOE believes that the DARHT EIS adequately identifies and analyzes the proposed action and the reasonable alternative means to achieve it. Therefore, DOE believes that its proposal to acquire enhanced radiographic capability meets the regulatory requirements for interim actions, and that any actions decided upon in the DARHT ROD would not be limited pending completion of the SS&M PEIS.

The DARHT project is likewise a permissible interim action pending completion of the LANL Sitewide EIS. DOE's need for enhanced radiographic capability to conduct science-based stockpile stewardship as directed by the President and Congress provides the independent justification for the project. That capability can be provided by implementing any of the alternatives analyzed in the DARHT EIS without requiring additional new facilities or changes in operation for existing facilities at LANL, since radiographic hydrotesting is an ongoing mission for LANL. Thus, deciding whether and how to provide enhanced radiographic capability will not prejudice any decisions resulting from the LANL Sitewide EIS.

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CHAPTER 3

PROPOSED ACTION AND ALTERNATIVES

This chapter describes the proposed action and alternative ways to accomplish it. It also describes considerations that are common to all alternatives, including those alternatives that were considered but not analyzed.

3.1 OVERVIEW

The alternatives analyzed in this environmental impact statement (EIS) would implement all or part of the Proposed Action. The Proposed Action is to provide an enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of the historical mission of the U.S. Department of Energy (DOE) and the near-term stewardship of the Nation's nuclear weapons stockpile. Those aspects of the DOE hydrodynamic testing and dynamic experiment program that would not change regardless of the course of action selected are described in this chapter as considerations common to all alternatives. DOE considered, but did not analyze in detail, other alternatives, which are described here along with an explanation as to why they would not meet the DOE's purpose and need for enhanced testing capability. The environmental impacts of all analyzed alternatives, along with other decision factors, are summarized. The discussion in this chapter is augmented by the classified supplement for this EIS.

The No Action Alternative would not meet the DOE's purpose and need for enhanced radiographic hydrodynamic testing but is provided as a basis of comparison. The next two alternatives address various ways to meet part or all of the purpose and need. The remaining alternatives would modify the DARHT Baseline Alternative to mitigate possible environmental impacts; these mitigation measures could also be applied to the other alternatives, but they are not expressly analyzed. For example, the Single Axis Alternative could be constructed instead of the dual-axis facility under the Upgrade PHERMEX Alternative as well as the modification to the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility analyzed under the Single Axis Alternative. However, because the environmental impacts would be similar, and within the expected bounds of the alternative analyzed, this EIS does not specifically analyze that particular option.

The alternatives analyzed are:

- **No Action Alternative:** DOE would continue to use the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility at the Los Alamos National Laboratory (LANL) and the Flash X-Ray (FXR) Facility at the Lawrence Livermore National Laboratory (LLNL) in support of its stockpile stewardship mission. Construction of the DARHT Facility would not be completed; the structure would be completed for other uses. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

- **DARHT Baseline Alternative:** DOE would complete and operate the DARHT Facility and phase out operations at PHERMEX. DOE may delay operation of the second axis of DARHT until the accelerator equipment in the first axis is tested and proven. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels. This alternative was called the preferred alternative in the draft EIS.

- **Upgrade PHERMEX Alternative:** Construction of the DARHT Facility would not be completed. Major upgrades would be constructed at PHERMEX, and the high-resolution radiographic technology planned for DARHT would be installed at PHERMEX, including a second accelerator for two-axis imaging. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

- **Enhanced Containment Alternative:** Three options are considered under this alternative: 1) the Vessel Containment Option, 2) the Building Containment Option, and 3) the Phased Containment Option. The Phased Containment Option is the preferred alternative.

> Note: Alternatives and options examined in the draft EIS encompass and bound potential impacts from the Phased Containment Option that was added to this final EIS.

This alternative is similar to the DARHT Baseline Alternative except that some or all tests would be conducted in a containment vessel or containment structure. All tests would be contained if a containment structure were used. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

- **Plutonium Exclusion Alternative:** Similar to the DARHT Baseline Alternative except that plutonium would not be used in any of the experiments at DARHT. In the future, DOE may perform some dynamic experiments with plutonium; those involving radiography would be conducted at PHERMEX and would be conducted in double-walled containment vessels.

- **Single Axis Alternative:** Similar to the DARHT Baseline Alternative except that only one accelerator hall would be completed and operated for hydrodynamic tests or dynamic experiments. The other hall would be completed for other uses. In the future, DOE may perform some dynamic experiments with plutonium; these would be conducted in double-walled containment vessels.

This final EIS identifies the Phased Containment Option of the Enhanced Containment Alternative as the preferred alternative. However, the draft EIS described the DARHT Baseline Alternative as preferred. This change is significant both technically and as an example of the National Environmental Policy Act (NEPA) process benefitting from public participation and comments. The draft EIS discussed containment using vessels or building options that would have been committed strongly to current technology. These options were not chosen then as a preferred approach because of limitations on operations at the firing point and an inability to fully meet programmatic needs at this time. However, the public comments were strongly weighted toward containment as a method to reduce environmental consequences as much as possible. DOE recognizes the environmental benefits of containment and, therefore, has developed and identified as the preferred alternative a third option, Phased Containment, which reduces environmental consequences while providing the technologists with flexibility in how to achieve specific environmental objectives.

3.2 PROPOSED ACTION

As discussed in chapter 2, DOE needs to ensure that the U.S. nuclear weapons stockpile remains safe, secure, and reliable. The Stockpile Stewardship and Management Program is DOE's program to gain the scientific understanding needed to assess the condition of nuclear weapons and to assure their continued safety, performance, and reliability. DOE has determined that, in the absence of nuclear testing, radiographic hydrodynamic testing and dynamic experiments are necessary to provide information regarding the condition and behavior of nuclear weapons primaries. DOE has determined that enhanced diagnostic capability is needed. DOE also has determined that no other currently available technique would provide a level of information comparable to that provided by enhanced high-resolution radiographic hydrodynamic testing and dynamic experiments. As discussed in chapter 2, these conclusions have been independently verified by panels of technical experts.

In response to the specified purpose and need, DOE proposes to provide an enhanced high-resolution radiographic capability to perform hydrodynamic tests and dynamic experiments in support of its historical mission and the near-term stewardship of the Nation's nuclear weapons stockpile. DOE's preferred approach would be to complete and operate the DARHT Facility with a phased-in enhanced containment of the tests.

3.3 CONSIDERATIONS COMMON TO ALL ALTERNATIVES

Certain aspects of the DOE's hydrodynamic test and dynamic experiments program would not change, regardless of which alternative would be implemented. The actual testing program may have programmatic constraints due to a variety of reasons, such as annual testing needs, funding considerations, or to ameliorate potential environmental impacts. The type of diagnostic experiment – e.g., optical, pin shot, or weapons geometry (explained below) – would not change even though the ability to obtain diagnostic information would vary among alternatives. The complex infrastructure needed to support hydrodynamic tests and dynamic experiments would not change. The operation of the FXR at LLNL and the Radiographic Support Laboratory (RSL) at LANL would not change. Also, under all alternatives, DOE could conduct dynamic experiments involving plutonium.

3.3.1 Hydrodynamic Tests

For many years, DOE has relied upon hydrodynamic tests to obtain certain types of information about the behavior of nuclear weapons primaries during the complex interactions expected in an implosion (see figure 1-2). Hydrodynamic tests use full weapons geometry. The fissile material inside the weapon is replaced with another material. Hydrodynamic tests are used to measure material motions and compression by using pins, optics, and radiography. Hydrodynamic tests are supplemented with static, dynamic, or high-explosives experiments. The information obtained is then used to develop calculations to predict the safety, performance, or reliability of the weapons device.

Pin shot hydrodynamic tests involve replacing the fissile material of a weapons primary with another material and inserting a post, called a blast pipe, with various lengths of electrical sensors, called pins, which radiate from its end. The blast pipe is highly shielded to protect the diagnostic equipment. High explosives are placed around the outside of the inert material and pin assembly and detonated to test the mock device. The pins record the movement of the implosion. The information obtained is used to improve the understanding of how the pit surface moves during the short period of time up to a few microseconds before criticality would be achieved in an actual weapon. Personnel extrapolate the pin shot data and estimate what would happen in an actual weapon up to the point of a nuclear explosion. These estimates become less certain as the estimated point of criticality is approached. After extrapolating the pin shot information, personnel calculate estimated changes in imploding shapes and stages of reactivity. The pin assembly and blast pipe affect the geometry of implosion, so this type of test does not exactly mimic the behavior expected during an actual weapons implosion. Pin shots do not provide information about the boost gas associated with a pit. Radiography is often used as an additional diagnostic with pin shots.

Radiographic hydrodynamic tests supply additional information needed to understand the behavior of an imploding pit, and information regarding mock-ups of boost gas. Unlike a pin shot, the entire weapons primary is replicated. These tests involve replacing the fissile material of a weapon with another material, detonating the high explosives, and taking very high-speed (60 to 200 nsec) x-ray photographs of the imploding device. Radiographic images of mock-up weapons can be taken at any point during an experiment, including up to the estimated point at which a nuclear explosion would occur in an actual weapon. They provide information about density and shape changes as the pit implodes. From this information, LANL personnel modify and improve calculations and infer more detailed information about an actual nuclear explosion.

To avoid risking security, health, and safety, weapons researchers use some surrogate materials for tests and experiments. Depleted uranium is often used to mock the weapons-grade plutonium. Depleted uranium has a higher density, greater strength, and a higher melting point than weapons-grade plutonium. Tantalum is used for some hydrodynamic tests. The density of tantalum is similar to that of weapons-grade plutonium, but, like depleted uranium, it has a higher strength and higher melting point. Lead is sometimes used, primarily to look at material ejected from the pit surface and joints. The density of lead is lower than weapons-grade plutonium, and lead has lower strength and a lower melting point.

The certainty of information for radiographic hydrodynamic tests increases with the number of views that are obtained. This applies to both sequential images and images taken from different viewpoints. The amount of information obtained from radiographic hydrodynamic tests also depends on the clarity of the image. This, in turn, depends on the resolution provided by the x-ray beam spot size (a smaller beam spot size provides greater resolution) and the penetration provided by the x-ray intensity. The dense pit materials, typically represented by depleted uranium, inhibit the penetration of the x-rays and inhibit the ability to obtain images of the imploding pit. To obtain better penetration, hence better images, other surrogate materials are sometimes used, such as tantalum, which allows better x-ray penetration.

Depleted uranium is also used for related mock-up components. For example, hydrodynamic tests are sometimes used to determine the effect that a large mass, such as a weapons secondary, would have on the physics of the imploding primary. The mock-ups of the weapons secondary are often made of depleted uranium.

Optical means are sometimes used to record information for a hydrodynamic test. Under this technique, light and conventional high-speed photography are used (instead of x-rays and radiography) to record the movement of materials in the weapons mock-up. Lasers are also used for high-speed photography and interferometry to provide additional diagnostic capability.

Static radiographs are sometimes mentioned in connection with hydrodynamic tests and dynamic experiments. These static radiographs are x-ray images taken shortly before the test or experiment is fired. Their purpose is to assure the experimenter that the device has not suffered an unacceptable or unknown change since assembly. The static radiograph thus provides a picture of the initial condition of the test or experiment.

3.3.2 Dynamic Experiments

While hydrodynamic tests examine interactions among parts of the primary, dynamic experiments explore broader issues regarding materials science. Dynamic experiments involve a variety of techniques. Depending upon the properties being examined, a variety of materials may be used. Dynamic motion is usually achieved by driving test materials with high explosives.

In the past, DOE has conducted dynamic experiments at PHERMEX using weapons-grade and other forms of plutonium metal. These experiments were conducted inside double-walled steel containment vessels. Plutonium is an extremely complex material, and DOE's understanding of its behavior is important to predict nuclear performance. In the future, DOE plans to conduct dynamic experiments to help understand the constitutive properties of plutonium, its equations-of-state (particularly under conditions involving high temperatures and pressures), and its surface behavior following shocks. Dynamic experiments may involve observing the effects that would occur on mixtures of plutonium isotopes and alloys or other adjunct materials, which would be chosen for purposes of the experiment, after being shocked by explosives-driven materials. As a matter of policy, dynamic experiments involving plutonium would always be conducted inside double-walled steel containment vessels. All experiments would be arranged and conducted in a manner such that a nuclear explosion could not result.

3.3.3 Infrastructure Requirements

Hydrodynamic testing and dynamic experiment operations require considerable infrastructure – facilities, equipment, and personnel – in support of test events. Hydrodynamic testing and dynamic experiment operations at PHERMEX take advantage of the existing infrastructure at LANL. If DARHT were to be completed and operated as proposed, those operations would take advantage of the same infrastructure. However, hydrodynamic testing and dynamic experiment operations at LANL are only a small proportion of the total workload at the LANL support facilities; these facilities support many other DOE activities at LANL such as weapons research, science, and waste management.

Hydrodynamic testing and high-explosives experiments are conducted in several phases, each requiring extensive interactions among personnel. Any given test requires direct support from several organizations, as well as additional indirect support such as security, clerical, maintenance, or monitoring personnel.

To conduct a hydrodynamic test, weapons researchers decide what kind of information is needed, and test designers and engineers determine how the information can be obtained. Special parts are designed, engineered, and fabricated for each test. The test configuration is assembled and inspected. The test assembly is transported to the firing test facility, temporarily stored until the test can be conducted, and set up at the firing site. Firing-site personnel, such as accelerator specialists and radiograph technicians, must assure that the equipment is ready to record the diagnostic information. The final test assembly is inspected, the shot is fired, and the diagnostic information recorded. The test materials are collected, recycled, or cleaned up, and the information obtained is analyzed. Computer projections are made to extrapolate the information, and the results are used to verify computational codes. Each part of the process is iterative; for example, a part manufactured for a hydrodynamic test first undergoes mechanical testing and inspection, and, if it appears inadequate, the parts designer and machinist may consult with both the weapons researchers and the test designers to develop a different part. The infrastructure requirements to support the different steps in the radiographic test experiments are summarized in table 3-1.

Table 3-1.–*Infrastructure Requirements for Typical Radiographic Test Experiments*

Activity	**Implementation Requirement**	**Infrastructure Capabilities and Resources[a]**
Experiment design and engineering	Weapons computer codes Hardware engineering specifications Test design	Scientists and engineers experienced in weapons work (TA-3) Component and assembly design engineers (TA-16) Hydrodynamic test engineers (TA-15)

Test materials and component fabrication	Parts design High-precision parts fabrication High-precision quality inspection High-explosives fabrication High-energy detonators Pin dome precision assembly and quality inspection Special materials: plastics, glues, foams, binders, organics Salt mock-ups	Component and assembly design engineers (TA-16) Precision manufacturing designers and facilities Facilities and operators for depleted uranium, beryllium, tantalum, tungsten, and high explosives (TA-3) Quality inspection instruments housed in controlled environment facilities (TA-16) High-explosives fabrication facilities Experienced fabrication engineers and safety engineers (TA-16) High-energy detonators design, fabrication, and testing facilities Experienced detonator designers, engineers, technicians, and safety engineers (TA-22) Assembly facilities near test facility Inspection instrumentation near test facility Experienced assembly designers, engineers, and technicians (TA-15) Chemistry laboratories, assembly facilities, technicians (TA-9) High-explosives fabrication facilities, technicians (TA-15)
Test assembly and inspection	High-explosives handling facility Precision mechanical inspection Penetrating x-ray nondestructive inspection and inspection	High-explosives facility Experienced high-explosives operators (TA-16) Mechanical inspection instrumentation housed in controlled environment facility (TA-16) Static radiographic testing instrumentation Experienced radiographic technicians (TA-8)

[a] Parentheses indicate LANL Technical Area where the activity or capability is located.

Table 3-1.–*Infrastructure Requirements for Typical Radiographic*

Test Experiments – Continued

Activity	**Implementation Requirement**	**Infrastructure Capabilities and Resources[a]**
Transportation to firing site and integral storage area	Secure containment Secure transport Secure (classified) interim storage area	Department of Transportation approved containers (TA-16) Department of Transportation approved vehicles; access via nonpublic roads or public road closures; safe secure transport security vehicles used with special shipping containers (TA-16) Approved secure storage facility in vicinity of firing site (TA-15)
Firing-site preparation	Perimeter control Multiple diagnostic capabilities Facility operations support Small firing-site support Test set-up and take-down	Security and safety control systems in place Engineering and administrative controls for safety Security and safety personnel (TA-15) Flash radiography instrumentation High-speed electronic recording instrumentation High-speed optical diagnostic test equipment Laser diagnostics equipment Microwave diagnostics equipment Experienced diagnostic test engineers and equipment operators Specific temperature, environmental controls for inspection and diagnostic equipment Facility, instrumentation and equipment calibration, maintenance and repair support, and technicians (TA-15) Machine shop Electronics calibration equipment Communication system and equipment Security support systems Plant operations support personnel Fire suppression personnel (TA-15) Equipment, personnel for qualifying detonations and characterizing high explosives (TA-40) Onsite mobile cranes, trucks, operators (TA-15)

[a] Parentheses indicate LANL Technical Area where the activity or capability is located.

Table 3-1.–*Infrastructure Requirements for Typical Radiographic*

Test Experiments – Continued

Activity	**Implementation Requirement**	**Infrastructure Capabilities and Resources**[a]
Uncontained testing	Materials recovery Materials recycle Materials processing Waste management Environmental monitoring Worker health and safety monitoring	Experienced recovery staff, equipment (TA-50) Materials classifiers, materials characterization facility and equipment, materials storage (TA-50) Reprocessing facilities for depleted uranium, beryllium, tantalum, tungsten, and high explosives processing for reuse; technicians, transportation (TA-50) Treatment, storage facilities, and staff for mixed waste, low-level radioactive waste, RCRA waste, sanitary waste Disposal facilities (offsite and onsite) (TA-54) Environmental scientists, sampling and analytical technicians, chemistry laboratory facilities (TA-3) Health physicists, industrial hygienists, and industrial safety specialists, monitoring equipment, laboratory facilities (TA-59)
Contained experiments	Containment vessel support Plutonium dynamic experiments	Vessel design engineers Vessel test engineers, facilities Vessel cleanout Debris-handling capabilities Material recovery, reprocessing Waste treatment Vessel staging and storage (TA-15) Plutonium fabrication, storage and handling Plutonium chemistry facilities Material processing and storage Specialized engineers, chemists, technicians, security, and worker safety personnel (TA-55)
Post-testing activities	Develop, digitize radiographs Analyze images, signals Develop and refine analytic tools	Radiographic facilities and technicians (TA-15) Custom computer analysis software (TA-15) Weapons components functional modeling capabilities, custom computer hardware and software, weapons personnel and technicians (TA-3)

[a] Parentheses indicate LANL Technical Area where the activity or capability is located.

DOE also intends to perform dynamic experiments with plutonium under all alternatives analyzed in this EIS. The infrastructure already in place at LANL provides a strong basis for the capability to perform these experiments. The plutonium processing capability provided at TA-55 is extensive and adequate for the required operations: chemical separation, alloy preparation, foundry capability, casting, and machining. This capability exists along with the proper radiation and health protection services, security controls, and protective force controls for conduct of plutonium operations.

Transportation of plutonium parts and high explosive assemblies can be conducted onsite at LANL or over roads that may be closed to the public. All of the required manufacturing, assembly, and testing facilities are onsite. Assembly can be performed within secure facilities with protective force controls already in place.

The existing diagnostic facilities provided at TA-15, when coupled with the proposed DARHT Facility, will provide strong analysis capability that is based on the extensive testing of explosive assemblies over the last 50 years; i.e., radiography, optical, laser, microwave, and firing site controls.

Plutonium processing and high-explosive assembly facilities have been developed to support a wide range of operations. The proposed testing program that would take place under any alternative comprises only a modest part of the workload of these facilities. However, because these facilities are already available, it would not be cost effective to duplicate them at another location.

3.3.4 Flash X-Ray Facility

The FXR Facility (Building 801 at Site 300) at LLNL is included in this EIS baseline because the facility is an integral part of the DOE's capability for hydrodynamic testing. Under all alternatives analyzed in this EIS, DOE would continue to operate FXR. The continued operation of FXR would not be affected by any of the alternatives discussed in this EIS. However, the level and scope of the testing program at FXR could be affected by decisions resulting from this review.

The FXR is a key facility used by DOE to address physics issues associated with the primary stage of a nuclear weapon and other types of experiments. PHERMEX and FXR are the two DOE facilities that currently provide hydrodynamic diagnostic capability for the stockpile stewardship program. DOE anticipates maintaining and operating FXR into the next century to support LLNL's weapons stockpile stewardship mission. It is possible that, in the future, DOE could propose activities at LLNL which might affect operation of FXR, but at this time no such proposals are foreseen except those discussed below.

LLNL has operated the FXR Facility since 1983 at their Site 300, making it 20 years newer than PHERMEX. Currently, FXR represents the best hydrodynamic testing capability available to the DOE. The FXR Facility contains a linear induction accelerator with an array of diagnostic capabilities that have been used to provide a detailed understanding of the behavior of the implosion systems (HPAIC 1992). FXR is a single, linear induction accelerator operating at 17 MeV to provide an x-ray dose greater than 285 rad from a spot size that is approximately the same as PHERMEX (Baker 1995; JASON 1994).

FXR is being upgraded as part of a larger revitalization project at Site 300 valued at $27.4 million (Baker 1995). The upgrades at Site 300 include a high-speed optics maintenance facility, a bunker support facility, diagnostic equipment for the bunkers, road upgrades, central control post, and a new water supply. A $5.3 million segment of the upgrade is scheduled to begin October 1995 and be completed in October 1997 (Baker 1995). This latter segment will increase the capability of FXR by allowing for two pictures to be taken along a single axis of the FXR accelerator; this is referred to as a double-pulse. However, the x-ray dose would be reduced to about 55 R per pulse. Following completion of the second upgrade, the replacement cost for FXR would be approximately $90 million.

All FXR explosive experiments are currently uncontained. In addition to the ongoing upgrades, DOE has funded studies to examine the option of using a containment facility at LLNL that would be capable of containing an explosion of up to 172 lb (80 kg) of high explosives (DOE 1992; HPAIC 1992). This potential containment facility is in the conceptual design stage. NEPA documentation for the proposed Contained Firing Facility (CFF) is in progress. During the construction period for CFF, DOE could not use FXR for hydrodynamic testing. Although the firing site is in compliance with current environmental regulations and does not adversely impact upon residential areas near Site 300, a containment facility would provide LLNL with additional flexibility to continue hydrodynamic tests and dynamic experiments, particularly in the event that future environmental regulations in California would restrict uncontained operations. Even with the planned upgrades and the inclusion of the proposed containment system, DOE has no plans to conduct experiments with plutonium at Site 300 (Multhauf 1995). DOE does not have the facility infrastructure at LLNL to support these types of experiments, and it would be unreasonably expensive (several hundred million dollars) to provide the required plutonium handling capability at LLNL. Accordingly, the FXR Facility, in current or upgraded mode or with single or dual axis capability, would not provide the enhanced capability that the DOE needs to diagnose dynamic experiments with plutonium. In the future, should DOE propose other major modifications to the FXR facility or its operations, the Department would conduct appropriate studies (including NEPA review if required) at that time.

3.3.5 Radiographic Support Laboratory

The RSL was the first part of the DARHT project at LANL. Construction started in 1988 and was completed in 1990. Under all alternatives analyzed in this EIS, DOE would continue to operate the RSL to support radiographic operations undertaken at LANL. The RSL is a 21,000-ft^2 (1,950-m^2) building located in Technical Area 15 (TA-15). The main functions of the RSL are development, calibration, testing, and repair of high-energy flash x-ray machines. The facility includes a radiographic machine room, control room, mechanical and electronics room, machine shop, and offices. In addition to supporting ongoing radiographic testing at the PHERMEX Facility, the RSL has been serving as a staging area for development of accelerator technology and the Integrated Test Stand that DOE proposes to use to achieve an enhanced radiographic hydrodynamic test capability.

Two separate panels of independent consultants convened by DOE studied the linear induction accelerator technology that DOE proposed to use, and they agreed that DOE needed to design and test the Integrated Test Stand as the front-end of the linear induction accelerator proposed to be installed at DARHT (DFAIC 1995, DOE 1993a). The same linear induction accelerator would be used under all alternatives analyzed in this EIS except that under the No Action Alternative an enhanced accelerator capability would not be installed in PHERMEX. However, under all alternatives, including the No Action Alternative, DOE would continue to perform accelerator research in support of flash x-ray technology and use the RSL facility in the same way it is used now.

3.3.6 Site Description

All of the alternatives analyzed in this EIS refer to the PHERMEX site and/or the DARHT site (figure 3-1). These sites are located in the southeastern part of LANL TA-15 on Threemile Mesa. TA-15 is located in the center of the high-explosives research, development, and testing area, in the southwestern part of LANL, which makes up about 20 mi^2 (52 km^2), or about half of the area of LANL (LANL 1994).

The PHERMEX site and the DARHT site are about 2,000 ft (600 m) apart. These locations constitute a single site for many of the environmental impacts. For the purpose of analysis, the combined sites are considered to be Area III in TA-15, as defined by LANL for safety, security, and control of the firing sites at PHERMEX and the DARHT Facility. Area III includes the mesa top from the southeast boundary of TA-15 extending northwestward a little over 1 mi (about 2 km) to a fence line near R-183 (figure 3-2).

The PHERMEX site, shown in figure 3-1, is a small complex of buildings and structures which have been used for hydrodynamic testing and dynamic experiments at LANL. The buildings, structures, and roadways at the PHERMEX site occupy about 11 ac (4 ha). About 120 ac (48 ha) of the mesa top lie behind the safety fence for PHERMEX and within TA-15. At PHERMEX, the mesa is about 1,500 to 2,000 ft (460 to 610 m) wide, bounded on the north by Potrillo Canyon, and on the south by Water Canyon.

The DARHT site is located to the west of the PHERMEX site, also in TA-15 on Threemile Mesa. The total area for the DARHT Facility is about 8 ac (2.3 ha). This area includes about 1 ac (0.4 ha) previously disturbed under the RSL contract for the DARHT Facility access road and utilities and 7 ac (2.3 ha) disturbed by the DARHT construction. Previous DARHT construction activities through 1994 account for the clearing of 14,000 board-feet of lumber. Potential impacts related to the future construction of the DARHT site are discussed in section 5.2.2.1.1 and section 5.2.5.1.1. At this site, the mesa is about 1,600 ft (490 m) wide. It is bounded on the north by the upper reaches of Potrillo Canyon and on the south by Water Canyon. The site lies only a few hundred feet from the mesa rim for Water Canyon.

The elevation on the mesa top in Area III is about 7,180 ft (2,190 m). In the vicinity of Area III, vegetation is mainly the Ponderosa pine plant community. This plant community within the 8 ac (2.3 ha) associated with DARHT has been altered due to construction. Any reptile, amphibian, bird, and large mammal populations have been displaced by these activities. Small mammals such as rodents would have been displaced temporarily and would likely return to the disturbed area. Soils on the nearby portions of the mesa top include the Pogna fine sandy loam, rock outcrop, and Seaby loam (LANL 1993). The surface is well drained, and the main aquifer lies approximately 1,200 ft (370 m) below the surface (Broxton et al. 1994). Beneath the site, the Bandelier Tuff is likely to be more than 700 ft (215 m) thick, and the underlying Puye formation makes up the remaining interval to the water table.

3.3.7 Development of Operating Procedures

Operating procedures are already in place at PHERMEX and would be used under the No Action Alternative. Under all of the other alternatives analyzed, LANL would develop operating procedures to assist with safe, secure operation of the facility. These procedures would reflect the recent modifications resulting from the April 1995 fire at PHERMEX involving lithium hydride contaminant waste. This incident led to the modification of the Access Control Procedure that now requires a prehazard briefing for the Fire Department and clearing of all debris at the site prior to every test or experiment involving explosives.

LANL policy provides general safety guidance and requires that procedures more specific to actual operations be developed within the operating group. The operating group would also prepare a plan for emergency response. To foster a general safety awareness within the operating group, periodic meetings would be held to emphasize the aspects and consequences of safety and emergency planning. Safety considerations would take precedence over operational necessity of the operating group.

3.3.8 Waste Management

Operations for any of the alternatives would result in five categories of waste: solid waste (nonhazardous, nonradioactive), hazardous waste, mixed radioactive and hazardous waste (mixed waste), low-level radioactive waste (LLW), and transuranic (TRU) waste. The amounts of waste produced would vary according to the number and types of tests performed each year. Chapter 5 contains estimates of the amounts of waste expected to be produced from these operations.

Solid waste would be disposed at the LANL Area J landfill in TA-54 or sent to an approved disposal facility. Hazardous waste would be taken to TA-54 for temporary storage awaiting treatment and disposal. Mixed waste would be treated and disposed according to the site treatment plan. Low-level radioactive waste would be disposed at the LANL low level waste disposal site in TA-54. Transuranic waste would be stored at LANL Area G in TA-54 awaiting packaging and certification for shipment to the Waste Isolation Pilot Plant (WIPP).

A single-walled vessel would be used in support of hydrodynamic tests for both the Phased Containment Option and the Vessel Containment Option. This vessel would be decontaminated and reused until the structural integrity of the vessel would dictate retirement of the vessel. The vessels would not require disposal as LLW; following decontamination, the vessels would be categorized as scrap metal. The generation of LLW would reduce waste from 12,500 ft^3/yr (350 m^3/yr), as proposed under the DARHT Baseline Alternative, to 3,600 ft^3/yr (101 m^3/yr) with 75 percent containment as achieved under the final stage of the Phased Containment Option of the Enhanced Containment Alternative. This constitutes a reduction from 4 to 2 percent of the total LANL LLW disposal at Area G.

A double-walled vessel that would be used in support of a dynamic experiment containing plutonium would be transported to the LANL Plutonium Handling Facility at TA-55 for decontamination procedures. Previous experience has indicated that the vessels would be categorized as TRU waste following decontamination. It is anticipated that the vessels would be cut into pieces to reduce their volume prior to certification for disposal at WIPP. DOE estimates that two vessels per year would be used in dynamic experiments. This would yield approximately 26,000 lbs (11,820 kg) of steel that could be TRU contaminated and thus require disposal as TRU waste. Material contaminated by alpha-emitting radionuclides, which are heavier than uranium, with half lives greater than 20 years and in concentrations greater than 100 nCi/g of material are categorized as TRU waste.

3.3.9 Decontamination and Decommissioning

Under all alternatives analyzed in this EIS, eventually DOE would no longer need PHERMEX or the DARHT Facility and would decontaminate and decommission (D&D) the structures. The structures would eventually be demolished as well.

The only difference among alternatives would be the timing of the eventual D&D. For example, under the No Action Alternative, Plutonium Exclusion Alternative, and Upgrade PHERMEX Alternative, DOE would continue to operate PHERMEX indefinitely, while under the DARHT Baseline Alternative, DOE would phase out operations at PHERMEX over a four-year transition period. DOE would then proceed with D&D and demolition of the structure when it is no longer needed. DOE estimates that the DARHT Facility has a 30-year design life, regardless of whether the structure is used for hydrodynamic tests and dynamic experiments, as under the DARHT Baseline Alternative, or for other uses, as under the No Action Alternative.

At the end of the useful life of either PHERMEX or DARHT, DOE would evaluate options for disposal of the facility. At that time DOE would perform engineering evaluation, environmental studies, and a NEPA review to assess the consequences of different potential courses of action.

D&D activities would result in the generation of mixed waste, radiological waste, and solid waste. Demolition would result in solid waste in the form of construction rubble and possibly other types of waste. These wastes would be treated and disposed.

DOE anticipates that alternatives for disposition of the two facilities would include:

- D&D and demolish the structures and release the site for unrestricted use
- D&D and demolish the structures and restrict use of the site
- Partial D&D and retain structures for unrestricted use
- Partial D&D and retain structures for modified or restricted use
- No D&D and retain structures for similar or modified use

DOE cannot anticipate which options may be considered reasonable in the future and so cannot assess these alternatives in this EIS.

3.4 NO ACTION ALTERNATIVE

The No Action Alternative describes the continuation of the current situation (status quo) that would be expected in the future if DOE did not implement the DARHT Baseline Alternative or any other alternative analyzed in this EIS. The No Action Alternative serves as a basis of comparison for all other alternatives analyzed. For this EIS, the No Action Alternative would be to continue to operate PHERMEX at LANL and FXR at LLNL and not acquire an enhanced radiographic hydrodynamic testing capability. However, the No Action Alternative is not static. DOE would use these facilities to support its science-based stockpile stewardship and management program to the greatest extent possible. Accordingly, the type and number of hydrodynamic tests and dynamic experiments could vary from the type and number used in the past, as program needs change.

Under the No Action Alternative, the following would occur:

- PHERMEX and FXR would continue to provide hydrodynamic test capability
- PHERMEX would undergo occasional maintenance and operational upgrades, but the facility could not be upgraded to achieve the enhanced radiographic capability proposed for DARHT.
- The partially constructed DARHT Facility would be mothballed, and construction would not resume until another use for the structure could be determined (e.g., office space or accelerator applications), and appropriate reviews, including design and NEPA review as appropriate, were completed
- The RSL would continue to support radiography technology and operations at LANL
- Three-dimensional or time-dependent information would be partially obtained at PHERMEX by conducting sequential tests of nominally the same design
- DOE would perform some dynamic experiments; those using plutonium would be conducted in double-walled containment vessels

Under this alternative, DOE would continue to operate PHERMEX well into the next century. As discussed in chapter 2, over time, maintenance of the facility would be increasingly difficult in the event that replacement parts become unavailable to maintain and operate the vintage accelerator.

Under this alternative, DOE would determine another use for the partially constructed DARHT Facility, and would complete the structure following redesign and other appropriate reviews. This may require additional NEPA review. For the purposes of this EIS, in order to serve as a basis of comparison for other alternatives, DOE has assumed that completing the structure would involve completing a concrete shell similar to the DARHT Facility; DOE recognizes that other types of uses may require modification to the structure and different construction materials or techniques, compatible with other requirements for structures within TA-15 or the larger explosives testing area.

3.4.1 Facility

PHERMEX was constructed in the 1960s and first operated in 1963; the north and south amplifier rooms were added in 1980 and the R-310 Multidiagnostics Operations Center in 1988. The PHERMEX Facility includes three major buildings and several other support buildings and structures (see figure 3-2).

Table 3-2 lists some of the PHERMEX buildings and their functions. PHERMEX uses a radio-frequency accelerator (instead of a linear induction accelerator, like that at FXR) that was designed and built at LANL specifically for radiography. The accelerator is unique in that it was designed for a maximum charge per pulse by using a very low frequency (50 Mhz) to provide maximum stored energy per pulse. Although PHERMEX is able to obtain several hundred amperes peak beam current, the voltage quickly drops, resulting in a beam energy spread that limits beam spot size (DFAIC 1995).

Table 3-2.–*PHERMEX Buildings and Their Functions*

Building	**Function**
R-185	Power Control Building for PHERMEX (two-story). Contains equipment for regular site power and heating, ventilation, and air conditioning (HVAC), and special equipment to generate and control high voltages, store electrical energy, generate and control radio-frequency energy, and control PHERMEX functions during a test shot. One of only two buildings at the facility that personnel are allowed to occupy during a test shot.
R-184	Houses the linear accelerator, PHERMEX, and its ancillary equipment that produce the x-rays for imaging a test shot. Accelerator's 25 to 30 MeV electron beam impinges on a tungsten target which then emits the x-ray beam. Has high voltage power supplies and radio-frequency equipment. Personnel are not allowed in the building when the accelerator is operating.
R-310	Multidiagnostics Operations Center, built in 1988. Has a control room for firing explosive tests independently or in conjunction with PHERMEX radiography. Houses diagnostic equipment associated with firing control and data collection from test shots. Second of the two buildings that may be occupied during a test shot.
Firing Area and R-349	Contains detonator firing equipment. Firing site can handle 150 lb[a] (68 kg) of explosives on the pad in front of the Building R-184 bullnose which protects the x-ray converter. Larger explosive charges, up to about 1,000 lb (454 kg), can be accommodated by moving the firing point up to a distance of 160 ft (48 m) to the east away from Building R-184.
[a] Throughout this EIS, quantities of explosives are mentioned. Although different explosive compounds may be used, quantities are always given as an equivalent amount of TNT, which serves as a standard reference.	

No new construction or site modification at PHERMEX is included in the No Action Alternative, with the exception of DOE's proposal to relocate the Ector machine. In 1991, DOE proposed moving Ector from Site R-306, TA-15, to the PHERMEX site. Site preparations to receive the Ector machine have been ongoing since 1992 and have consisted of installing a concrete pad and an above-ground oil tank. Ector is an existing 30-year-old x-ray diagnostic machine that is scheduled to be moved to the PHERMEX site in 1995 or 1996 for experiments in which a wide-field-of-view, medium-resolution radiograph of an entire assembly being tested is needed simultaneously with a high-resolution radiograph of the same test. Ector could be used to image the large-scale motion of the lower-density region of an experiment while PHERMEX images a smaller high-density region of the same test. Ector would not require a separate building. DOE has completed NEPA review of certain site preparation activities that could be used for Ector and will complete all required NEPA review before the proposed relocation of Ector to the PHERMEX site is done. Use of Ector at PHERMEX would eventually be phased out.

Under the No Action Alternative, a double-walled steel containment vessel would be used at the firing-site facility to contain emissions and debris from selected dynamic experiments, particularly those involving plutonium.

3.4.2 Operations

The historic operational baseline for PHERMEX is described in appendix B. The PHERMEX Facility can detonate high-explosive charges up to 150 lb (70 kg) located at the principal firing point. If larger high-explosive charges are necessary, such charges up to about 1,000 lb (454 kg) would be located at firing points to the east along the accelerator axis. For such experiments, a temporary expendable blast shield would be constructed as necessary to mitigate blast effects. Both uncontained and contained shots are fired at PHERMEX.

Typical requirements to conduct a radiographic test are listed in table 3-1. Operations specific to PHERMEX can be divided into six steps: planning, assembly, placement, diagnostic verifications, firing, and post firing. Typically, the need and the initial planning for a test shot involve several LANL organizations (see section 3.3.3). Experts within the division that operates PHERMEX often participate in the planning aspects related to mechanical support, placement, and diagnostics. Completed assemblies are usually prepared elsewhere and delivered to the firing site. The Access Control Office (ACO) monitors transportation activities within the PHERMEX controlled area. A limited number of assembly operations, such as electrical connections at the firing point, may be performed at the TA-15 site.

Before a shot is fired, the firing supervisor clears the firing point of personnel and makes the final connections to the high-explosive assembly. The firing supervisor contacts the ACO for a list of personnel in the PHERMEX area and accounts for each one. No one is allowed to enter or exit the area until the shot is fired. Clearance patrolmen make a sweep from the PHERMEX site out to the designated control point and set up a roadblock. The roadblock remains in place until the shot is fired and the area is declared safe by the firing supervisor. The firing supervisor, clearance patrolmen, and the ACO maintain radio contact during the firing procedure. Fire suppression personnel and equipment remain in standby at the designated control point during the firing procedures.

Activation of the detonators occurs just before the PHERMEX x-ray machine is pulsed and is controlled by the facility safety system. Operation of the PHERMEX radiographic beam is controlled by physical interlocks and a machine visual disconnect terminal. The system includes an explosives visual disconnect terminal. For pin test assemblies, the pins are connected to their power supply just prior to firing and comprise the pin diagnostic network. The pin diagnostic network connections are protected in a manner similar to connections for the detonator circuit.

Prior to use, all simulated weapons assemblies are monitored for the presence of fissile material according to pit verification procedures. This monitoring is performed and verified by the firing supervisor and a member of the firing crew.

After the shot has been fired and the site declared safe, the clearance patrolmen remove the roadblocks and firemen on standby enter the area to control fires. The operating crew enters the firing area, collects any diagnostic data, and moves the film cassette to another building for dismantling. Film cassettes are heavily armored containers that protect the x-ray film from the explosive blast. Other detectors, using scintillators and recording cameras (generically known as "gamma-ray cameras"), could also be used and would be protected in similar cassettes. Post-firing activities include cleaning up the firing site and collecting firing-site debris. Cleanup and debris removal are often scheduled only after a sequence of shots. If a containment vessel has been used, the vessel is moved by truck to another LANL facility for opening, cleaning, and refurbishing.

Personnel who are engaged in recovery or cleanup activities typically are required to wear protective clothing as deemed necessary by the LANL Environment, Safety, and Health radiation control technician. Contamination of the firing point by undetonated explosives is highly unlikely, but remotely possible. If such contamination occurs, cleanup under a Special Work Permit is required before the firing point may be used again.

The PHERMEX operating crew includes personnel to field an experiment and support personnel to maintain the PHERMEX accelerator and all of the site's ancillary equipment. The number of workers with radiation safety training and available to be assigned to tasks at or near the PHERMEX firing area currently ranges from 67 to 77. Only nine radiation workers are required at one time. Some of the support personnel for a test typically include two electronics technicians for the diagnostic chamber, two or more PHERMEX operators, two staff members to provide physics support, one or more mechanical technicians for maintenance and upgrades, two clearance personnel, a firing crew of three technicians, a photographic technician to handle and process the x-ray films, and additional personnel depending on the diagnostics fielded for a test shot. Most of these people also support other programmatic efforts unrelated to PHERMEX.

3.5 DARHT BASELINE ALTERNATIVE

Under the DARHT Baseline Alternative, DOE would complete construction and operate both axes of the DARHT Facility. An artists' conception of the DARHT Facility is shown in figure 1-1. If the DARHT Facility becomes operational, DOE would phase out operation of PHERMEX over approximately four years. The DARHT Baseline Alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL. Under the DARHT Baseline Alternative, a steel containment vessel could be used at the firing site facility to contain emissions and debris from selected dynamic experiments; experiments involving plutonium would be conducted inside a double-walled steel vessel.

The DARHT Facility responds to DOE's need to obtain enhanced hydrodynamic testing capability. Through its weapons research and design expertise at LANL, DOE developed DARHT to provide enhanced diagnostic capability to study the behavior of nuclear weapons. DARHT was designed specifically to provide three-dimensional information and to obtain deeply penetrating, high-resolution radiographic images.

DARHT would be used to study the three-dimensional implosion of mock nuclear weapons primaries. DARHT would enable imaging through very thick, dense materials; take multiple, very brief snapshots from two different lines of sight; and provide images of very high resolution. Completion and operation of the first axis of DARHT would produce radiographic images with significantly higher spatial resolution and penetration than is now possible at either PHERMEX or FXR. With completion and operation of the second axis, DOE would be able to obtain three-dimensional data as well as time-sequenced images taken within millionths of a second or at arbitrary times.

Compared to the present capability at PHERMEX and FXR, the DARHT Facility would:

- Provide higher resolution of the entire imploded primary area

- Provide more information content in each radiographic image because of the reduction in beam size proposed for DARHT and the corresponding increase in resolution

- Provide two independent views, taken at right angles to each other, of the systems being tested; this capability could be used to provide either three-dimensional data or provide information at two slightly different times, whichever would be more important in observing a particular system

- Provide this increased information content over the full field of view of the machine, which would encompass a full-scale mockup of the system to be tested

- Provide up to a seven-fold increase in x-ray strength, compared to PHERMEX

DARHT was first proposed in the early 1980s as a diagnostic facility to be used as part of LANL's ongoing weapons research and development mission. DARHT was intended, then as now, to assist in evaluating the safety, performance, and reliability of existing weapons. In addition, at that time hydrodynamic testing at DARHT, in conjunction with underground nuclear testing, was intended to assist in designing new nuclear weapons and replacement parts.

The DARHT Facility would provide a flash radiographic capability for the testing of high explosives systems and components. Other types of electronic, optical, and photographic diagnostics would also be available at the site. Timing options would allow triggering of the two x-ray beams either simultaneously or with slight delays. Simultaneous images from the two axes would provide for three-dimensional data while sequential images would aid in studying the time history of a test assembly.

DOE may install, test, and prove the linear induction accelerator equipment in the first axis (the southeast accelerator hall) before purchasing, assembling, and installing the accelerator equipment in the second axis. This would be to ensure that the accelerator technology will perform as anticipated before incurring the expense of equipment for the second axis. Accordingly, DOE has split the expenditure for the second axis equipment into a separate budget line item for the remainder of the project. This is in keeping with the recommendations of independent panels of consultants convened by DOE to review technology plans (HPAIC 1992; DFAIC 1995; DOE 1993a). Although the two 1992 reports suggested delaying construction of the second axis until the first axis was tested and proven, in 1992 DOE approved funding for construction of accelerator halls for both axes. DOE allowed for site preparation and construction for both accelerator halls to proceed at the same time to avoid undue disruption to operation of the first axis while the second accelerator hall was constructed. The accelerator halls and associated diagnostic areas were modified to accommodate the recommendations of the various panels and to ensure that the DARHT Facility could provide diagnostics used by LLNL, and thereby function as a shared user facility (DOE 1993a).

Hydrodynamic and explosives operations proposed for the DARHT firing-site facility are similar to those currently undertaken at the PHERMEX facility, which is located approximately 2,000 ft (600 m) to the east of the DARHT site. The DARHT Facility would provide increased information and improved radiographic diagnostic capability over PHERMEX because of the increased temporal and spatial resolution and two lines of sight. Although the DARHT Facility is designed to provide more and better data for each shot, the total number of shots per year would remain about the same as for the No Action Alternative.

Hydrodynamic testing at the DARHT Facility would consist of observations of explosive systems in combination with surrogate materials, such as depleted uranium or tantalum, which simulate the behavior of weapons materials but are physically incapable of producing energy from nuclear reactions during testing. In addition, the facility could be used for testing systems such as high-velocity impacts and explosive forming of metals.

3.5.1 Facility

The DARHT Facility would consist of a new accelerator building, with two accelerator halls, firing point, and the associated support and diagnostic facilities at the DARHT site (see figure 3-3). The proposed firing point would be at the juncture of x-ray beams produced by two electron beam accelerators oriented at right angles to each other to provide dual-axis, line-of-sight radiographs. The accelerators would be housed in halls about 225 ft (70 m) long by 50 ft (15 m) wide. The existing RSL, which supports all radiographic machines at TA-15, would be used to support the DARHT Facility.

Construction of the DARHT Hydrotest Firing Site (HFS) began in May 1994, and construction was halted on January 27, 1995, by preliminary injunction from the U.S. District Court, Albuquerque, New Mexico. At that time, approximately 34 percent of the construction of the HFS was complete. The completed construction includes installation of an earthen berm on the northern side of the DARHT site as a radiation protection measure. It is estimated that construction, installation, and testing activities for the first axis would take an additional 38 months, and 66 months for both axes, if this alternative were to be implemented.

3.5.2 Operations

The steps necessary to conduct a radiographic test are shown in table 3-1. The DARHT Facility would be able, by design, to detonate high explosives charges up to 150 lb (70 kg) located at the dual axis firing point. If larger high explosives charges were necessary, charges up to 500 lb (230 kg) would be located at a firing point to the northwest along the axis of the southeast accelerator to provide sufficient distance between the firing site and the building. For such experiments, a temporary expendable blast shield would be constructed to mitigate blast effects.

All LANL firing sites have an established exclusion zone that is a safety feature to provide protection to personnel and structures while testing takes place. During a test, the exclusion zone is the area that is cleared of any personnel before each shot. There are limitations on the types and design of structures that can be built within exclusion zones. The high-explosive testing area at LANL comprises 20 mi^2 (52 km) and includes several high-explosive test facilities (see section 3.3.6). Each test facility has a defined exclusion zone. The radius of each zone is based on the amount of high explosive for which the facility is designed. The proposed DARHT Facility would have an exclusion zone of 2,500 ft (950 m).

The operations to be performed at the proposed facility would be similar to those currently performed at, and proposed for, the PHERMEX facility. Some differences arise because there would be two x-ray machines to coordinate with a test detonation, and the DARHT x-ray machines would not be identical in their operating parameters to the PHERMEX machine. The operational tasks include design; assembly and placement of the test assembly at the firing point; setting up and checking out the diagnostic apparatus; executing the experiment from a remote control room; and completing post-firing tasks associated with securing the firing pad and cleanup. Preliminary data reduction is usually done onsite to determine the success of the experiment.

One of the few differences between operations at the DARHT and existing PHERMEX Facilities would be the operation of two accelerators from the remote control room in the two-axis mode of operation. Since there would be two buildings containing accelerators, only minor upgrades to most existing operating procedures and administrative controls would be needed. Multiple x-ray pulses generated by a single axis could also be achievable. However, the new technology of DARHT would result in changes to electronic operation and control of the facility.

Accelerators at the DARHT Facility would produce a sharply focused x-ray beam that would be much faster than that of PHERMEX (approximately 60 nsec pulse width) and with a much higher x-ray dose. The electron beam would be converted into an intense x-ray beam emanating from a spot size that is approximately one-third that of PHERMEX. Figure 3-4 presents a comparison of spot size for PHERMEX, FXR, and DARHT.

Since publication of the draft EIS, DOE has decided to propose incorporating upgraded accelerator and x-ray diagnostic equipment within the proposed DARHT facility. This proposal would apply to all alternatives that include DARHT accelerators. By simply extending the accelerators to increase the minimum electron-beam energy 25 percent to a nominal 20-MeV and by enhancing existing equipment to generate a higher-current beam, DOE proposes to increase the output x-ray dose to 550 to 1650 R (depending upon the final accelerator operating point that would be determined upon commissioning the facility) while maintaining the small x-ray spot size. The existing DARHT facility design supports this option, so no increase in facility footprint or services would be required, although capital costs would increase as shown in section 5. The performance history of electron accelerators for flash radiography shows that machine performance improves considerable in a few years from the original startup. This type of improvement is expected for DARHT as appropriate technology becomes available and such capabilities as a dose stretch of 2000 R or more, increased beam energy up to approximately 30 MeV, and the generation of multiple pulses are possible while remaining within the bounds of this EIS.

The accelerator could also be operated in a second mode without the production of x-ray beams. In this mode of operation, the electron beam would be stopped within a graphite target (beam stop) placed within the building near the exit of the accelerator. Tantalum shielding would be used to enclose x-ray production in the beam stop. This mode would be used during testing and beam-tuning operations in preparation for beam production for an actual test. Operational procedures in this mode would be essentially the same as in the x-ray production mode.

Explosives would not be stored, handled, or processed inside any DARHT building. Explosives operations would be performed in accordance with approved procedures and at other locations on the site. Conventional high explosives consisting of bare charges and clad devices would be positioned outside the DARHT structure and detonated at the firing point. Several kinds of test and x-ray preparation activities, identical to those conducted at PHERMEX, would be conducted at the firing point prior to detonation. These include positioning and mechanical alignment of the test assembly relative to the x-ray beam, establishing and verifying the cabling for diagnostics, and resistance measurement testing of the detonators to be used in the hydrodynamic test.

During preparations for a test, repetitively pulsing the accelerators would be necessary to focus and adjust the electron and/or x-ray beams. Tuning of the accelerator components, without high-explosive operations, is expected to account for a very large fraction of the operation of the accelerator.

The proposed facility would use lasers both for lining up radiographic tests and for diagnostic purposes in optical tests. Operation of both the helium-neon laser and the solid state lasers (Neodymium: yttrium aluminum garnet with harmonic generator) to be employed in the accelerator rooms at the DARHT Facility would be performed in accordance with standard industrial safety practices. Further administrative and engineering controls in accordance with LANL procedures would be used for laser operation. Only operators who have been trained and certified in laser operation would be allowed to operate the lasers when used for alignment and checkout. When used as a diagnostic in an experiment, the lasers would be operated from the control room.

When containment would be used for a test shot, the blast products would remain in the containment vessel that would be taken to another LANL facility for cleaning and refurbishing. The contained blast debris would be taken to appropriate processing or disposal facilities according to the nature of the debris.

In 1988, a U.S. Environmental Protection Agency (EPA) radiological air emissions approval to construct the DARHT Facility under 40 CFR Part 61, the National Emission Standards for Hazardous Air Pollutants regulations, was obtained for the DARHT Baseline Alternative. This approval limits the annual expenditure of uranium to 440 lb (200 kg). This limit was based on the amount of depleted uranium used at PHERMEX during the mid-1980s. However, since that time, underground nuclear testing has ceased, programmatic objectives have changed, and a limit of 1,540 lb (700 kg) would be required to meet all objectives under this alternative. For example, safety tests of full-scale systems involving accident scenarios with stockpiled systems in sympathetic detonation would expend more depleted uranium per test than a single system test of the type envisioned at the time the permit was obtained. During a hydrodynamic test, ascertaining the proper function of certain stockpiled components that contain tritium could also be needed. These tests would be expected to release a small amount of tritium, and the maximum annual release would be less than 0.06 in^3 (1 mL, 3 Ci) of tritium. A new EPA approval would be needed for DARHT to operate at these new limits, and until it is obtained, operations at the DARHT Facility would be bounded by the current approval.

Sanitary wastes from the DARHT Facility would be handled by a septic system at the facility. Water for cooling accelerator components would pass through a cooling tower that has an average blowdown of 2,000 gal/d (7,600 L/d).

3.6 UPGRADE PHERMEX ALTERNATIVE

Under the Upgrade PHERMEX Alternative, DOE would upgrade PHERMEX with the new high-resolution radiographic technology developed for DARHT (see figure 3-5). (The existing PHERMEX x-ray machine is not technically capable of meeting DOE's need for enhanced high-resolution radiography.) PHERMEX would be remodeled and enlarged to accept the new equipment. Under this alternative, DOE would obtain improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, and would construct a second accelerator hall to provide the capability to obtain three-dimensional and time-sequence data. As in the DARHT Baseline Alternative, the accelerator equipment for the second axis may be procured and installed after the equipment in the first axis was installed, tested, and proven. As in the DARHT Baseline Alternative, a steel containment vessel could be used at this firing site facility to contain emissions and debris from selected dynamic experiments; experiments involving plutonium would be conducted inside a double-walled steel vessel.

As discussed earlier in this chapter, some of the potential measures discussed for the DARHT Baseline Alternative could be applied to this alternative; however, they are not expressly analyzed. For example, DOE could decide to enlarge the existing single axis at PHERMEX and equip it with the enhanced radiographic capability originally planned for the DARHT Facility. Although this would not meet all of the DOE's programmatic objectives, the environmental impacts of such an approach would be within the range of impacts expected from the alternatives analyzed in this EIS.

The DARHT Facility would not be completed, but the partially constructed concrete shell of the firing site facility would be put to other uses, as described in the No Action Alternative. The Upgrade PHERMEX Alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL. During the upgrade construction, expected to last a little over four years, DOE would suspend its hydrodynamic testing program at LANL. During this time, DOE would be limited in its ability to use radiographic techniques in assessing problems that might arise in the stockpile.

3.6.1 Facility

Under the Upgrade PHERMEX Alternative, DOE would install the proposed enhanced hydrodynamic capabilities at the present PHERMEX Facility site. The PHERMEX structures and equipment would be used to the extent possible, but extensive replacements of and modifications to the present PHERMEX Facility would be required. Because only the enhanced radiographic technology developed for DARHT is currently available to provide the capability needed, and because the linear induction accelerator planned for DARHT is the only currently available technology to provide the needed capability, the radio-frequency accelerator now at PHERMEX would be removed and replaced with a linear induction accelerator. The new accelerator is physically larger than the existing accelerator, and would not fit in the existing accelerator hall. The existing hall would have to be extensively remodeled.

Under the conceptual design for this upgrade, the two accelerator halls and other buildings for the firing site would be sized and laid out similarly to the plans for the DARHT Facility. Orientation of the complex would be consistent with the existing accelerator hall at the PHERMEX site, with the first upgraded accelerator hall being an extension of the existing hall and the second hall constructed at a right angle to the first. The demolition of several existing structures and cleanup of existing debris would be necessary before construction could begin on facilities under the Upgrade PHERMEX Alternative.

The existing PHERMEX building would be used under the Upgrade PHERMEX Alternative, but the structure would require substantial modification. The current PHERMEX diagnostic buildings are not appropriately configured for the Upgrade PHERMEX Alternative and would be demolished and replaced. The underground tunnels, which interconnect buildings, would be removed where necessary and abandoned in place if no longer needed. The mechanical and electrical systems at PHERMEX are inappropriate for DARHT technology and would be replaced. Cleanup, demolition, construction, installation, and testing activities associated with the Upgrade PHERMEX Alternative would require approximately 51 months to complete.

No new transmission lines would be required for the upgraded PHERMEX Facility; however, new water, fire protection, and gas lines would be installed to meet the requirements of the upgraded facility. A new sanitary sewer would also be required.

3.6.2 Operations

The operations to be performed at the upgraded PHERMEX Facility would be identical to those planned for the DARHT Facility. These operational tasks are described in section 3.5.2.

3.7 ENHANCED CONTAINMENT ALTERNATIVE

The Enhanced Containment Alternative differs from the DARHT Baseline Alternative in that it assumes the addition of a means (i.e., containment) to prevent the release of most or all airborne emissions, metal fragments, and other debris resulting from firing-site operations. The containment could be either portable steel vessels or a permanent building.

The DARHT draft EIS analyzed both a Vessel Containment Option and a Building Containment Option. These options pose hypothetical "bounding" situations; however from a programmatic standpoint either option would have serious design or operating limitations. Therefore, DOE has developed a third option, called the Phased Containment Option, to take advantage of the environmental mitigation effect of enhanced vessel containment while still allowing the DARHT Facility to be completed quickly to meet the need for enhanced radiographic capability as soon as possible. The Phased Containment Option has replaced the DARHT Baseline Alternative as DOE's preferred alternative.

Under the Building Containment Option, the concrete containment structure would have to be very large in comparison to the firing site to contain the overpressure from an explosive test; DOE would forego the capability for experiments or tests using larger amounts of high explosives or some other specific types of large tests because of the structural limitations of the building. Also, this option would place limits on DOE's ability to conduct dynamic experiments with plutonium because of the difficulty in moving the large, double-walled steel containment vessels needed for plutonium experiments in and out of the containment building.

Under the Vessel Containment Option, the EIS analysis assumes that the DARHT Facility would operate from the first with a certain percentage of tests and experiments conducted inside modular single-walled steel containment vessels. However, the number of tests that could be conducted early in the operating life of the facility would be significantly reduced if this limitation were imposed. Although some conceptual work has been done, DOE has not yet designed the vessels. DOE would have to perfect a prototype vessel before fabricating all the vessels intended. Also, the Vessel Containment Option depends on construction of a vessel cleanout facility; the design for this building could not be finalized until after the prototype vessels were perfected to determine the specific details of cleanout equipment and techniques. DOE estimates that it would take approximately 10 years beyond the availability date for the DARHT Facility to complete these activities and be able to conduct a full schedule of contained tests. However, by phasing in the vessel prototyping program, within about 10 years DOE could achieve the same environmental protection results as could be obtained under the Vessel Containment Option without adversely affecting the program. For the first 10 years, environmental mitigation would be less than would occur under the DARHT Baseline Alternative but greater than would occur under the Vessel Containment Option; thus the Phased Containment Option is "bounded" by the other two situations.

Under either the Vessel Containment Option or the Phased Containment Option (once fully implemented), DOE would conduct most hydrodynamic tests and dynamic experiments using containment vessels. On a case-by-case basis, DOE might opt to conduct certain types of tests as uncontained, such as those using a very large explosives charge (larger than the containment vessel rating for the active phase); those requiring complex diagnostics (such as certain optics or laser tests) that cannot be achieved using a containment vessel; those requiring measurement of material movement beyond the confines of the vessel; or those using a very small explosives charge or small amounts of hazardous materials where use of the vessel would not be practical, cost-effective, or environmentally significant. For the purpose of this EIS analysis, DOE estimates that up to about 25 percent of all tests might need to be uncontained under either the Vessel Containment Option or the fully implemented Phased Containment Option. Under the Building Containment Option, all hydrodynamic tests and dynamic experiments would be contained. Dynamic experiments involving plutonium would always be conducted in a double-walled steel containment vessel under any approach.

Under the Vessel Containment Option or the fully implemented Phased Containment Option, DOE would expect to immediately use a sufficient number of vessels and their related infrastructure for containment of 75 percent of the experiments with materials made from beryllium, depleted uranium, or Resource Conservation and Recovery Act characteristic metals. For the contained experiments, at least 99 percent by mass of these materials would be retained as a result of using a single-walled containment vessel. Although DOE expects that any such vessel system would be designed to be highly effective, for the purpose of this EIS, DOE has made a conservative assumption that the single-walled containment vessel system might fail and allow a release of some material to the outside environment up to 5 percent of the time. Such a failure would be expected to release gaseous by-products of the detonation and possibly small fragments. Experiments using plutonium would always be done within double-walled vessels that have been demonstrated to fully contain these types of tests and would not lead to environmental release.

Use of either the portable steel containment vessels or the addition of a permanent containment building to the DARHT structure would require construction of a separate cleanout facility, in addition to the construction for the DARHT Baseline Alternative. Under either the Vessel Containment Option or the Phased Containment Option (preferred alternative), this would be a separate vessel cleanout facility for cleaning out the portable steel vessels and recycling materials as appropriate. Two alternative sites that are being considered for this facility are shown in figure 3-6 (Larson 1995). An existing firebreak road would be improved and paved to provide access to either site.

Under the Building Containment Option, a separate cleanout facility would be constructed near the containment building at the DARHT Facility to assist in periodic cleanout of the containment building and recycling materials as appropriate. Other than slight modifications to the DARHT Facility parking lot, no additional access road would be required for the cleanout facility. Compared to the DARHT Baseline Alternative, DOE would have to immediately acquire several additional portable single-walled containment vessel systems under the Vessel Containment Option. For the Phased Containment Option (preferred alternative), the first phase would include the fabrication of a prototype vessel system and local, portable recycling capability. The second phase would require construction of five additional vessels and a separate vessel cleanout facility.

Under this alternative, DOE would obtain greatly improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, but would forego some degree of image resolution due to scattering and loss of x-ray penetration caused by the containment vessel or structure. Under the preferred alternative, DOE may perform a limited number of selected experiments unconfined (no vessel) when the best possible resolution would be a critical need.

3.7.1 Facility

This section describes the facility that would be constructed at the DARHT site to implement the Enhanced Containment Alternative. Under this alternative, if single-wall steel vessels were used, a separate vessel cleanout facility, about 12,000 ft^2 (1,115 m^2) would be built near the DARHT site to recycle the vessels and experimental material after each use. Double-wall vessels would be handled the same as under the No Action Alternative, and would not be treated at this facility. The vessel cleanout facility would include a vessel and debris cleanout area and handling equipment to minimize secondary waste generation and personnel exposure during cleanout operations. Any secondary waste would then be transferred to a LANL disposal area. Under this approach, several new containment vessels would be purchased or fabricated. If a permanent building for containment were added to the current DARHT plans, the separate vessel cleanout facility for shot debris would still be needed.

A containment structure would add about 13,000 ft^2 (1,200 m^2) to the DARHT building, but all of this additional area would be within the original DARHT Facility area. Portions of the earthen berm around the northern side of the site would have to be removed to build the containment structure and provide access to the building, but the berm would no longer be needed for its original purpose, which was to provide radiation shielding. Under the Building Containment Option, a cleanout facility for shot debris would still be needed.

3.7.1.1 Containment Vessels

LANL has experience in using containment vessels for explosives tests up to 44 lb (20 kg) of high explosives and is presently developing a new design of reusable, transportable vessels for use with higher explosive loadings which would have a full suite of diagnostic capabilities. A prototype containment vessel for a 110-lb (50-kg) high explosive load is in the design stage (see figure 3-7). This single-walled vessel would be modular in design to allow users to modify the vessel geometry to accommodate different experiments and shot configurations. The vessel would consist of a 14-ft (4.3 m) diameter cylindrical shell with four ports for extension modules and a removable hemispherical top shell. The extension modules would be 6 ft (2 m) in diameter, 8 ft (2.5 m) long, and could be specifically configured to accommodate a particular experiment or diagnostic. Each extension module would have five ports: one on top for placing diagnostic equipment in the module and two ports on each side that can accommodate optical windows. The vessels would be fabricated from a state-of-the-art military steel so that field repairs and modifications would be possible. A support and alignment system would provide adjustments to align experiments for radiography or other diagnostics. This type of vessel would not be used for dynamic experiments with plutonium; these experiments would be conducted in double-walled vessels of a different design (see section 3.3.2).

DOE has considered proposing a Contained Explosives Test Complex, which would expand DOE's current capabilities for contained experiments. The Test Complex would provide for 15-ft (5-m) diameter vessels for firing capability up to 440 lb (200 kg) in addition to the 110-lb (50-kg) vessels described above and the support complex for containment vessels.

3.7.1.2 Containment Building

A containment building would be attached to the planned DARHT structure at its north end; it would enclose the firing point and extend to the northwest aligned with the axis of the southeast accelerator hall. This addition would extend to approximately the center line of the existing earthen berm. A concept for such a building, designed to contain a 185-lb (85-kg) test explosion at the DARHT firing point is shown in figure 3-8 (LANL 1995). A 625-lb (285-kg) test explosion could be accommodated in this building at the firing point shown about 40 ft (12 m) northwest of the dual-axis firing point, but only one accelerator could be used for imaging a test there. Preconceptual design is used to assist general layout and analyses of tradeoffs between chamber volume and resulting maximums for internal temperatures and pressures.

The walls, floor, and roof of the chamber that would contain a test explosion would be reinforced concrete 5 to 6 ft (1.5 to 1.8 m) thick. The roof would also have 6 ft (2 m) of gravel above the concrete to prestress the roof against explosive pressure. Replaceable fragment shielding would protect the inside surfaces of the chamber. In the design shown, the containment area within the building would be about 10,400 ft^2 (970 m^2), and its volume would be about 260,000 ft^3 (7,360 m^3) as fixed by the maximum charge of 625 lb (285 kg). If a maximum of only 185 lb (85 kg) of high explosives is to be fired, the building could be sized down by shortening its length in the northwest direction. The need to cool and vent the resultant hot atmosphere, up to 650–F (343–C), would require a large robust mechanical cleanup system. A support area within the containment building would also be necessary to provide decontamination for personnel and other services during cleanup and shot preparation. Construction of the containment building would add, at a minimum, about one year to the DARHT construction schedule (LANL 1995).

3.7.1.3 Vessel Cleanout Facility

A conceptual sketch of the proposed vessel cleanout facility is shown in figure 3-9. The facility would be constructed at TA-15 if portable single-wall steel vessels were used for containment, or a similar facility would be constructed near the containment building if such a building were used. The approximate size of the building would be 12,000 ft^2 (1,115 m^2). The main components of this facility would be two large bays, a debris processing room, and an analytical laboratory. Under the preferred alternative, the vessel cleanout facility would be constructed under Phase 1 and put on-line during Phase 2 of the implementation of this option.

3.7.2 Operations

Under the Enhanced Containment Alternative, operations at the DARHT Facility would be the same as for the DARHT Baseline Alternative for the accelerators and their ancillary equipment. However, differences in operations would arise for setting up a test assembly and for post-shot operations to clean up the test shot products. Three operational options would be possible depending on whether the approach to containment would be to use portable steel vessels, a containment building, or a phased development and implementation of portable steel vessels. With steel vessels or a containment building, there would be an exclusion area as for uncontained shots, but it would be reduced appropriately.

3.7.2.1 Vessel Containment Option

To set up a shot, a new or refurbished single-wall steel vessel would be delivered to the firing area by a heavy-duty tractor-trailer unit. The facility set-up crew would transfer the vessel to the firing point using a crane. The crew would also attach tested extension modules (figure 3-7) to the vessel if needed to accommodate the test assembly for a particular test. The main vessel and its attached extension modules would then constitute the containment vessel. Removing the hemispherical top to the vessel would provide access so the test assembly could be placed or assembled in the vessel. The containment vessel would have an electrical pass-through and optical ports for the test assembly and diagnostics.

Following a shot, the containment vessel would pass through several steps to render it safe, remove internal debris, and prepare it for subsequent reuse. First, the vessel's post-shot atmosphere would be vented and pumped out through high-efficiency particulate (HEPA) filters. A crane would be used to place the vessel on a trailer, and the vessel would be transported away from the DARHT Facility to adjacent vessel cleanout and test refurbishment facilities. The vessel would remain on the trailer during the cleanout and preparation process by using a mechanism to rotate the vessel-trailer assembly 90 degrees to facilitate cleanout.

Operations at the vessel cleanout facility would include single-wall vessel cleanout, debris recovery/ decontamination, vessel decontamination, recovery of process fluids for reuse, and solidification of nonrecoverable materials from the process for disposal. Debris would be emptied from the vessel and separated by size. Large pieces of debris would be decontaminated in a cleaning tray using a polymeric extractant solution that binds and solubilizes radioactive and toxic metals. The cleaned debris would be stored for recycling. Fine debris not suitable for recovery would be transferred into a reaction tank where it would be agitated with the polymer extractant, and the resulting slurry would subsequently be filtered to collect the solids. Following cleanout, the emptied vessel would be moved to secondary containment in the wet bay, sprayed for further decontamination using polymeric extractant, and finally rinsed. Metal-loaded polymer from the extraction and wash processes would be collected in a tank for extraction of the metal and regeneration of the polymer.

Cleaned vessels would be moved on their trailers to an existing building (R-285) for refurbishing. The refurbishing operations might include detection and repair of damaged areas, painting the interior, installation of shot supporting fixtures and diagnostics, and pressure tests.

3.7.2.2 Building Containment Option

The blast chamber in the containment building would be approximately 48 ft (15 m) wide by 160 ft (49 m) long (see figure 3-8); walls would be no closer than 17 ft (5.1 m) to the dual-axis firing point; and the chamber would have a 25-ft (8-m) floor-to-ceiling interval. However, access to the chamber, proximity of the inner surfaces, and the need for portable lighting affect the efficiency of experiment setup compared to uncontained testing.

Before a shot, the firing crew would verify that no personnel were in any portion of the containment building and that the mechanical systems affecting containment were functional. Following the detonation of a maximum charge, gases and aerosols would fill the blast chamber; the pressure and temperature would not exceed 20 psi (14,060 kg/m^2) and 650– F (343– C), respectively. This pressure would bleed off through blast valves into the treatment area where the gases would be mixed with sufficient ambient air to allow filtration through HEPA filters. The process of venting and purging gases would take about two hours. Following purging, an automated wash system using three ceiling-mounted, retractable water cannons would spray the walls and ceiling with water or other solutions. Wash-down water or solutions would be collected in floor drains connected to a collection tank, filtered, and stored for reprocessing. Following the wash down, a decontamination team wearing protective clothing would enter and clean the chamber to make it safe for minimally protected personnel to enter. Venting, purging, cleanup, and testing of the chamber are estimated to take approximately two days using four workers. In addition, replacement of damaged fragment shielding would be an ongoing activity.

The processes for recovering debris from the containment building would be similar to those described for the portable steel vessels. The vessel cleanout facility would be sited near the containment building. Debris resulting from detonations within the blast chamber would be segregated and reclaimed. Polymer extractant solutions would be used for decontaminating chamber surfaces.

3.7.2.3 Phased Containment Option (Preferred Alternative)

Under the preferred alternative, containment for tests and experiments at DARHT would be provided according to an incremental, phased plan. This approach has the advantage of allowing the lessons learned in each phase to be incorporated in the next phase and provides for a lower overall cost (capital plus operating costs) as well as a lower initial expenditure for design and capital cost.

The Phased Containment Option has been added to the containment options presented in the draft EIS to meet two objectives: 1) to improve the long-term average containment of materials used in the tests and experiments, and 2) to allow the DARHT Facility to meet programmatic goals as soon as possible while developing improved containment technology. To mitigate potential adverse environmental impacts, this option establishes materials release goals that would be met by using the containment vessels and augmented cleanup of debris from shots that necessarily must be uncontained. The environmental impacts would also decrease over time because vessels with larger capacity would be developed that would allow larger tests to be conducted with containment instead of as uncontained tests. Under this option, less material would be released to the environment compared to the DARHT Baseline Alternative.

Containment will be phased into DOE's long-term hydrodynamic testing program according to the following plan.

– Phase 1 – Demonstration: A prototype vessel system and portable cleanout unit would be used to contain 5 percent of the material over a 5-year period. During this period, a permanent vessel cleanout facility would be constructed and an additional vessel system specified and fabricated, incorporating experience gained during this phase.

– Phase 2 – Containment: A five-vessel containment system and a permanent vessel cleanout building would contain 40 percent of the material over the second 5-year period.

– Phase 3 – Enhanced Containment: Based on experience, vessels would be improved for use with 75 percent or more of the material over the next 20-year period.

– Phase 4 – 440-lb (200-kg) Containment Option: If justified by the development effort and operating experience, a 440-lb (200-kg) vessel may be developed to contain a greater percentage of material.

Figure 3-10 shows a step function plot that represents the phased implementation of the preferred alternative. The resulting average containment would reach the environmental release reduction goals proposed in the Enhanced Containment Alternative over a period of 10 years with a smaller impact on operations and lower initial capital expenditures.

Phase I would be a demonstration phase of this option because this type of vessel has not previously been used at DOE and, thus, the operation of the system is not well established. If technological problems were to be encountered using this vessel, then the percentage reduction of materials released to the environment, as described by the different phases of this option, would be obtained by the following methods: altering the number of experiments or tests, using nonhazardous materials where possible, or picking up materials near the firing point beyond those which are normally retrieved.

The DARHT Baseline Alternative (section 3.5) serves as the baseline for the phased containment discussion. The DARHT Baseline Alternative analysis shows that open-air hydrodynamic testing would result in releases that were less than one percent of the total regulatory limits for most release pathways and only a few percent of the limit for the remainder. The use of containment is not driven by a regulatory concern. Rather, the benefit of reducing the amounts of materials released is directly related to environmental stewardship and a desire to mitigate or eliminate required cleanup activities at the end of the facility lifetime. Therefore, the optimum environmental benefit is derived from concentrating resources on tracking and control of a few important constituent materials: depleted uranium, lithium hydride, beryllium, lead, and tritium.

In addition to containment, three other methods for limiting the annual releases of the experimental materials of concern would be used: material replacement, improved post-shot recovery techniques, and a programmatic strategy for experiment planning and scheduling. Soil remediation technology and surrogate material replacement techniques would be developed and the advantages of these techniques would be compared with containment methods. The most effective combination of these methods would then be installed at the firing site so that the reduced release goals for phased containment would be realized. Finally a programmatic planning strategy for experiments would provide assurance that the total releases over any 5-year period would not be above the goals set for the Phased Containment Option. The combined reduction from all these methods would be used to meet the relatively stringent requirements placed on the operation by the Phased Containment Option (preferred alternative). A brief outline of the steps in the preferred alternative is given in the following subsections.

3.7.2.3.1 Phase 1 _ Demonstration (5 Years)

Concurrently with the commissioning of the DARHT Facility, a prototype containment vessel system would be fabricated and used to contain up to 5 percent of the experimental material at DARHT. A portable cleanout unit would also be developed, manufactured, and stored in the vicinity of the DARHT Facility. Cleanout would consist of the use of the same techniques for material separation and scavenging with polymer extractant as described in section 3.7.2.1. However, the processing would be performed using open-air manipulation of the vessel segments, coupled with the use of portable tanks and trucks for holding and transporting both the polymer solutions and the recycled material. Any resulting solid and liquid waste streams would be transferred to the appropriate LANL group. Post-shot recovery methodologies would also be enhanced and implemented as appropriate during this phase of operation. Construction would begin on a permanent vessel cleanout facility.

3.7.2.3.2 Phase 2 _ Containment (5 Years)

Based on the experience gained during Phase 1, a permanent vessel cleanout facility would be put into operation. Five vessels and additional vessel segments would be fabricated as justified by operational experience. Up to 40 percent of the experimental material would be contained during this phase. Containment goals would be met or exceeded through the use of a combination of techniques: containment, material replacement, post-shot recovery, and program management.

3.7.2.3.3 Phase 3 _ Enhanced Containment (Remainder of Facility Lifetime)

Experience gained during Phase 1 and Phase 2 would allow the final containment techniques to be developed that could result in containment of up to 75 percent of the experimental material. The DOE would meet the release reduction goals of this phase through the use of the combination of techniques discussed above. The desirability of using containment versus soil remediation would be reevaluated carefully at the time of the implementation of this phase. The decision to develop a vessel capable of containing a 440-lb (200-kg) charge would also be made at the time of the implementation of this phase.

3.8 PLUTONIUM EXCLUSION ALTERNATIVE

Under the Plutonium Exclusion Alternative (referred to in the Notice of Intent as the "Institutional Control Alternative"), DOE would complete and operate DARHT as described in the DARHT Baseline Alternative but would limit use of the facility to exclude any applications involving experiments with plutonium. There are two programmatic impacts associated with the Plutonium Exclusion Alternative: 1) DOE would not obtain the higher resolution information for dynamic experiments with plutonium; and 2) DOE would continue to maintain and operate PHERMEX in addition to DARHT. This alternative is analyzed to provide a basis of comparison between the environmental impacts expected to occur if the DARHT Facility were used to conduct contained dynamic experiments with plutonium (the DARHT Baseline Alternative) or not used for contained dynamic experiments with plutonium. DOE would conduct dynamic experiments with plutonium at PHERMEX or other facilities. This alternative would not be expected to affect future operations at the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities.

3.8.1 Facility

The facilities required under the Plutonium Exclusion Alternative are identical to those described for the DARHT Baseline Alternative at the DARHT site.

3.8.2 Operations

Operations at the DARHT Facility under the Plutonium Exclusion Alternative would be the same as those described for the DARHT Baseline Alternative except that DOE would not incorporate plutonium into any of the experiments at DARHT. The DARHT Baseline Alternative specifies containment for experiments that incorporate plutonium. Under the Plutonium Exclusion Alternative, containment vessels would be used for selected experiments involving hazardous materials. There would be no differences in facility operations for uncontained tests and no differences in the explosion products that might be deposited on the firing site or the surrounding area.

3.9 SINGLE AXIS ALTERNATIVE

Under the Single Axis Alternative, DOE would complete construction of the DARHT Facility with one accelerator hall and would operate only a single axis of DARHT with one accelerator. The second hall (second axis) would not be completed as an accelerator hall for DARHT but could be put to other uses such as office space. Under this alternative, DOE would obtain greatly improved high-resolution capability, as compared to the present capability at PHERMEX and FXR, but would forego the capability to obtain three-dimensional, rapid-time-sequenced data.

Under the Single Axis Alternative, operation of PHERMEX would be phased out. This alternative is not expected to affect future operations of the RSL at LANL, the FXR at LLNL, or other smaller explosive test facilities at LANL and LLNL.

3.9.1 Facility

The facility for the Single Axis Alternative would be identical to that for the DARHT Baseline Alternative at the DARHT site except that DOE would not install an accelerator and its ancillary equipment in the southwest accelerator hall. Figure 3-3 shows the layout of the DARHT Facility. The southeast accelerator hall would be completed as planned to provide the single-axis, x-ray radiographic capability. The DARHT firing site, associated support and diagnostic facilities, and the RSL would all be considered part of the single-axis facility.

Construction at the DARHT site would be nearly the same for the Single Axis Alternative as for the DARHT Baseline Alternative. The entire firing-site complex would be completed under this alternative, but only the basic structure of the southwest accelerator hall would be finished as planned. The interior finish would depend on how that space might best be used, and that determination would be made at a later date. Possible uses for the southwest wing include storage, office space, or laboratory space for research efforts.

3.9.2 Operations

Operations under the Single Axis Alternative would be similar to those under the DARHT Baseline Alternative, but they would be somewhat simplified by the need to coordinate only one x-ray machine with the test assembly detonation. Operation of the single x-ray machine would be the same as its operation as part of a dual x-ray system. Under the Single Axis Alternative, some tasks might be reduced in number or scope, but all of the activities described as part of the DARHT Baseline Alternative would remain. The high-explosive testing program would be modified to single-axis capabilities and would be similar to that for the No Action Alternative.

More emphasis would be placed on studying the late stages of hydrodynamic phenomena under the Single Axis Alternative, resulting in less use of blast-protected, electronic-position-indicating diagnostics compared to the No Action Alternative. However, more total shots would be required to synthesize three-dimensional and time-sequence data and to address reproducibility among shots. Therefore, the cost and yearly progress of the testing program would be similar to the No Action Alternative.

For this alternative, use of heavy equipment inside the accelerator hall, such as overhead cranes, would be about half of that needed for the DARHT Baseline Alternative. On the other hand, use of heavy equipment on the firing point would be the same as for the DARHT Baseline Alternative.

3.10 ALTERNATIVES CONSIDERED BUT NOT ANALYZED IN DETAIL

A NEPA review specifies the purpose and need for an agency to take action, describes the action that the agency proposes to meet that purpose and need, and identifies reasonable alternatives to meet part or all of the purpose and need. A potential alternative may be dismissed from a NEPA review as unreasonable if it would not meet part or all of the agency's purpose and need to take action, or for such reasons as taking too long to implement, being prohibitively expensive, or being too speculative in nature. An agency does not need to analyze an alternative that would not be responsive to the specified purpose and need.

The DOE considered, but did not analyze in detail, several alternatives in addition to those discussed above. None of the following would meet DOE's need for enhanced radiographic hydrodynamic test capability. These include:

- Alternative sites
- Alternative location at LANL
- Alternative facilities
- Consolidation
- Use of FXR
- Alternative types of tests
- Relinquishing reliability of the nuclear stockpile
- Weapons design
- No hydrodynamic testing
- Other programmatic alternatives
- Other mission alternatives

3.10.1 Alternative Sites

As an alternative to constructing and operating the DARHT Facility at LANL, construct and operate the facility at an alternative site.

DOE considered, but dismissed as unreasonable, the alternative of locating, constructing, and operating the DARHT Facility at a site other than LANL. DOE's need for hydrodynamic test facilities for weapons work is limited to those needed to support testing programs for LANL and LLNL. DOE has no need to construct hydrodynamic test facilities at non-DOE sites.

As discussed in section 3.3.3, LANL already has infrastructure in place to support its dynamic experiments and hydrodynamic testing program. This infrastructure supports operations at the PHERMEX Facility and other smaller LANL firing sites. The same infrastructure would be needed to support hydrodynamic testing and dynamic experiments at the DARHT Facility. Although other DOE sites have some of this infrastructure in place, no other DOE site currently has all the infrastructure in place to support all aspects of hydrodynamic tests and dynamic experiments being done at PHERMEX or proposed to be done at DARHT. DOE considers that this would represent an unreasonably expensive option to replicate some or all the infrastructure at another DOE site to support a facility with the same capability as the proposed DARHT Facility. It would not be cost-effective for DOE to replicate support facilities solely to support hydrodynamic testing or dynamic experiments.

In the future, DOE may choose to change facilities or operations at LANL or other DOE sites for other reasons. However, any such changes would be the result of separate DOE proposals in response to a different Departmental need and would be subject to appropriate reviews, including a NEPA review.

DOE considered two alternative means of conducting LANL's hydrodynamic testing at a site other than LANL:

– **Single Site:** Locate and construct the proposed radiographic hydrodynamic test facility at another site, make use of existing infrastructure at that site, and construct the remaining infrastructure at that site

– **Multi-Site:** Locate and construct the proposed radiographic hydrodynamic test facility at another site and make use of existing infrastructure at that site, supplemented by existing infrastructure at LANL or other sites

Neither alternative was considered to be reasonable for reasons described in the following sections.

3.10.1.1 Single Site

Replicating all the infrastructure needed to support a hydrodynamic test program or dynamic experiments at a single site other than LANL would be unreasonably expensive. Although theoretically all of the support facilities could be constructed and operated at another site, depending on the infrastructure already in place at the site, this could increase the cost of the DARHT Facility several times.

Depending on the location of the alternative site, DOE could incur extensive travel costs because LANL personnel would have to oversee the LANL testing program at another site, which would involve travel of several people at least once a week. If the other site had a hydrodynamic test or dynamic experiment program of its own (as does LLNL), the number of shots that could be scheduled to support both programs could be limited; this could be detrimental to both. In the event that the radiographic hydrodynamic test or dynamic experiment capability were to be located elsewhere, DOE would have to continue to operate and maintain PHERMEX to support smaller tests or dynamic experiments at LANL that would not be cost-effective to transport to the other site. DOE would therefore have to invest substantial capital to repair the facility to keep it viable over the long term, in addition to constructing and maintaining the enhanced radiographic test facility. This would not meet the need to replace PHERMEX.

Besides LANL, LLNL, the Nevada Test Site (NTS), and Pantex have some hydrodynamic testing infrastructure in place. However, they are considered to be unreasonable alternatives to LANL for siting a testing facility to support the proposed action because they would require expensive additional specialized infrastructure to support the hydrodynamic tests and dynamic experiments under the Proposed Action. In addition, as discussed above, DOE would need to continue to operate and maintain PHERMEX, which does not meet the need to replace the existing PHERMEX radiographic capability.

– **LLNL:** LLNL is the only DOE site, besides LANL, which has the capability currently in place to support hydrodynamic tests. However, LLNL is considered unreasonable to support a LANL hydrodynamic testing facility for two reasons. First, the type, size, and number of shots that LANL would require in addition to the number of shots that LLNL already conducts could unduly burden the support infrastructure that currently exists at LLNL, unless personnel and equipment were replicated. This would be considerably more costly than the proposed DARHT Facility. Second, without a major additional investment, LLNL could not provide the material recovery/recycle capability and waste treatment, storage, and disposal to support LANL's program in addition to its own. In addition, DOE does not conduct dynamic experiments with plutonium at LLNL. It would be unreasonably expensive to replicate the required infrastructure needs at LLNL for the sole purpose of supporting a facility as small as the proposed DARHT Facility.

– **NTS:** NTS has supported a testing program with experiments similar to hydrodynamic tests. However, NTS is considered unreasonable to support a radiographic hydrodynamic testing facility in the near term because NTS does not now have the required material recovery/recycle capability. It would be unreasonably expensive to replicate the required infrastructure needs at NTS for the sole purpose of supporting a facility as small as the proposed DARHT Facility.

– **Pantex:** Pantex has supported high explosives testing. However, Pantex is considered unreasonable to support a radiographic hydrodynamic testing facility in the near term because Pantex does not currently have any of the required infrastructure other than instrumented firing sites. In addition, currently the site could not support dynamic experiments with plutonium. It would be unreasonably expensive to replicate the required infrastructure needs at Pantex for the sole purpose of supporting a facility as small as the proposed DARHT Facility.

3.10.1.2 Multi-Site

Making use of multiple sites presents logistical problems that would be unreasonably inefficient and expensive to overcome. DOE believes that the quality of the hydrodynamic testing program would be degraded by splitting among multiple sites the testing functions for the improved capability needed. Collocated personnel achieve a certain synergism and efficiency in their interactions; this would be lost if personnel involved in different stages of a test event were located at different sites. Depending on the split, the ability to fix in-process mistakes or to iterate a design feature could be slowed to the point that test schedules could not reliably be met. Splitting the mission responsibility among sites would dilute the focus achieved by consolidating at a single institution, and would also blur lines of funding and responsibility. DOE would incur significant costs for transporting equipment, materials, and personnel among multiple sites and LANL. As described for a single site, travel costs would increase, the number of shots could be limited, and LANL would have to continue to operate and maintain PHERMEX, which does not meet the need to replace the existing PHERMEX radiographic capability.

DOE has considered whether each of the different steps of the hydrodynamic testing process could take place at a location other than LANL. Although some aspects could take place at various DOE sites, transportation, firing-site support, and materials management (materials reprocessing and recycling, and waste treatment and disposal) are limiting factors. Sites with some infrastructure in place include LLNL, at Livermore, California; NTS, near Las Vegas, Nevada; and the Pantex Plant, near Amarillo, Texas.

– Transportation of test assemblies: Shipping assembled hydrodynamic test assemblies is difficult. An assembled pin shot cannot be transported for more than a short distance because the diagnostic sensors must be very precisely located and are very susceptible to dislocation when moved. If transported, they must be moved only under controlled conditions (secure transport, very stable shipping container, very slow speeds). If public roads were used, either the road would have to be closed to the public (as is now the case at LANL), or safe, secure, transport vehicles would have to be used.

– Firing site: High explosive testing areas require a large buffer zone for safety reasons and perimeter-limited access for security and safety reasons. Several DOE sites are large enough to provide adequate secure buffer zones for a hydrodynamic test or dynamic experiment firing site. However, to operate a radiographic hydrodynamic test or dynamic experiment facility would require that several collocated support functions be available at the firing site. This would be a limiting factor for an alternative site because it would be difficult and expensive to replicate all the support facilities that would have to be located in the vicinity of the firing site. The site would have to have appropriate permits and licenses to allow for high explosives work. Other than LANL, LLNL is the only DOE site with in-place, firing-site support capability sufficient to support radiographic hydrodynamic tests or dynamic experiments. LLNL facilities are sized and scheduled to handle their own testing program, and the additional shots sufficient to support LANL's testing program could unreasonably burden the existing LLNL facilities. The NTS has firing sites and is currently qualifying a firing site to conduct radiographic hydrodynamic tests, which would use large charges of high explosives. Pantex has instrumented firing sites used to test high explosives, but these firing sites are not currently configured to support the required radiographic hydrodynamic testing and dynamic experiments, and to do so, besides being very expensive, would conflict with the current use of these sites.

– Materials Management: Materials management includes materials reprocessing and recycling, waste treatment, and disposal. Waste processing and disposal are limiting factors. Cleanup and recycling operations for hydrodynamic tests and dynamic experiments require specialized handling techniques. An alternative site would have to have the means to treat and dispose of debris and other waste hardware after a test is complete, and to collect, process, and recycle reusable materials. This would include the ability to clean out and, if necessary, dispose of large containment vessels. LANL is the only site with the requisite facilities in place. Although LLNL has waste processing, disposal, and recycling facilities in place that are sufficient to handle their own hydrodynamic testing program, it does not have facilities in place to handle containment vessels or sufficient capability to handle LANL's waste stream in addition to its own. NTS has a waste disposal capacity that is used by other DOE sites, but does not have in place the specialized facilities required to support the Proposed Action.

3.10.2 Alternative Location at LANL

As an alternative to constructing DARHT at the proposed sites, construct DARHT at an alternative site at LANL.

In the 1980s, DOE considered different locations at LANL for the DARHT Facility, and determined that the proposed site was preferable. The proposed site is within the explosives testing area and makes use of existing infrastructure such as access roads and utilities. Replicating the proposed facility at another location at LANL would result in duplicating infrastructure and related construction that has already occurred, with no programmatic gain or increase in onsite safety.

3.10.3 Alternative Types of Facilities

As an alternative to constructing a hydrodynamic testing facility, use an alternative type of facility to conduct diagnostic experiments.

The DARHT Facility responds to DOE's need for enhanced capability for hydrodynamic testing and dynamic experiments. No other type of facility provides hydrodynamic testing capability other than a hydrodynamic testing facility. An alternative type of hydrodynamic testing facility that could produce the needed capability in the near-term would be essentially a replication of the DARHT Facility. DOE and LANL have spent more than 10 years optimizing the design of DARHT; DOE does not consider it reasonable to spend additional time and expense to develop additional design studies for alternative facilities that would not meet the specified need nor add programmatic value.

DOE proposes to install a linear induction accelerator as the basis for the radiography equipment at the DARHT Facility. Other types of accelerators are available, such as radio-frequency, pulsed-power, or inductive-voltage-adder accelerators, and theoretically they could be used to power a radiography machine. However, these have not yet been demonstrated to provide the necessary radiographic performance to meet DOE's stated proposal and need. DOE may choose to incorporate modified or improved technology over the life of the project as it becomes available, particularly to provide cost, performance, and schedule benefits. The equipment proposed to be installed in DARHT, if the facility is completed and operated, was designed to improve on the technology and equipment used at FXR (which is also a linear induction accelerator). The technology proposed for the DARHT Facility has been reviewed by two independent technical panels, DARHT Feasibility Assessment Independent Consultants (DFAIC) and Independent Consultants Reviewing Integrated Test Stands (ITS); both have concurred with the technology proposed (DFAIC 1992; DOE 1993a). DOE does not consider it reasonable to revisit the technical evaluation of the currently available technology for the enhanced capability proposed, or to await possible development of future technologies that are now considered either speculative or inferior to the proposed technology for the intended use.

DOE has conceptualized a multi-axis, multi-time Advanced Hydrotest Facility (AHF) for the next generation of advanced hydrotesting capability. If proposed, this facility could provide up to eight radiographic views of the primary's implosion. In the longer term, this facility may help assure weapons reliability and safety without nuclear testing. The AHF would be based on new and emerging technology. This conceptualized facility has not yet reached the stage of a firm Departmental proposal. Both facility requirements and candidate or potential technologies require development and validation. The DARHT Facility would provide information useful for the design of the AHF, and experience gained from its operation would be important in optimizing the operations of this advanced facility (JASON 1994). AHF is not considered to be a reasonable alternative to the DARHT Facility for the following reasons: it is still only a concept, the technology to support AHF is not yet developed or proven, and the conceptual design and development of the technology for AHF would take several years to complete, as would the process of siting studies, construction design, and appropriate NEPA review. The conceptual AHF is one of the facilities under consideration in the *Stockpile Stewardship and Management Programmatic Environmental Impact Statement* (PEIS).

3.10.4 Consolidation

As an alternative to operating more than one hydrodynamic test facility, consolidate hydrodynamic testing capability at one site.

The DOE has historically maintained hydrodynamic testing capability at both LANL and LLNL; it would not be advantageous to fulfilling the mission of the DOE to maintain hydrodynamic testing facilities at only one site. DOE has proposed DARHT to be a shared user facility but has not proposed shutting down hydrodynamic testing capability at either LLNL or LANL. Consolidating LANL's testing program with LLNL's at LLNL is discussed section 3.10.1.3., and is dismissed as unreasonable. DOE has not identified any need to consolidate LLNL's testing program with LANL's at LANL. Consolidation at one site is therefore not considered as a reasonable alternative to the DARHT Baseline Alternative.

3.10.5 FXR

As an alternative to operating DARHT, modify and upgrade the FXR facility at LLNL to provide the capabilities proposed for DARHT.

DOE is in the process of upgrading the FXR Facility under a separate proposal. Under this type of alternative, in addition to the already proposed upgrades, FXR would be remodeled and enlarged to construct a second accelerator hall to accept the new technology developed for DARHT, and PHERMEX would continue to operate at LANL. This is considered unreasonable as an alternative for the Proposed Action because DOE does not conduct dynamic experiments with plutonium at LLNL and it would require several hundred million dollars to duplicate the required plutonium handling capability. In the future, should DOE propose to provide three-dimensional capability at LLNL, a separate NEPA review would be prepared at that time if required.

3.10.6 Alternative Types of Tests

As an alternative to operating DARHT, use an alternative type of test to conduct diagnostic experiments.

Although hydrodynamic testing is used in conjunction with other types of testing capability, such as computer modeling or nuclear testing, no other type of experimental facility will produce the diagnostic results of a hydrodynamic testing facility. The President, Congress, and the Secretaries of Energy and Defense have determined that the Nation needs to maintain and improve its hydrodynamic test capabilities that reside with DOE. The purpose of the Proposed Action is to provide improved hydrodynamic test capability. Other types of tests would not meet the Agency and National need for the type of information that can only be obtained from hydrodynamic tests. DOE will continue to use other diagnostic tools, such as computer modeling, in conjunction with hydrodynamic testing, as has been done for more than 30 years.

3.10.7 Relinquishing Reliability of the Nuclear Stockpile

As an alternative to operating DARHT, relinquishing the goal of maintaining the reliability of nuclear weapons would mean that hydrodynamic testing (hence the DARHT Facility) would not be needed.

The alternative of not maintaining the integrity of the nuclear weapons stockpile does not meet the direction from the President and Congress to maintain a safe, secure, and reliable nuclear deterrent as a cornerstone of National defense. Thus, this alternative is not considered to be reasonable.

3.10.8 Weapons Design

As an alternative to operating DARHT to ensure weapons safety and reliability, operate DARHT to design prototype weapons, and study impacts on the Nation's nonproliferation objectives and the impact of fabricating prototype weapons.

As discussed in section 3.5, in the 1980s, DOE proposed to operate DARHT to provide enhanced hydrodynamic testing capability in support of the Nation's nuclear weapons design program, as well as in support of ensuring safety and reliability of stockpiled nuclear weapons. As stated in section 2.3.4, in the event that this Nation decides as a matter of policy that new nuclear weapons should again be developed, we would use all appropriate means at our disposal to accomplish this. Hydrodynamic testing, along with many other tools, could be used to assist in weapons development. However, in 1991, the President stated that the United States would not design new nuclear weapons in the foreseeable future; any decision to reverse this policy would come from the President and Congress. Accordingly, DOE does not at this time need to propose, design, or construct new facilities to assist with new weapons design. In any event, the environmental impacts of hydrodynamic tests at the DARHT Facility, the existing hydrodynamic testing facilities, or other alternatives analyzed in this EIS would vary by the number of test shots, size of explosive charge, materials used, and the design of the facility, not the intended application of test results.

3.10.9 No Hydrodynamic Testing Alternative

As an alternative to operating DARHT, do not construct or operate any hydrodynamic testing facility, and do not conduct hydrodynamic tests.

As discussed in chapter 2, the President and Congress have directed DOE to ensure the safety, performance, and reliability of the weapons stockpile, and to maintain and enhance its hydrodynamic testing capability in order to perform this task. A proposal not to conduct hydrodynamic testing would not meet this purpose.

3.10.10 Other Programmatic Alternatives

As an alternative to operating DARHT, use alternative means to conduct the Nation's stockpile stewardship program.

As discussed in chapter 2, the PEIS will analyze alternative means to conduct the Nation's stockpile stewardship program. The relationship of the DARHT EIS to that PEIS is discussed in that chapter. The President and Congress have determined that, as one aspect of conducting stockpile stewardship, the Nation needs to maintain and improve its hydrodynamic test capabilities that reside with DOE. The DARHT Facility responds to that purpose and need.

3.10.11 Other Mission Alternatives

As an alternative to operating DARHT as part of the DOE weapons program, consider an alternative nonweapons mission for DOE or LANL.

The nuclear weapons mission of DOE is established by law. Alternative missions for LANL do not respond to the purpose and need specified in this EIS. Accordingly, nonweapons missions are not considered to be reasonable alternatives to the DARHT Baseline Alternative.

DOE anticipates that the *LANL Sitewide EIS* discussed in chapter 2 will examine the cumulative impacts of facility operations in support of the mission assignments at LANL and that the PEIS discussed in chapter 2 will examine the impacts of alternative ways to perform the Stockpile Stewardship and Management Program. If, in the future, DOE would eliminate weapons research at LANL, including hydrodynamic testing, the Department would examine the need for additional NEPA review. This review would be used to determine the disposition of existing weapons research facilities at LANL, including any hydrodynamic test facilities existing at that time. DOE currently has no plans to withdraw weapons research work from LANL.

Comparison of Preferred Alternative,

Draft and Final EIS

Since the publication of the draft DARHT EIS, DOE has changed its preferred alternative to the Phased Containment Option of the Enhanced Containment Alternative. The preferred alternative identified in the draft EIS is now called the DARHT Baseline Alternative. Environmental impacts associated with the final EIS preferred alternative as compared to the draft EIS preferred alternative are shown below:

_ The concentration of uranium in water, as a percent of the drinking water standard, would be lower by about a factor of 10

_ Soil contamination would be lower by about 40 percent

_ Regional employment, labor income, and goods and services would be increased by about 25 percent

_ The amount of low-level waste generated would be reduced by more than 50 percent over the life of the project

_ Population dose from routine operations would be lowered by over 40 percent, although doses would be low in either case and no latent cancer fatalities (LCFs) would be expected

_ Air quality would degrade by about factor of four from operational releases of metals, but would still be less than 0.05 percent of applicable standards in all cases

_ Estimated radiation doses to workers from routine operations would be low and no LCFs would be expected, although exposure to depleted uranium in the vessel cleanout facility would result in radiation doses about five times higher

_ Potential radiation doses to the public and noninvolved workers due to hypothetical accidents would be low and no LCFs would be expected, although under these accident scenarios exposure to depleted uranium would result in radiation doses about 10 to 20 times higher due to the more concentrated nature of the dispersal plume ejecting from the containment vessel

_ Irreversible commitment of concrete and diesel fuel during construction and natural gas and electricity during operations would be 10 to 20 percent higher

Other potential impacts, including impacts from routine operations and accidents involving plutonium, would be essentially the same between the two alternatives.

3.11 COMPARISON OF ALTERNATIVES

The following tables comparatively summarize the alternatives analyzed in this EIS in terms of their expected environmental impacts and other possible decision factors. Table 3-3 compares the environmental impacts of the alternatives as discussed in detail in chapter 5; for the most part, environmental impacts would be expected to be similar among the alternatives analyzed.

Table 3-3.–*Summary of the Potential Environmental Impacts of the Alternatives*

Factor, Measure	**No Action**	**DARHT Baseline** **Alternative**	**Upgrade** **PHERMEX** **Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion** **Alternative** **Single Axis** **Alternative**
				Vessel	**Building**	**Phased**		
Land Resources Acreage committed PHERMEX (ac) DARHT (including RSL) (ac)	11 8	11 8	11 8	11 9[a]	11 8	11 9[a]	11 8	11 8
Air Quality **Construction** Maximum percent of standard[b] NO_2 PM_{10} SO_2 **Operations** Maximum percent of standard[b] NO_2 PM_{10} SO_2 Be Heavy Metal Lead	1.6 5 1 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 0.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 2.2 0.003 0.0002 0.02 0.007	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001	3.3 11 2.2 1.4 2.2 0.003 0.00005 0.005 0.001
Noise (qualitative)	Possible nuisance	Possible nuisance	Possible nuisance	75% reduction	Nuisance unlikely	Possible nuisance, phasing to 75% reduction	Possible nuisance	Possible nuisance

Water Resources Depleted uranium contamination, % drinking water standard (after millennia)	<1	<1	<1	<0.1	<0.1	<0.1	<1	<1

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table 3-3.–*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	**No Action**	**DARHT Baseline** **Alternative**	**Upgrade** **PHERMEX** **Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion** **Alternative** **Single Axis** **Alternative**
				Vessel	**Building**	**Phased**		
Soils Depleted uranium contamination area (ac) Max. concentration (approx.) (ppm)	15 9,000	15 5,000	15 9,000	15 2,000	15 1,000	15 3,000	15 5,000	15 5,000

Biotic Resources Habitat reduction[c] (ac) Threatened, endangered and sensitive species Disturbance by noise	None None Some	None When mitigated, none Some	None None Some	1 When mitigated, none 75% reduction	1 None Near zero	1 When mitigated, none Some, phasing to 75% reduction	None When mitigated, none Some	None When mitigated, none Some
Cultural Resources (qualitative)	None	When mitigated, none	None	When mitigated, none	None	When mitigated, none	When mitigated, none	When mitigated, none
Socioeconomics (Annual impacts, 1996 to 2002) Employment (FTE) Regional labor income (millions) Regional goods & services (millions)	–[d] –[d] –[d]	191 $ 4.1 $ 6.8	199 $ 4.3 $ 6.9	321 $ 6.8 $ 12.0	238 $ 5.1 $ 8.4	253 $ 5.4 $ 9.0	273 $ 4.9 $ 8.6	104 $ 2.2 $ 3.8

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table 3-3.–*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	**No Action**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**		**Plutonium Exclusion Alternative** **Single Axis Alternative**

				Vessel	**Building**	**Phased**		
Human Health	7×10^{-4}	7×10^{-4}	7×10^{-4}	5×10^{-4}	5×10^{-4}	6×10^{-4}	7×10^{-4}	7×10^{-4}
Depleted Uranium	30	30	30	13	8	17	30	30
Public, 30-yr life of project	None	None	None	None	None	None	None	None
MEI dose (rem)	0.3	0.3	0.3	0.6	0.6	0.6	0.3	0.3
Population dose (person-rem)	9	9	9	60	60	60	9	9
Latent cancer fatalities	None	None	None	None	None	None	None	None
Workers, 30-yr life of project	3×10^{-10}	3×10^{-10}	3×10^{-10}	3×10^{-10}	3×10^{-10}	3×10^{-10}	3×10^{-10}	3×10^{-10}
Average dose (rem)	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-7}	3×10^{-7}
Collective dose (person-rem)	None	None	None	None	None	None	None	None
Latent cancer fatalities	9×10^{-9}	9×10^{-9}	9×10^{-9}	9×10^{-9}	9×10^{-9}	9×10^{-9}	9×10^{-9}	9×10^{-9}
Plutonium	None	None	None	None	None	None	None	None
Public, 30-yr life of project	No impact	No impact	No impact	No impact	No impact	No impact	No impact	No impact
MEI dose (rem)								
Population dose (person-rem)								
Latent cancer fatalities								
Noninvolved Workers, 30-yr life of project								
Collective dose (person-rem)								
Latent cancer fatalities								
Workers								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table 3-3.–*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	**No Action**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative Single Axis Alternative**
				Vessel	**Building**	**Phased**		
Facility Accidents	15	15	15	15	15	15	15	15
Involved workers, worst case	6 x 10^{-4}	6 x 10^{-4}	6 x 10^{-4}	1 x 10^{-2}	1 x 10^{-3}	1 x 10^{-2}	6 x 10^{-4}	6 x 10^{-4}
explosion related fatalities	1.9	1.9	1.9	17	1.7	17	1.9	1.9
Depleted Uranium	None	None	None	None	None	None	None	None
Public	7 x 10^{-4}	7 x 10^{-4}	7 x 10^{-4}	5 x 10^{-2}	5 x 10^{-3}	5 x 10^{-2}	7 x 10^{-4}	7 x 10^{-4}
MEI dose (rem)	76	76	76	76	76	76	76	76
Population dose (person-rem)	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Latent cancer fatalities	12	12	12	12	12	12	12	12
Noninvolved worker dose (rem)	160	160	160	160	160	160	160	160
Plutonium								
Public (95th percentile								
meteorology)								
MEI dose (rem)								
Population dose (person-rem)								
Latent cancer fatalities								
Noninvolved worker dose (rem)								
Transportation	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Workers, 30-yr life of project	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}	3 x 10^{-9}
Dose (rem)	None	None	None	None	None	None	None	None
Public, 30-yr life of project								
Population dose, (person-rem)								
Latent cancer fatalities								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table 3-3.–*Summary of the Potential Environmental Impacts of the Alternatives – Continued*

Factor, Measure	**No Action**	**DARHT Baseline** **Alternative**	**Upgrade** **PHERMEX** **Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion** **Alternative** **Single Axis** **Alternative**
				Vessel	**Building**	**Phased**		
Waste Generated, Annual	9,400	9,400	9,400	9,400	9,400	9,400	9,400	9,400
Solid Sanitary Waste (ft^3)	310	310	310	310	310	310	310	310
(non-hazardous, non-radioactive)	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Hazardous (lb)	1	1	1	1	1	1	1	1
Solid	12,500	12,500	12,500	3,600	360	5,700[e, f]	12,500	12,500
Liquid	2	2	2	2	2	2	2	2
Mixed Waste (55-gal drums)								
Low-Level Waste (ft^3)								
TRU Waste (tons) (steel vessels)								
Unavoidable Adverse Impacts	See soils	See soils	See soils	See soils	See soils	See soils	See soils	See soils

Irreversible and/or Irretrievable	15,000	15,000	28,000	16,000	22,000	16,000	15,000	15,000
Commitment of Resources	9,500	11,500	17,000	12,500	18,200	12,500	11,500	11,500
Construction	365	365	750	365	450	365	365	365
Concrete (yd^3)	1,540	1,540	1,540	1,540	1,540	1,540	1,540	1,540
Diesel fuel (gal)	8,700	10,400	13,000	13,300	14,800	12,600[e, g]	10,400	10,400
Electricity (MWh)	550	2,250	2,500	2,600	2,900	2,500[e, g]	2,250	1,350
Operations	None	None	None	None	None	None	None	None
Depleted uranium (lb/yr)								
Natural gas (ft^3/yr)								
Electricity (MWh/yr)								
Long-term Productivity								
(qualitative)								

[a] Includes 1 ac (0.4 ha) for the vessel cleanout facility.

[b] The values presented here represent the maximum pollutant concentrations as a percent of the respective standard. Impacts for NO_2, PM_{10}, and SO_2 are compared to 24-h, 24-h, and 3-h standards, respectively. Percentages of annual air quality standards are much less. Construction impacts are from fugitive dust or construction equipment emissions; operations impacts are from emissions from the natural gas boiler or hydrodynamic testing.

[c] Habitat reduction refers to the change of habitat to another use. Analyses of impacts was limited to future activities; therefore the 8 ac (2.4 ha) previously disturbed at the DARHT site are not reflected here. Only the Enhanced Containment Alternative would result in an additional use of land for the vessel cleanout facility (see footnote a).

[d] The calculated socioeconomic impacts are derived using PHERMEX operation figures as a baseline. Thus, under standard modeling procedures there are no additional impacts calculated.

[e] Annual average over 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[f] Maximum annual impact similar to the DARHT Baseline Alternative. Minimum annual impact similar to the Vessel Containment Option.

[g] Maximum annual impact similar to the Vessel Containment Option. Minimum annual impact similar to the DARHT Baseline Alternative.

Table 3-4 summarizes facility construction and operations factors. The entries in this table are self-explanatory for the most part. However, the material releases information needs explanation. These entries represent estimated annual material releases to the environment immediately after high-explosive tests conducted at PHERMEX or the DARHT Facility. Subsequent cleanups are not considered in the estimated amounts. As discussed in section 3.7, under the Enhanced Containment Alternative, for the Vessel Containment and the Phased Containment options, this EIS conservatively assumes that the vessels would be used for most, but not all, tests, and that the single-wall containment vessels may have a leak rate of 1 percent and a maximum failure rate of 5 percent. The gaseous products from the detonation of high explosives (90 percent) would not be contained, and the remaining products would consist of carbon soot. In general, the impacts from accidents with single-walled containment vessels are higher than for uncontained tests, because the releases are more concentrated and are closer to the ground. For all alternatives, any future dynamic experiments using plutonium would be conducted within double-walled vessels that have been demonstrated to fully contain the tests and yield no measurable releases. Table 3-5 compares the hydrodynamic testing capabilities that would be expected under the alternatives analyzed.

Table 3-5.–*Comparison of Facility Attributes*

Attribute	**No Action Alternative (Baseline)**	**DARHT Baseline Alternative**	**Upgrade PHERMEX Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative** **Single Axis Alternative**
				Vessels	**Building**	**Phased**		
Image Quality	Baseline for comparison, does not meet needs	Best resolution, penetration meets needs	Best resolution, penetration meets needs	Better resolution, penetration meets most needs	Better resolution, penetration meets most needs	Better resolution, penetration meets most needs	Best resolution, penetration meets needs	Best resolution, penetration meets needs
3-D Capability	Only with multiple shots that introduce inconsistency and increase costs	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Only with multiple shots that introduce inconsistency and increase costs
Time-sequence Capability	Only with multiple shots that introduce inconsistency and increase costs	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Better quality and available with single shot	Only with multiple shots that introduce inconsistency and increase costs
Testing Efficiency	Baseline for comparison	Best, fewer tests and lower cost to obtain same data	Best, fewer tests and lower cost to obtain same data	Worst, more time to cycle tests	Worst, more time to cycle tests	Near Best[a] Intermediate[b] Worst[c]	Best, fewer tests and lower cost to obtain same data	Best, fewer tests and lower cost to obtain same data
Firing Point Materials Released	Baseline for comparison	Reduced 15 percent	Reduced 15 percent	Reduced 75 percent	Reduced 95 percent	Reduced 50 percent	Reduced 15 percent	Reduced 15 percent
Time Frame for Operation	Currently available	Single Axis ready 38 months after ROD, dual Axis in 66 months	Dual Axis ready 71 months after ROD	Single Axis ready 38 months after ROD, dual axis in 66 months	Dual Axis ready 77 months after ROD	Single Axis ready 38 months after ROD, dual axis in 66 months	Single Axis ready 38 months after ROD, dual axis in 66 months	Single Axis ready 38 months after ROD
Miscellaneous	High-power R tubes may become unavailable		No testing at LANL for 51 months	New vessel cleanout center, costs may discourage small experiments, no overhead diagnostics	New vessel cleanout center, costs may discourage small experiments, no overhead diagnostics	New vessel cleanout center, costs may discourage small experiments, no overhead diagnostics	Maintaining DARHT and PHERMEX increases cost	One accelerator hall available for a secondary use

[a] Phase 1, the first five years of operation [b] Phase 2, the second five years of operation [c] Phase 3 the final 20 years of operation

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CHAPTER 4

AFFECTED ENVIRONMENT

This chapter describes the environments that may be affected by the Proposed Action, whether the DARHT Baseline Alternative, No Action Alternative, or another analyzed alternative is chosen by DOE for implementation.

The Los Alamos National Laboratory (LANL) is located in north-central New Mexico in Los Alamos and Santa Fe counties. Most of LANL and the surrounding community development is situated on mesa tops. The areas that may be affected by the Proposed Action include land use, air quality and noise, water resources, geology and soils, biotic resources, cultural and paleontological resources, socioeconomic environment, and radiological and hazardous chemical environment. The scope of the affected environment differs from discipline to discipline, and the approach in this chapter is to describe the portion of the geographic area that is relevant to each resource type. Sufficient detail is presented for assessing the consequences of the analyzed alternatives for each area of the affected environment. The discussion in this chapter is augmented by the classified supplement for this EIS.

The PHERMEX site and the DARHT site, which are about 2,000 ft (600 m) apart, essentially constitute a single site for many of the environmental impact analyses. For the impact analyses, the combined sites are considered to be Area III (shown in figure 3-2) in Technical Area 15 (TA-15), as defined by LANL for safety, security, and control of the firing sites at PHERMEX and the DARHT Facility. In order to maintain clarity, the following terminology conventions are used in this chapter:

- "Site" refers to Area III containing both the PHERMEX and DARHT facilities.
- "PHERMEX site" or "DARHT site" refers to the area at, and immediately around, each respective facility.

This chapter describes the affected environment using information drawn from existing data on the specific technical areas (TAs), facilities and projects conducted in these areas, and LANL environmental protection/monitoring programs supporting compliance objectives. The data used to characterize the affected environment, while not all from the same calendar year(s), are the most recent and relevant published data available. These data are presented as representative of the conditions of the affected environment.

4.1 LAND RESOURCES

The study area for Land Resources is limited to Los Alamos National Laboratory (LANL) and its adjacent lands. LANL is located in north-central New Mexico, 60 mi (97 km) north-northeast of Albuquerque, 25 mi (40 km) northwest of Santa Fe, and 20 mi (32 km) southwest of Española in Los Alamos and Santa Fe counties. The associated communities of Los Alamos and White Rock are in Los Alamos County. Figure 4-1 shows the geographical location of LANL. The 28,000-ac (11,300-ha) LANL site and adjacent communities are situated on the Pajarito Plateau, which consists of a series of finger-like mesas separated by deep canyons that run from the Jemez Mountains on the west toward the Rio Grande Valley on the east. Mesa tops range in elevation from approximately 7,800 ft (2,400 m) on the west to about 6,200 ft (1,900 m) on the east (LANL 1994a). The developed acreage of LANL consists of 30 active Technical Areas (TAs) (see figure 3-1).

4.1.1 Land Use

Most developments within Los Alamos County are confined to mesa tops. The surrounding land is largely undeveloped with large tracts north, west, and south of the LANL site administered by the U.S. Forest Service (Santa Fe National Forest) the National Park Service (Bandelier National Monument), and Los Alamos County (figure 4-2). The San Ildefonso Pueblo borders the LANL site to the east (LANL 1994a).

Area III [approximately 1,400 ac (567 ha)] is located within TA-15 on Threemile Mesa, with Cañon de Valle to the southwest, Potrillo Canyon to the northeast, and Water Canyon to the south. The topography in the vicinity is varied, ranging from steep, precipitous canyon walls to gently sloping mesa tops. The elevation of Threemile Mesa ranges from 7,100 to 7,300 ft (2,165 to 2,225 m). The Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility and the Radiographic Support Laboratory (RSL) lie within Area III (as shown in figure 3-2). Eight ac (3 ha) of land at Area III have been disturbed for DARHT construction (Chastain 1995).

PHERMEX has a 4,100-ft (1,250-m) radius exclusion zone available, but typically a 2,460-ft (750-m) radius zone is used (shown in figure 4-3). The areas of these zones are 1,212 and 436 ac (490 and 176 ha), respectively. These exclusion zones are the areas surrounding the firing point that are cleared of all personnel for a test shot; they are concentric and are partially shared with exclusion areas for other test shot facilities. Facilities and development in this exclusion zone are limited to those needed in direct support of the firing site or which have use restrictions to ensure compatibility in the firing site. The *LANL Site Development Plan* (LANL 1994) defines a larger area, about 20 mi^2 (50 km^2), as the High Explosives Research and Development and Testing area; it separates explosives activity from noncompatible uses.

The major public roads that are used at LANL include State Road 501, State Road 4, and Pajarito Road. State Roads 501 and 4 are the closest to TA-15 (figure 4-1). Threemile Mesa is limited to Federal use, with no plans to release any portion of this mesa for public use.

4.1.2 Visual Resources

The topography of LANL affords spectacular views of the surrounding landscape of forested mountains, deep canyons, and the Rio Grande Valley. The mountain scenery, unusual geology, varied plant communities, and archeological heritage create a diverse visual environment. The scenery contrasts greatly with the functional industrial facilities of LANL. A majority of LANL's parking lots, security gates, and service and storage yards are highly visible to employees and visitors using public roads (LANL 1990). Most structures are cinderblock, frame, or metal, painted various shades of tan. Many of these buildings were constructed in the 1940s, 1950s, and 1960s.

Area III, which is not visible from public roads, contains the same visual resources as LANL. However, at Area III, the facilities are widely separated, so that vistas include canyons, mesas, and forests with occasional buildings. Immediately following a large test at Area III, the smoke plume may be briefly visible offsite.

4.1.3 Regional Recreation

The public is allowed limited access to certain areas of LANL. An area north of Ancho Canyon between the Rio Grande and State Road 4 is open to the public for selected recreation activities such as hunting and hiking. Vehicles and certain activities, such as woodcutting, are prohibited. Portions of Mortandad and Pueblo Canyons are also open to the public. TA-15, including Area III, is restricted to the public, except for specially permitted activities. An archeological site (the Otowi tract), northwest of State Road 502 near White Rock, is open to the public, subject to restrictions imposed by regulations that protect cultural resources (LANL 1993a).

Although they are not on the LANL site, other recreational areas are nearby. Located immediately south of LANL (figure 4-2), Bandelier National Monument is a popular public attraction. Natural beauty, Indian ruins, abundant wildlife, and historic structures are present. It has 65 mi (105 km) of maintained hiking trails that range from easy to strenuous (Los Alamos County Chamber of Commerce 1995). Another portion of Bandelier National Monument, located north of White Rock and south of State Road 502, is open to the public. The Jemez Mountains rise above Los Alamos to the west and offer a vast array of scenic attractions. This mountainous terrain in the Santa Fe National Forest offers the public opportunities for fishing, hunting, skiing, hiking, swimming, camping, and horseback riding.

4.2 AIR QUALITY AND NOISE

The study area for this section includes LANL and the surrounding areas where affected air may move or where noise may be perceived. This section describes the climate, air quality, noise, and air monitoring at LANL and TA-15. LANL quantifies and assesses the radiologic and nonradiologic air emissions to determine compliance with the Federal standards set by the U.S. Environmental Protection Agency (EPA) and State standards set by the New Mexico Environmental Improvement Board. All of the areas within LANL and its surrounding counties are designated as attainment areas with respect to the National Ambient Air Quality Standards (NAAQS). These standards define levels of air quality that are necessary, with an adequate margin of safety, to protect the public health (primary standards) and the public welfare (secondary standards).

4.2.1 Meteorology and Climatology

Los Alamos has a semiarid, temperate mountain climate. The climate averages for atmospheric variables such as temperature, pressure, moisture, and precipitation are based on observations made at the official LANL weather station at TA-59 from 1961 through 1990. The meteorological conditions described here are representative of conditions on the Pajarito Plateau at an elevation of approximately 7,200 ft (2,190 m) above sea level (LANL 1994a). The TA-59 weather station is approximately 2 mi (3 km) north of TA-15 and is considered representative of the weather conditions at TA-15.

In July, the average daily high temperature is 81 ºF (27 ºC), and the average nighttime low temperature is 55 ºF (13 ºC). The average January daily high is 40 ºF (4 ºC), and the average nighttime low is 17 ºF (-8 ºC). The highest recorded temperature is 95 ºF (35 ºC), and the lowest recorded temperature is -18 ºF (-28 ºC). The large daily range in temperature of approximately 23 ºF (13 ºC) results from the site's relatively high elevation and dry, clear atmosphere, which allows high insolation during the day and rapid radiative losses at night (LANL 1994a).

The average annual precipitation is 18.7 in (48 cm) but is quite variable from year to year. The lowest recorded annual precipitation is 6.8 in (17 cm), and the highest is 30.3 in (77 cm). The maximum precipitation recorded for a 24-hour period is 3.5 in (9 cm). Because of the eastward slope of the terrain, there is a large east-to-west gradient in precipitation across the plateau. White Rock often receives about 5 in (13 cm) less annual precipitation than the official weather station at TA-59, and the eastern flanks of the Jemez Mountains often receive about 5 in (13 cm) more (Bowen 1992).

Approximately 36 percent of the annual precipitation normally occurs from thundershowers during July and August. Winter precipitation falls primarily as snow, with accumulations of about 59 in (150 cm) seasonally (LANL 1993a). The highest recorded snowfall for one season is 153 in (389 cm), and the highest recorded snowfall for a 24-hour period is 22 in (56 cm). In a typical winter season, snowfall equal to or exceeding 1 in (2.5 cm) will occur on 14 days, and snowfall equal to or exceeding 4 in (10 cm) will occur on 4 days. The snow is generally dry; on the average, 20 units of snow at LANL are equivalent to 1 unit of water (LANL 1994a).

Los Alamos winds are generally light, averaging 6.3 mi/h (10 km/h). Strong winds are most frequent during the spring when peak gusts during this season often exceed 50 mi/h (80 km/h). The highest recorded wind gust is 77 mi/h (124 km/h). The semiarid climate promotes strong surface heating by day and strong radiative cooling by night. Because the terrain is complex, heating and cooling rates are uneven over the LANL area, which results in local thermally generated winds. The distributions of wind direction and wind speed for the four measurement stations (located at TA-6, TA-49, TA-53, and TA-54) on the plateau are shown in figures 4-4 and 4-5 (LANL 1994a). The wind roses presented in these figures provide general information of the daytime and nighttime wind conditions surrounding TA-15.

During sunny, light-wind days, an upslope air flow often develops over the plateau in the morning hours. This flow is more pronounced along the western edge of the plateau, where the flow is 650 to 1,650 ft (200 to 500 m) deep. By noon, southerly flow usually prevails over the entire plateau.

At measurement sites closer to the eastern edge of the plateau, wind roses show a weak secondary peak in the daytime wind direction in the northeast sector. These northeasterlies also show up in the wind roses for observations made at 300 ft (92 m) and 1,670 ft (510 m) above the ground. They are thought to result from cold air drainage down the Rio Grande Valley that persists into the early morning hours (LANL 1994a).

The prevailing nighttime flow along the western edge of the plateau is west-southwesterly to northwesterly. These nighttime westerlies result from cold air drainage off the Jemez Mountains and the Pajarito Plateau; the drainage layer is typically 165 ft (50 m) deep in the vicinity of TA-3. At sites farther from the mountains, the nighttime direction is more variable but usually has a relatively strong westerly component. Just above the drainage layer, the prevailing nighttime flow is southwesterly, with minor peaks in the distribution around northwest and northeast. At 1,673 ft (510 m) above the ground, the wind direction distribution exhibits a broad, flat peak covering the whole western half of the compass (LANL 1994a).

Atmospheric flow in the canyons is quite different than over the plateau. Data collected from Los Alamos Canyon suggest that at night a cold air drainage fills the lower portion of the canyon more than 75 percent of the time. The flow is steady and continues for about an hour after sunrise when it ceases abruptly and is followed by an unsteady up-canyon flow for a couple of hours. Down-canyon flow begins again around sunset, but the onset time appears to be more variable than cessation time in the morning (LANL 1994a).

4.2.2 Severe Weather

Thunderstorms are common at LANL, with 61 occurring in an average year. A thunderstorm day is defined as a day in which either a thunderstorm occurs or thunder is heard nearby. Most thunderstorm days occur during July and August, the so-called monsoon season. During this time of year, large-scale southerly and southeasterly winds bring moist air into New Mexico from the Gulf of Mexico and the Pacific Ocean. The combination of moist air, strong sunshine, and warm surface temperatures encourages the formation of afternoon and evening thundershowers, especially over the Jemez Mountains. Upper air winds often move the thunderstorms over TA-15. The resultant drainage patterns are discussed in section 4.4.1. No tornadoes have been reported to have touched down in Los Alamos County.

Lightning in LANL can be frequent and intense during some thunderstorms. Because lightning can cause occasional brief power outages, lightning protection is an important design factor for most facilities at LANL and the surrounding area. Lightning protection is used at PHERMEX and has designed into the alternatives.

Hail is also very common at LANL. In fact, the area around Los Alamos has the most frequent hailstorms in New Mexico. Typically, the hailstones have diameters of about 0.25 in. (0.6 cm), with a few somewhat larger. Some storms produce measurable accumulation on the ground. Rarely, hailstorms cause significant damage to property and plants. Very little hail damage is expected on hydrodynamic testing operations.

Large-scale flooding is not common in New Mexico. However, flash floods from heavy thunderstorms are possible in susceptible areas, such as arroyos, canyons, and low spots. Severe flooding has never been observed in Los Alamos, but heavy downpour combined with already saturated soil caused flash flooding in Los Alamos on August 4, 1991. Flooding washed out sewer lines in Pueblo Canyon, with extensive flooding of streets and basements. This type of flooding is possible at TA-15 and could serve as a mechanism to transport contaminants.

Flooding is possible in the spring from snowmelt, although snowmelt flooding is usually confined to the larger rivers in the state. However, snowmelt can cause muddy conditions in the LANL area, along with minor flooding of streams in the Jemez Mountains (Bowen 1992). Flooding from snowmelt is not expected to impact TA-15.

4.2.3 Atmospheric Dispersion

The irregular and complex terrain at LANL affects the atmospheric dispersion. The terrain and forests create an aerodynamically rough surface, forcing increased horizontal and vertical turbulence and dispersion. The dispersion generally decreases at lower elevations where the terrain becomes smoother and less vegetated, and canyons also limit dispersion by channeling air flow. The frequent clear skies and light winds cause good daytime vertical dispersion, especially during the warm season.

Clear skies and light winds have a negative effect on dispersion at night, creating strong, shallow surface inversions. The inversions are especially strong during the winter. Overall dispersion is greater in the spring during strong winds. However, vertical dispersion is the greatest during summer afternoons (Bowen 1992).

4.2.4 Air Quality

The criteria pollutants – nitrogen dioxide (NO_2), carbon monoxide (CO), hydrocarbons, particulate matter, and sulfur dioxide (SO_2) – make up approximately 79 percent of the stationary source emissions at LANL. The source of these criteria pollutants is combustion in power plants, steam plants, asphalt plants, and local space heaters. Toxic and other hazardous pollutants represent the remaining 21 percent of emissions from stationary sources at LANL. These emissions are generated by equipment surface cleaning, coating processes, and acid baths, and include gases, vapors, metal dust, and miscellaneous emissions such as wood dust, hazardous gases, and plastics (LANL 1994a).

Table 4-1 shows the results of two studies that estimated emissions of nonradioactive chemicals. The 1987 emissions inventories were designed to collect information on emissions of these chemicals for the state's toxic air pollutant registration regulation. The 1990 inventory expanded the list of chemicals and sources and was designed to give LANL an estimate of its overall emissions. Data from the 1987 and 1990 inventories represent the only available listings of chemical emissions for LANL. The main difference between the two inventories is that the 1990 estimates included the emissions from the boilers, which accounts for the large emissions of nitrogen dioxide, carbon monoxide, and particulate matter. The amount and type of nonradioactive chemical emissions will also change from year to year as experiments change (LANL 1994a).

Table 4-1.–*Summary of Total LANL Estimated Emissions of Nonradioactive Air Pollutants*[a]

***in 1987 and 1990*[b] *that may be Associated with Area III at TA-15*[c]**

Pollutant	1987 Emissions (lb/yr)[d]	1990 Emissions (lb/yr)	Pollutant	1987 Emissions (lb/yr)	1990 Emissions (lb/yr)
Nitrogen dioxide Nonmethane hydrocarbons Particulate Matter Ammonia	_[e] 10,872 _ 3,816	118,772 6,377 5,629 1,761	Hydrogen fluoride as Fluorine Trichlorethylene Aluminum welding fumes	6 1,229 _	534 463 271
Nitric acid Hydrogen chloride Methyl alcohol	1,674 1,832 4,437	1,457 1,407 1,298	Heavy metals Tungsten (insoluble) Ethylene glycol	_ _ 50	251 241 159
Isopropyl alcohol Acetic acid Welding fumes (not otherwise listed)	829 96 253	1,188 1,184 1,127	Nickel metal Aluminum (metal and oxide) Softwood	_ 5 525	122 89 88
Wood dust (certain hard woods) Nitrogen oxide	_ 1,049	1,003 944	Mineral oil mist Cyclohexane Lead	13 9 _	76 62 57
Stoddard solvent Kerosene	941 15,265	583 574	Hydrogen peroxide Chlorine	17 29	43 29

[a] Only pollutants with 1990 emissions of 25 lb/yr or more are reported here.

[b] Data for these two years are not adjusted for changes in LANL activities. Only those materials likely to be used at a hydrodynamic testing facility are listed here.

[c] This table represents pollutants associated with Area III operations. Emissions stated in this table are for the entire LANL

Site. For a complete listing of LANL emissions see the 1992 LANL Environmental Surveillance Report.

[d] Conversion factor: 1 lb/yr = 0.454 kg/yr.

[e] Data not collected for these pollutants.

Source: Adapted from LANL 1994a

Natural atmospheric and fallout radioactivity levels fluctuate and affect measurements made during LANL's air sampling program. Worldwide background airborne radioactivity is largely composed of fallout from past atmospheric nuclear weapons tests, natural radioactive constituents from the decay of thorium and uranium attached to dust particles, and materials resulting from interactions with cosmic radiation (for example, natural tritiated water vapor produced by interactions of cosmic radiation and stable water). Levels of background radioactivity in the atmosphere are summarized in table 4-2. Note that the measurements taken in Santa Fe on the roof of the Public Employment Retirement Association Building by the EPA are similar to those taken by LANL as regional background values (LANL 1994a).

Table 4-2.–*Average Background Concentrations of Radioactivity*

in the Regional Atmosphere

Radioactive Constituent	**Units**	**Santa Fe 1988-1991**	**New Mexico[a] 1992**	**DOE Guideline 5400.5 for Uncontrolled Area**
Tritium	10^{-12} _Ci/mL	–	0.3 (0.8)[b]	200,000
Uranium (natural)	pg/m^3	58.2 (19.5)	92.0 (15.0)	100,000
Uranium-234	10^{-18} _Ci/mL	22.5 (7.5)	30.6 (9.0)	90,000
Uranium-235	10^{-18} _Ci/mL	0.8 (0.4)	2.6 (0.7)	100,000
Uranium-238	10^{-18} _Ci/mL	22.5 (7.5)	28.8 (8.0)	100,000
Plutonium-238	10^{-18} _Ci/mL	0.3 (0.2)	0.6 (3.8)	30,000
Plutonium-239, 240	10^{-18} _Ci/mL	0.2 (0.1)	1.5 (2.2)	20,000
Americium-241	10^{-18} _Ci/mL	–	1.3 (4.1)	20,000

[a] Data are annual averages from the regional stations (Española, Pojoaque, Santa Fe) and were taken by LANL during 1992.

[b] Uncertainties (± 2_) are in parentheses.

Source: LANL 1994a

The annual air emissions reports for CY 1992 (DOE 1993b) and CY 1993 (DOE 1994) have estimated the radiological dose assessment from nonpoint sources, as defined by the Clean Air Act, such as the experiments conducted at TA-15. In 1992, the contribution from TA-15 operations to the Effective Dose Equivalent from all LANL operations for the maximally exposed individual [located approximately 2,600 ft (800 m) north-northeast of the Los Alamos Meson Physics Facility stack in TA-53] was 9×10^{-6} rem of the total of 7.9×10^{-3} rem (DOE 1993b). In 1993, the estimated dose from TA-15 operations was 6.6×10^{-5} rem (DOE 1994), which was higher for TA-15 but still very small. These values are less than 1 percent of the total annual LANL dose to the public.

Particulate radionuclide matter in the atmosphere is primarily caused by the resuspension of soil, which is dependent on current meteorological conditions and human disturbance. Windy, dry days can increase the soil resuspension, whereas precipitation (rain or snow) can wash particulate matter out of the air. Consequently, there are often large daily and seasonal fluctuations in airborne radioactivity concentrations caused by changing meteorological conditions.

Construction of the DARHT Facility, which is 34 percent complete, affected the air quality of the immediate area. Dust and auto emissions increased during the period of construction because of the increase in vehicles and construction machinery in the area.

4.2.5 Air Monitoring

The visibility at and near LANL has been monitored since 1988 at the Bandelier National Monument southwest of LANL off of State Road 4 (see figure 4-1). Visibility monitoring quantifies how well the visible information (i.e., images) is transmitted through the atmosphere to an observer some distance away.

The data are measured according to the Standard Visual Range (SVR), which can be interpreted as the farthest distance that a large black feature can be seen on the horizon. From summer 1993 to spring 1994, the SVR was measured during a four-hour average variation in visual air quality (excluding weather-affected data) at Bandelier National Monument. The SVR ranged from approximately 48 to 103 mi (77 to 166 km). This is a typical visibility range for the area according to data collected since 1988 (Air Resource Specialists 1994).

LANL operates or accesses a network of nonradiological ambient air monitors to routinely measure criteria pollutants, beryllium, acid precipitation, and visibility (see table 4-3). The nonradiological monitoring network consists of a variety of monitoring stations: 1 onsite criteria pollutant monitoring station, 17 beryllium monitors, 1 perimeter acid rain monitor, and 1 perimeter visibility monitoring station (LANL 1994a). Beginning in FY 1995, no measurements of the criteria pollutants are being made by LANL on a continuing basis because past observed values were low relative to standards. Measurements are made on an as-needed basis for activities with potential for pollution (Jardine 1995).

Table 4-3.–*Nonradiological Ambient Air Monitoring Results in the LANL Region for 1992*

Pollutant	**Averaging Time**	**Unit**	**New Mexico Standard**	**Federal Standards**		**Measured Concentration**
				Primary	**Secondary**	
Sulfur dioxide[a]	Annual arithmetic mean	ppm	0.02	0.03	0.05	0.0005
	24 hours	ppm	0.10	0.14		0.009
	3 hours	ppm				
	1 hour	ppm				
Total suspended particulate matter	Annual Geometric Mean	_g/m^3	60			
	30 days	_g/m^3	90			
	7 days	_g/m^3	110			
	24 hours[c]	_g/m^3	150			
PM_{10}[a]	Annual arithmetic mean	_g/m^3		50	50	8
	24 hours	_g/m^3		150	150	21
Ozone[a]	1 hour	ppm	0.06	0.12	0.12	0.076
Nitrogen dioxide[a]	Annual arithmetic mean	ppm	0.05	0.053	0.053	0.002
	24 hours	ppm	0.10			0.02
	1 hour	ppm				
Lead	Calendar quarter	_g/m^3		1.5	1.5	
Beryllium[b]	30 day	_g/m^3	10			0.02
Heavy Metals	30 days	_g/m^3	10			

[a] Measurements made at Bandelier Monitoring Compound.

[b] Measurement made at TA-52.

[c] Maximum concentration, not to exceed more than once per year.

Source: LANL 1994a

The 1992 sampling network for ambient airborne radioactivity consists of 55 continuously operating air sampling stations, including 17 offsite locations (3 regional and 14 perimeter), 14 onsite stations, and 5 onsite waste site stations. One station at TA-18 is inactive. The regional monitoring stations, 18 to 28 mi (29 to 45 km) from LANL, are located in Española, Pojoaque, and Santa Fe (figure 4-6). The data from these stations are used as reference points for determining regional background levels of atmospheric radioactivity. Ambient air is routinely sampled for beryllium, tritium, isotopic plutonium and uranium, americium, iodine, gross alpha, beta, and gamma activity. Table 4-4 presents 1992 radionuclide releases from LANL operations (LANL 1994a).

Table 4-4.–*1992 Airborne Releases*

of Radionuclides from LANL Operations

Radionuclide	Units	Activity Released 1992
Tritium	Ci	1,298
Phosphorus-32	_Ci	9
Uranium	_Ci	242[a]
Plutonium	_Ci	12
Gaseous mixed activation products	Ci	71,950
Mixed fission products	_Ci	275
Particulate/vapor activation products	Ci	0.73
Spallation products	Ci	< 0.1

[a] Does not include uncontained hydrodynamic testing. Reported releases are measured at 88 LANL discharge locations.

Source: LANL 1994a

Later in 1993, three air monitoring stations (76, 77, and 78 in figure 4-6) were added downwind of the firing site for PHERMEX and DARHT. The monitoring stations are about 320 to 3,300 ft (100 to 1,000 m) northeast of the firing site. Samples collected at these stations are analyzed for isotopic uranium, isotopic plutonium, gross alpha, beta, gamma, and beryllium (Jacobson 1995).

4.2.6 Noise

Noise measurements have been made in the standard unit for measuring noise levels in the A-weighted decibel (dBA) scale. Two kinds of noise are emitted from TA-15 – peak (or impact), which is high-level and short-duration noise, and continuous, which is of moderate level and relatively lengthy duration.

Continuous noise at TA-15 results from background noise and from construction activities (such as the construction of DARHT which is currently halted). Background noise levels range from 31 to 35 dBA at the vicinity of the Bandelier National Monument entrance and State Road 4 (Vigil 1995). Background noise levels at White Rock range from 38 to 51 dBA (Burns 1995). The higher background noise levels at White Rock result from a greater amount of traffic. A sound level of 60 dBA is characteristic of normal conversation level.

The sources of peak noise are explosive experiments at PHERMEX and the surrounding TAs. Peak noise measurements of a test using 20 lb (9 kg) of trinitrotoluene (TNT) at TA-14 (northeast of TA-15) at a distance of 750 ft (230 m) from the source ranged from 140-148 dBA. Noise measurements on March 11, 1995, from 150 lb (70 kg) of TNT at PHERMEX showed levels of 71 dBA at State Highway 4 [closest public approach, 1.3 mi (2 km)], 60 dBA near the state highway entrance to Bandelier National Monument [nearby permanent residences, 2.6 mi (4.3 km)], and about 70 dBA in White Rock [a nearby residential community, 4 mi (6.4 km)]. These noise measurements were collected as the opportunity arose in connection with tests to measure airwaves and ground vibrations from simulated test shots. Currently, these are the only available data that relate to noise impacts from proposed operations at DARHT. More extensive data to account for varying atmospheric conditions would be useful, but the data obtained in the communities were consistent with expectations.

When recent construction was under way at the DARHT site, it included use of heavy equipment such as dozers, loaders, backhoes, and generators. While actual noise measurements were not made during the use of the heavy equipment, existing data are available to quantify the range of noise levels. The mean level of noise from these equipment types ranges from 81 to 85 dBA (Chastain 1995 and Wyle Labs 1981).

4.3 GEOLOGY AND SOILS

The geology of the affected environment includes consideration of two perspectives:

- The broad area that is the source of geologic phenomena (such as earthquakes) that could affect the proposed facility
- The immediate area where the hydrodynamic test facility would be located and might subsequently impact the environment.

This section of the EIS first describes the geologic setting of the broader area and then progresses toward the greater specificity of local geologic pressures and features of the Pajarito Plateau, where the site is located.

4.3.1 Geology

The broad geological area described here is in north-central New Mexico (see figure 4-1). The Pajarito Plateau lies between the Jemez Mountains on the west and the Rio Grande on the east (figure 4-7). Although Precambrian rocks more than a billion years in age are found in deep drill holes in the LANL region, the most important geologic events for understanding the environment occurred during the past 32 million years, particularly the last million years.

The primary controlling feature in the region is the Rio Grande rift that begins in northern Mexico, trends northward across central New Mexico, and ends in central Colorado. The rift owes its origins to tension along the crest of a broad, gentle crustal uplift some 32 million years ago. The rift now comprises a series of basins formed by faulting that dropped the basin rocks relative to the uplift, usually much more deeply on either the east or west margins. These basins are filled with sediments derived from highlands to the east and west as well as occasional lake deposits and lava flows. The rift basin in the Los Alamos and Santa Fe area is the Española Basin.

Faulting associated with the rifting provided conduits for volcanic activity such as the basaltic lavas that are interbedded with the basin-filling sediments. In addition, the deep faulting helped localize the expression of some major trends in volcanic activity. The volcanic vents in and near the Jemez Mountains lie at the intersection of a northeast trend of volcanic centers and the western edge of the Española Basin of the Rio Grande rift (Seager and Morgan 1979). Deposits from these Jemez Mountains vents buried the basin-filling sediments and the adjacent uplands over an area of more than 800 mi^2 (2,100 km^2).

The climactic eruptions occurred about 1.5 to 1.1 million years ago; during this time the Bandelier Tuff was laid down in a sequence of ash falls from individual eruptions in the series. Also, during these eruptions, the crater, Valles Caldera, formed by collapse when a great volume of magma was ejected along the ring-shaped fractures that now define the caldera structure.

The Rio Grande rift, along with its faulting and volcanism, is complicated in detail and is the subject of both extensive literature and ongoing research. This is evident in descriptive documents with extensive bibliographies that have been published by Turin and Rosenburg (1994), Wong et al. (1995), LANL (1993a), and Gardner and House (1987). The geologic summary provided here is generalized to the level of information needed for environmental assessment.

The major portion of LANL is underlain by the Tshirege member of the Bandelier Tuff, a sequence of ashfall strata dipping slightly to the south-southeast. Along the eastern portion of LANL, canyons have exposed underlying strata within the Bandelier Tuff and older, deeper formations.

4.3.2 Structure and Stratigraphy

Structure and stratigraphy are the key elements of the local geologic environment. The geologic structure at the site is dominated by three fault zones: the Pajarito, Rendija Canyon, and Guaje Mountain faults. These faults are clearly expressed by surface offsets at some locations and inferred from geologic evidence at others. Figure 4-8 shows the results of recent mapping of faults, including the young faulting that is significant to LANL in general and the proposed site in particular (Wong et al. 1995). The figure distinguishes between clearly observable faulting and photo lineaments that may indicate connections or extensions of the faults. Other geologic maps often show simpler and more continuous faults.

The Pajarito fault is thought to mark the currently active western boundary of the Española Basin (Wong et al. 1995). Prior to the Jemez Mountains volcanism, the basin boundary may have been farther west and under the present Valles Caldera. The Rendija Canyon and Guaje Mountain faults are shorter and secondary to the Pajarito fault. However, a recent investigation determined that all three faults are geologically young and are capable of producing future earthquakes (see table 4-5) (Wong et al. 1995).

Table 4-5.–*Major Faults at LANL*

Name	**Approximate Length (mi)**	**Type[a]**	**Most Recent Movement**	**Maximum Earthquake[b] (Mw)**
Pajarito	29	Normal, East Side Down	multiple in past 100,000 to 200,000 years	7
Rendija Canyon	6	Normal, West Side Down	8,000 to 9,000 years ago	6.5
Guaje Mountain	8	Normal, West Side Down	4,000 to 6,000 years ago	6.5

[a] Normal Fault: a steep to moderately steep fault for which the movement is downward for the rocks above the fault zone.

[b] Mw denotes the moment magnitude scale (Katsuyuki 1995), which is physically based and calibrated to the Richter local magnitude scale at the lower values.

Source: Wong et al. 1995

Earthquakes in the region are not always well correlated with faults that are expressed in the surface geology. Figure 4-8 shows the epicenters for reported earthquakes near LANL from 1873 through 1992 (Wong et al. 1995). A few of these epicenters are near the Pajarito and Rendija Canyon faults. However, the epicenter determinations necessarily have some uncertainties, and the true locations may be somewhat different. The important conclusion from both the geologic and seismic evidence is that faulting in the region is an ongoing process.

Figure 4-9 is a general cross section of the area from the east edge of the Jemez Mountains across the Pajarito Plateau to the Rio Grande (DOE 1979). This cross section shows the Pajarito fault, the Precambrian basement rocks, the basin-filling sediments, volcanic rocks of the Jemez Mountains, and the volcanic Bandelier

Tuff that forms the Pajarito Plateau.

A stratigraphic section for TA-67, about 1 mi (1.6 km) north of the proposed site is shown in figure 4-10 (adapted from Broxton et al. 1994). The Tshirege member of the Bandelier Tuff is divided into several distinct units. Units 4 and 3 are important as contributors to the mesa-top soils. Unit 3, because of its welding, is a comparatively strong rock and resists erosion sufficiently to form the mesa topography. Units 2 and 3, as well as the nonwelded bed between them, contribute to the soils in the canyons.

The main aquifer below the proposed site is estimated to be in the Puye formation some 1,100 to 1,200 ft (335 to 365 m) below the mesa top. The porosity, permeability, and fracture flow (if present) for these formations are described in section 4.4 on water resources and in appendix E4.

4.3.3 Soils

Several distinct soils have developed on the Pajarito Plateau as the result of interactions among the bedrock, surface morphology, and local climate. Nyhan et al. (1978) mapped these soils as shown in figure 4-11. The mineral components of the soils on Threemile Mesa are in large part derived from the Bandelier Tuff, but other underlying formations are locally important elsewhere on the Pajarito Plateau. Alluvium derived from the plateau, the Jemez Mountains, and windblown deposits contributes to soils in the canyons and also on some of the mesa tops. Layers of pumice from the El Cajete eruption in the Jemez Mountains and windblown sediment from beyond the Pajarito Plateau are also significant components of many soils on the plateau.

Soils on the mesas can vary widely in thickness and are typically thinnest near the edges of the mesas, where bedrock is often exposed. The walls of the canyons often consist of steep rock outcrops and patches of shallow, undeveloped colluvial soils. South-facing canyon walls are steep and usually have little or no soil material or vegetation. In contrast, the north-facing walls generally have areas of very shallow, dark-colored soils and are more heavily vegetated (LANL 1993a).

Soils at the proposed site on Threemile Mesa have been mapped but not studied in detail (Nyhan et al. 1978). These soils at the proposed site are mapped as the Pogna fine sandy loam, rock outcrop, and sandy loam that formed in material weathered from tuff on gently to strongly sloping mesa tops. Typically, these soils are light brownish grey, fine sandy loam, or sandy loam, over tuff bedrock at 10 to 20 in (25 to 51 cm).

Detailed soil studies at Pajarito Mesa, about a mile north of the DARHT site, can provide general expectations for the origin of both the surface and buried soils at the proposed site. The two localities have similar bedrock, topography, and local climate. Near-surface stratigraphic units on Pajarito Mesa include two general soil-stratigraphic units (pre- and post-60,000 years old) and an older consolidated alluvium (perhaps greater than 1 million years old) (Broxton et al. 1994).

The uppermost soil-stratigraphic unit at Pajarito Mesa includes the El Cajete pumice (about 60,000 years old) and overlying deposits. These deposits comprise the loosest material at Pajarito Mesa and are the deposits most susceptible to collapse. The average thickness of these deposits in mesa-top trenches is about 3 ft (0.9 m), although the deposits are probably thinner away from the mesa top. Pure deposits of El Cajete pumice generally occur as small patches beneath the mesa top. The pumice deposit reaches a maximum of 2.8 ft (0.85 m) thick. Elsewhere, the pumice is mixed into the fine-grained mesa-top soils (Broxton et al. 1994). A patch of El Cajete pumice is visible in an excavation for the DARHT site.

Beneath the El Cajete pumice are older, consolidated soils that have thicknesses ranging from 0.2 to 6.7 ft (0.06 to 2.04 m), with their base typically occurring 4 to 6 ft (1 to 2 m) below the surface. This unit typically has a relatively high clay content and holds vertical walls (Broxton et al. 1994).

On Pajarito Mesa, some deposits of old, consolidated alluvium and associated pumice beds were found. These deposits may exceed 1 million years in age. They are up to 7 ft (2 m) thick, with their base up to 11 ft (3 m) below the surface. This unit is very cohesive and holds vertical walls.

The soil around PHERMEX is contaminated with materials which were part of the experiments exposed to high explosives. DOE has conducted studies, including aerial surveys using helicopters and soil-sampling surveys, that indicate that elevated levels of depleted uranium are found on the firing point (Fresquez and Mullen 1995). These studies indicate that gamma radiation levels decrease uniformly until only natural background levels are detected at about 460 ft (140 m) from the firing point. Another study (not radiological) indicated that approximately 90 percent of the depleted uranium remains within 490 ft (150 m) of the firing point (McClure 1995). No depleted uranium has been observed in samples obtained outside LANL.

4.3.4 Site Stability

Site stability could be affected by natural and engineered slopes near the hydrodynamic test facilities, erosional retreat of cliffs forming the mesa rims, and shaking from seismic ground motion. Engineering geology studies did not identify any slope stability problems at the DARHT site nor did they report any near-surface materials that would fail to support the buildings during seismic shaking (Korecki 1988). The PHERMEX site has similar near-surface geology, and has not experienced any slope stability problems during its operations since 1963. Geology studies of the stability of rocks near the rim of nearby Pajarito Mesa concluded that placing disposal facilities more than 200 ft (60 m) from the mesa rim would be adequate to ensure the integrity of such facilities for periods exceeding 10,000 yr (Reneau 1994). PHERMEX is, and the DARHT Facility would be, more than 200 ft (60 m) from the mesa edge. Seismic shaking may be an important triggering mechanism for major rock falls.

The three faults listed in table 4-5 control the estimates of seismic hazard at TA-15 because of their lengths, proximity, and evidence of geologically young movement. The maximum earthquakes could cause damage to structures not designed to resist such large earthquakes. It's important to note that the maximum earthquake on any of these faults would be a rare event. The WCFS report infers annual probabilities on the order of 10^{-4}, which corresponds to a return period of 10,000 yr. Even moderate earthquakes on these faults would have return periods of hundreds to thousands of years.

The firing-site facilities are engineered to withstand the blast wave and ground motion from detonating high explosives. However, vibratory ground motion from blasts has been raised as a possible concern for other structures, specifically for standing walls at cultural resources such as the Nake'muu ruin. Vibratory ground motion from detonation of high explosives was measured in conjunction with noise measurements (Vibronics 1995). Peak ground motion (particle velocity) for the energy transmitted through the ground was found to be less than the ground motion caused by the air wave pulse when it arrived. This result is reasonable because the high explosives are placed above ground and their energy is not transferred into the ground as efficiently as in blasting for construction or mining. These measurements indicate that ground motion from test shots would have less effect on structures than the corresponding air-wave pulse.

4.4 WATER RESOURCES

This section describes the surface and ground water resources at LANL. LANL continuously monitors these resources for primary pollutants and radionuclides. Area III has no streams or surface water bodies, but there are ground water resources; a portion of the main aquifer is present below the site.

4.4.1 Surface Water

The Rio Grande is the major source of surface water in north-central New Mexico. All surface water drainage and ground water discharge from the Pajarito Plateau ultimately arrives at the Rio Grande. The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 14,300 mi^2 (37,037 km^2) in southern Colorado and northern New Mexico. The flow at Otowi has ranged from a minimum of 60 ft^3/s (1.7 m^3/s) in 1902 to 24,400 ft^3/s (691 m^3/s) in 1920. The river transports about 1 million tons of suspended sediments past Otowi annually (LANL 1993a).

The major canyons that contain reaches of perennial streams inside LANL are Pajarito, Water, Ancho, and Chaquehui Canyons. Los Alamos, Water, and Pajarito Canyons, and perennial streams originate upstream of LANL facilities or effluent discharge points (see figure 4-7) (LANL 1993a).

Perennial streams in the lower portions of Ancho and Chaquehui Canyons extend to the Rio Grande without being depleted. In lower Water Canyon, the perennial stream is very short and does not extend to the Rio Grande. In Pajarito Canyon, Homestead Spring feeds a perennial stream only a few hundred yards long, followed by intermittent flows for varying distances, depending on climate conditions (LANL 1993a).

Springs between 7,900 and 8,900 ft (2,408 and 2,713 m) elevation on the eastern slope of the Jemez Mountains supply base flow throughout the year to the upper reaches of Cañon de Valle, Los Alamos, Pajarito, and Water Canyons. These springs discharge water perched in the Bandelier Tuff and Tschicoma Formation at rates from 0.0045 to 0.30 ft^3/s (0.0001 to 0.0085 m^3/s). The volume of flow from the springs is insufficient to maintain surface flow within more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium (LANL 1993a).

Eleven drainage areas, with a total area of 82 mi^2 (212 km^2), pass through the eastern boundary of LANL. Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year from some drainages. Los Alamos, Pajarito, and Water Canyons have drainage areas greater than 10 mi^2 (26 km^2). Pueblo Canyon has 8 mi^2 (21 km^2), and all others have less than 5 mi^2 (13 km^2). Theoretical maximum flood peaks range from 24 ft^3/s (0.7 m^3/s) for a 2-year recurrence to 686 ft^3/s (19 m^3/s) for a 50-year recurrence. The overall flood risk to LANL and TA-15 buildings is low because nearly all the structures are located on the mesa tops, from which runoff drains rapidly into the deep canyons (LANL 1993a).

4.4.2 Ground Water

Ground water in the LANL area occurs in four modes – in shallow alluvium in canyons, perched water, in the unsaturated zone between the surface and the main aquifer, and the main aquifer (LANL 1994a).

Threemile Canyon has a small drainage area that heads on the Pajarito Plateau, and ephemeral streamflow occurs in response to snowmelt runoff and from seasonal storms. The presence of a permanent perched or alluvial water body in this canyon is possible. Potrillo Canyon heads on the Pajarito Plateau at TA-15. Streamflow in the channel results from snowmelt and runoff from seasonal storms. The stream channel in the upper reaches of the watershed in TA-15 is cut directly into the Bandelier Tuff. There is little to no alluvial fill in this reach; therefore, it is unlikely that a permanent alluvial deposit exists in this canyon. No alluvial aquifers were found in the watershed further downstream where streamflow discharge is greater due to a larger contributing area (LANL 1993b).

Cañon de Valle heads on the flanks of the Sierra de los Valles. Cañon de Valle receives small amounts of recharge from springs in its uppermost reaches, but because of evapotranspiration and infiltration, streamflow from this source does not reach West Jemez Road. Cañon de Valle receives effluent from permitted wastewater discharge in the reaches below West Jemez Road but above TA-15.

Water Canyon is a large canyon that heads on the flanks of Sierra de Los Valles. Several springs discharge from perched aquifers in the tuff in upper Water Canyon. A short distance downstream from the confluence of Water Canyon and Cañon de Valle is Beta Hole, drilled along the side of the canyon floor to test a horizon at about 180 ft (55 m) down; no saturated sediments were found at any level in this hole. However, because of the hole's placement, it did not test sediments close to the channel axis where saturated shallow sediments most likely would be found. Further down the canyon within 1 mi (1.6 km), two other wells drilled in the 1960s in the canyon bottom found saturated sediments that suggest the possibility of local perched water in the canyon bottom. If a perched water zone exists there, it must be limited in areal extent, because two additional wells show this alluvium to be dry at a distance of about 1.5 mi (2.5 km) from Beta Hole. In addition, any such saturation of canyon bottom sediments could be temporal. Recent observations have noted the presence of small springs issuing from the lower slopes of Cañon de Valle, Pajarito, and Threemile canyons. There is considerable debate among hydrogeologists as to the source(s) of this spring flow. A possible source is perched ground water within the Bandelier Tuff. It is unknown whether such a perched water zone is present immediately under the DARHT site. There is a possibility of perched water zones lying above basalt flows that interfinger with sediment beds at intermediate depth.

The main aquifer in the LANL area is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Santa Fe Group, a sequence of basin-filling sediments, passing into the lower part of the Puye Formation beneath the central and western part of the Pajarito Plateau (LANL 1994a). Based on the regional water table contour map presented in figure 4-10, the depth of the main aquifer beneath TA-15 is estimated to vary from about 1,150 to >1,200 ft (350 to >365 m) below the mesa tops, with depths increasing to the west and from valley bottoms to mesa tops (figure 4-12). Aquifer hydrologic characteristics vary (LANL 1993b). Recent drilling results suggest that the main aquifer may be as shallow as 650 ft (198 m) (Gardner et al. 1993).

The aquifer beneath TA-15 is located within the layers of rock known as the Chino Mesa basalts, Puye conglomerate, and the Santa Fe Group, as shown in figure 4-13. These units are composed of various rock types – basalts, interflow breccias, conglomerates, sandstones, and siltstones. Not all of these rocks transmit water equally well. Thick basalts, siltstones, and fine-grained sandstones will not yield water as readily as coarse-grained conglomerates, sandstones, highly jointed basalts, and coarse sediments. To maximize production, supply and test wells are completed within a thick section of the aquifer to draw

from multiple, highly permeable layers (figures 4-13 and 4-9) (LANL 1993a). The water in the aquifer moves from the main recharge area in the Valles Grande in the Jemez Mountains eastward towards the Rio Grande, where there is some discharge into the river through seeps and springs.

LANL, the nearby communities of Los Alamos and White Rock, and Bandelier National Monument are entirely dependent on ground water for their water supply. The water supply is primarily obtained from well fields. About 4.1 million gal/day (16 million L/day) are used by these communities (DOE 1993a). During 1992, total production from the wells and gallery for potable and nonpotable use was 3.9 million gal/d (15 million L/d) (LANL 1994a).

4.4.3 Water Monitoring

LANL monitors surface waters and ground waters to detect any contaminants from LANL. Measurable concentrations of radionuclides from operations (primarily during the early years) have been transported by surface water offsite to Pueblo and Los Alamos Canyons. Surface water transport almost certainly is the predominant mechanism for redistributing many of the contaminants at the DARHT site. Important contaminant transport mechanisms associated with surface water include:

- Erosion and sedimentation (sediment and contaminant accumulation) of contaminated surface and near-surface materials
- Infiltration of surface water that may be contaminated, or movement of water through a contaminated deposit that in turn carries contamination deeper into the soil/rock profile
- Movement of contaminants in surface water as solutes, suspended sediments, and bedload phases. (LANL 1993a).

Los Alamos, Sandia, and Mortandad Canyons currently receive treated industrial or sanitary effluent. Pueblo Canyon does not receive LANL effluents. Surface waters in these canyons are not a source of municipal, industrial, or agricultural water supply. Only during periods of heavy precipitation or snowmelt would waters from Pueblo, Los Alamos, or Sandia Canyons extend beyond LANL boundaries and reach the Rio Grande.

In Mortandad Canyon, no surface runoff to LANL's boundary has occurred since studies were initiated in 1960. Pueblo Canyon received both untreated and treated industrial effluents from 1944 to 1964. It currently receives treated sanitary effluents from Los Alamos County treatment plants in its upper and middle reaches.

Existing wastewater generation from LANL is approximately 183 million gal/yr (693 million L/yr) (DOE 1993a). Permitted effluent discharges at LANL emerge from 2 sanitary wastewater treatment facilities and 124 industrial outfalls. These outfalls include power plant discharges (1 outfall), boiler blowdown (2 outfalls), treated cooling wastewater (40 outfalls), noncontact cooling wastewater (44 outfalls), radioactive wastewater (1 outfall), high explosive production facilities wastewater (18 outfalls), photographic laboratory rinse wastewater (14 outfalls), asphalt plant wastewater (1 outfall), printed circuit board process wastewater (1 outfall), and sanitary wastewater (2 outfalls) (LANL 1994a).

Surface water sampling station locations near TA-15 are presented in figure 4-14. The radiochemical, trace metals, and chemical quality analyses of samples taken at Pajarito Canyon, Water Canyon, and Ancho Canyon at the Rio Grande are listed in tables 4-6 and 4-7 (LANL 1994a).

Table 4-6.–*Radiochemical Analyses of Surface Waters at LANL*

Location (Map Designation _ see figure 4-10)	**Tritium (nCi/L)[a]**	**Sr-90 (pCi/L)**	**Cs-137 (pCi/L)**	**Total Uranium (_g/L)**	**Pu-238 (pCi/L)**	**Pu-239,240 (pCi/L)**	**Am-241 (pCi/L)**	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**	**Gross Gamma (pCi/L)**	**Gross Gamma (counts/ min/L)**
Water Quality Criteria	20,000 pCi/L[b]	8 pCi/L[b]	120 pCi/L[c]	–[d]	1.6 pCi/L[c]	1.2 pCi/L[c]	1.2 pCi/L[c]	15 pCi/L[b, e]	–[e]	–[d]	
Pajarito Canyon (47)[f]	0.4 (0.3)[h]	NA[i]	1.8 (1.2)	< 0.2[j] (0.0)	-0.013 (0.013)[k]	0.018 (0.011)	NA	0 (1)	5 (1)	0 (90)	
Water Canyon at Beta (48)a[g]	0.3 (0.3)	NA	53.60 (67.70)	0.3 (0.0)	-0.004 (0.004)	0.004 (0.004)[g]	NA	NA	NA	NA	10 (80)
Ancho at Rio Grande (36)[f]	0.4 (0.3)	0.0 (1.5)	3.3 (1.3)	0.4 (0.2)	-0.004 (0.004)	0.022 (0.012)	0.032 (0.030)	1 (1)	5 (1)	-30 (90)	

[a] Tritium as tritiated water in moisture distilled from sample.

[b] Maximum Contaminant Level (MCL) National Primary Drinking Water Regulations [40 CFR 141].

[c] U.S. Department of Energy derived concentration guides (DCG) for drinking water (DOE Order 5400.5).

[d] No specified limit.

[e] Screening limits for Gross Alpha are 5 pCi/L and for Gross Beta are 50 pCi/L.

[f] Results from 1992 sampling.

[g] Results from 1991 sampling (most recent data available) (LANL 1993).

[h] Radioactivity counting uncertainties (± one standard deviation) are shown in parentheses.

[i] NA means analysis not performed, lost in analysis, or not completed.

[j] Less than (<) means measurement was below the specified detection limit of the analytical method.

[k] Measurements of radiochemical samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique. Consequently, individual measurements can result in values of positive or negative. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative number values are included in the population calculations.

Source: Adapted from data LANL 1994a and LANL 1993

Table 4-7.–*Surface Water Quality Monitoring at LANL*

Parameter	**Units of Measure**	**Water Quality Criteria**	**Pajarito Canyon[a] (47)[b]**	**Water Canyon at Beta[c] (48)**	**Ancho at Rio Grande[a] (36)**
Aluminum	mg/L	0.05[f]	0.09	2.5	0.05
Beryllium	mg/L	0.004[g]	0.0026	<0.0003[e]	<0.0005
Bicarbonate	mg/L	–[d]	95	61	55
Calcium	mg/L	–[d]	25	15	14
Carbonate	mg/L	–[d]	<5	<2	16
Chlorine	mg/L	250[f]	17	9	3
Copper	mg/L	1[f]	<0.005	<0.002	0.007
Fluorine	mg/L	4[g]	0.3	<0.2	0.4
Magnesium	mg/L	–[d]	6.3	5	3.2
Mercury	mg/L	0.002[g]	<0.0001	<0.0002	<0.0001
Nitrate	mg/L	10[g]	0.12	2.7	0.91
pH	pH units[h]	6.5 _ 8.5[f]	7.2	6.8	8.9

Phosphorus	mg/L	_[d]	0.0	0.2	<0.0
Potassium	mg/L	_[d]	4	4	2
Sodium	mg/L	_[d]	21	19	12
Sulfate	mg/L	250[f]	4	7	4
Total Dissolved Solids	mg/L	500[f]	196	168	90
Total Hardness	mg/L	_[d]	88	58	48

[a] Results from 1992 sampling.

[b] Sampling locations shown in figure 4-14.

[c] Results from 1991 sampling (most recent data available).

[d] No specified limit.

[e] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.

[f] Maximum contaminant level (MCL) for secondary constituents, applicable to drinking water system, given

here for comparison only [40 CFR 143].

[g] MCL for primary constituents, applicable to drinking water systems, National Primary Drinking Water Regulations, given here for comparison only [40 CFR 141].

[h] Standard Units.

Source: Adapted from LANL 1994a and LANL 1993c

The perched alluvial ground water in offsite reaches of Pueblo and Los Alamos Canyons also shows the ongoing influence of both industrial and sanitary effluents. The hydraulic connections, and any associated flow rates, between known occurrences of perched, intermediate-depth ground water and the main aquifer are not known.

Ground water sampling station locations and results of analyses are presented in figures 4-15 and 4-16 and tables 4-8 and 4-9. Ground water samples from wells are collected after sufficient water has been pumped or bailed to ensure that the sample is representative of the aquifer (LANL 1994a).

Table 4-8.–*Radiochemical Analyses of Ground Water Samples for 1992 at the Main Aquifer on the LANL Site*

Location	**Tritium (nCi/L)**	**Sr-90 (pCi/L)**	**Cs-137 (pCi/L)**	**U (_g/L)**	**Pu-238 (pCi/L)**	**Pu-239,240 (pCi/L)**	**Am-241 (pCi/L)**	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**	**Gross Gamma (pCi/L)**
Water Quality Criteria	20,000 pCi/L[a]	8 pCi/L[a]	120 pCi/L[b]	_[c]	1.6 pCi/L[b]	1.2 pCi/L[b]	1.2 pCi/L[b]	15 pCi/L[d]	_[d]	_[c]
Main Aquifer Onsite Test Wells										

Test Well DT-5A	0.3 (0.3)[e]	NA[f]	1.6 (1.1)	0.2 (0.1)	-0.005[g] (0.030)	-0.005 (0.020)	NA	1 (0)	2 (0)	40 (100)
Test Well DT-9	0.2 (0.3)	NA	1.3 (1.2)	< 1.0[h] (0.0)	-0.004 (0.030)	0.017 (0.020)	0.008 (0.030)	1 (1)	9 (1)	160 (100)
Test Well DT-10	0.1 (0.3)	NA	1.5 (1.1)	< 1.0 (0.0)	0.005 (0.030)	0.005 (0.020)	0.013 (0.030)	1 (1)	3 (0)	170 (100)
Water Supply Wells										
Well PM-2	0.2 (0.3)	NA	0.6 (1.0)	<0.6 (0.0)	0.008 (0.010)	0.008 (0.010)	0.020 (0.010)	0 (1)	2 (0)	50 (90)
Well PM-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Well PM-5	0.2 (0.3)	NA	0.3 (1.0)	<0.6 (0.0)	0.010 (0.012)	0.060 (0.019)	0.028 (0.015)	0 (1)	3 (1)	10 (90)

[a] Maximum Contaminant Level (MCL) National Primary Drinking Water Regulations [40 CFR 141].

[b] U.S. Department of Energy derived concentration guides (DCG) for drinking water (DOE Order 5400.5).

[c] No specified limit.

[d] Screening limits for Gross Alpha are 5 pCi/L and for Gross Beta are 50 pCi/L.

[e] Radioactivity counting uncertainties (±1 Standard Deviation) are shown in parentheses.

[f] NA means analysis not performed, lost in analysis, or not completed.

[g] Measurements of radiochemical samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values are sometimes obtained that are lower than the minimum detection limit of the analytical technique. Consequently, individual measurements can result in values of positive or negative. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative numbers values are included in the population calculations.

[h] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.

Source: LANL 1994a

Table 4-9.–*Water Quality Criteria and Ground Water Monitoring Results at LANL*[a]

Parameter	**Units of Measure**	**Water Quality Criteria**	**Test Well DT-5A[b]**	**Test Well DT-9[b]**	**Test Well DT-10[b]**	**Supply Well PM-2[b]**	**Supply Well PM-5[b]**
Aluminum	mg/L	NA[c]	<0.02[d]	0.26	0.16	<0.03	<0.03
Beryllium	mg/L	NA	<0.0020	0.0020	0.0016	<0.0020	0.0020
Bicarbonate	mg/L	NA	51	51	66	47	74
Calcium	mg/L	NA	9	20	10	10	13
Carbonate	mg/L	NA	<5	<5	<5	<5	<5
Chlorine	mg/L	250[e]	2	3	3	2	3

Copper	mg/L	1[e]	<0.003	0.800	<0.100	<0.003	<0.003
Fluorine	mg/L	NA	0.4	0.6	0.5	0.2	0.3
Magnesium	mg/L	NA	2.3	5.4	3.0	2.9	4.7
Mercury	mg/L	0.002[f]	<0.0001	<0.0002	<0.0002	<0.0001	<0.0001
Nitrate	mg/L	10[f]	0.33	0.28	0.19	0.34	0.30
pH	pH units[g]	6.5 _ 8.5[e]	7.6	7.9	8.2	7.9	7.5
Phosphorus	mg/L	NA	NA	NA	NA	0.0	0.1
Potassium	mg/L	NA	2	2	1	2	2
Sodium	mg/L	NA	11	22	9	11	14
Sulfate	mg/L	250[e]	3	3	3	3	3
Total Dissolved Solids	mg/L	500[e]	128	114	92	144	170
Total Hardness	mg/L	NA	31	72	37	36	51

[a] Results from 1992 sampling.

[b] These well locations are shown on figure 4-15.

[c] NA means analysis not performed, lost in analysis, or not completed.

[d] Less than symbol (<) means measurement was below the specified detection limit of the analytical method.

[e] Maximum contaminant level (MCL) for secondary constituents, applicable to drinking water system, given here for comparison only [40 CFR141].

[f] MCL for primary constituents, applicable to drinking water systems, National Primary Drinking Water Regulations, given here for comparison only [40 CFR141].

[g] Standard Units.

Source: LANL 1994a

In 1991, in an effort to better understand the nature of recharge (replenishment of ground water) to the main aquifer in the Los Alamos area, LANL initiated a study to help define the sources and times of recharge. These studies include a range of geochemical and geochronological techniques to help identify ages and potential sources of water in the main aquifer.

"Age of water" means the time elapsed since the water, as precipitation, entered the ground and became isolated from the atmosphere. The precipitation at the time of entry into the ground is assumed to have contained atmospheric equilibrium amounts of both tritium and carbon-14. Therefore, the amount of tritium and carbon-14 in the aquifer would be an indicator of the water's age. Radioactive carbon-14 is mainly from natural sources, while tritium comes from both natural sources and fallout from atmospheric nuclear weapons testing. For comparative purposes, the studies included a series of isotope (tritium) and age-dating (carbon-14) measurements on ground water samples.

LANL has also collected samples from the test wells and the water supply production wells that penetrate the main aquifer and tested them with a variety of radioactive and stable isotope measurements. At present, a number of measurements of carbon-14 and low-level tritium are available that permit some preliminary estimates of the age of the water in the main aquifer at various locations (Gallaher 1995).

Before atmospheric nuclear testing, the tritium levels in atmospheric water were about 20 pCi/L, or about 6 tritium units (TU). By the mid 1960s, tritium in atmospheric water in northern New Mexico reached a peak level of about 6,400 pCi/L (2,000 TU) (annual average for 1963 to 1964). Since then, both radioactive decay and dilution by mixing through the global hydrologic cycle have reduced the concentrations of tritium in atmospheric water. At present, general levels of atmospheric water in northern New Mexico are about 30 pCi/L (10 TU). As a basis for comparison, the present EPA and New Mexico state drinking water standard is 20,000 pCi/L (6,200 TU). Routine compliance with the drinking water regulations is done by liquid scintillation counting with a detection limit of about 300 to 700 pCi/L (100 to 220 TU) (Gallaher 1995). See table 4-10 for the results of the most recent analyses from samples taken at wells near TA-15 (Gallaher 1995).

Table 4-10.–*Summary of Carbon-14 and Tritium-based*

Age Estimates for Wells Near TA-15

Well Locations	**Carbon-14 (% modern)**	**Carbon-14 Age Estimates**			**Tritium (pCi/L)[c] Tritium Age Estimates**	
		Minimum[a]	**Maximum[b]**		**Piston Flow[d]**	**Well Mixed[e]**
Los Alamos Supply Wells (Main Aquifer)						
PM-1	18.5	5,620	14,000	1.65	>45	>3,000
PM-2	62.7	50	3,860	1.59	>45	>3,000
PM-3	23.9	4,950	11,800	0.45	>70	>9,000
PM-3 @ 987 ft	28.2	6,770	10,500	0.42	>70	>9,000
PM-3 @ 1,226 ft	24.5	7,700	11,600	0.26	>70	>10,000
PM-3 @ 1,650 ft	22.9	7,910	12,200	0.03	>100	>10,000
PM-3 @ 2,000 ft	23.9	6,390	11,800	0.10	>100	>10,000
PM-5	53.7	1,040	5,140	0.29	>70	>10,000
Los Alamos Test Wells (Main Aquifer)						
DT-5A	57.6	1,810	4,560	0.23	>80	>10,000
DT-9	69.1	163	3,060	0.45	>70	>9,000
DT-10	82.0	<0[f]	1,640	1.33	~55	>4,500

[a] Assumes dilution by "dead" carbon from dissolution of carbonates, estimated by ratios of carbon isotopes.

[b] Assumes radioactive decay only, no dilution by dissolution of carbonates.

[c] 3.24 pCi/L = 1 Tritium Unit (TU); one tritium atom in 10^{18} hydrogen atoms.

[d] Piston Flow model assumes no mixing or dilution with other water.

[e] Well Mixed model assumes complete mixing in reservoir, inflow = outflow, no other inputs.

[f] Applying dilution factor (footnote[a]) results in meaningless minimum age.

Source: Gallaher 1995

Four watersheds, each with an established stream channel drainage network, are present within TA-15. These watersheds are Threemile Canyon, Potrillo Canyon, Water Canyon, and Cañon de Valle. These watersheds may be affected by runoff from the PHERMEX firing site that potentially is contaminated with depleted uranium and other materials released during explosive testing. However, environmental surveillance data, the Potrillo Canyon study, and simulations of uranium, beryllium, and lead migration have not revealed adverse impacts due to runoff from PHERMEX. A fifth watershed, Pajarito Canyon, receives runoff from a small, undeveloped area within TA-15 (LANL 1993a).

The presence of either perched or alluvial aquifers in Threemile, Potrillo, Cañon de Valle, or Water Canyons has not been confirmed; however, the geology and hydrology of these canyons are clearly consistent with the existence of perched and alluvial aquifers (LANL 1993a). These four perched or alluvial aquifers are within the influence of TA-15 operations.

There are no wells in TA-15; therefore, all inferences on the main aquifer beneath this technical site have been drawn from information derived from supply wells and deep test wells near TA-15 (table 4-11 and figure 4-15) (LANL 1993a). Data in the table are measures of the amount of water and its ability to move through the rocks.

Table 4-11.–*Hydrological Characteristics*

of Supply and Test Wells Near TA-15

Well	**Saturated Thickness (ft)**	**Specific Capacity (gpm/ft)**	**Transmissivity (gpd/ft)**	**Field Coefficient of Permeability (gpd/ft^2)**
PM-2	1,426	23.1	40,000	28
PM-4	1,828	36.8	44,000	24
DT-5A	643	5.7	11,000	17
DT-9	498	22	61,000	122
DT-10	324	16	36,100	111

Well locations shown on figure 4-14.

Source: LANL 1993

4.5 BIOTIC RESOURCES

The LANL area contains a diversity of plant communities (figure 4-17) due in part to the dramatic 5,000-ft (1,500-m) elevational change from the Rio Grande on the east, to the Jemez Mountains 12 mi (20 km) on the west, and to the many canyons with abrupt surface slope changes that dissect the area (figure 4-7 shows the location of many of these features). Biological surveys of LANL have been carried out at various times – most recently in 1995 – to identify the plant and animal communities and species of the area. These studies were summarized by Dunham (1995), Risberg (1995), and Keller and Risberg (1995). Plant and animal species found in these surveys are listed in appendix F. This section describes the terrestrial resources, wetlands, and aquatic resources, and addresses threatened and endangered species at LANL, the DARHT site, and the proposed vessel cleanout facility sites.

4.5.1 Terrestrial Resources

Ecological diversity in terrestrial landscapes is typified by plant communities (assemblages of similar plant forms, each of which is dominated by one or two major species). Six major vegetative community types are found in Los Alamos County. Three of them – juniper-grassland, piñon-juniper, and ponderosa pine – are predominant, each occupying about one-third of LANL (figure 4-17). The other three are mixed-conifer, spruce-fir, and subalpine grassland (Risberg 1995).

The juniper-grassland community is found along the Rio Grande on the eastern border of the Pajarito plateau and extends upward on the south-facing sides of the canyons at 5,600 to 6,200 ft (1,700 to 1,900 m). Principal species in this community include one-seeded juniper (*Juniperus monosperma*), skunk bush sumac (*Rhus trilobata*), and sagebrush (*Artemisia spp*).

The piñon-juniper community, generally found in the 6,200- to 6,900-ft (1,900- to 2,100-m) elevation range, includes large portions of the mesa tops and north-facing slopes at the lower elevations. This woodland consists of stands of piñon pine (*Pinus edulis*) and one-seeded juniper, both dominant, and includes grasses such as blue grama (*Bouteloua gracilis*) and galleta (*Hilaria jamesii*) (Travis 1992).

The ponderosa pine community is found in the western portion of the plateau and on mesa tops in the 6,900- to 7,500-ft (2,100- to 2,300-m) elevation range. This community is characterized by ponderosa pine (*Pinus ponderosa*) as the primary overstory vegetation. It also contains Douglas fir (*Pseudotsuga menziesii*), Gambel oak (*Quercus gambelii*), mountain muhly (*Muhlenbergia montana*), and little bluestem grass (*Andropogon scoparius*) (Travis 1992).

The mixed conifer, at 7,500 to 9,500 ft (2,300 to 2,900 m), interfaces with the ponderosa pine in the deeper canyons and north slopes and extends to the west from the higher mesas on the slopes of the Jemez Mountains. The major species found here include quaking aspen (*Populus tremuloides*), Engelmann spruce (*Picea* *engelmannii*), Douglas fir, limber pine (*Pinus flexilis*), and white fir (*Abies concolor*). This community also has an understory of bearberry (*Arctostaphylos uvaursi*), creeping barberry (*Berberis repens*), and various grasses and forbs (Travis 1992).

The subalpine grassland is mixed with the spruce fir community at elevations of 9,500 to 10,500 ft (2,900 to 3,200 m). The pronounced east-west canyon and mesa orientation, with accompanying differences in soils, moisture, and solar radiation, produces an interlocking finger effect, resulting in transitional overlaps of plant and animal communities within small areas (DOE 1979). Species within this community include blue spruce (*Picea pungens*), Engelmann spruce, and mountain muhly.

The top of Threemile Mesa is characterized by piñon-juniper and ponderosa pine communities. The dominant overstory species are ponderosa pine, one-seed juniper, and piñon pine. Oak species (*Quercus spp.*) dominate the shrub layer. The dominant understory species are blue grama, mountain muhly, galleta, and big bluestem (*Andropogon gerardii*) grasses. A mixed-conifer forest of Douglas fir and mountain muhly covers the north-facing slopes. The south-facing slopes support a ponderosa pine forest and piñon-juniper woodland with ponderosa pine and wavyleaf oak (*Quercus undulata*). Douglas fir and open ponderosa pine forests make up the canyon bottom.

Undeveloped areas within LANL provide habitat for a diversity of terrestrial wildlife. Species lists have been compiled from observational data and published data, but the occurrence of some species has not been verified (Risberg 1995). Invertebrates at LANL include a number of ant species collected in 1986 as well as many other invertebrates (Risberg 1995). Among vertebrates, the collared lizard (*Crotaphytus collaris*), eastern fence lizard (*Sceloporus undulatus*), and whiptail lizard (*Cnemidophorus spp.*) are some of the reptiles found at LANL. Typically, these are found at elevations between 6,265 and 7,000 ft (1,910 and 2,134 m). Bird species which nest in the area include the Mexican spotted owl (*Strix occidentalis lucida*), great-horned owl (*Bubo virginianus*), and red-tailed hawk (*Buteo jamaicensis*) among the raptors, and Say's phoebe (*Sayornis saya*), lesser goldfinch (*Carpodacus psaltria*), and American robin (*Turdus migratorius*) among other types. Overwintering species include the scrub jay (*Aphelocoma coerulescens*), common raven (*Corvus corax*), and house finch (*Carpodacus mexicanus*) (Travis 1992, Keller and Risberg 1995).

Some of the larger mammals at LANL are the American black bear (*Ursus americanus*), coyote (*Canis latrans*), and raccoon (*Procyon lotor*) while the smaller species include the Mexican woodrat (*Neotoma mexicana*), deer mouse (*Peromyscus maniculatus*), Abert's squirrel (*Sciurus aberti*), and cottontail rabbit (*Sylvilagus nuttalli*) (Risberg 1995). The most important and prevalent big game species at LANL are the Rocky Mountain mule deer (*Odocoileus hemionus*) and Rocky Mountain elk (*Cervus canadensis*). LANL lands have traditionally been a transitional area for wintering elk and deer. More recently, these two species have been using LANL property on a year-round basis.

Throughout LANL's history, developments within various technical areas have caused significant alterations in the terrain and the general landscape of the Pajarito Plateau. These alterations have resulted in significant changes in land use by most groups of wildlife species, particularly birds and larger mammals that have large seasonal and/or daily ranges. Certain projects required the segregation of large areas, such as mesa tops, and in some cases, project areas were secured by virtually impenetrable fences around their perimeters. These have undoubtedly caused some species of wildlife, such as elk and deer, to alter their land use patterns by cutting off or altering seasonal and/or daily travel corridors to wintering areas, breeding habitat, foraging habitat, and bedding areas, as well as other necessary habitats.

In 1980, elk were primarily using the southwestern portion of LANL (White 1981). In addition, critical calving areas and important high-use areas were identified, all of which were primarily in the west and southwest part of LANL. Since 1980, the number of elk using LANL lands has increased significantly. Studies of elk conducted from 1991 to 1993 (Risberg 1995) reveal increased use of habitats north and northeast of previously documented high-use areas (White 1981). There have also been recent concerns about increases in motor vehicle accidents involving elk and deer in the LANL area (Kirk 1995). In general, however, little is known of habitat use patterns, population trends, and characteristics of elk on the Pajarito Plateau.

4.5.2 Wetlands

Wetlands have characteristics of both aquatic and terrestrial systems and include riparian (streambank) and floodplain ecosystems. Riparian areas are characterized by an abundance of deciduous and moisture-loving species. In the Southwest these zones have a higher diversity of plants providing cover, food, and breeding areas for a wider diversity of animals than the surrounding arid areas.

A 1992 LANL field study at TA-15 determined that no wetlands existed in the immediate area where the DARHT site is located (Dunham 1995). The proposed sites for the vessel cleanout facility building (see figure 3-6) were surveyed on July 6, 1995; it was determined that no wetlands existed on the sites. However, natural wetland areas, both floodplain and riparian, occur in some canyons of TA-15, and more extensive wetlands have developed as a result of effluent outfalls from LANL facilities (LANL 1993a). Floodplains are located at the bottom of Potrillo, Water, Threemile, and Pajarito Canyons, and Cañon de Valle (Dunham 1995). Narrow riparian areas line the intermittent stream channels in the canyon bottoms and in the perennial channel in Pajarito Canyon. These riparian zones consist of arroyos with water flowing intermittently during the spring runoff and summer monsoon season (usually July into August). The U.S. Fish and Wildlife Service (USFWS) has mapped the floodplain areas of LANL (figure 4-18).

The canyon riparian zones manifest a mixed-conifer tree canopy dominated by ponderosa pine. The understory layer is a mixed-deciduous woodland, dominated by boxelder (*Acer negundo*). The shrub layer consists of various oak (*Quercus*) species along with mountain mahogany (*Cercocarpus montanus*) and Apache plume (*Fallugia paradoxa*). The herbaceous layer is dominated by redtop (*Agrostis spp.*), accompanying other grasses, notably bluegrass (*Poa spp.*), bromegrass (*Bromus spp.*), and blue grama. This layer also contains a number of forbs, particularly meadowrue bedstraw (*Thalictrum fendleri*) (Dunham 1995).

4.5.3 Aquatic Resources

Aquatic habitats at LANL are limited to the Rio Grande and several springs and intermittent streams in the canyons. These habitats currently receive National Pollutant Discharge Elimination System (NPDES)-permitted wastewater discharges. The springs and streams at LANL do not support fish; however, many other aquatic species thrive in these waters (DOE 1993a; Cross 1994; Bennett 1994).

4.5.4 Threatened and Endangered Species

The Mexican spotted owl is listed as a federally listed threatened species. These owls were first observed in canyons within 2 mi (3.2 km) of the DARHT site by a 54 LANL Ecological Studies Team in the spring of 1995. These sightings were confirmed in June 1995 and, in addition, a nest site was found approximately 0.4 mi (0.6 km) from the DARHT construction site. Two young were fledged from this nest during the 1995 breeding season (March 1 to August 31).

Canyons surrounding the DARHT site provide nesting, roosting, and foraging habitats for the Mexican spotted owl. Foraging habitat near the DARHT site has been diminished by the removal of 7 ac (2.8 ha) of ponderosa pine/piñon-juniper vegetation. A slight decrease in prey abundance may have resulted from this removal. Vegetation loss may also add to noise impacts that affect owls; however, the topography and vegetation within the surrounding canyons also reduce sound levels over much of the nesting and roosting habitat.

There are eleven other species that are listed as threatened or endangered by either the USFWS or the New Mexico Department of Game and Fish that may occur on the proposed DARHT or vessel cleanout facility sites. Twelve more are considered candidates for inclusion on the federal endangered or threatened list (table 4-12). The most recent biological survey did not find any of these other species within the project site; however, highly suitable habitat exists for many of these species within the project area (Keller and Risberg 1995).

Table 4-12.–*Threatened, Endangered, and Candidate Species Potentially Present at Area III, TA-15*

Scientific Name	**Common Name**	**Status**	**Habitat**	**Potential for Occurrence**
PLANTS				
Fritillaria atropurpurea	Checker lily[c]	SE[f]	Mixed conifer	Low to Moderate
Lilium philadelphicum	Wood lily[c]	SE[f]	Ponderosa to mixed conifer, cliffs 6,000 to 10,000 ft (1,829 to 3,048 m)	Low to Moderate
Mammillaria wrightii	Wright's fishook cactus[c]	SE[f]	Desert grassland to piñon-juniper 3,000 to 7,000 ft (914 to 2,134 m)	Unlikely to Low [i]
Opuntia viridiflora	Santa Fe cholla[c]	FC[e],SE[f]	Piñon-juniper 7,200 to 8,000 ft (2,195 to 2,438 m)	Unlikely to Low [i]
Pediocactus papyracanthus	Grama grass cactus[a,c]	FC[e]	Grasslands, piñon-juniper woodlands 5,000 to 7,300 ft (1,524 to 2,225 m)	Unlikely to Moderate [i]
ANIMALS				
Plethodon neomexicanus	Jemez Mountain salamander[a]	FC[e], SE[g]	Densely wooded, shady canyons	Unlikely to Low
Accipiter gentilis	Northern goshawk[a,b,c]	FC[e]	Ponderosa; dense, mature, or old-growth coniferous forest	Low to Moderate
Buteo regalis	Ferruginous hawk[a]	FC[e]	Grasslands	Unlikely to Low [i]
Buteogallus anthracinus	Common black hawk[c]	SE[g]	Riparian with cottonwood	Unlikely [i]
Cynanthus latirostris	Broad-billed hummingbird[b,c]	SE[g]	Riparian woodlands	Unlikely [i]
Empidonax traillii extimus	Southwestern willow flycatcher[c]	FE[e], SE[g]	Riparian woodlands dominated by cottonwoods 3,700 to 8,900 ft (1,147 to 2,759 m)	Unlikely [i]
Falco peregrinus	Peregrine falcon[a,b,c]	FE[e], SE[g]	Ponderosa-piñon, streams and lakes	Low
Haliaeetus leucocephalus	Bald eagle[a,b,c]	FE[e], SE[g]	Riparian near streams and lakes	Unlikely to Low [i]
Ictinia mississippiensis	Mississippi kite[c]	SE[h]	Riparian and shelterbelts	Unlikely [i]
Lanius ludovicianus	Loggerhead shrike[a]	FC[e]	Grasslands, open woodland	Unlikely to Low [i]

Plegadis chihi	White-faced ibis[a]	FC[e]	Streams, marshes, ponds	Unlikely [i]
Strix occidentalis lucida	Mexican spotted owl[a,b,c]	FT[e]	Mixed conifer; mountains and canyons, uneven-aged, multi-storied forest with closed canopy	High
Euderma maculatum	Spotted bat[a,b,c]	FC[e], SE[g]	Ponderosa, piñon-juniper, cliffs and rock crevices	Low

Table 4-12.–*Threatened, Endangered, and Candidate Species Potentially Present at Area III, TA-15 – Continued*

Scientific Name	**Common Name**	**Status**	**Habitat**	**Potential for Occurrence**
Myotis evotis	Long-eared myotis[c]	FC[e]	Spruce-fir community	High
Myotis lucifugus occultus	Occult little brown bat[a]	FC[e]	Mountains, caves, and hollow trees	Unlikely [i]
Myotis thysanodes	Fringed myotis[c]	FC[e]	Water bodies at various elevations	High
Myotis volans	Long-legged myotis[c]	FC[e]	Ponderosa pine and higher elevations, water bodies	High
Myotis yumanensis	Yuma myotis[c]	FC[e]	Permanent watercourses	High
Ochotona princeps nigrescens	Goat peak pika[a]	FC[e]	Lava boulders	Unlikely [i]
Zapus hudsonius luteus	New Mexican jumping mouse[a]	FC[e], SE[g]	Near streams and vegetation	Low

[a] From U.S. Department of Interior Fish and Wildlife Service letter, January 23, 1995 (USFWS 1995).

[b] From Biological and Floodplain/Wetland Assessment for the DARHT, 1995 (Risberg 1995).

[c] From Biological and Floodplain/Wetland Assessment for OU 1086, TA-15, 1995 (Dunham 1995).

[d] From Draft Biological and Floodplain/Wetland Assessment for the Dual-Axis Radiographic Hydrodynamics Test Facility (DARHT) (Keller and Risberg 1995).

[e] From U.S. Department of the Interior Fish and Wildlife Service Memo, June 19, 1995 (USFWS 1995).

[f] From New Mexico Energy, Minerals and Natural Resources Department, NMFRCD Rule No. 91-1.

[g] From New Mexico Department of Game and Fish, Regulation #682, 11/30/90.

[h] Until recently, listed as State endangered by the New Mexico Department of Game and Fish.

[i] Suitable habitat for this species does not occur in the proposed project area (Keller and Risberg 1995).

STATUS:

SE: State Endangered: New Mexico-listed species protected as threatened or endangered under the Wildlife Conservation Act.

FC: Federal Candidate "...[Any species] for which the USFWS has on file enough substantial information of biological vulnerability and threat, [or] for which other information now in the possession of the USFWS indicates that proposing to list them as threatened or endangered is possibly appropriate..." [Federal Register Vol. 56, No. 255].

FE: Federal Endangered: "...Any species that is in danger of extinction throughout all or a significant portion of its range" [Federal Register Vol. 56, No. 255].

FT: Federal Threatened: "...any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." (Endangered Species Act of 1973).

POTENTIAL FOR OCCURRENCE:

Unlikely _ Suitable habitat for species does not exist within or near operable unit.

Low _ Potential for occurrence due to habitat requirements but not found during field survey or not known to occur in general project area.

Moderate _ Known to occur in habitat similar to project area or general area of operable unit.

High _ Species observed during field survey or known populations exist near project area.

Note: Potential for occurrence sometimes given as a range due to variations in findings by different researchers at various times.

4.6 CULTURAL AND PALEONTOLOGICAL RESOURCES

This section provides a summary evaluation of the prehistoric and historic cultural resources within a 2,500-ft (750-m) radius of shrapnel of the DARHT site. The published data on cultural and paleontological resources were presented relative to the DARHT site, rather than the site as defined in the introduction. There are other archeological sites within the PHERMEX hazard radius of 4,000 ft (1,250 m) of that facility, but none have standing walls other than those at Nake'muu.

Prehistoric cultural resources refer to any material remains of items used or modified by people prior to the establishment of a European presence in the upper Rio Grande valley in the early 17th century (Spanish Colonial and Territorial Periods as shown on table 4-13). Historic cultural resources include all material remains and any other physical alterations of the landscape since the arrival of Europeans in the region. An overview of the prehistory and history of the LANL area is summarized in table 4-13 (Larson 1995).

Table 4-13.–*Summary of Cultural Periods for the Central Pajarito Plateau*

	Cultural Period	**Years**	**Characteristics**
Prehistoric	Paleo-Indian Period	10,000 B.C. to 4,000 B.C.	Small groups of big game hunters who may have followed game herds along the Rio Grande, with trips onto the Pajarito Plateau to procure obsidian and other resources. This period is represented at LANL by occasional surface finds of diagnostic projectile points made from both local obsidian and exotic unidentified chert.
	Archaic Period	4,000 B.C. to A.D. 600	Small groups who may have used the Pajarito Plateau for hunting and for seasonal uses of certain wild plants. This period is represented at LANL as scatters of lithic tools, chipping debris, and diagnostic projectile points. Little research has been conducted for this period; it is possible that buried habitation sites are also present at LANL.
	Early Developmental Period	A.D. 600 to 900	Settled hunter-gatherers living in semi-subterranean pithouses and making simple pottery. Some possible pithouse locations and associated artifacts have been identified at LANL, but identification is tenuous.
	Late Developmental Period	A.D. 900 to 1100	Small groups of maize horticulturalists who also relied to a great extent on gathering wild plants. Sites are typically small adobe, sometimes crude masonry, pueblo structures. Very few sites from this period are at LANL; most of those recorded are located close to the Rio Grande in the vicinity of Chaquehui Mesa and Lower Water Canyon.
	Coalition Period	A.D. 1100 to 1325	Maize horticulturalists. Early sites are adobe and masonry rectangular structures, and later sites are large masonry enclosed plaza roomblocks of over 100 rooms. Most of the ruins recorded at LANL can be attributed to this time period; 700 ruins have been recorded. Some researchers attribute the increase in site density to migration while others see the increase in site numbers as a result of local population growth.

	Classic Period	A.D. 1325 to 1600	Intensive maize horticulturists. Settlements on the Pajarito Plateau aggregated into three population clusters with outlying one- to two-room fieldhouses. The central site cluster consists of four temporally overlapping sites: Navawi, Otowi, Tsankawi, and Tsirege. Otowi and Tsirege are at LANL. These ruins are ancestral to the Tewa speakers now living at San Ildefonso Pueblo.
Historic	Spanish Colonial and Territorial Periods	A.D. 1600 to 1900	Grazing and seasonal use of the Plateau during this time by non-Indian groups is highly probable but has not been thoroughly documented.
	Homesteading Period	A.D. 1890 to 1943	This was an outgrowth of the earlier undocumented use of the plateau for cattle grazing, timbering, and farming activities. Hispanic and Anglo homestead era sites are characterized by wooden cabin and corral structures, rock or cement cisterns, and scattering of debris associated with household and farming/grazing activities. In 1918 the Los Alamos Ranch School, a school for boys, was founded in present day Los Alamos.
	Post 1943	A.D. 1943 to Present	In the 1940s during the early stages of the Manhattan Project, many of the Los Alamos Ranch School buildings were appropriated for use by the U.S. Government. The central portion of the Pajarito Plateau is now owned by either the Federal government, Los Alamos County, San Ildefonso Pueblo, or by private citizens.

Types of prehistoric sites identified in the vicinity of LANL include large multi-room pueblos, pithouse villages, field houses, talus houses, cave kivas, shrines, towers, rockshelters, animal traps, hunting blinds, water control features, agricultural fields and terraces, quarries, rock art, trails, campsites, windbreaks, rock rings, and limited activity sites. Approximately 75 percent of LANL has been inventoried for cultural resources. Coverage for some inventories has been less than 100 percent; however, about 60 percent of LANL has received 100 percent coverage. Over 975 prehistoric sites have been recorded; about 95 percent of these sites are considered eligible or potentially eligible for the National Register for Historic Places (NRHP) (DOE 1993a).

4.6.1 Prehistoric Archeological Resources

Three field surveys were conducted and a fourth is planned to determine the presence of archeological and historical cultural resources in the area of potential effects for the DARHT site. Each is described below. The first survey was conducted between June 1987 and November 1988 in the DARHT construction area and involved examination of 24.7 acres (10 ha). Three archeological sites were recorded in the construction area. Laboratory of Anthropology (LA) 71408, LA 71409 and LA 71410 (tables 4-14 and 4-15). The New Mexico State Historic Preservation Officer (NM SHPO) concurred that these sites were eligible for the National Register of Historic Places (NRHP) based solely on their research potential (Criterion D) in correspondence with the DOE dated February 21, 1989) (Merlan 1989). An additional archeological site was also discussed in this report, LA 12655, also known as "Nake'muu," and will be discussed below.

Table 4-14.–*Archeology Sites within a 2,500-ft (750-m)*

Radius of the DARHT Firing Site

Site Number[a,b]	Site Type	Tech Area	General Location	National Register Eligibility
Q 65	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 76	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
Q 78	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 87	Rock shelter	15	Water Canyon	Eligible _ Criterion D
Q 88	Water control structure	15	Mesita del Potrillo	Not eligible
Q 90	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 91	Cavate	15	Water Canyon	Not eligible
Q 105	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D

Q 111	Cavate	15	Water Canyon	Eligible _ Criterion D
Q 112	Rock art	15	Water Canyon	Eligible _ Criterion D
Q 113	Rock shelter	15	Water Canyon	Eligible _ Criterion D
Q 114	Cavate	15	Water Canyon	Eligible _ Criterion D
Q 140	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 142	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 146	Recent structure (Laboratory era)	15	Potrillo Canyon	Eligible _ Criterion D
Q 147	Historic structure	15	Potrillo Canyon	Eligible _ Criterion D
Q 159	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4663	Single roomblock pueblo	15	Threemile Mesa	Eligible _ Criterion D
LA 4664	Single roomblock pueblo	15	Threemile Mesa	Eligible _ Criterion D
LA 4665	Enclosed plaza pueblo	15	Threemile Mesa	Eligible _ Criterion D
LA 4667	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4668	One- to three-room structure	15	Threemile Mesa	Not eligible (excavated)
LA 4669	One- to three-room structure	15	Threemile Mesa	Eligible _ Criterion D
LA 12657C	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657D	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657E	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657F	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657G	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 89759	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 89760	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 71408	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D, SHPO concurrence
LA 71409	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D, SHPO concurrence
LA 71410	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D, SHPO concurrence
LA 12655	Nake'muu _ enclosed plaza pueblo	15	Mesita del Potrillo	Eligible _ Criteria C & D, SHPO concurrence

[a] LA - New Mexico Laboratory of Anthropology number; Q - LANL Field Number

[b] Certain sites are not listed as a result of consultations with Indian tribes, but are considered in the impact analysis. These consultations were conducted in accordance with AIRFA, NHPA, ARPA, and other cultural resources laws and regulations.

Source: Larson 1995

Table 4-15.–*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m)*

Radius of the PHERMEX Firing Site

Site Number[a]	**Site Type**	**Tech Area**	**General Location**	**National Register Eligibility**
2,500-ft Radius				
Q 77	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4665	Enclosed plaza pueblo	15	Threemile Mesa	Eligible _ Criterion D
LA 4668	One- to three-room structure	15	Threemile Mesa	Not eligible (excavated)
LA 4669	One- to three-room structure	15	Threemile Mesa	Eligible _ Criterion D
LA 108732	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108733	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 61	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 73	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 74	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 75	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 83	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 84	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 85	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 86	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 145	Rock shelter	36	Potrillo Canyon	Eligible _ Criterion D
Q 155	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
W 15	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
W 16	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D

W 19	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4667	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108734	Rock shelter	15	Water Canyon	Eligible _ Criterion D
LA 108735	Water control feature	15	Potrillo Canyon	Not eligible
LA 108736	Artifact scatter	15	Potrillo Canyon	Eligible _ Criterion D
LA 108737	Cavate	15	Mesita del Potrillo	Not eligible
LA 108745	Historic structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108746	Historic rockpile and artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 62	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
Q 64	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
Q 66	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
Q 67	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
Q 69	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 70	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 72	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 92	Cavate	15	Water Canyon	Eligible _ Criterion D
Q 138	Water control feature	15	Mesita del Potrillo	Not Eligible
Q 144	Rock art	36	Potrillo Canyon	Eligible _ Criterion D
V 6	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
V 9	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
LA 4682	Enclosed plaza pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4683	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
LA 21366	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
LA 71408	Single roomblock pueblo	15	Water Mesa	Eligible _ Criterion D,SHPO Concurrence
LA 71410	One- to three-room structure	15	Water Mesa	Eligible _ Criterion
LA 89759	One- to three-room structure	49	Frijoles Mesa	

Table 4-15.–*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m)*

Radius of the PHERMEX Firing Site – Continued

Site Number[a]	**Site Type**	**Tech Area**	**General Location**	**National Register Eligibility**

LA 89760	One- to three-room structure	49	Frijoles Mesa	D,SHPO Concurrence
LA 108731	Artifact scatter	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108738	One- to three-room structure	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108739	Cavate	15	Water Canyon	Eligible _ Criterion D
LA 108740	Rock Art	15	Water Canyon	Eligible _ Criterion D
LA 108743	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
LA 108744	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
4,000-ft Radius				
Q 63	Artifact scatter	36	Mesita del Potrillo	Eligible _ Criterion D
Q 68	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 71	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 79	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 80	Water control feature	36	Mesita del Potrillo	Eligible _ Criterion D
Q 81	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
Q 82	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
Q 137	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
Q 139	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
V 2	Water control feature	36	Mesita del Potrillo	Not Eligible
V 3	Water control feature	36	Mesita del Potrillo	Not Eligible
V 4	Water control feature	36	Mesita del Potrillo	Not Eligible
V 5	Water control feature	36	Mesita del Potrillo	Not Eligible
V 7	One- to three-room structure	36	Mesita del Potrillo	Eligible _ Criterion D
V 12	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
V 13	Water control feature	36	Mesita del Potrillo	Not Eligible
V 14	Water control feature	36	Mesita del Potrillo	Not Eligible
LA 4664	Single roomblock pueblo	15	Threemile Mesa	Eligible _ Criterion D
LA 4679	Single roomblock pueblo	36	Mesita del Potrillo	Eligible _ Criterion D
LA 4680	One- to three-room structure	36	Mesita del Potrillo	Not eligible (excavated)
LA 4681	Single roomblock pueblo	15	Mesita del Potrillo	Eligible _ Criterion D
LA 4686	One- to three-room structure	15	Mesita del Potrillo	Not eligible (excavated)
LA 4696A	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 4697A	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D

LA 4697B	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 12655A	Enclosed plaza pueblo	37	TA-16 Mesa	Eligible _ Criterion C,SHPO Concurrence
LA 12657E	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657F	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657G	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 71409	Single roomblock pueblo	15	Water Mesa	Eligible _ Criterion D,SHPO Concurrence
LA 89761	Artifact scatter	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89762	Cavate	49	Branch of Water Canyon	Potentially eligible _ Crit. D
LA 89763	Rock shelter	49	Water Canyon	Potentially eligible _ Crit. D
LA 108741	Rock shelter	15	Water Canyon	Eligible _ Criterion D
Q 95	One- to three-room structure	15	Potrillo Canyon	Eligible _ Criterion D
Q 96	Cavate	15	Potrillo Canyon	Eligible _ Criterion D

Table 4-15.–*Archeology Sites within a 2,500-ft (750-m) and 4,000-ft (1,250-m)*

Radius of the PHERMEX Firing Site – Continued

Site Number[a]	**Site Type**	**Tech Area**	**General Location**	**National Register Eligibility**
LA 4698	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 4698	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 4699	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 4699	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657	Single roomblock pueblo	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 12657	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 13286	Cairn	15	Threemile Mesa	Not eligible (excavated)
LA 21322	Artifact scatter	36	Potrillo Canyon	Potentially eligible _ Crit. D
LA 89736	Artifact scatter	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89738	Artifact scatter	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89739	Water control feature	49	Frijoles Mesa	Not Eligible

LA 89740	Artifact scatter	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89741	Artifact scatter	49	Frijoles Canyon	Potentially eligible _ Crit. D
LA 89742	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 89744	Rubble Mound	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89745	Rubble Mound	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89746	Rubble Mound	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 89756	One- to three-room structure	49	Frijoles Mesa	Eligible _ Criterion D
LA 89757	Artifact scatter	49	Frijoles Mesa	Potentially eligible _ Crit. D
LA 108742	Cavate	15	Water Canyon	Eligible _ Criterion D

[a] LA - New Mexico Laboratory of Anthropology number; Q - LANL Field Number.

Source: Larson 1995

The second survey was conducted in the summer of 1992 as part of a larger survey conducted for the LANL Environmental Restoration (ER) Program site characterizations of TA -15, -16, and -49. The larger ER survey included areas within the 2,500-ft (750-m) hazard radius around the DARHT firing point. A total of 35 archeological sites have been located as a result of these two surveys. Thirty-two of these are eligible for nomination to the NRHP under criterion D (research potential), and one archeological site (Nake'muu) is also eligible under criterion C (excellent state of preservation) (tables 4-14 and 4-15). The remaining resources were recommended as not eligible for nomination to the NRHP because their research potential has been exhausted through data retrieval. Evaluations of potential effect for individual cultural resources and recommendations/concurrences for "determinations of no effect" and/or "determinations of no adverse effect" will be presented in chapter 5. The third survey was conducted on July 6, 1995, in the proposed vessel cleanout facility areas (figure 3-6) and no archeological sites were found.

A fourth survey is under way to identify cultural resources in the remaining unsurveyed areas within the 2,500-ft (750-m) radius. Additional archeological sites recorded in this survey are anticipated to be similar to those previously recorded as eligible for the National Register under criterion D. The evaluation of cultural resources identified in this survey will be coordinated with the NM SHPO for concurrence of eligibility determinations and potential effects.

The Nake'muu site, LA 12655, is an enclosed plaza pueblo located 1,100 ft (335 m) to the southwest from the DARHT Facility. Unique architectural features are still visible, making it eligible for NRHP nomination under both criteria D and C. The NM SHPO concurred in this determination in correspondence to the DOE dated February 21, 1989 (SHPO 1989). This site is an irregular-shaped pueblo of possibly 50 rooms. The site has been described as the best-preserved ruin in this region.

This site is unusual in that it is located at a high elevation, 7,175 ft (2,187 m), and is built on bedrock somewhat distant from agricultural resources as compared to other similar sites in the LANL area. Nake'muu is positioned on a high point of rocks above the junction of Cañon de Valle and Water Canyon, which at first appears to be for defensive purposes, yet the mesita above the ruin to the west allows easy access to it, and there is no sign of any defensive work west of the site (Larson 1988).

Assigning occupational dates to the Nake'muu site is difficult. Based on masonry style, which is notable for the large size of tuff masonry blocks and excellent workmanship, the ruin resembles other classic period sites on the Pajarito Plateau. The roomblock arrangement around a central plaza is also more typical of Classic Period ruins than of Early Coalition ruins. There is very little pottery on the surface of the site. It is possible that trash was thrown over the steep canyon walls, leaving very little in the way of datable material immediately near the site (Larson 1988). The fourth survey will investigate the area in Water Canyon and Cañon de Valle below Nake'muu and will resurvey the mesa where Nake'muu is located in an effort to find additional cultural material that can be used to establish the dates of occupation for the pueblo.

LA 71408 and LA 71409 are located outside the construction zone proper, but early plans for the facility placed the access road adjacent to the sites. The access road was re-sited in 1989 to avoid contact with the site boundaries, and the two sites were fenced to protect them from any accidental disturbance during construction work. The NM SHPO, in correspondence to the DOE dated February 21, 1989, stated satisfaction "... that adequate consideration has been given to measures to avoid adverse effects to the recorded sites." (Merlan 1989)

LA 71410 is located in the construction zone under the earth berm to the north of the firing point. Realignment of the berm in order to avoid disturbing this archeological site would have exposed Nake'muu to more potential debris from blasting (see chapter 5 for a full discussion). At the request of the Pueblo San Ildefonso (Torres 1994) and with the concurrence of the NM SHPO (Merlan 1994), LA 71410 was thoroughly recorded and then capped with clean earth on April 26, 1994, and buried several days later under the earth berm.

4.6.2. Historical Resources

There are two Manhattan Project/Early Cold War buildings in the 2,500-ft (750-m) radius which are potentially eligible for inclusion on the NRHP under criterion

A: Control Chamber B (TA-15-9) and Firing Pit H/Camera Chamber (TA-15-92). The PHERMEX Facility itself, although not 50 years old, is also potentially eligible for NRHP inclusion because of its association with the Cold War. A thematic NRHP nomination of LANL structures associated with the Manhattan Project and the Cold War Era is ongoing.

4.6.3. Native American Cultural Resources

Cultural resources are of special importance to Native Americans. Those resources, located on LANL, may consist of prehistoric sites with ceremonial features such as kivas, village shrines, petroglyphs, or burials, or may consist of traditional cultural properties with no observable man-made features. Figure 4-19 shows the locations of Native American reservations in the immediate vicinity of LANL. Consultations with local Native Americans to identify any such cultural resources have been conducted in the past and are currently ongoing. These consultations will continue, as appropriate, throughout the life of activities at DARHT and PHERMEX.

In the spring of 1993, consultations with San Ildefonso Pueblo were renewed. On December 6, 1993, a tribal representative visited LA 71410, LA 714108, and LA 71409 to discuss mitigation alternatives for LA 71410. A copy of the 1988 cultural resource survey report was given to this representative to present to the tribal council. On January 27, 1994, the DOE sent a copy of the cultural resource survey report and all relevant SHPO consultation to the governor of San Ildefonso Pueblo and specifically asked for recommendations for mitigation of LA 71410. Council representatives visited LA 71408, LA 71409, and LA 71410 on February 7, 1994. Another copy of the original 1988 cultural resource survey report was sent on February 11, 1994, to the governor of San Ildefonso Pueblo, the Native American group with the most direct claim to descent from the prehistoric inhabitants of what is now TA-15. No response was received. Representatives from San Ildefonso Pueblo, Jemez Pueblo, and Cochiti Pueblo were given a briefing on the DARHT project on December 2, 1994, and visited Nake'muu as well as LA 71408 and LA 71409 (LA 71410 had already been buried beneath the earth berm). Native American input on possible effects to unidentified traditional cultural properties was requested during this visit. During May, June, and July of 1995, DOE consulted with representatives of the four Accord Tribal governments (San Ildefonso, Santa Clara, Jemez, and Cochiti) on the content of the draft EIS, specifically in regard to the provisions of AIRFA. Numerous comments on the draft were recorded from the Tribal governments. In particular, concerns regarding the identification of archeological and cultural resources in the draft EIS were resolved through changes in this final EIS. DOE will continue to consult with the four Accord tribes on a government-to-government basis to ensure protection of traditional cultural properties.

4.6.4 Paleontological Resources

No paleontological sites are reported on Threemile Mesa, and the near-surface stratigraphy is not conducive to preserving plant and animal remains. These near-surface materials are volcanic ash and pumice that may have been hot when deposited. Occasionally, some charcoal is found at the base of an ashfall. The deposits date mostly from about one million years ago and have a total thickness of about 750 ft (229 m).

4.7 SOCIOECONOMIC ENVIRONMENT

Any major changes in activities undertaken at LANL have the most immediate socioeconomic effects on LANL employees and their respective communities. These communities are located throughout Los Alamos, Santa Fe, and Rio Arriba counties in north-central New Mexico (see figure 4-1). The LANL Office of Community Relations estimates that 91.6 percent of the LANL employees reside in this tri-county region (LANL 1994c). Furthermore, the U.S. census estimated that 95.6 percent of the Los Alamos County workforce resided in this tri-county region in 1990 (Bureau of the Census 1994). Based on both considerations, any major changes in activities at the LANL site would potentially have their most immediate socioeconomic effects on residents in this tri-county region. A description of this affected environment is provided in the following sections based on a summary of its demographic, economic, and social characteristics.

4.7.1 Demographic Characteristics

The predominant population in the region-of-interest is white caucasian with 50.1 percent having Hispanic ethnic background (see table 4-16). Native Americans residing in Los Alamos, Rio Arriba, and Santa Fe counties account for 5 percent of the general population. Extending this region to include Sandoval county increases the percentage of Native Americans to just under 10 percent of the greater general population. The Pueblos of San Ildefonso, Cochiti, Jemez, and Santa Clara are important centers of these Native American populations.

Table 4-16.–*Demographic Profile of the Population*

in the Tri-County Region-of-interest

Parameters	**Los Alamos**	**Santa Fe**	**Rio Arriba**	**Regional Total**
Total Population (1990)	18,115	98,928	34,365	151,408
Households (1990)	7,213	37,840	11,461	56,514
Persons per Household (1990)	2.50	2.54	2.97	2.67

Race (1990) _ Percent of Total Population White Black Native American Asian Other	94 1 1 2 2	80 1 3 1 15	70 1 15 1 13	79 1 5 1 14
Ethnicity (1990) Hispanic Percent of total population	2,008 11.1	48,939 49.5	24,955 72.6	75,902 50.13
Ages (1990) Percent under 18 Percent 65 and over	26.0 9.2	26.0 10.1	32.4 9.7	27.6 9.90
Education (1990) _ Persons 25 years and older Percent High School Graduate or Higher Percent Bachelor's Degree or Higher	94.7 53.4	82.6 32.3	65.9 10.3	80.7 30.5
Income (1989) Median Household Income ($) Per Capita Income ($) Percent of Persons Below Poverty Line	54,801 22,900 2.4	29,403 15,327 13.0	18,373 7,859 27.5	30,408 14,538 15.0
Source: Bureau of the Census 1994				

Some 62.5 percent of the total population in the tri-county region is between the ages of 18 and 65. Approximately 80.7 percent of this population has completed high school, and 30.5 percent has attained a baccalaureate degree or higher. A significant difference exists in educational attainment levels within the region, as evidenced by Los Alamos and Rio Arriba counties.

The median and per capita income levels of the population in the region were $30,408 and $14,538 in 1990. While both of these income levels are close to their respective state averages of $27,623 and $14,254, there are very significant differences in income levels among the various counties. At the time of the 1990 Census, it was estimated that 15 percent of the tri-county residents fell below official poverty thresholds. Poverty thresholds vary by size of family and number of related children under 18 years (Bureau of the Census 1990). For example, in 1989, $14,990 was the official poverty threshold for a family of five persons.

4.7.2 Economic Base

This section summarizes the economic base of the tri-county region. An overview of the economic base is shown in figure 4-20 in terms of income and expenditure flows between LANL, households, businesses, and governments.

LANL is the largest employer in the tri-county region. Its *direct* economic impact on the tri-county region is significant even after deducting procurement and wage/ salary payments made outside the tri-county region – denoted as leakage(s). For FY 1993, the LANL payroll for the tri-county region was $450 million for 7,256 full-time personnel (LANL 1994c). During the same year, LANL spent approximately $220 million in procurement in the tri-county region (LANL 1994c). Therefore $670 million ($450 + $220) in direct income was available for households and businesses to make additional purchases of products and services within or outside the tri-county region. A description of employment and wage earnings by economic sector within the tri-county region is provided in table 4-17.

Table 4-17.–*1993 Employment and Wage Profile in the Tri-County Region-of-interest*

Economic Sectors	**Santa Fe**				**Los Alamos**		**Rio Arriba** **Total**	
	Employment	**Total Wages (in millions)**	**Employment**	**Total Wages (in millions)**	**Employment**	**Total Wages (in millions)**	**Employment**	**Total Wages (in millions)**
Agriculture	364	$ 6.08	28	$ 0.42	59	$ 0.55	451	$ 7.05
Construction and Mining	3,120	65.57	170	2.90	382	6.87	3,672	75.34
Manufacturing	2,016	48.24	63	1.27	315	5.01	2,394	54.52
Transportation and Utilities	1,056	26.18	66	1.29	268	8.37	1,390	35.84
Trade	12,725	190.80	1,236	19.40	1,480	18.50	15,441	228.70
F.I.R.E.	2,311	69.21	341	8.38	216	3.96	2,868	81.55
Services	13,520	281.33	4,424	133.38	2,331	35.76	20,275	450.47
Government Federal State LANL Local	1,510 9,104 NA 3,613	51.54 225.84 NA 75.27	190 157 7,256 1,081	7.38 1.88 450.00 29.55	455 493 NA 1,426	11.96 9.87 NA 25.89	2,155 9,754 7,256 6,120	70.88 237.59 450.00 130.71
Totals	49,339	$1,040.06	15,012	$ 655.85	7,425	$ 126.74	71,776	$1,822.71
Percent Unemployment	4.9		2.1		11.8		5.5	

Sources: The covered employment and wage figures presented here are based on counts of employees covered under the New Mexico Unemployment Compensation Law, consistent with the ES-202 series reported to the U.S. Bureau of Labor and Statistics (New Mexico Department of Labor 1994). The reported unemployment figures are published by the U.S. Department of Census (Bureau of the Census 1994). Note that the employment and wage data are based on survey data by place of residence while the unemployment data is based on survey information reported by place of work.

The average annual employment in the tri-county region during CY 1993 covered 71,776 workers who earned a total of $1.82 billion in wages (New Mexico State Department of Labor 1994). At the sectoral level, employment and wages were highest in the service, State or Federal Governments (including LANL), and gross trade sectors of the regional economy. Together these sectors accounted for 76 percent of the employment and 79 percent of the wages in the regional economy. Meanwhile, the unemployment rate for the tri-county region as a whole was 5.5 percent.

The sectoral patterns of employment and wages are significantly different from county to county. Employment and wages during 1993 were highest in Santa Fe, followed by Los Alamos and Rio Arriba counties. Meanwhile, the unemployment rate in Rio Arriba County during 1993 was nearly three times that of Santa Fe County and more than five times that of Los Alamos County.

The flow of income and expenditures from LANL also generates direct State and local tax revenue. In FY 1993, LANL paid $41 million in payroll taxes and $6 million in additional tax payments within the tri-county region. Consequently, significant changes in the level of LANL activities could potentially affect government tax revenues, payments, and services in the tri-county region.

The operating costs associated with PHERMEX for FY 1994 were about $3.5 million. The allocation for FY 1995 is $4.2 million. These annual costs are considered reasonably typical. This funding provides support for operating personnel, physics support, clearance staff, firing crew, fire department, LANL's facility space tax, contractor support, facility scheduling, and a safety and environmental compliance program. Contractor support includes janitorial services, routine maintenance, minor upgrades, and firing point cleanup. DOE has invested about $1 million per year in maintenance, minor upgrades, and replacement parts for PHERMEX. This would be expected to increase each year as long as the facility is operated. The current amount is less than 0.2 percent of LANL's total annual expenditures.

4.7.3 Community Infrastructure and Social Services

This section describes community infrastructure and social services within the tri-county region. Table 4-18 lists the status of occupied and vacant housing units in the tri-county region and the number of new private housing units authorized by building permits for the period 1990-1992 (Bureau of the Census 1994).

Table 4-18.–*Status of Housing Infrastructure by County in the Region-of-interest*

Criteria	Los Alamos	Santa Fe	Rio Arriba	Total
Total housing units (1990)	7,565	41,464	14,357	63,386
Occupied Units	7,213	37,840	11,461	56,514
Owner occupied (1990)	5,367	25,621	9,218	40,206
Percent owner occupied (1990)	74.4	67.7	80.4	71
Median value (1990)	$126,100	$103,300	$58,800	NA
Renter occupied (1990)	1,846	12,219	2,243	16,308
Median gross rent (1990)	$467	$489	$285	NA
Vacant units (1990)	352	3,624	2,896	6,872
Vacancy rate	4.7	8.7	20.2	10.8
New housing building permits (1990-1992) Percent of 1990 housing stock	119 1.6	1188 2.9	28 0.2	1,335 NA
Source: Bureau of the Census 1994				

In 1990, the tri-county region contained a total of 63,386 housing units, of which 40,206 were owner-occupied and 16,308 were renter-occupied. The median value of owner-occupied units was $126,100 in Los Alamos County, which is higher than both other counties in the region. The median gross rent was lowest in Rio Arriba County and about the same in both Los Alamos and Santa Fe Counties. Coincidentally, the vacancy rate was lowest in Los Alamos County and highest in Rio Arriba County. Santa Fe County appeared to be the fastest growing county in the region, as measured by the number of new housing permits issued during the period 1990 to 1992 relative to the existing housing stock in 1990.

Community infrastructure is further defined by education and health-care infrastructure in the tri-county region. Each county government provides its own public education and health-care services. Table 4-19 lists the status of these two elements by county.

Table 4-19.–*Education and Health Care Infrastructure by County in the Region-of-interest*

Criteria	Los Alamos	Santa Fe	Rio Arriba	Total

Total School Enrollment[a] (1990) College (1990)	5,020	25,743	9,651	40,414
Elementary or high school (1990)	1,288	6,727	1,808	9,823
Percent public (1990)	3,236	17,363	7,316	27,915
	96.2	90.6	91.7	
Number of Schools[a] (1994)	12	67	23	102
Public (1994)	7	25	14	46
Private (1994)	5	42	9	56
Community Hospitals (1990)	1	1	1	3
Number of beds (1990)	53	226	54	333
Number of physicians (1990)	42	228	26	296

[a] The figures presented are for county school districts. Only in the case of Los Alamos County are they comparable to the county-wide figures.

Source: The figures on pupil enrollment and health care services are from the U.S. Census County Data Book, 1994 (Bureau of the Census 1994). The figures on number and composition of schools in the county districts are from the New Mexico State Department of Education (1994).

In 1990, student enrollment totaled 40,414 in selected school districts throughout Los Alamos, Santa Fe, and Rio Arriba counties (Bureau of the Census 1994). These students attended 102 schools within the tri-county region (New Mexico State Department of Education 1994). Similarly, health care services and facilities are heavily concentrated in Santa Fe County relative to the other two counties in the region.

4.7.4 Environmental Justice

Under Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, Federal agencies are responsible for identifying and addressing the possibility of disproportionately high and adverse health and environmental impacts of programs and activities on minority and low-income populations. Hereafter, minority populations refer to all people of color, exclusive of white non-Hispanics. Low-income populations refer to household incomes below $15,000 per year. Figures 4-21 through 4-24 illustrate the percentages of minority populations and low-income households within a 10-, 30-, and 50-mi (16-, 48-, and 80-km) radius of the site. This area spans portions of Los Alamos, Rio Arriba, Santa Fe, and Sandoval counties.

Figure 4-21 also illustrates that a relatively small proportion of Hispanics or Native Americans live within a 10-mi (16-km) radius. A much larger concentration of minority populations resides between 10, 30, and 50 mi (16, 48, and 80 km) from the site (figures 4-21 and 4-22). Table 4-20 describes the geographic distribution of these minority populations in relation to distance from the site. Of a total population of 18,115 persons living within a 10-mi (16-km) radius of the proposed site, minorities account for 14 percent of the population. In contrast, minorities account for 65 percent of the general population living 10 to 30 mi (16 to 48 km) from the site. The overall percentage of minorities within 30 and 50 mi (48 and 80 km) from the site exceeds the white non-Hispanic segment of the population.

Table 4-21 and figures 4-23 and 4-24 provide similar descriptions of the concentration of low-income households within 10, 30, and 50 mi (16, 48, and 80 km) of the site. Of a total of 55,411 households in the 30-mi (48-km) radius, 13,536 (24 percent) had incomes below $15,000. However, the number of these relatively low-income households increases sharply beyond the 10-mi (16-km) radius. Only 581 (2 percent) households had incomes below $15,000 within 10 mi (16 km) from the site while 12,995 (23 percent) households had equally low incomes between 10 and 30 mi (16 and 48 km) from the site. Within a 50-mi (80-km) radius of the site, 18,519 (24 percent) households had annual incomes of $15,000 or less in 1990.

Table 4-20.–*Distribution of Population by Ethnicity*

within a 50-mi (80-km) Radius of the DARHT Site

Population Group	Population within a 10-mi (16-km) Radius of the Site	Population within a 10- to 30-mi (16- to 48-km) Radius of the Site	Population within a 30-mi (48-km) Radius of the Site	Population within a 50-mi (80-km) Radius of the Site

Total	18,115	133,028	151,143	214,727
Total Nonminority	15,556	47,059	62,615	99,257
Total MinorityHispanic OriginNative American Other Minority	2,559	85,969	88,528	115,470
	1,933	72,470	74,403	92,954
	154	12,368	12,522	19,421
	472	1,131	1,603	3,095
Percent Minority	14	65	59	54
Percent Nonminority	86	35	41	46
Source: Bureau of the Census 1994				

Table 4-21.–*Distribution of Population by Income*

within a 50-mi (80-km) Radius of the DARHT Site

Income Class	**No. of Households within a 10-mi (16-km) Radius of the Site**	**No. of Households within a 10- to 30-mi (16- to 48-km) Radius of the Site**	**No. of Households within a 30-mi (48-km) Radius of the Site**	**No. of Households within a 50-mi (80-km) Radius of the Site**
Total Households	7,211	48,200	55,411	77,448
< $15,000	581	12,955	13,536	18,519
$15,000 to $24,999	597	9,582	10,179	14,531
$25,000 to $34,999	704	7,694	8,398	12,983
$35,000 to $49,999	1,281	7,943	9,224	13,600
$50,000 to $74,999	2,092	6,389	8,481	11,283
$75,000 to $99,999	1,219	1,792	3,011	3,572
$100,000 or more	737	1,845	2,582	2,960
Source: Bureau of the Census 1994.				

4.8 RADIOLOGICAL AND CHEMICAL ENVIRONMENT

This section describes the radiological and chemical environments at LANL and Area III.

4.8.1 Regional Environment

The regional study area for the radiological and chemical environment includes LANL and a number of sampling stations up to approximately 20 mi (30 km) from LANL. LANL routinely monitors for radioactive and nonradioactive pollutants on LANL sites and in the surrounding region.

4.8.1.1 Radiological

Many of the activities that take place at LANL involve handling radioactive materials and operating radiation-producing equipment. Radiological doses are calculated to estimate the potential health impacts of any releases of radioactivity to the public. Standards exist which limit the maximum effective dose equivalent (EDE) to the public. The DOE's public dose limit (PDL) is 100 mrem/yr EDE received from all pathways, and EPA restricts the EDE received by air to 10 mrem/yr. These values are in addition to those from normal background, consumer products, and medical sources, which total about 300 to 350 mrem/yr. Both standards apply to locations of maximum probable exposure to an individual in an offsite, uncontrolled area.

EPA-approved methods were used to calculate radiation doses to the public from LANL emissions and demonstrate compliance with National Emissions Standards for Hazardous Air Pollutants (NESHAP) requirements [40 CFR 61]. EPA-approved methods do not allow LANL to take into account shielding or occupancy standards. In 1992, that EDE was 7.9 mrem, which is in compliance with EPA standards of 10 mrem/yr from the air pathway (DOE 1993b). However, in 1990, the Los Alamos Meson Physics Facility (LAMPF) at LANL exceeded the EPA annual standard for radionuclide emissions and was cited. The maximum probability of a latent cancer fatality from such a dose would be 4 x 10^{-6}. The estimated maximum EDE resulting from LANL operations in 1993 was 5.6 mrem (DOE 1994). Thus, 1992 is considered a representative year for recent LANL operations. The 1993 EDE shows a reduction which may be indicative of DOE's change in mission which halted production of weapons.

DOE directs use of site-specific input data, where available, and realistic dose calculation estimates for annual site environmental reporting. In 1992, the estimated maximum EDE resulting from LANL operations was 6.1 mrem, taking into account shielding by buildings (30 percent reduction) and occupancy (100 percent for residences, 25 percent for businesses). The maximum probability of a latent cancer fatality from such a dose would be 3 x 10^{-6}. This dose is 6 percent of DOE's 100 mrem/yr PDL for all pathways (LANL 1994a). Approximately 95 percent of the dose (DOE 1993b) was from external radiation from short-lived, airborne emissions from a linear particle accelerator at LAMPF.

In 1992, the annual collective dose to the population from operations at LANL was 1.4 person-rem. No latent cancer fatalities (7 x 10^{-4} LCFs) would be expected among the members of the population. Table 4-22 presents a comparison of the 1992 annual EDEs with DOE dose limits and background values. The estimated maximum EDE from LANL operations is less than 2 percent of the 346 mrem received from background radiation and other sources in Los Alamos during 1992 (figure 4-25).

Table 4-22.–*Comparison of 1992 Annual Effective Dose Equivalents Near LANL*

Operations with Dose Limits and Background

Criteria	**Maximum Individual Dose**[a]	**Average Dose to Nearby Residents**		**Collective Dose**[b]
		Los Alamos	**White Rock**	
Dose Attributable to LANL	6.1 mrem	0.12 mrem	0.11 mrem	1.4 person-rem
Location	Residence north of TA-53	–	–	Area within 50 mi (80 km) of LANL
Natural Background	340 mrem	340 mrem	327 mrem	72,000 person-rem
DOE Public Dose Limit	100 mrem	–	–	–
Percentage of Public Dose Limit	6.1	0.12	0.11	–
Percentage of Background	2	0.04	0.03	0.002

[a] The maximum individual dose to any individual at or outside LANL at sites where the highest dose rate occurs (the location of the maximum exposed individual [MEI]). Calculations take into account occupancy (the fraction of time a person is actually at that location) and shielding by buildings, as specified by the DOE 5400.5 for calculating public dose limits (PDL).

[b] Collective dose to population within 50 mi (80 km) of LANL.

[c] This value includes a radon contribution on the order of 200 mrem, but such a value can vary considerably.

Source: LANL 1994a

LANL measures environmental external penetrating radiation (including x-rays, gamma rays, and charged-particle contributions from cosmic, terrestrial, and LANL sources) with thermoluminescent dosimeters (TLDs) at 166 locations within three independent networks, including 4 regional and 23 perimeter offsite locations (Jacobson 1995 and LANL 1994a). The locations of these networks are onsite at LANL and offsite (perimeter and regional) at the LANL boundary north of the LAMPF, and at low-level radioactive waste management areas as shown in figure 4-26 (LANL 1994a). The natural terrestrial components are primarily from the decay of potassium-40 and the radionuclides in the decay chains of thorium and uranium. In 1992, the annual average TLD measurement taken from offsite regional stations was 102 mrem. This offsite average was generally the same as the average TLD measurement taken from perimeter stations and onsite stations which averaged 119 mrem and 128 mrem, respectively (LANL 1994a). The average dose at the Frijoles Mesa station, which is the closest station to PHERMEX, was 119 mrem.

Samples of foods (produce, fish, and honey) are collected and analyzed for radioactivity in an effort to monitor potential contamination in the food chain resulting from LANL operations (figure 4-27). The two main objectives of the foodstuffs monitoring program are to:

- Compare levels of radionuclides in foodstuffs collected from offsite regional (background) areas to levels in foods collected from LANL and perimeter areas
- Calculate any additional radiation dose to LANL and area residents (Los Alamos and White Rock) based on the data collected.

The data also are compared to radiation protection standards recommended by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements (LANL 1994a).

In 1992, surface- and bottom-feeding fish were collected upstream of LANL at Abiqui, Heron and/or El Vado reservoirs, and downstream of LANL at Cochiti reservoir to determine tissue radiation levels. The mean total uranium level in the surface-feeding fish was 1.2±1.5 (2–) ng/dry g for the upstream reservoirs and 5.4 ±18.6 (2–) ng/dry g for the downstream reservoir. In the bottom-feeding fish, the mean total uranium level was 5.2±8.0 (2–) ng/dry g for the upstream reservoirs and 8.8±6.4 (2–) ng/dry g for the downstream reservoir (Fresquez et al. 1994a).

Elk *(Cervus elaphus)* spend the winter in areas at LANL that may contain radioactivity above natural and/or worldwide fallout levels. A LANL study found no significant differences in radionuclide contents in any tissue samples collected from elk on LANL lands compared with elk collected from offsite locations (Fresquez et al. 1994b).

4.8.1.2 Chemical

The regional chemical environment is described by background chemical data for soils and the LANL activities that may produce hazardous/toxic wastes. Some activities at LANL use chemicals that may present a significant risk to humans and the environment.

Recent background chemical data for soils collected at Los Alamos are shown in table 4-23. These data were collected from soils, which may have application for fill or reworked unconsolidated material found at the townsites and other disturbed areas of LANL. Table 4-23 contains chemical data for all soils and fracture fill material and chemical data from the A horizons, the uppermost soils found on the Pajarito Plateau at LANL.

Table 4-23.–*Background Concentrations*

of Selected Elements in Soils at LANL

Element	**All Soils and Fracture Fill Materials (ppm)[a] Mean**	**Horizon A[b] Concentration (ppm)[a]**
Be	1.23 2.37[c]	0.71
Cu	6.6	6.5
Pb	16.7 28.36[c]	15.8
U	0.94	0.9

[a] Using SW846 _ An EPA toxicity characteristic leaching procedure test method.

[b] Horizon A is the uppermost soil horizon characterized during background investigation.

[c] Hydrofluoric acid used in sample dissolution.

Source: Longmire 1994

4.8.2 Local Environment

This section describes the local radiological and chemical environment.

4.8.2.1 Radiological

In 1992, PHERMEX operations contributed less than 1 percent of the total dose from LANL operations to the maximally exposed members of the public from LANL operations. The annual collective dose to the population from operations at PHERMEX was approximately 0.1 person-rem. No latent cancer fatalities (5×10^{-5} LCFs) would be expected among the members of the population.

PHERMEX is an insignificant contributor to environmental levels of tritium. Honey samples are periodically collected and analyzed for radioactivity in an effort to monitor potential contamination in the food chain resulting from TA-15 operations. Tritium levels in honey collected from TA-15 from 1979 to 1993 ranged from 0.5 to 26.0 (± 6.0) pCi/mL (Fresquez et al. 1995).

The soil around PHERMEX is contaminated with materials that were part of the experiments that used high explosives. DOE has conducted studies, including aerial surveys using helicopters and soil-sampling surveys, that indicate that elevated levels of depleted uranium are found on the firing point (Fresquez and Mullen, 1995). A detailed discussion of these studies can be found in section 4.3.3.

4.8.2.2 Chemical

Materials released during open-air tests at the PHERMEX Facility have resulted in low but observable quantities of lead, beryllium, and mercury on or near the firing site. Soil sample surveys conducted in 1993 indicate that no lead, beryllium, or mercury are observed beyond 200 ft (60 m) of the firing point (Fresquez 1994). This survey is described in detail in appendix D.

4.9 HISTORY OF ACCIDENTS AT PHERMEX

Two environmental occurrences or spills have been reported since 1991, the first year that occurrence reporting database information was available. In 1992, there was a transitory discharge to the PHERMEX outfall of 0.49 ppm cyanide, in excess of the NPDES permit level of 0.2 ppm cyanide. This occurrence was traced to a single discharge of film processing chemicals, discharged when film bath chemicals were exchanged. In 1995, seven Los Alamos firemen were exposed to smoke and potential detonation by-products when a firing-site debris pile near PHERMEX caught on fire as a result of a firing site detonation. All firemen were checked for exposure to depleted uranium and potential hazardous substances in the pile; all results were negative.

During the most recent ten-year period (1985 to 1994), the statistics for PHERMEX indicate that there was a total of 19 lost work days. None of these injuries – a contusion, a concussion, and numerous back strains caused by common workplace accidents – were considered serious. There have been no accidents associated with the detonation of explosives.

The PHERMEX accidents, environmental occurrences, and spills reported above have been minor and had negligible consequences to workers, the environment, and the public. A summary of accidents which may occur at the PHERMEX facility is shown in table 4-24.

Table 4-24.–*Hazards at Hydrodynamic Test Facilities*

Hazard	**Location**	**Comments**
Ionizing Radiation Exposure Personnel inside exclusion areas during beam pulsing	Accelerator bay, optical room, and firing pad	Beam pulse with up to 2,000 rad x-rays at one meter on axis
Electrical Personnel in contact with the power supplies or capacitor banks Personnel in contact with laser power supplies	Accelerator room and power supply rooms Accelerator bay and laser rooms	Power supplies with voltages up to 4MV, high energy-densities in capacitor banks Power supplies with voltages up to 35kV
High Explosive Blast Personnel in the hazard radius exclusion area during testing Accidental detonation of explosive	Firing site exclusion area Firing pad	Area radius is 2,500 ft (750 m), personnel OK in R-184 and R-310
NonIonizing Radiation Operating personnel intersect laser beam	Laser room	

Mechanical Crane maintenance and operation	Accelerator bay, power supply rooms, equipment and assembly rooms	Potential for misuse
Occupational Slippery surfaces due to fluids	Accelerator bay, power supply rooms, equipment room	Leaks or spills from tanks, valves, or connections
Gases Helium Sulfur hexafluoride	Firing pad, diagnostics area Accelerator hall, power supply room	Used to drive high-speed cameras Leaks from spark gaps
Chemicals/Solvents Acetone, ethanol	Accelerator bay and assembly room	Inhalation hazards
Fire Insulating oil Wicking of insulating oil Acetone, ethanol Electrical control cables, high voltage cables, and components Fire from parked vehicles Natural gas Trash and rag accumulation Forest or brush fire	Accelerator bay and power supply rooms Power supply rooms Accelerator bay and assembly room Accelerator bay, power supply rooms, equipment room Parking and delivery area Equipment room Accelerator bay, power supply rooms, equipment room External to building	EXXON 1830 type insulating oil has a flash point above 330ºF (149ºC) Oil soaked rags Volatile cleaning solvents Faulty items may cause sparks to ignite oil, etc. Gasoline in fuel tanks Hot water boiler Ignition source for oil May arise from explosives or natural causes
Natural Phenomena High Winds Lightning Earthquake	TA-15 TA-15 TA-15	Damage to utilities Damage to utilities Damage to any of LANL infrastructure, design level is 0.22 G for DARHT, current expectation is 0.5 to 0.6 G for max. earthquake.

LANL has developed and maintains an emergency management system that, through emergency planning, emergency preparedness, and effective response capabilities, is capable of responding to and mitigating the potential consequences of emergencies. The Emergency Management Plan incorporates in one document a description of the entire process designed to plan for, respond to, and mitigate the potential consequences of an emergency (LANL 1994a). PHERMEX has an emergency response plan and procedures to initiate a sitewide response, if necessary, through the sitewide program. The PHERMEX plan requires pre-staging of the LANL fire department for uncontained detonations.

4.10 REFERENCES CITED IN CHAPTER 4

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CHAPTER 5

ENVIRONMENTAL CONSEQUENCES

This chapter describes the potential environmental impacts associated with the various alternatives:

_ No Action Alternative (status quo)

_ DARHT Baseline Alternative [complete and operate the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility]

_ Upgrade Alternative [upgrade the Pulsed High Energy Radiation Machine Emitting X-Rays (PHERMEX) Facility to DARHT capabilities]

_ Enhanced Containment Alternative (operate the DARHT Facility with containment options)

_ Vessel Containment Option

_ Building Containment Option

_ Phased Containment Option (preferred alternative)

_ Plutonium Exclusion Alternative (no experiments with plutonium at the DARHT Facility)

_ Single Axis Alternative (operate only one axis of the DARHT Facility).

This chapter describes the potential environmental impacts, or changes, which would be expected to occur over the next 30 years if any of the alternatives analyzed in this EIS were implemented. Environmental impacts are described in terms of the various aspects of the affected environment which would be expected to change over time. The environmental impacts expected from the No Action Alternative are those associated with maintaining the status quo. The impacts from the No Action Alternative are discussed first to provide a basis of comparison for the impacts expected from the other alternatives. The environmental impacts that would be expected if any other alternative were to be implemented are described as a comparison to the impacts of No Action _ whether the impacts would be the same or different. The discussion in this chapter is augmented by the classified supplement for this EIS.

Aspects of the environment which would not be expected to be affected (changed) as a result of implementing any of the six alternatives analyzed are not discussed in this EIS. In most cases, impacts among the six alternatives are similar, and are cross-referenced but not repeated in detail. The analyses in this EIS indicate that there would be very little difference in the environmental impacts among the alternatives analyzed. The major discriminators among alternatives would be: 1) potential impacts from depleted uranium contamination to soils, which would be substantially less under the Enhanced Containment Alternative, and 2) commitments of construction materials, which would be substantially greater under the Upgrade PHERMEX Alternative. A summary table of impacts is provided at the end of chapter 3 (table 3-3). The table provides direct comparisons of expected consequences for each environmental factor across the alternatives.

The evaluation of potential environmental impacts addresses those of the new Phased Containment Option, included under the Enhanced Containment Alternative. Other alternatives and options previously evaluated in the draft EIS encompass and bound potential impacts from the Phased Containment Option. The Phased Containment Option is identical to the Vessel Containment Option for most (20 years) of the 30-year planned operation period for DARHT.

Sums and products of numbers in the chapter may not appear consistent because of rounding. Unless otherwise stated, the word dose refers to the effective dose equivalent.

5.1 NO ACTION ALTERNATIVE

This section presents the expected environmental consequences associated with the No Action Alternative.

5.1.1 Land Resources

5.1.1.1 Land Use

Continued dedication of about 11 ac (4 ha) in Technical Area (TA) 15 of the 28,000-ac (11,300-ha) Los Alamos National Laboratory (LANL) site for use of the PHERMEX Facility and 8 ac (3 ha) previously disturbed for DARHT construction would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns.

5.1.1.2 Visual Resources

The PHERMEX Facility is an unobtrusive facility located in an isolated piñon/ponderosa pine forest area and is not accessible or readily visible from offsite; therefore, its continued use would have no impact on visual resources.

5.1.1.3 Regional Recreation

Although a variety of recreational opportunities are offered in the vicinity of LANL, only those individuals in areas relatively near TA-15 might be negatively impacted on occasion by noise associated with uncontained test firings at the PHERMEX site. Otherwise, no impacts on regional recreation would be expected.

5.1.2 Air Quality and Noise

Impacts on nonradiological air quality and the potential for noise impacts associated with the No Action Alternative of continued operation of PHERMEX are discussed in this section.

5.1.2.1 Air Quality

Air quality impacts in this section are presented for the maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality and Noise.

5.1.2.1.1 Construction

Under the No Action Alternative, construction of the DARHT Facility would not be completed for its intended use. However, the structure would be completed in some fashion for other uses. It was assumed that any alternate construction activities would be less extensive and have no more than one-half of the potential air quality impacts of those for the DARHT Baseline Alternative. Air quality impacts from construction under the DARHT Baseline Alternative are presented in section 5.2.2.1.1. Construction impacts of the alternatives on air quality are compared in table 3-3.

5.1.2.1.2 Operations

Pollutant emissions are primarily from hydrodynamic testing, in particular, the detonation of high-explosive materials and suspension of associated test materials. High explosives would emit NO_2 and particulate matter (all of the aerosolized material is assumed to be respirable, i.e., classed as PM_{10}). The explosives used in testing do not contain sulfur compounds; however, minor amounts of SO_2 would be released from diesel-powered forklifts or other equipment used in setting up the tests. Estimates of air quality impacts from operations are provided in table 5-1. The standards for NO_2 and SO_2 are adjusted for elevation, based on the New Mexico Air Pollution Control Bureau Dispersion Modeling Guidelines. This adjustment provides an extra measure of conservatism.

Table 5-1._*Impacts on Air Quality from Operations under*

the No Action Alternative

Pollutant	Averaging Time	Concentration at Maximally Impacted Point of Unrestricted Public Access (_g/m^3)	Percent of Regulatory Limit[a]
NO_2	Annual 24-h	0.004 2	0.06 1.4
PM_{10}	Annual 24-h	0.01 3.3	0.02 2.2
SO_2	Annual 24-h 3-h	2×10^{-4} 0.006 0.03	0.0005 0.003 0.003

Beryllium	30 days	5×10^{-6}	0.00005
Heavy Metals[b]	30 days	5×10^{-4}	0.005
Lead	Calendar Quarter	2×10^{-5}	0.001

[a] Uses the applicable regulatory limit shown in Table 4.3.

[b] Sum of the air concentration of uranium and lead.

Note: Applies to all alternatives except the Enhanced Containment Alternative.

Includes impacts from hydrodynamic testing and boiler emissions.

NO_2 and PM_{10} are from hydrodynamic testing and boiler emissions.

SO_2 is from boiler emissions.

Beryllium, heavy metals, and lead are from hydrodynamic testing.

The annual usage of depleted uranium, lead, and beryllium are shown in table 3-4 and were assumed to be 1,540 lb (700 kg), 30 lb (15 kg), and 20 lb (10 kg), respectively. Twenty-five percent of this inventory was assumed to be released during the 30-day averaging time for beryllium and heavy metals, and 50 percent was assumed released during the calendar quarter averaging time for lead. Analysis assumptions are shown in appendix C, table C1-8. Concentrations of beryllium and heavy metals are regulated by the New Mexico Ambient Air Quality Standards, and concentrations of lead are regulated under the National Ambient Air Quality Standard. Average concentrations of these metals and the fraction of the applicable standards are shown in table 5-1. The ambient air concentrations for uranium, lead, and beryllium are for the maximally exposed individual (MEI) located 0.9 mi (1.5 km) southwest of the site. Impacts on ambient air from testing operations are considered minor. See table 4-3 for a listing of the nonradiological ambient air quality standards.

Increases in the annual concentrations of NO_2 and PM_{10} over ambient would be small; concentrations of these pollutants would remain well within the applicable standards. Maximum offsite 24-h PM_{10} concentration would be on the order of the average ambient air concentration of PM_{10}, but the combination of the two (PHERMEX-related concentration plus ambient air concentration) would be less than five percent of the most stringent air quality standard.

Although the accelerator is pulsed about 25,000 times per year, the duration of the pulse is about 200 nsec. Hence, the total operating time would be about 5 thousandths of a second per year, suggesting that formation of ozone would be negligible.

Waste wood from the platforms used to support the experiments is taken to TA-36 for disposal in an open burn permitted by the New Mexico Environment Department (NMED). This wood is potentially contaminated with high explosives and/or depleted uranium. Dose dispersion calculations performed in support of the permit application estimated the effective dose equivalent at the nearest resident of 1×10^{-8} rem to 3×10^{-8} rem (DOE 1993). The NMED Air Quality Bureau concluded that there would be no health effects from this source (NMED 1993).

Other radiological impacts on air quality are described in section 5.1.8, Human Health.

5.1.2.2 Noise

Noise predictions were based on measurements made March 11, 1995, during a series of test explosions designed to investigate noise and shock wave behavior. Uncontained hydrodynamic testing, using high explosives similar to those used in the past at PHERMEX [150 lb (70 kg) maximum] would not exceed daytime standards for noise at nearby locations, such as Los Alamos or White Rock (appendix C, Air Quality and Noise). To be within Los Alamos County residential noise guidelines, propagated levels between 65 and 75 dBA are prohibited to exceed a duration of 10 min for a given hour between 7:00 am and 9:00 pm. Operating procedures and safety concerns limit the number of detonations to no more than three in one hour period; hence, it is not possible to exceed this limit. Noise exceeding 75 dBA is not permitted. However, because blast noise is sensitive to meteorological conditions, peak daytime standards of 75 dBA may be exceeded for large tests under unfavorable weather conditions, particularly at the ranger residence at Bandelier National Monument. For other than small tests close to the facility, nighttime standards (53 dBA) probably would be exceeded.

The general good health and abundance of wildlife in the Bandelier National Monument and on the LANL site indicate no impact on populations of wildlife from operations at the site. However, during the previously mentioned tests, browsing mule deer exhibited a startle and flight response on the first test, indicating that wildlife have not become indifferent to firing noise. On the other hand, birds did not appear to be disturbed by the noise.

Worker protection from noise would be provided in the form of ear muffs or ear plugs depending on the expected noise levels associated with PHERMEX activities.

Because of the limited amount of vehicular traffic associated with the operation of PHERMEX, traffic would not be a significant source of additional noise. Vehicular noise is exempted from Los Alamos County noise regulations.

5.1.3 Geology and Soils

Impacts of the No Action Alternative on geology and soils are described in the following subsections.

5.1.3.1 Geology

Continued operation of the PHERMEX facility would incur no new geologic hazards. PHERMEX has more than 30 years of operations history without site stability problems (see section 4.3.4, Site Stability).

5.1.3.2 Seismic

Seismically induced rockfalls could occur at the mesa rims, but the annual probability for earthquakes is low, and the PHERMEX facility has sufficient setback from the mesa rim to be unaffected by these rockfalls during its design life (see section 4.3.4, Site Stability). Vibratory ground motion resulting from the detonation of high explosives is small, in general, being less than the ground motion pulse caused by the air wave from the same detonation.

Although seismic events damaging buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the PHERMEX Facility that would result in any offsite environmental impacts.

5.1.3.3 Soils

Operating PHERMEX for an additional 30 years at a moderately higher level of testing, as compared to that of the last 32 years, would result in soil contamination levels approximately double those observed today at PHERMEX. Under the No Action Alternative, maximum average depleted uranium soil contamination in the vicinity of the firing point is not anticipated to be greater than about 9,000 ppm uranium after 30 more years of operation (see appendix D.6). The present PHERMEX firing site has a soils contamination circle around the firing point of about a 460-ft (140-m) radius. Inside this circle, soils are at or above the background concentration for uranium; outside this circle, soils exhibit background concentrations. Because the variety and magnitude of explosive charges to be used in future tests will resemble those previously tested at PHERMEX, the area around the firing point where soils would exhibit uranium concentrations above background is anticipated to remain approximately the same, i.e., a circle with a 460-ft (140-m) radius. The area of land contaminated above background would be about 15 ac (6 ha). Soils sampling has shown that beryllium and lead contamination falls to background levels much closer to the firing point than uranium contamination. Thus, the soil contamination circle defined for uranium would apply to the other metals of interest. Concentrations of metal contaminants in sediments within drainage channels may approximately double; however, depleted uranium concentrations have been observed to significantly decrease with increasing distance from the firing point. Contaminants within the soil contamination circle would be available for migration in surface runoff to the canyons and deep drainage through the mesa.

5.1.4 Water Resources

Water resources examined for impact in the No Action Alternative are:

_ Surface water and sediment in Potrillo and Water canyons, which discharge into the Rio Grande

_ The main aquifer underlying Threemile Mesa

The water quality of surface water entering the discharge sink in Potrillo Canyon (see appendix E3) is assumed to be an estimate of the quality of water that may ultimately recharge the main aquifer from this area. Stream losses to the bed of Water Canyon are analyzed for their potential to migrate through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and communicate contaminants through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix E2). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that a realistic value of solubility for beryllium in LANL waters was at its drinking water standard of 4 _g/L [40 CFR 141.62]. A realistic value for lead solubility in LANL waters was at its maximum concentration level (MCL) of 50 _g/L [40 CFR 141.11] and approximately a factor of three above its action level of 15 _g/L [40 CFR 141.80]. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, copper, or aluminum. The solubility of uranium in LANL waters appeared to be substantially above its proposed MCL value, and therefore its migration was modeled to estimate impact on the water resource.

5.1.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the No Action Alternative. In this alternative, the transport by surface runoff during the past 32 years for releases of depleted uranium, beryllium, and lead and for releases during the next 30 years from the PHERMEX site was analyzed. Table 5-2 shows the simulated peak concentration of contaminants in the infiltrated water at the discharge sink in Potrillo Canyon and at Water Canyon channels below the source. Details of the analysis and the treatment of runoff, storm water, and cooling water blowdown discharge at the DARHT site are described in appendix E3.

Table 5-2._*Contaminant Concentrations and Time-to-peak for the No Action Alternative*

Contaminant	**Discharge Sink (Potrillo Canyon)**	**Reach 12 (Water Canyon)**	**Reach 13 (Water Canyon)**	**Reach 14 (Water Canyon)**	**Reach 15 (Water Canyon)**	**Rio Grande (in solution)[a]**	**Rio Grande (on sediment)**
Peak Concentration Depleted Uranium Beryllium Lead	(in _g/L) 2 1.1 x 10^{-3} 4.2 x 10^{-3}	(in _g/L) 2.8 x 10^{1} 1.6 x 10^{-3} 3.9 x 10^{-3}	(in _g/L) 6 7.0 x 10^{-4} 2.2 x 10^{-3}	(in _g/L) 1.7 3.0 x 10^{-4} 5.0 x 10^{-4}	(in _g/L) 6.6 x 10^{-1} 1.4 x 10^{-4} 1.8 x 10^{-4}	(in _g/L) **6.8 x 10^{-1}** 1.4 x 10^{-4} 1.9 x 10^{-4}	(in _g/g) 6.8 x 10^{-2} 1.4 x 10^{-5} 3.6 x 10^{-4}
Time, years Depleted Uranium Beryllium Lead	360 4,340 5,000	40 740 1,850	90 4,350 2,570	100 2,570 2,570	100 4,130 4,660	100 4,130 4,660	100 4,130 4,540

[a] Concentration of surface water entering Rio Grande; bold number in this column is basis for water resource number in tables S-1 and 3-3.

Note: Drinking Water Standards:

Uranium, 20 _g/L [56 FR 33050]

Beryllium, 4 _g/L [40 CFR 141.62]

Lead, 15 _g/L [40 CFR 141.80]

Table 5-3._*Peak Input Concentrations under No Action Alternative to Water Canyon Reaches*

and Threemile Mesa Predicted by Surface Runoff-sediment-contaminant Transport Model

Location	**Contaminant**		
	Uranium (_g/L)	**Beryllium (_g/L)**	**Lead (_g/L)**
Drinking Water Standards	20 [56 FR 33050]	4 [40 CFR 141.62]	15 [40 CFR 141.80]
Threemile Mesa	**300,000**	4	**50**

Water Canyon Reach 12	**28**	0.002	0.004
Water Canyon Reach 13	5.9	0.0007	0.002
Water Canyon Reach 14	1.7	0.0003	0.0005
Water Canyon Reach 15	0.7	0.0001	0.0002

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Potrillo and Water Canyons but still remain well below drinking water standards. Drinking water standards for beryllium and lead are 4 and 15 _g/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. While releases of depleted uranium to the discharge sink of Potrillo Canyon are an order-of-magnitude below the proposed MCL (20 _g/L), simulations reveal that concentrations of depleted uranium in surface waters released to Water Canyon immediately below PHERMEX could be slightly above the proposed MCL. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. As shown in table 5-2, the quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the drinking water standard for uranium and several orders-of-magnitude below the drinking water standards for beryllium and lead.

5.1.4.2 Ground Water

Two analyses of depleted uranium, beryllium, and lead migration were conducted. Stream losses into the bed of Water Canyon were analyzed to estimate the migration of contaminants through the vadose zone to the main aquifer. Similarly, infiltration carrying metal in solution into the mesa top at the PHERMEX firing point was analyzed to estimate contaminant migration to the main aquifer.

The peak concentrations of contaminants in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the PHERMEX facility are shown in table 5-3. For those cases where the drinking water standards (shown in bold) are exceeded, analyses are necessary. Only three cases must be modeled: depleted uranium in the uppermost reach of Water Canyon and depleted uranium and lead on the mesa top at the firing point. However, all releases of beryllium and lead were analyzed to better understand the influence of dispersion and sorption on the migration of these and less mobile metals.

Analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.02 _g/L after nearly 20,000 years in soil water being delivered to the main aquifer. Simulation of depleted uranium migration through the mesa to the main aquifer showed a peak concentration of about 150 _g/L after approximately 40,000 years. Water Canyon stream losses yield soil water entering the main aquifer at concentrations well below the proposed MCL for uranium (20 _g/L); however, releases from the firing point on the mesa top yield soil water concentrations approximately eight times the MCL. Simulation of lead migration through the mesa to the main aquifer showed a peak concentration of 26 _g/L in soil water entering the aquifer, nearly double the drinking water standard. Upon entering the main aquifer, the small-scale and low-volume releases from the mesa top would be dispersed in the aquifer and further mixed either with ground water (if it were recovered in the municipal water supply well), or with the waters of the Rio Grande. The average yield of the Pajarito Field wells of 2.7 ft^3/s (7.7 x 10^{-2} m^3/s) is assumed to be representative of a water supply well which could be developed in the vicinity of Threemile Mesa (see appendix E4). The total flow rate of contaminated water from the mesa top firing point would be 1.1 x 10^{-3} ft^3/s (3.2 x 10^{-5} m^3/s). This gives a concentration reduction factor greater than 2,000, more than sufficient to reduce the concentrations of depleted uranium and lead in municipal water supplies to levels well below the drinking water standards. Based on the average annual flow rate of the Rio Grande [~1,500 ft^3/s (~42 m^3/s) at Otowi], the reduction factor would be even greater for ground water release to the Rio Grande.

Both beryllium and lead releases to the stream bed of Water Canyon and the mesa were analyzed for migration to the main aquifer. The quality of surface water infiltrating the stream bed and mesa is initially below drinking water standards for both these metals (i.e., 4 and 15 _g/L respectively); therefore, releases to the main aquifer will be well below the drinking water standards after undergoing dispersion and sorption in the vadose zone. After 100,000 years in the canyon, beryllium release is less than 0.001 _g/L, and the lead release is less than 1.0 x 10^{-5} _g/L. From the mesa, the beryllium release is less than 4 _g/L.

Releases to the ground water pathway from operation under the No Action Alternative would not adversely impact ground water quality.

5.1.5 Biotic Resources

Biotic resources examined for impact in the No Action Alternative include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species.

5.1.5.1 Terrestrial Resources

Both construction and operation impacts were evaluated for terrestrial resources.

5.1.5.1.1 Construction Impacts

Under the No Action Alternative, no further construction-related impacts to terrestrial biological resources would be expected at the PHERMEX or DARHT sites. Impacts for small and large mammals and birds would continue from construction that has already altered approximately 8 ac (3 ha) of piñon-juniper/ ponderosa pine habitat (Risberg 1995). Further losses of habitat and harassment to biota from noise and human activities would not occur. Populations of plants and animals from surrounding areas may reinvade the site and colonize those parts of the site that provide habitat. Habitat destruction has already caused small mammals formerly occurring there to disperse into similar surrounding habitat. Some small losses may have occurred due to increased vulnerability to predation or absence of suitable habitat. It is not known if the increased density of small mammals resulting from this emigration would have any impacts on populations already inhabiting the surrounding area. There likely would have been a population readjustment based on habitat availability.

5.1.5.1.2 Operation Impacts

Test fragments originating from continued use of PHERMEX are highly unlikely to further impact terrestrial biota; however, tests often start grass fires. These fires are quickly controlled by the firefighters who are stationed outside the exclusion fence at the time of the tests. However, some disturbance, and possibly mortality, with respect to some individual plants and animals might occur. Confirmed nesting sites and hunting areas for the red-tailed hawk and the Cooper's hawk have been documented in the PHERMEX site vicinity; other raptors, such as the American kestrel, the flammulated owl, and the great-horned owl use the area. Although not listed as threatened or endangered, these species are protected from collection and maiming under the Migratory Bird Treaty Act (Risberg 1995). No additional impacts to these species are expected under this alternative.

The concentration of depleted uranium and metals in the soil and plants is expected to remain negligible. Consequently, no additional impacts to biotic resources due to biological uptake of these substances is expected to occur under this alternative.

5.1.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.1.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 are expected.

5.1.5.4 Threatened and Endangered Species

It is unlikely that ongoing activities at PHERMEX would change the attractiveness of the area for potential use by threatened or endangered species. The concentration of depleted uranium and metals in prey or food of threatened and endangered species is expected to remain negligible. Ingestion of these substances is not expected to have any consequences to these populations. Ongoing activities should have no adverse impacts to the nesting Mexican spotted owls in the vicinity.

5.1.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the No Action Alternative are described in the following subsections.

5.1.6.1 Archeological Resources

Continuation of normal operations of the PHERMEX Facility would not change any direct or indirect impacts on known archeological sites eligible for the National Register. Debris from 30 years of testing at PHERMEX is observable in the immediate vicinity of archeological sites, especially those sites within the 490-ft (150-m) blast radius. This debris, however, has not changed the research potential of any of the identified archeological sites. As stated, an additional archeological survey is under way in those areas unsurveyed. A minimal number of new archeological sites is expected to be found as a result of this survey, but any new sites would be expected to be similar in nature to those already recorded. Impacts to any new sites are therefore expected to be the same as for the sites previously identified.

Seismic tests conducted on March 11, 1995 (Vibronics 1995) indicated that potential impacts due to the air waves is a greater concern than vibratory ground motion. An explosion of 150 lb of TNT at PHERMEX would give an overpressure of 0.02 psi (12 kg/m^2) at Nake'muu. This overpressure, 0.02 psi (12 kg/m^2), is approximately one-tenth the amount for window breakage and would not affect the standing walls at Nake'muu (DOE 1992, table D.4-4).

5.1.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.1.6.3 Native American Resources

There would be essentially no impacts on Native American cultural resources.

5.1.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, the occurrence of paleontological resources is not anticipated; no potential effects are postulated.

5.1.7 Socioeconomics and Community Services

Environmental impacts on socioeconomics and community services for the No Action Alternative are presented in the following subsections.

5.1.7.1 Demographic Characteristics

The No Action Alternative would not stimulate any change in the existing demographic characteristics of communities within the region-of-interest, as described in section 4.7.1.

5.1.7.2 Economic Activities

The No Action Alternative is not expected to have a significant impact on the level of economic activity in the region-of-interest. Under this alternative, the PHERMEX facility would continue operations while DARHT-related capital funding would be phased out during FY 1995 and FY 1997, as indicated in table 5-4. Under the No Action Alternative, the DARHT Facility, which is currently 34 percent complete and under a stop-work court injunction, would be completed for some other use. This construction will not disturb any additional area, but does represent economic activity under the alternative. The funding of PHERMEX operations would continue to support a variety of personnel, including operations support staff, physics support staff, security clearance staff, and a firing crew. The operations funding also covers the costs of facility scheduling, facility space tax, and safety and environmental compliance.

Table 5-4._*Capital-funded Construction and Operating Costs*

for the No Action Alternative (in millions of 1995 dollars)

Year/Cost	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Capital	6.6	5.8	1.0	0	0	0	0	0	13.4
Operations and Maintenance	4.2	4.1	4.1	4.0	4.0	3.9	3.9	3.9	32.2

The underlying cost data in table 5-4 were provided by LANL (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup, nor do they include any decontamination or decommissioning costs associated with either the proposed DARHT or PHERMEX facilities. The construction and operations costs were adjusted for future price escalation based on the escalation price change index for U.S. Department of Energy (DOE) defense-related construction projects (Pearman 1994; Anderson 1995). A discussion of the analytical model, assumptions, and procedures underlying the economic impact analysis of the various DARHT alternatives relative to the No Action Alternative is provided in appendix G, Socioeconomic Environment.

5.1.7.3 Community Infrastructure and Services

The existing community infrastructure in the region-of-interest under the No Action Alternative would be the same as described in section 4.7.3. No significant change in the existing community infrastructure under the No Action Alternative is expected.

5.1.7.4 Environmental Justice

No significant adverse environmental impacts are identified with the continued operation of the PHERMEX Facility. Specifically, these environmental impacts include offsite air emissions and noise caused by the detonation of high explosives (section 5.1.2) and surface or underground water contamination (section 5.1.4). Also, no significant human health impacts appear to exist from either the release of radioactive or hazardous material or from exposing receptors onsite (workers) or offsite (section 5.1.8). Continued PHERMEX Facility operations would have no known disproportionate adverse health or environmental impact on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.1.8 Human Health

This section presents the impacts to the health of the public and workers from routine operations that would be conducted at the PHERMEX Facility under the No Action Alternative. Impacts may potentially result from routine release and atmospheric transport of radioactive and hazardous material from the facility firing site as a result of planned detonations. Detailed results and methods and assumptions used in calculating potential impacts are described in appendix H, Human Health.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the PHERMEX site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-7} the dose of depleted uranium for chronic releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over-estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used, rather than an explosive atmospheric dispersion model (see appendix H, Human Health).

DOE plans to perform dynamic experiments that would involve high-explosive driven mixtures of plutonium isotopes and alloys, which would be chosen for the purposes of the experiment. DOE has analyzed the impacts of dynamic experiments with plutonium that would be expected to occur under all six alternatives analyzed in the DARHT EIS. All such experiments would be conducted inside double-walled steel containment vessels. All experiments would be arranged and conducted in a manner such that a nuclear explosion could not result.

5.1.8.1 Public

Potential impacts to the MEI were evaluated at three locations in the vicinity of the PHERMEX site: Los Alamos, White Rock, and Bandelier. These locations are representative of the neighboring residential clusters in close proximity to LANL. Potential impacts to the surrounding population were also calculated. Potential radiological and nonradiological impacts are presented in the sections below.

5.1.8.1.1 Radiological Impacts

The maximum annual radiation dose to any nearby resident from routine operations would not exceed 2 x 10^{-5} rem EDE. Using a risk conversion factor of 5 x 10^{-4} latent cancer fatalities (LCFs) per person-rem for members of the public, the estimated maximum probability of a latent fatal cancer from this dose would be about 1 x 10^{-8}. The estimated maximum cumulative dose to an individual over the anticipated 30-year life of the project would be about 7 x 10^{-4} rem. The estimated maximum probability of a latent cancer fatality from this dose would be about 4 x 10^{-7}.

The annual collective dose to the population residing within 50 mi (80 km) of the PHERMEX site would be about 0.9 person-rem EDE. Latent cancer fatalities would not be expected among the population from this dose (5 x 10^{-4} LCFs). Over the 30-year operating lifetime, the population dose would be about 30 person-rem (1 x 10^{-2} LCFs).

The contribution from plutonium to the maximum annual individual dose would be about 2 x 10^{-10} rem over the 30-year lifetime of the project. The maximum probability of an LCF would be about 8 x 10^{-14}. The contribution from plutonium to the population dose would be about 3 x 10^{-7} person-rem over the lifetime of the project. Latent cancer fatalities would not be expected (1 x 10^{-10} LCFs).

5.1.8.1.2 Nonradiological Impacts

Members of the public might also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 4 x 10^{-11}. Toxicological effects from releases of uranium, beryllium, lead or lithium hydride would not be expected (maximum Hazard Index of 1 x 10^{-7}). The cumulative probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 1 x 10^{-9}. The maximum Hazard Index expected in the first year immediately after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 1 x 10^{-7}. Toxicological effects would not be expected.

Cancer from exposure to beryllium released during a year of normal operations (total incidence of 4 x 10^{-7} cancers) would not be expected in the population in a 50-mile (80-km) radius.

5.1.8.2 Noninvolved Workers

A noninvolved worker is defined as a LANL employee who works in TA-15, but is not directly involved with the facility operations. This worker would be assumed to work continuously 2,500 ft (750 m) distant from the firing site. This distance would be based on a hazard radius that would typically be put in place for hydrodynamic testing. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994).

The annual dose to a nearby noninvolved worker would be 2 x 10^{-5} rem EDE. Using a risk conversion factor of 4 x 10^{-4} LCFs per person-rem for workers, the maximum probability of an LCF from such a dose would be about 9 x 10^{-9}. Over the 30-year anticipated operating life of the facility, the same noninvolved worker's cumulative dose would be about 7 x 10^{-4} rem. The maximum cumulative probability of contracting a fatal cancer from this dose would be about 3 x 10^{-7}.

A noninvolved worker could also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 3 x 10^{-11}. Toxicological effects from releases of uranium, beryllium, lead, or lithium hydride would not be expected (maximum Hazard Index of 2 x 10^{-7}). The probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 9 x 10^{-10}. The maximum Hazard Index expected after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 1 x 10^{-7}. Toxicological effects would not be expected.

The estimated dose to a noninvolved worker over the 30-year project life from hypothetical routine releases of plutonium would be 6 x 10^{-10} rem. The maximum probability of an LCF from such a dose would be about 2 x 10^{-13}.

5.1.8.3 Workers

Average dose to workers at the facility was estimated to be no more than 0.01 rem EDE annually. The maximum probability of such a worker contracting a latent fatal cancer would be 4 x 10^{-6}. Over the 30-year operating life of the facility, an involved worker's maximum probability of contracting a latent fatal cancer would be about 1 x 10^{-4}. The annual collective worker dose was estimated to be about 0.3 person-rem/year. No LCFs would be expected among the worker population from this dose (1 x 10^{-4} LCFs). The cumulative worker dose over the anticipated 30-year life of the project would be about 9 person-rem. No LCFs would be expected among the worker population from this dose (4 x 10^{-3} LCFs). There would be no routine exposure to plutonium; therefore, these dose estimates include potential exposures to plutonium and were based on past PHERMEX operating experience. No operating information was available on exposure to chemicals or metals. The risks of exposure to these materials would be expected to be similarly low to those for radiation exposure.

Worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable. Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

5.1.9 Facility Accidents

This section presents the impacts from postulated facility accidents to members of the public, nearby noninvolved workers, and workers at the facility. The bounding accident evaluated under the No Action Alternative was the inadvertent detonation of a test assembly on the PHERMEX firing site. Accident initiation events are not addressed; instead, the accidents were evaluated on a "what if" basis even though the likelihood of occurrence is very small. More detailed results, identification of postulated facility accidents, and methods of analysis are described in greater detail in appendix I, Facility Accidents. Much of the technical basis for the health impact of the accident analysis is included in appendix H, Human Health. Transportation-related accidents are described in section 5.7, except for plutonium transportation accidents, which are included under accidental detonations below.

Radiological impacts may result from exposure to depleted uranium and tritium released from the PHERMEX site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-8} the dose of depleted uranium for acute releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used, rather than an explosive atmospheric dispersion model (see appendix H, Human Health).

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Future experiments with plutonium would always be conducted in double-walled containment vessels, and these experiments could not reasonably be expected to result in any release of plutonium to the environment. However, for purposes of this EIS, health consequences of hypothetical accidental releases of plutonium have been estimated and are provided below and in appendix I. Potential health consequences of exposure to plutonium are well understood (Sutcliffe et al. 1995).

5.1.9.1 Public

Potential impacts to individual members of the public from accidents involving depleted uranium were evaluated for three nearby points of public access _ State Road 4, Pajarito Road, and the Bandelier National Monument. The MEI was located at the State Road 4 location, approximately 0.9 mi (1.5 km) southwest of the site. An individual at this location under the assumed accident and exposure conditions would receive a radiation dose of about 6×10^{-4} rem EDE. The maximum probability of an LCF from such a dose would be about 3×10^{-7}. The maximum probability of a beryllium-induced cancer would be about 4×10^{-10}. Toxicological effects would not be expected, as no more than 0.01 mg of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled, and these inhalation intakes would be less than 0.1 percent of the applicable immediately dangerous to life and health (IDLH) equivalent intake values. Additional results are presented in appendix I, Facility Accidents.

Population impacts of acute accidental releases were evaluated for the direction that would result in the highest impact. Population in the maximally exposed, 22.5-degree sector (east through southeast) out to 50 mi (80 km) is about 50,000 (appendix H, Human Health, table H-6). The maximally exposed population sector in relation to distributions of minority and low-income populations within 30 mi (48 km) of DARHT is shown in Figures 5-1 and 5-2. Dose to the population in the maximally exposed direction (east-southeast) would be about 1.9 person-rem. Latent fatal cancers among the population would not be expected from this dose (9×10^{-4} LCFs). Cancer would not be expected among the population from exposure to beryllium (total incidence of 1×10^{-6} cancers).

Accidents involving plutonium were evaluated on a "what-if" basis, assuming the accident did occur without considering the very low probability of occurrence. It is important to note that any accidents involving plutonium would not be nuclear detonations, but rather detonations of the high explosive that could disperse particles of plutonium. Potential dose to an MEI of the public from accidental detonation of a plutonium-containing assembly was estimated to be about 76 rem. The maximum probability of an LCF from this dose would be about 0.04. Potential dose from a containment breach was estimated to be about 14 rem to the MEI. The maximum probability of an LCF from this dose would be about 0.007.

Population impacts of hypothetical acute releases of plutonium were evaluated using both 50th and 95th percentile atmospheric dispersion factors. Plume depletion due to natural settling and deposition processes and diffusion of released material across an entire exposed sector were considered. Dose in the maximally exposed sector from an accidental detonation was estimated to range from 9,000 to 24,000 person-rem. Latent cancer fatalities in the population would be expected to range from 5 to 12. Dose from a containment breach was estimated to range from 210 to 560 person-rem. No LCFs would be expected among the population from this dose (0.1 to 0.3 LCFs).

In addition to calculating the potential dose to the population in the hypothetical maximally-exposed sector, at the request of the State of New Mexico Environment Department and various American Indian pueblos, the potential dose to the populations of a number of individual communities in the vicinity of LANL were calculated. The communities included in this evaluation and the results of calculations are presented in appendix I.

5.1.9.2 Noninvolved Workers

For the bounding accident analysis, a noninvolved worker was assumed to be outside the facility hazard radius, at a distance of 2,500 ft (750 m), and exposed to the plume of material released from the detonation during the entire period of passage. This distance was based on a hazard radius that would typically be put in place for hydrodynamic tests. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994). This worker would receive a radiation dose of about 7×10^{-4} rem EDE. The maximum probability of LCF from this dose would be about 3×10^{-7}. The maximum probability of a beryllium-induced cancer would be about 5 x 10^{-10}. Toxicological effects would not be expected, as no more than 3.5 x 10^{-7} oz (0.01 mg) of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled, and these inhalation intakes would be less than 0.1 percent of the applicable IDLH equivalent intake values. Additional results are presented in appendix I, Facility Accidents.

Potential impacts to noninvolved workers from hypothetical accidents involving plutonium were evaluated at 2,500 ft (750 m) and 1,300 ft (400 m) from both the inadvertent detonation and containment breach accidents. Potential impacts from the inadvertent detonation were estimated to be 90 rem and 160 rem at 2,500 ft (750 m) and 1,300 ft (400 m), respectively, with corresponding maximum probabilities of LCFs from these doses of 0.04 and 0.06. Potential impacts from the containment breach were estimated to be 20 rem and 60 rem at 2,500 ft (750 m) and 1,300 ft (400 m), respectively, with corresponding maximum probabilities of LCFs from these doses of 0.09 and 0.02. These are substantially less than the potential impacts to the public because the plutonium would largely disperse up and over noninvolved workers.

5.1.9.3 Workers

Workers may be subject to explosive, radiological, chemical, and industrial hazards while working at the PHERMEX Facility. These hazards are typically expected within normal industrial or laboratory workplaces and are controlled by worker protection programs in place at LANL. High explosives and radioactive material are not allowed in PHERMEX; therefore, only ordinary industrial and laboratory hazards are present inside the PHERMEX Facility. The firing site is where accidents outside the scope of normal industrial or laboratory accidents (that is, those involving high explosives and direct exposure to high levels of ionizing radiation) might occur.

Accidents on the PHERMEX firing site could range from those with trivial consequences to those that could be fatal to involved workers. Of greatest consequence would be the inadvertent detonation of high explosives on the firing site when workers are present, which, if it were to occur, might result in up to 15 worker fatalities. This accident is considered unlikely because of comprehensive training requirements, strict procedural control, physical interlocks and control of the fireset (detonating equipment), and limited personnel access. In the late 1950s, an explosives accident resulted in the deaths of four LANL workers (not associated with PHERMEX operations). That accident caused an extensive overhaul and upgrade of the explosive safety program. Since that accident, LANL has not experienced a high-explosive-related fatality, and such accidents are no longer considered reasonably foreseeable.

A possible second accident on the firing site with serious consequences outside the scope of ordinary industrial or laboratory hazards would be the direct exposure of a worker to the ionizing radiation pulse produced by the PHERMEX accelerator. Although this accident would be extremely unlikely, a worker could receive a very high acute radiation dose, delivered over a fraction of a microsecond, to a localized portion of the body. The potential for occurrence is reduced by physical lockout of accelerator controls when personnel are present on the firing site, high training requirements, strict procedural control, access control, and the fact that the accelerator beam pulse is very short-lived, lasting less than a microsecond. Direct exposure of workers to the accelerator beam has never occurred at LANL firing sites.

Impacts to workers from accidents involving plutonium would be essentially the same as those discussed above. An inadvertent detonation could result in up to 15 fatalities from blast effects, while no impacts would be expected from a containment breach, since all involved workers would be inside the facility and protected from material releases.

5.1.10 Waste Management

Wastes generated under the No Action Alternative would be subject to treatment, storage, and/or disposal in other LANL Technical Areas. Transportation of these wastes would be conducted following U.S. Department of Transportation (DOT) guidelines and using DOE- or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

Mixed waste would consist of depleted uranium contaminated with lead. The amount of mixed waste to be stored would be small and not expected to exceed one 55-gal (0.2-m^3) drum or 220 lb (100 kg) per year. The volume of nonhazardous solid sanitary waste would be approximately one dumpster load per week.

During the two-year period from March 1992 through February 1994, the PHERMEX Facility disposed approximately 6,700 ft^3 (190 m^3) of low-level radioactive waste (LLW), representing up to four percent of the total LLW volume disposed at LANL during that period. Using depleted uranium usage as an indicator of overall program activity and LLW generation rates, estimates can be made of future waste generation levels. Since approximately 880 lb (400 kg) of depleted uranium were used at PHERMEX during this two-year period, approximately 1,800 ft^3 (50 m^3) LLW would be generated per 220 lb (100 kg) of depleted uranium used per year.

Yearly usage of depleted uranium under the No Action Alternative would be about 1,500 lb (700 kg). Applying the LLW generation rate of 1,800 ft^3 (50 m^3)/220 lb (100 kg), the estimated total LLW generated and disposed under the No Action Alternative would be about 12,500 ft^3 (350 m^3). The bulk of this waste would be the gravel and soil that is removed with the detonation debris. Total volume of waste generated would depend on the frequency of the firing-site detonations and periodic cleanup. Assuming the total LANL LLW disposal volume in future years will be 1.8 x 10^5 ft^3 (5,000 m^3)/yr (Bartlit et al. 1993), the No Action Alternative would contribute no more than seven percent of the total LANL LLW volume. (The *LANL Sitewide EIS* will address the near-term waste management matter at LANL. The long-term strategy for waste management throughout the DOE-complex, including LANL, will be analyzed in the Department's Draft Waste Management Programmatic EIS [DOE/EIS-0020D], to be released in September 1995.) Approximately 310 lb (140 kg) of solid hazardous waste and 2,500 lb (1,100 kg) of liquid hazardous waste would be disposed. This is based on estimated historical hazardous waste generation rates at the PHERMEX Facility of 220 lb (100 kg) of the solid hazardous waste and 1,800 lb (800 kg) of liquid hazardous waste disposed for every 1,100 lb (500 kg) of depleted uranium used in normal PHERMEX operations.

DOE estimates that up to two double-walled vessels per year would be used in support of the dynamic experiments involving plutonium that could be conducted at LANL. Two vessels would weigh approximately 26,000 lbs (11,820 kg); this steel may be contaminated to a level requiring handling and disposal as TRU waste. These vessels would either be cut into pieces for size reduction or disposed intact; however, the final waste configuration of the vessels has not been determined. The maximum volume of TRU waste would be equal to one TRUPACT-II container per year if the vessels are cut into pieces or two TRUPACT-II containers per year if the vessels are disposed intact.

5.1.11 Monitoring and Mitigation

5.1.11.1 Monitoring

Environmental monitoring currently performed at LANL would continue under the No Action Alternative. Existing stations for monitoring external penetrating radiation and radioactive and hazardous substances in air, water, soil, and sediment would be used to monitor the environmental impacts of the facility. Air-monitoring stations added in 1993 would serve as an enhanced air-monitoring network for the PHERMEX Facility.

5.1.11.2 Mitigation

Consequences of activities under the No Action Alternative were not considered to be of sufficient magnitude to warrant mitigation measures that would differ significantly from the measures currently applied as part of normal operations at PHERMEX. However, the DARHT Facility would be completed for other uses to be determined. Construction noise associated with the completion of the facility would be mitigated to minimize noise impacts on the surrounding environment as much as possible.

5.1.12 Decontamination and Decommissioning

After continued operations for an indefinite period, the PHERMEX facility would become a candidate for decommissioning. While a decontamination and decommissioning (D&D) plan and NEPA review would be conducted at that time, the activities and impacts associated with D&D can be summarized as:

_ Conversion of about 15,200 ft^2 (1,400 m^2) of office and laboratory space, or its demolition and disposal of the rubble as sanitary waste

_ Salvage of useable items of equipment, instruments, machined parts, etc. to other LANL uses

_ Characterization of wastes and treatment, storage and disposal of nonhazardous solid waste, hazardous, radioactive, and/or mixed wastes from the facilities and support equipment, containment vessels, and testing instrumentation

Nonhazardous solid waste would be expected to be disposed at the Los Alamos County landfill. Appreciable waste volumes could result if buildings are demolished. Radioactive wastes are expected to be disposed in Los Alamos low-level waste facilities; however, the volumes would be expected to be negligible compared to LANL annual low-level waste volumes.

Hazardous and mixed-waste disposal requirements are expected to not exceed two to five times the annual PHERMEX generation rates, the higher value reflecting negotiated cleanup levels meeting RCRA "clean closure" criteria. These wastes would be treated and disposed in accordance with LANL RCRA permit requirements. It is not determined at this time whether onsite or offsite disposal would be chosen. The quantities would not be expected to appreciably impact existing treatment or disposal capacities.

5.2 DARHT BASELINE ALTERNATIVE

This section presents the expected environmental consequences associated with the DARHT Baseline Alternative.

5.2.1 Land Resources

5.2.1.1 Land Use

Dedication (facility is already partially constructed) of about 8 ac (3 ha) in TA-15 of the 28,000-ac (11,300-ha) LANL site for completion of construction and operation of the DARHT Facility would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns. The disposition of the 11 ac (4 ha) associated with PHERMEX is unknown at this time.

5.2.1.2 Visual Resources

The DARHT Facility, partially constructed, would be an unobtrusive facility located in an isolated piñon/ponderosa pine forest area and would not be accessible or readily visible from offsite; therefore, its use should have no impact on visual resources.

5.2.1.3 Regional Recreation

Although a variety of recreational opportunities are available in the vicinity of LANL, only those individuals in areas relatively near TA-15 might be negatively impacted (startled) on occasion by noise associated with uncontained test firings at the DARHT site. Otherwise, no impacts on regional recreation would be expected.

5.2.2 Air Quality and Noise

Impacts on nonradiological air quality and the potential for noise impacts associated with the DARHT Baseline Alternative are discussed in this section.

5.2.2.1 Air Quality

Air quality impacts for the DARHT Baseline Alternative in this section are presented for the maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality and Noise.

5.2.2.1.1 Construction

Air quality impacts for the DARHT Baseline Alternative were evaluated for emissions during both construction and operation phases of DARHT. Construction activities would emit NO_2, SO_2, and respirable particulates (PM_{10}). As a by-product of construction activities, PM_{10} would be emitted in the form of fugitive dust from moving earth. Table 5-5 presents air quality impacts from construction activities to complete the planned DARHT construction activities. It includes impacts from fugitive dust (PM_{10}) and construction equipment emissions (NO_2 and SO_2). Section 3.3.6 provides additional discussion of prior impacts associated with DARHT construction.

Table 5-5._*Impacts on Air Quality from Construction Activities*

Pollutant	**Averaging Time**	**Concentration at Maximally Impacted Point of Unrestricted Public Access (_g/m^3)**	**Percent of Regulatory Limit[a]**
NO_2	Annual	0.04	0.06
	24-h	4.8	3.3
PM_{10}	Annual	0.8	1.6
	24-h	17	11
SO_2	Annual	0.003	0.007
	24-h	0.3	0.1
	3-h	22	2.2

[a] Uses the applicable regulatory limit shown in table 4-3.

Note: These impacts from construction activities apply to all alternatives except the No Action Alternative, which is assumed to have impacts about one-half of those listed. PM_{10} is a measure of fugitive dust while SO_2 and NO_2 are construction equipment emissions.

During the construction phase, the maximum offsite increases in ambient NO_2, SO_2, and PM_{10} from construction equipment would be very small, producing impacts well within the air quality standards. The offsite impact of fugitive dust emissions would also be small; the maximum increase in the 24-h average PM_{10} concentration would be about 10 percent of the Federal standard. The use of standard dust suppression measures would further lower projected impacts.

5.2.2.1.2 Operations

Impacts on air quality from routine operations in the DARHT Baseline Alternative would be substantially the same as in the No Action Alternative, described in section 5.1.2.1.2.

Although DOE estimates that the accelerators are pulsed about 25,000 times per year, the duration of the pulse is about 60 nsec. Hence, the total operating time would be less than about two thousandths of a second per year, suggesting that formation of ozone would be negligible. Even if the estimate of the number of pulses per year was low by a factor of ten, this conclusion would not change.

5.2.2.2 Noise

Noise in the DARHT Baseline Alternative would not be significantly different from that described for the No Action Alternative in section 5.1.2.2.

5.2.3 Geology and Soils

Impacts of the DARHT Baseline Alternative on geology and soils are described in the following subsections.

5.2.3.1 Geology

Geotechnical investigations (Sergent 1988) found no potential problems for the DARHT Facility. PHERMEX has over 30 years of operation history without site stability problems (see section 4.3.4, Site Stability). It is the best analogue for future DARHT operation.

5.2.3.2 Seismic

Seismically induced rockfalls could occur at the mesa rim, but the annual probability for earthquakes is low, and the DARHT Facility has sufficient setback from the mesa rim to be unaffected by these rockfalls during its design life (see section 4.3.4, Site Stability). Vibratory ground motion resulting from the detonation of high explosives is small, in general, being less than the ground motion pulse caused by the air wave from the same detonation.

Although seismic events that damage buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the DARHT Facility that would result in any offsite environmental impacts.

5.2.3.3 Soils

Operating DARHT for the next 30 years at a moderately higher level of testing, as compared to that of the last 32 years of operating the PHERMEX Facility, is anticipated to result in soil contamination levels somewhat above, but not greatly above, those observed today at PHERMEX. Under the DARHT Baseline Alternative, maximum average depleted uranium soil contamination in the vicinity of the firing point is not anticipated to be greater than about 5,000 ppm after 30 years of operation (see appendix D.6). The present PHERMEX firing site has a soils contamination circle around the firing point of about a 460-ft (140-m) radius. Inside this circle, soils are at or above the background concentration for uranium; outside this circle, soils exhibit background concentrations. Because the variety and magnitude of explosive charges to be used in future tests at DARHT will resemble those previously tested at PHERMEX, the area around the firing point where soils would exhibit uranium concentrations above background is anticipated to remain approximately the same, i.e., a circle with a 460-ft (140-m) radius. The area of land contaminated above background would be about 15 ac (6 ha). Soils sampling has shown that beryllium and lead contamination falls to background levels much closer to the firing point than uranium. Thus, the soil contamination circle defined for uranium would apply to the other metals of interest. Concentrations of metal contaminants in sediments within drainage channels are expected to be similar to those seen today in drainage channels at PHERMEX. Contaminants within the soil contamination circle would be available for migration in surface runoff to the canyons and deep drainage through the mesa.

5.2.4 Water Resources

Water resources examined for impact in the DARHT Baseline Alternative are:

_ Surface water and sediment in Water Canyon, which discharges into the Rio Grande

_ The main aquifer underlying Threemile Mesa

Stream losses to the bed of Water Canyon are analyzed for their potential to migrate through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and to communicate through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix E2). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that a realistic value of solubility for beryllium in LANL waters was at its drinking water standard of 4 _g/L [40 CFR 141.62]. A realistic value for lead solubility in LANL waters was at its MCL of 50 _g/L [40 CFR 141.11] and approximately a factor of three above its action level of 15 _g/L [40 CFR 141.80]. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, copper, or aluminum. The solubility of uranium in LANL waters was found to be substantially above its proposed MCL value, and therefore its migration was modeled to estimate impact on the water resource.

5.2.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the DARHT Baseline Alternative. In this alternative, the transport by surface runoff during the next 30 years for releases of depleted uranium, beryllium, and lead from the DARHT site was analyzed. Table 5-6 shows the simulated peak concentration of contaminants in the infiltrated water in Water Canyon below the source. Details of the analysis and the treatment of runoff, storm water, and cooling water blowdown discharge at the DARHT site are described in appendix E3.

Table 5-6._*Contaminant Concentrations and Time-to-peak for the DARHT Baseline Alternative*

Contaminant	**Reach 12 (Water Canyon)**	**Reach 13 (Water Canyon)**	**Reach 14 (Water Canyon)**	**Reach 15 (Water Canyon)**	**Rio Grande (in solution)[a]**	**Rio Grande (on sediment)**
Peak Concentration Depleted Uranium Beryllium Lead	(in _g/L) 3.0 x 10^{1} 3.2 x 10^{-3} 7.7 x 10^{-3}	(in _g/L) 6.3 1.4 x 10^{-3} 4.4 x 10^{-3}	(in _g/L) 1.8 6.0 x 10^{-4} 1.0 x 10^{-3}	(in _g/L) 7.1 x 10^{-1} 2.4 x 10^{-4} 2.9 x 10^{-4}	(in _g/L) **7.3 x 10^{-1}** 2.4 x 10^{-4} 2.9 x 10^{-4}	(in _g/g) 7.3 x 10^{-2} 2.4 x 10^{-5} 5.8 x 10^{-4}
Time (yr) Depleted Uranium Beryllium Lead	30 740 1,850	90 4,350 2,570	100 2,570 2,570	100 4,130 4,540	100 4,130 4,540	100 4,130 4,540

[a] Concentration of surface water entering Rio Grande; bold number in this column is basis for water resource number in tables S-1 and 3-3.

Note: Drinking Water Standards:

Uranium, 20 _g/L, [56 FR 33050]

Beryllium, 4 _g/L [40 CFR 141.62]

Lead, 15 _g/L [40 CFR 141.80]

Table 5-7._*Peak Input Concentrations for the DARHT Baseline Alternative to Water Canyon Reaches and Threemile Mesa Predicted by Surface Runoff-sediment-contaminant Transport Model*

Location	**Contaminant**		
	Uranium (_g/L)	**Beryllium (_g/L)**	**Lead (_g/L)**
Drinking Water Standards	20 [56 FR 33050]	4 [40 CFR 141.62]	15 [40 CFR 141.80]
Threemile Mesa	**300,000**	4	**50**
Water Canyon Reach 12	**30**	0.003	0.008
Water Canyon Reach 13	6.3	0.001	0.004
Water Canyon Reach 14	1.8	0.0006	0.001
Water Canyon Reach 15	0.7	0.0002	0.0003

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Water Canyon but still remain well below drinking water standards. Drinking water standards for beryllium and lead are 4 and 15 _g/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. Simulations reveal that concentrations of depleted uranium in surface waters released to Water Canyon immediately below DARHT could be slightly above the proposed MCL (20 _g/L). The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. As shown in table 5-6, the quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the drinking water standard for uranium and several orders-of-magnitude below the drinking water standards for beryllium and lead.

5.2.4.2 Ground Water

Two analyses of depleted uranium, beryllium, and lead migration were conducted. Stream losses into the bed of Water Canyon were analyzed to estimate the migration of contaminants through the vadose zone to the main aquifer. Similarly, infiltration carrying metal in solution into the mesa top at the DARHT firing point was analyzed to estimate contaminant migration to the main aquifer.

The peak concentrations of contaminants in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the DARHT Facility are shown in table 5-7. For those cases where the drinking water standards are exceeded (shown in bold), analyses are necessary. Only three cases were modeled: depleted uranium in the uppermost reach of Water Canyon, and depleted uranium and lead on the mesa top at the firing point. Releases of beryllium and lead from Water Canyon sediments and releases of beryllium from the mesa to the soil column were not analyzed in this case because the solution concentrations entering the soil column are at or below the drinking water standards. Similar releases to the uppermost reach of Water Canyon were analyzed in the No Action Alternative and were shown to be negligible (see section 5.1.4.2). Because of sorption and dispersion within the vadose zone, and solubility limits in Los Alamos waters, the metals beryllium, copper, and aluminum would not represent a hazard through the ground water pathway.

Analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.02 _g/L after nearly 20,000 years in soil water being delivered to the main aquifer. Simulation of depleted uranium migration through the mesa to the main aquifer showed a peak concentration of about 80 _g/L after approximately 40,000 years. Water Canyon stream losses yield soil water entering the main aquifer at concentrations well below the proposed MCL for uranium (20 _g/L); however, releases from the firing point on the mesa top yield soil water concentrations approximately four times the MCL. Simulation of lead migration through the mesa to the main aquifer showed a peak concentration of approximately 6 _g/L in soil water entering the aquifer, less than half the action level of 15 _g/L in the drinking water standard. Upon entering the main aquifer, the small-scale and low-volume releases from the mesa top would be dispersed in the aquifer and further mixed either with ground water (if it were recovered in the municipal water supply well), or with the waters of the Rio Grande. The average yield of the Pajarito Field wells of 2.7 ft^3/s (0.07665 m^3/s) is assumed to be representative of a water supply well which could be developed in the vicinity of Threemile Mesa (see appendix E4). The total flow rate of contaminated water from the mesa top firing point would be 1.1 x 10^{-3} ft^3/s (3.2 x 10^{-5} m^3/s). This gives a concentration reduction factor greater than 2,000, more than sufficient to reduce the concentration of depleted uranium in municipal water supplies to levels well below the proposed MCL. Based on the average annual flow rate of the Rio Grande [~1,500 ft^3/s (~42 m^3/s) at Otowi], the reduction factor would be even greater for ground water release to the Rio Grande.

Releases to the ground water pathway from operation under the DARHT Baseline Alternative do not adversely impact ground water quality.

5.2.5 Biotic Resources

Biotic resources examined for impacts under the DARHT Baseline Alternative include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species.

5.2.5.1 Terrestrial Resources

Both construction and operations impacts were evaluated for terrestrial resources.

5.2.5.1.1 Construction Impacts

Under the DARHT Baseline Alternative, further construction at the DARHT site would have little, if any, further impact on vegetation. Ground clearing and initial construction has already disturbed approximately 8 ac (3 ha) of mixed piñon-juniper/ponderosa pine habitat used by various species, and only about 0.25 ac (0.1 ha) would be further disturbed. Erosion control and revegetation of disturbed areas implemented during construction would be completed. These actions would minimize soil erosion. Section 3.3.6 provides additional details of the DARHT site.

Further construction at the DARHT site would have little, if any, further impact on the populations of small mammals that formerly inhabited the site. It is also likely that some small mammals, especially mice, would reinvade the disturbed area associated with the buildings.

Large mammals (deer, elk, coyote, bear, raccoon) use the DARHT site as habitat, mostly in a transient fashion, and it is unlikely that further construction would add to the present disruption of their use of this site (Risberg 1995).

Further construction at the DARHT site would not change the area of piñon-juniper/ponderosa pine habitat used by birds for roosting, feeding, and reproduction.

Some piñon-juniper/ponderosa pine habitat has already been disturbed by previous construction, and any reptiles and amphibians inhabiting the DARHT site have either been killed or displaced. Further impacts from completing the construction of DARHT would not be expected.

5.2.5.1.2 Operation Impacts

Further impacts to the DARHT site vegetation would be limited to effects from fires occurring during testing operations. These fires are quickly controlled by the firefighters who are stationed outside the exclusion fence at the time of the tests.

Impacts upon wildlife would be caused by repetitive, short-term disturbances from site activities. These impacts would be insignificant to overall population levels of common species, individuals, and thus populations of rare species such as the Mexican spotted owl, would not be adversely affected. DOE and the U. S. Fish and Wildlife Service (USFWS) have negotiated mitigation measures to reduce operational impacts to any threatened or endangered species in the vicinity of the DARHT and PHERMEX facilities (see section 5.11 and appendix K). Evidence from PHERMEX demonstrates that pollutant contamination of soil and plants outside the blast area is not above background levels.

5.2.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.2.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 are expected.

5.2.5.4 Threatened and Endangered Species

It is unlikely that completion of DARHT construction would change the attractiveness of the area for potential use by threatened or endangered species. Completion of construction and operations of the DARHT Facility would not cause any adverse impacts to the nesting Mexican spotted owls in the vicinity. DOE and the USFWS have negotiated a plan to eliminate the potential for adverse impacts to these birds (see section 5.11 and appendix K).

5.2.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the DARHT Baseline Alternative are described in the following subsections.

5.2.6.1 Archeological Resources

Archeological resources were evaluated from both construction and operations perspectives.

5.2.6.1.1 Construction

Completion of the DARHT Facility construction under the DARHT Baseline Alternative would not be expected to have any direct or indirect impacts on known archeological sites eligible for the National Register. Existing TA-15 security measures that restrict general access would continue to provide protection for possible intentional or incidental impacts from human activities.

5.2.6.1.2 Operations

Potential impacts related to detonation of high explosives at the designated firing point could result from 1) vibratory ground motion, 2) air waves, and 3) dispersal of metal fragments and other airborne debris.

Vibratory ground motion could induce structural instability to standing walls but would not affect other attributes of archeological sites which contribute to their research potential. Since none of the known archeological sites in the area of potential effects has standing walls, with the exception of Nake'muu, ground wave motion has the potential to affect only Nake'muu. This potential is minimal because the location of Water Canyon between the firing point and Nake'muu serves as a barrier which absorbs most of the motion. As stated, seismic tests conducted on March 11, 1995 (Vibronics 1995) indicated that potential impacts due to the air waves is a greater concern than vibratory ground motion.

Air waves would have no effect on those archeological sites whose eligibility for the National Register is based solely on their research potential. Air waves would have minimal effect on the structural stability of standing walls at Nake'muu. An air wave of 0.08 lb/in^2 (0.6 kPa) from a test blast at the PHERMEX firing point was measured at Nake'muu on March 11, 1995, from an explosion of 150 lb (70 kg) of TNT. This pressure is approximately one half of the air pressure required for window breakage (DOE 1992, table D.4-4). Although no structural damage resulted from this particular test, the cumulative impacts from similar air waves are unknown. In general, quantitatively assessing the effects air waves and ground motion could have on prehistoric structures is difficult because the baseline structural integrity of these sites is unknown. This site would be monitored for any adverse effects, and mitigation measures would be taken if necessary.

Flying debris would have no impact on those archeological sites whose eligibility for the National Register is based solely on their research potential. Flying debris, depending on the size and velocity, could impact those cultural resources which are eligible for the National Register for additional reasons (Criteria A, B, or C). No known prehistoric cultural resources in the area of potential effects have been identified as eligible under Criteria A or B (association with important events or people).

Because Nake'muu is eligible for the National Register under Criterion C based on its well-preserved standing walls, flying debris of sufficient size and velocity could result in an adverse effect. This potential was mitigated in the design stage of the project by aligning one wing of the DARHT building itself between the blast area and Nake'muu so that most blasting debris on a trajectory towards Nake'muu would be deflected away from Nake'muu. Using the height of the DARHT building alone as a barrier wall, some particles would be projected over that wall in the direction of Nake'muu. However, the only particles which would have the velocity to reach Nake'muu would be less than one inch in diameter. By the time they reach Nake'muu, they would no longer be propelled by the force of the blast itself, but would be falling to the ground by gravity alone. Based on the number of shots anticipated for the life of the DARHT Facility, the probability that any particles would reach Nake'muu was determined to be small and they would fall without sufficient force and size to affect the site. Constructing an additional barrier on top of the building would decrease even further the number of particles with the potential to reach Nake'muu. In a February 21, 1989, correspondence between the NM SHPO and the DOE, the SHPO concurred that "it is unlikely that the proposed activity will have any effect on the values for which LA 12655 [Nake'muu] is considered significant. However, I do agree that test activities should be monitored by a LANL Archaeologist, as discussed in your letter, to ensure that this assessment of effort is correct. If site damage to important site values is observed during the monitoring visits, further consultation will be necessary to determine appropriate measures to reduce adverse effects of test activities" (SHPO 1989).

The calculations above were made for explosions up to 150 lb (70 kg) of TNT originating specifically at the dual-axis firing point. Explosions exceeding this weight, anticipated to be about 500 lb (230 kg) TNT, require relocation of the firing point away from the dual-axis spot. In this situation, the shielding effect of the DARHT building would be reduced. The potential for blast debris from the larger explosions reaching Nake'muu would be mitigated by temporary construction of a sand bag revetment to create a blast shield. The blast overpressure measured during the March 11, 1995, tests scaled for 500 lb (230 kg) indicate a pressure of 0.12 lb/in^2 (0.8 kPa) at Nake'muu, which is still below the value of 0.2 lb/in^2 (1.4 kPa) required for window breakage (DOE 1992, table D.4-4). This overpressure, 0.12 lb/in^2 (0.8 kPa), is very conservative since the mitigating effects of the canyon are not included. Other data suggest that the canyon can reduce overpressure by as much as one half (Vibronics, Inc., 1995).

If determined to be desirable, additional characterization of the potential impact of DARHT operation on Nake'muu may be conducted. For example, options include design and implementation of a long-term monitoring procedure at Nake'muu and/or completion of a structural assessment of architectural elements. If necessary, several mitigation options are available, such as stabilization of standing masonry walls.

5.2.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.2.6.3 Native American Resources

There would be essentially no impacts on Native American cultural resources.

5.2.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, it is unlikely that paleontological resources exist at the DARHT site; no potential effects are postulated.

5.2.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the DARHT Baseline Alternative are presented in the following subsections.

5.2.7.1 Demographic Characteristics

The DARHT Baseline Alternative would not have any significant impact on the existing demographic characteristics of communities in the region-of-interest, as described in section 4.7.1.

5.2.7.2 Economic Activities

The DARHT Baseline Alternative encompasses completing construction and operation of the dual-axis facility. The DOE would complete construction and begin operation of the first axis of the proposed DARHT Facility by FY 1999. At that time, the operating costs of DARHT would replace PHERMEX operating costs, although construction expenditures would continue until the completion of the second DARHT axis in FY 2001. For the purpose of estimating the economic impacts (employment, labor income, and output) of the DARHT Baseline Alternative, the analysis recognizes the incremental construction and operating expenditures associated with the DARHT Baseline Alternative, relative to ones associated with the No Action Alternative. The estimated capital construction expenditures, shown in table 5-8, do not include any site cleanup nor decommissioning and decontamination of the dual-axis facility at the end of its lifetime. The direct and indirect economic impacts of the proposed alternative are described below.

Table 5-8._*Capital-funded Construction and Operating Costs*

for the DARHT Baseline Alternative (in millions of 1995 dollars)

Year/Cost	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**

Capital	6.6	29.5	17.9	26.8	24.0	0.6	0	0	105.3
Operations and Maintenance	4.2	4.1	4.1	4.0	5.9	5.8	5.8	5.7	39.6

Over the period FY 1996 to FY 2002, the DARHT Baseline Alternative is estimated to generate 191 full-time equivalent jobs in the regional economy, 80 directly related to project construction and operating expenditures, and 111 indirectly generated by subsequent indirect spending and income generation within the regional economy. Over the same time period, the DARHT Baseline Alternative is estimated to generate an annual average of $4.1 million of regional labor income, $1.7 million directly related to the project, and $2.4 million indirectly generated through subsequent indirect spending in the regional economy. Finally, the DARHT Baseline Alternative is estimated to generate an annual average of $6.8 million of goods and services in the regional economy, $3.4 million directly generated by the project, and $3.4 million indirectly generated by subsequent indirect spending within the regional economy.

The underlying cost data were provided by LANL (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup nor decontamination and decommissioning at either the DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.2.7.3 Community Infrastructure and Services

The DARHT Baseline Alternative would not have any significant impact on the existing community infrastructure in the region-of-interest, as described in section 4.7.3.

5.2.7.4 Environmental Justice

Referring to other sections of the EIS, no significant adverse environmental impacts are identified with the construction or operation of the DARHT Facility under the DARHT Baseline Alternative. The impacts considered include air and noise emissions caused during facility construction and subsequent operations (section 5.2.2), and the potential for surface or ground water contamination (section 5.2.4). Any foreseeable impacts on air, noise, or water quality during the course of normal operations would not pose significant health impacts on human populations (section 5.2.8) and would fall within regulatory compliance requirements. Accordingly, DARHT Facility construction and planned operation under the DARHT Baseline Alternative would have no known disproportionate adverse health or environmental impact on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.2.8 Human Health

Potential human health impacts under the DARHT Baseline Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.2.9 Facility Accidents

Potential impacts of facility accidents under the DARHT Baseline Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.9.

5.2.10 Waste Management

Potential impacts of the DARHT Baseline Alternative on waste management would be essentially the same as for the No Action Alternative, described in section 5.1.10.

5.2.11 Monitoring and Mitigation

5.2.11.1 Monitoring

Potential impacts that would need to be monitored under the DARHT Baseline Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.11.

5.2.11.2 Mitigation

Under normal operating conditions, two potential impacts would appear to warrant mitigation. Specific actions would be taken to minimize disturbance of the Mexican spotted owls inhabitating canyons near the DARHT site. Noise from construction equipment and activities would be minimized as much as possible. Operational noise from detonations would also be conducted to minimize disturbance. Facility lighting would be placed to direct illumination away from the canyons at night.

Protection of the Nake'muu archeological site might be necessary under certain detonation test configurations. Detonations would be shielded, if necessary, to avoid fragment impact to the site. No other archeological sites in the hazard radius have standing walls that would require mitigation activities. Other mitigation measures taken would not differ significantly from measures currently taken as part of normal operations at the PHERMEX Facility. Mitigation activities for cultural resources are presented in section 4.6. Construction noise associated with completing the facility would be mitigated to minimize noise impacts on the surrounding environment as much as possible.

5.2.12 Decontamination and Decommissioning

Potential impacts of decontamination and decommissioning under the DARHT Baseline Alternative would be similar to those described for the No Action Alternative in section 5.1.12. The following differences from D&D activities and impacts for the No Action Alternative would be expected:

_ Increased salvage and conversion to other uses because of the presence of two accelerator facilities and their buildings

_ Increased soil, gravel, and debris resulting from the repositioning of the firing site from the PHERMEX location

5.3 UPGRADE PHERMEX ALTERNATIVE

This section presents the expected environmental consequences associated with the Upgrade PHERMEX Alternative.

5.3.1 Land Resources

Potential impacts on land resources in the Upgrade PHERMEX Alternative would be essentially the same as those for the No Action Alternative, described in section 5.1.1.

5.3.2 Air Quality and Noise

5.3.2.1 Air Quality

Potential impacts of the Upgrade PHERMEX Alternative on air quality essentially would be the same as those for the No Action Alternative for operations, described in section 5.1.2.1.2, and the DARHT Baseline Alternative for construction activities, described in section 5.2.1.1.

5.3.2.2 Noise

Because the period of construction would be somewhat longer and some construction would probably take place to convert the existing DARHT Facility to other uses, construction noise would be generated for a period longer than in the DARHT Baseline Alternative. However, construction noise would not be expected to be noticeable away from the construction site. Disturbance of wildlife during operations would be about the same as with the No Action Alternative, described in section 5.1.2.2.

5.3.3 Geology and Soils

Potential impacts of the Upgrade PHERMEX Alternative on geology and soils would be essentially the same as those for the No Action Alternative, described in section 5.1.3.

5.3.4 Water Resources

Potential impacts of the Upgrade PHERMEX Alternative on surface and ground water would be essentially the same as those for the No Action Alternative, described in section 5.1.4.

5.3.5 Biotic Resources

Impacts on biotic resources in the Upgrade PHERMEX Alternative would be essentially the same as those for the No Action Alternative, described in section 5.1.5.

5.3.6 Cultural and Paleontological Resources

Potential impacts on cultural and paleontological resources in the Upgrade PHERMEX Alternative would be essentially the same as those for the No Action Alternative, described in section 5.1.6.

5.3.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Upgrade PHERMEX Alternative are presented in this section. Potential impacts on demographic characteristics, community infrastructure and services, and environmental justice would be essentially the same as the No Action Alternative and are described in sections 5.1.7.1, 5.1.7.3, and 5.1.7.4, respectively. Potential impacts on economic activities are presented in the following paragraphs.

The Upgrade PHERMEX Alternative involves upgrading the present PHERMEX Facility to accommodate new technology developed for DARHT. Under this alternative, the DOE is expected to complete construction and begin operation of the upgraded PHERMEX Facility in FY 2002. During the upgrade of the PHERMEX Facility, construction costs would be incurred along with PHERMEX operating costs (see table 5-9). To estimate the regional economic impacts of the Upgrade PHERMEX Alternative, the analysis recognizes additional construction and operating expenditures under the Upgrade PHERMEX Alternative, relative to those associated with the No Action Alternative. The estimated capital construction expenditures do not include any site cleanup nor D&D of the dual-axis facility at the end of its lifetime.

Table 5-9._*Capital-funded Construction and Operating Costs for*

Upgrade PHERMEX Alternative (in millions of 1995 dollars)

Year/Cost	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Capital	6.6	36.6	33.7	21.7	14.8	10.2	3.1	0	126.7
Operations and Maintenance	4.2	4.1	4.1	4.0	4.0	4.0	3.9	6.0	34.3

Over the period FY 1996 to FY 2002, the Upgrade PHERMEX Alternative is estimated to generate 199 full-time equivalent jobs in the regional economy, 82 directly related to project construction and operating expenditures, and 117 indirectly generated by consecutive rounds of spending and regional income generation. The Upgrade PHERMEX Alternative is also estimated to generate an annual average of $4.3 million of regional labor income, $1.8 million directly related to the project, and $2.5 million indirectly generated through consecutive rounds of spending in the regional economy. Finally, the Upgrade PHERMEX Alternative is estimated to generate an annual average of $6.9 million of goods and services in the regional economy, $3.3 million directly generated by the project, and $3.7 million indirectly generated by consecutive rounds of spending in the regional economy.

The underlying cost data were provided by LANL (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup nor D&D of either the proposed DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.3.8 Human Health

Potential impacts of the Upgrade PHERMEX Alternative on human health would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.3.9 Facility Accidents

Potential impacts of facility accidents under the Upgrade PHERMEX Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.9.

5.3.10 Waste Management

Potential impacts of the Upgrade PHERMEX Alternative on waste management would be essentially the same as for the No Action Alternative, described in section 5.1.10.

5.3.11 Monitoring and Mitigation

Monitoring and mitigation measures taken under the Upgrade PHERMEX Alternative would be essentially the same as the No Action Alternative, described in section 5.1.11.

5.3.12 Decontamination and Decommissioning

Impacts of decontamination and decommissioning under the Upgrade PHERMEX Alternative would be essentially the same as in the No Action Alternative described in section 5.1.12; however, the buildings partially constructed for DARHT would also be subject to D&D evaluation.

5.4 ENHANCED CONTAINMENT ALTERNATIVE

This section presents the expected environmental consequences associated with the Enhanced Containment Alternative. Three options were analyzed under this Alternative, as described in section 3.7: the Building Containment, Vessel Containment, and Phased Containment (preferred alternative) options. No significant differences in potential environmental impacts were determined among the three options; in many cases (see tables S-1 and 3-3) potential impacts would be essentially identical. Minor differences were determined in impacts to, or caused by air quality operations, noise, soil contamination, biotic and cultural resources (without mitigation), socioeconomics, human health, low-level waste generation, and commitment of resources. These are discussed below.

5.4.1 Land Resources

5.4.1.1 Land Use

The Vessel Containment, Building Containment, and Phased Containment (preferred alternative) options under this alternative require a building addition for the cleanout facility. To accommodate all of these options, it is anticipated that 1 ac (0.4 ha) of land would have to be cleared for construction, in addition to the 8 ac (3 ha) of land previously disturbed by DARHT. Under the Vessel Containment and Phased Containment (preferred alternative) options, an existing 0.25-mi long (0.4-km long) firebreak road would be improved by widening, grading, and paving to provide access to the proposed vessel cleanout facility. This would lead to the potential for about 0.5 ac (0.2 ha) additional disturbance on either side of the existing road. Dedication of land for the cleanout facility or access road would be consistent with current and past land uses at LANL and would have no reasonably foreseeable impact on established local land-use patterns.

5.4.1.2 Visual Resources

The proposed DARHT Facility and the cleanout facility under any of the containment options would be unobtrusive and located in an isolated piñon/ ponderosa pine forest area. The buildings would not be accessible or readily visible from offsite; therefore, they should have no impact on visual resources.

5.4.1.3 Regional Recreation

Although a variety of recreational opportunities are available in the vicinity of LANL, only those in areas relatively near TA-15 might be negatively impacted by noise associated with test firings at the proposed DARHT site. Test firings within the containment building would be expected to have no impacts on recreational resources. Under the Vessel Containment and Phased Containment (preferred alternative) options, it is possible that some tests would be conducted without using a containment vessel. These tests would have the same small potential for impacts on nearby recreation as other alternatives using uncontained test firing.

5.4.2 Air Quality and Noise

Impacts on nonradiological air quality and the potential for noise impacts associated with the Enhanced Containment Alternative are discussed in this section.

5.4.2.1 Air Quality

Air quality impacts for the Enhanced Containment Alternative are presented in this section for maximally impacted point of unrestricted public access. These impacts were determined using methods described in appendix C, Air Quality and Noise.

5.4.2.1.1 Construction

Pollutant emissions during the construction phase of all three options of the Enhanced Containment Alternative would be essentially the same as those for the DARHT Baseline Alternative. Pollutant emissions associated with constructing a containment structure (Building Containment Option) or the vessel cleanout facility under the Enhanced Containment Alternative have not been quantified. However, additional impacts from the construction of either structure would be expected to be minimal.

5.4.2.1.2 Operations

Potential air quality impacts from operations under the Enhanced Containment Alternative would be very similar for all three of the options analyzed. As shown in table 5-10, the calculated values for nitrogen dioxide and sulfur dioxide are essentially the same for all options and alternatives, while PM_{10} values vary slightly among alternatives. Annual PM_{10} air concentrations for the Enhanced Containment Alternative options are about the same among these options but are about 20 percent lower than those for other alternatives. The maximum short-term (24-h) of PM_{10} concentrations would differ among the enhanced containment options. The Vessel Containment and Phased Containment options would have short-term releases from uncontained detonations; potential short-term air quality impacts would be higher than the Building Containment Option and similar to those of the other alternatives analyzed.

Table 5-10.*_Impacts on Air Quality from Operations under the*

Enhanced Containment Alternative

Pollutant	**Averaging Time**	**Concentration at Maximally Impacted Point of Unrestricted Public Access (_g/m^3)**	**Percent of Regulatory Limit[a]**

NO_2	Annual 24-h	0.04 2	0.06 1.4
PM_{10}	Annual 24-h	0.008 0.4[c] 3.3[d]	0.02 0.2[c] 2.2[d]
SO_2	Annual 24-h 3-h	2×10^{-4} 0.006 0.03	0.0005 0.003 0.003
Beryllium	30 days	2×10^{-5}	0.0002
Heavy Metals[b]	30 days	0.002	0.02
Lead	Calendar Quarter	1×10^{-4}	0.007

[a] Uses the applicable regulatory limit from table 4-3.

[b] Sum of the air concentration of uranium and lead.

[c] Building Containment Option

[d] Vessel Containment and Phased Containment options.

Note: NO_2 and PM_{10} are from hydrodynamic testing and boiler emissions.

SO_2 is from boiler emissions.

Beryllium, heavy metals, and lead are from hydrodynamic testing. Includes impacts from hydrodynamic testing and boiler emissions.

Calculated values for beryllium, heavy metals, and lead for all of the enhanced containment options are essentially the same when analyzed over the 30-year project life because of the greater impact of containment releases on air quality. The Phased Containment Option would have less impact during the early years of the option because of the greater fraction of uncontained detonations. Although somewhat counter intuitive, the major reason for this is because uncontained detonations under these options allow for greater atmospheric dispersion with subsequently less air quality impact than releases from containment. The uncontained detonations were modeled as elevated releases [325 ft (99 m)] simulating explosive dispersion, while containment releases were modeled as near ground level releases. Additional discussion of atmospheric releases and modeling is provided in appendix C1, Air Quality, and appendix H, Human Health.

5.4.2.2 Noise

Under all options of the Enhanced Containment Alternative, impacts associated with noise and blast pressure waves would be reduced compared to the No Action Alternative. Uncontained detonations under the Vessel Containment and Phased Containment options could potentially have noise and blast wave impacts of the same magnitude as for the No Action Alternative. The number of detonations would be reduced by 75 percent under the Vessel Containment Option and from 5 to 40 to 75 percent under the different phases of the Phased Containment Option.

Noise associated with construction and construction worker traffic would occur until completion of the DARHT Facility and the containment building or cleanout facility under all of the containment options. However, construction noise would not be expected to be noticeable away from the construction site. Disturbance of wildlife during operations would be about the same as with the No Action Alternative (appendix C, Air Quality and Noise).

5.4.3 Geology and Soils

Impacts of the Enhanced Containment Alternative on geology and soils are described in the following subsections.

5.4.3.1 Geology

Geologic impacts under the Enhanced Containment Alternative would be similar to those under the DARHT Baseline Alternative, described in section 5.2.3.1.

5.4.3.2 Seismic

Seismic impacts under the Enhanced Containment Alternative would be similar to those under the DARHT Baseline Alternative, described in section 5.2.3.2.

Although seismic events that damage buildings would have an impact on mission goals, no scenarios were identified wherein a seismic event could trigger an action at the proposed DARHT Facility that would result in any offsite environmental impact.

5.4.3.3 Soils

The three options under the Enhanced Containment Alternative present lower soils contamination levels than the No Action and DARHT Baseline alternatives. The three options are the Vessel Containment Option, the Building Containment Option, and the Phased Containment Option (preferred alternative).

Under the Vessel Containment Option, an estimated maximum of 12 percent of the DARHT Baseline Alternative inventory could be released in the vicinity of the firing point if highly unlikely events were to occur. This 12 percent is made up of two types of releases. Under the Vessel Containment Option some uncontained detonations would be conducted, up to 25 percent of the total annual depleted uranium expenditures of 1,540 lb (700 kg) or a maximum of 385 lb (175 kg) per year. Of this depleted uranium inventory, 70 percent would be removed from the firing point during routine cleanup activities leaving 30 percent for migration in the environment. To be conservative, it is assumed no beryllium or lead would be removed from the firing point during routine cleanup. Of the remaining 75 percent of the inventory shot in containment, releases are assumed to occur in no more than 6 percent of the cases. Note that total release from these 6 percent of contained tests would be highly unlikely; however, to be conservative complete release is assumed. Thus, 7.5 percent (i.e., 0.25 x 0.30) release occurs during uncontained experiments and up to 4.5 percent (0.75 x 0.06) release occurs during contained experiments; a total of 12 percent. Assuming no cleanup of beryllium or lead, their percentage of inventory remaining in firing site soils is estimated to be no more than 29.5 percent of their original inventory. Thus, annual releases of depleted uranium, beryllium, and lead would be 185, 6.5, and 10 lbs (84, 3, and 4.4 kg), respectively. These annual releases would occur for 30 years.

Soil contamination under the Building Containment Option would be somewhat less than that under the Vessel Containment Option. Under the Building Containment Option, 6 percent of the annual inventory will be released to the environment under highly unlikely circumstances. It is further assumed that none of the contamination will be removed from the soils through routine cleanup activities. Thus, annual releases of depleted uranium, beryllium, and lead would be 92, 1.3, and 2 lbs (42, 0.6, and 0.9 kg), respectively. These annual releases would occur for 30 years.

Soil contamination under the Phased Containment Option would be somewhat more than under the Vessel Containment Option. Releases would be characterized by decreasing uncontained experiments in three phases over two 5-year periods, finally decreasing to about 25 percent uncontained experiments level after 10 years. For the three time periods (i.e., 5, 5, and 20 years), over the 30-year operation of the facility, the uncontained to containment percentages of annual inventory expended would be 95 and 5, 60 and 40, and 25 and 75. Under cleanup and operational assumptions identical to those under the Vessel and Building Containment Options, the percentages of annual inventory for depleted uranium deposited in the firing site soils for the three periods are 28.8, 20.4, and 12 percent. The percentages of annual inventory deposited in firing site soils for beryllium and lead for the three periods are 95.3, 62.4, and 29.5. During the first 5-year period, annual releases of depleted uranium, beryllium, and lead would be 444, 21, and 31 lbs (200, 9.5, and 14 kg), respectively. During the second 5-year period, the annual releases of depleted uranium, beryllium, and lead would be 315, 14, and 21 lbs (143, 6.2, and 9.4 kg), respectively. During the final 20-year period, the annual releases of depleted uranium, beryllium, and lead would be 185, 6.5, and 10 lbs (84, 3, and 4.4 kg), respectively.

For each of the options of the Enhanced Containment Alternative, the circle of contaminated soil at the firing point under the Enhanced Containment Alternative is assumed to be no greater than that for the No Action and DARHT Baseline alternatives. Thus, the circle of soil centered on the firing point exhibiting uranium concentrations above background would be no greater than a 460-ft (140-m) radius. The area of land contaminated above background for uranium, beryllium, and lead would be no greater than 15 acres (6 ha).

5.4.4 Water Resources

Water resources examined for impact in the Enhanced Containment Alternative are:

_ Surface water and sediment in Water Canyon, which discharges into the Rio Grande

_ The main aquifer underlying Threemile Mesa

Stream losses to the bed of Water Canyon are analyzed for their potential to release contaminants through the vadose zone to the main aquifer. Infiltration is examined for its ability to carry metals in solution into the mesa top at the firing point and to transport contaminants through the unsaturated zone to the main aquifer. Supporting information on deep drainage, the geochemistry of metals in LANL waters and sediments, surface water modeling, and vadose zone and ground water modeling as applied in this EIS can be found in appendix E.

A combination of data review and geochemical analysis was used to determine the solubility and sorption characteristics of several metals in the LANL water and soil/sediment environment (see appendix E2). Because they represent the largest fraction of expended materials in the tests to be conducted, depleted uranium, beryllium, lead, copper, and aluminum were all studied. The study revealed that a realistic value of solubility for beryllium in LANL waters was at its drinking water standard of 4 _g/L [40 CFR 141.62]. A realistic value for lead solubility in LANL waters was at its MCL of 50 _g/L [40 CFR 141.11] and approximately a factor of three above its action level of 15 _g/L [40 CFR 141.80]. Values of solubility for both copper and aluminum were both found to be substantially below their secondary drinking water standards. Thus, while the analysis examines the migration of beryllium and lead to gain insight into their migration and behavior in the environment, there is no need to simulate beryllium, copper, or aluminum because their solute concentrations at the source are at or below their respective drinking water standards. The solubility of uranium in LANL waters was found to be substantially above its proposed MCL value, and therefore its migration was modeled to estimate its potential impact on the water resource.

5.4.4.1 Surface Water

The hydrology-sediment-contaminant transport modeling procedure described in appendix E3 was applied to assess the potential impacts of the three options under the Enhanced Containment Alternative. In this alternative, the transport by surface runoff of the 30 years of future releases of depleted uranium, beryllium, and lead from the DARHT site was analyzed. Table 5-11 shows the simulated peak concentration of contaminants in the infiltrated water in Water Canyon below the source. Details of the analysis and treatment of runoff, storm water, and cooling water blowdown discharge at the DARHT site are described in appendix E3.

Table 5-11.*_Contaminant Concentrations and Time-to-peak for the*

Enhanced Containment Alternative

Contaminant	**Reach 12 (Water Canyon)**	**Reach 13 (Water Canyon)**	**Reach 14 (Water Canyon)**	**Reach 15 (Water Canyon)**	**Rio Grande (in solution)[a]**	**Rio Grande (on sediment)**
Vessel Containment Option						
Peak Concentration	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/g)
Depleted Uranium	2.5×10^{1}	4.8	1.4	5.4×10^{-1}	**5.6×10^{-1}**	5.6×10^{-2}
Beryllium	3.2×10^{-3}	1.4×10^{-3}	6.0×10^{-4}	2.4×10^{-4}	2.4×10^{-4}	2.4×10^{-5}
Lead	7.7×10^{-3}	4.4×10^{-3}	1.0×10^{-3}	2.9×10^{-4}	2.9×10^{-4}	5.7×10^{-4}
Time, years	17	90	100	100	100	100
Depleted Uranium	740	4,350	2,570	4,130	4,130	4,130
Beryllium	1,850	2,570	2,570	2,640	2,640	2,640
Lead						
Building Containment Option						
Peak Concentration	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/g)
Depleted Uranium	17.6	3.28	9.4×10^{-1}	3.7×10^{-1}	**3.8×10^{-1}**	3.8×10^{-2}
Beryllium	3.2×10^{-3}	1.4×10^{-3}	6.0×10^{-4}	2.4×10^{-4}	2.4×10^{-4}	2.4×10^{-5}
Lead	6.2×10^{-3}	2.5×10^{-3}	4.4×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	2.8×10^{-4}

Time, years	17	90	100	100	100	100
Depleted Uranium	740	4,350	2,570	4,130	4,130	4,130
Beryllium	530	530	530	530	530	750
Lead						
Phased Containment Option						
Peak Concentration	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/L)	(in _g/g)
Depleted Uranium	26	4.9	1.4	5.6×10^{-1}	**5.7×10^{-1}**	5.7×10^{-2}
Beryllium	3.2×10^{-3}	1.4×10^{-3}	6.0×10^{-4}	2.4×10^{-4}	2.4×10^{-4}	2.4×10^{-5}
Lead	7.7×10^{-3}	4.4×10^{-3}	1.0×10^{-3}	2.9×10^{-4}	2.9×10^{-4}	5.8×10^{-4}
Time, years	17	90	100	100	100	100
Depleted Uranium	740	4,350	2,570	4,130	4,130	4,130
Beryllium	1,850	2,570	2,570	2,640	2,640	2,640
Lead						

[a] Concentration of surface water entering Rio Grande; basis for water resource number in tables and S-1 and 3-3.

Note: Drinking Water Standards:

Uranium, 20 _g/L [56 FR 33050]

Beryllium, 4 _g/L [40 CFR 141.62]

Lead, 15 _g/L [40 CFR 141.80]

Because of their low solubility, the concentrations of beryllium and lead reach a plateau in their release to Water Canyon but still remain well below drinking water standards. Drinking water standards for beryllium and lead are 4 and 15 _g/L, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. Depleted uranium in surface water released to Water Canyon immediately below DARHT is slightly above the proposed MCL of 20 _g/L for the Vessel Containment and Phased Containment options, and slightly below the proposed MCL for the Building Containment Option. The Rio Grande is the nearest offsite access point for surface water carrying contamination from the firing point. As shown in table 5-11, the quality of surface water entering the Rio Grande under each of the options is forecast to be over an order-of-magnitude below the drinking water standard for uranium and several orders-of-magnitude below the drinking water standards for beryllium and lead.

5.4.4.2 Ground Water

Two analyses of depleted uranium, beryllium, and lead migration were conducted for the three options of the Enhanced Containment Alternative. The two analyses involved 1) infiltration carrying contaminants into the mesa top at the DARHT firing point and 2) infiltration of contaminants from the stream bed of Water Canyon. Both sources of infiltration and contamination were analyzed to estimate contaminant migration into the main aquifer.

The peak concentrations of contaminants in infiltration to Threemile Mesa and in surface water losses from the uppermost reach of Water Canyon opposite the DARHT Facility are shown in table 5-12. For those cases where the drinking water standards are exceeded (shown in bold), analyses were conducted. Only three cases must be modeled _ depleted uranium and lead on the mesa top at the firing point and depleted uranium in the uppermost reach of Water Canyon. Other metals and locations were not analyzed because sorption and dispersion within the vadose zone would only further reduce soil water concentrations that enter the soil column at concentrations at or below the drinking water standards.

Table 5-12.*_Peak Input Concentrations for the Enhanced Containment Alternative to Water Canyon Reaches and Threemile Mesa Predicted by Surface Runoff-sediment-contaminant Transport Model*

Location	**Contaminant**		
	Uranium **(_g/L)**	**Beryllium** **(_g/L)**	**Lead** **(_g/L)**
Drinking Water Standards	20 [56 FR 33050]	4 [40 CFR 141.62]	15 [40 CFR 141.80]
Vessel Containment Option			
Threemile Mesa	**142,000**	4	**50**
Water Canyon Reach 12	**25.3**	0.003	0.008
Water Canyon Reach 13	4.8	0.001	0.004
Water Canyon Reach 14	1.4	0.0006	0.001
Water Canyon Reach 15	0.5	0.0002	0.0003
Building Containment Option			
Threemile Mesa	**71,000**	4	**50**
Water Canyon Reach 12	**17.6**	0.003	0.006
Water Canyon Reach 13	3.3	0.001	0.003
Water Canyon Reach 14	0.9	0.0006	0.0004
Water Canyon Reach 15	0.4	0.0002	0.0002
Phased Containment Option			
Threemile Mesa	**250,000**	4	**50**
Water Canyon Reach 12	**26**	0.003	0.008
Water Canyon Reach 13	4.9	0.001	0.004
Water Canyon Reach 14	1.4	0.0006	0.001
Water Canyon Reach 15	0.6	0.0002	0.0003

For the Vessel Containment Option, analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.05 _g/L after 18,000 years in soil water being delivered to the main aquifer. Analysis of the migration of depleted uranium and lead through the mesa to the main aquifer showed a peak concentration of 32 and 1 x 10^{-3} _g/L after approximately 42,000 and 100,000 years, respectively. Thus, while releases of lead in soil water are well below the drinking water standard action level of 15 _g/L, the release of depleted uranium from the mesa top yields soil water entering the main aquifer at concentrations less than twice the proposed MCL.

For the Building Containment Option, analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.04 _g/L after 18,000 years in soil water being delivered to the main aquifer, well below the proposed MCL for uranium (20 _g/L). Analysis of the migration of depleted uranium and lead through the mesa to the main aquifer showed a peak concentration of 16.1 and

1.5 x 10^{-7} _g/L after approximately 42,000 and 100,000 years, respectively. Thus, the release of lead in soil water is well below the drinking water standard action level of 15 _g/L, and the release of depleted uranium from the mesa top yields soil water entering the main aquifer at concentrations below the MCL.

For the Phased Containment Option, analysis of depleted uranium migration through the vadose zone arising from releases to the stream bed of Water Canyon showed a peak concentration of about 0.06 _g/L after 18,000 years in soil water being delivered to the main aquifer. Analysis of the migration of depleted uranium and lead through the mesa to the main aquifer showed a peak concentration of 43 and 2 x 10^{-3} _g/L after approximately 42,000 and 100,000 years, respectively. Thus, while releases of lead in soil water are well below the drinking water standard action level of 15 _g/L, the release of depleted uranium from the mesa top yields soil water entering the main aquifer at concentrations about twice the proposed MCL.

Upon entering the main aquifer, the small-scale and low-volume releases from the mesa top would be dispersed in the aquifer and further mixed either with ground water (if it were recovered in the municipal water supply) or the waters of the Rio Grande. The average yield of the Pajarito Field wells of 2.7 ft^3/s (7.7 x 10^{-2} m^3/s) is assumed to be representative of a water supply well that could be developed in the vicinity of Threemile Mesa (see Appendix E4). The total flow rate of contaminated water from the mesa firing point would be 1.1 x 10^{-3} ft^3/s (3.2 x 10^{-5} m^3/s). This gives a concentration reduction factor greater than 2,000, more than sufficient to reduce the concentration of depleted uranium in municipal water supplies to levels well below the proposed MCL. Based on the average annual flow of the Rio Grande at Otowi (Graf 1993) between 1910 and 1985 of 1.1 x 10^6 ac-ft [1.5 x 10^3 ft^3/s (42 m^3/s)], the reduction factor would be even greater for ground water release to the Rio Grande.

Releases to the ground water pathway from operation under the Enhanced Containment Alternative would not adversely impact ground water quality.

5.4.5 Biotic Resources

Biotic resources examined for impacts under the Enhanced Containment Alternative include terrestrial resources, wetlands, aquatic resources, and threatened and endangered species.

5.4.5.1 Terrestrial Resources

Both construction and operations impacts were evaluated for terrestrial resources.

5.4.5.1.1 Construction Impacts

All of the containment options under the Enhanced Containment Alternative would necessitate the construction of either a containment building or a vessel cleanout facility in TA-15. For the containment and cleanout buildings, an additional removal of piñon-juniper/ponderosa pine habitat of about 1 ac (0.4 ha) would be incurred with a resulting disturbance and displacement of associated wildlife. Under the Vessel Containment and Phased Containment (preferred alternative) options, an existing 0.25-mi long (0.4-km long) firebreak road would be improved by widening, grading, and paving to provide access to the proposed vessel cleanout facility. This would lead to the potential for about 0.5 ac (0.2 ha) additional disturbance on either side of the existing road. See section 5.1.5.1 for a description of these types of impacts.

5.4.5.1.2 Operation Impacts

Impacts would be essentially the same as the DARHT Baseline Alternative (section 5.2.5.1.2) except that disruption of wildlife from noise associated with detonations would likely be lessened, considerably so for the Building Containment Option. Noise associated with operation of the cleanout facility would be minimal.

5.4.5.2 Wetlands

Although floodplains lie at the bottom of Potrillo Canyon and Cañon de Valle, no wetlands lie within TA-15; thus, no impacts to wetlands would occur (Risberg 1995).

5.4.5.3 Aquatic Resources

No additional impacts to the aquatic resources located within the canyons surrounding TA-15 are expected.

5.4.5.4 Threatened and Endangered Species

Potential impacts on threatened and endangered species under the Enhanced Containment Alternative would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.5.4.

5.4.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources under the Enhanced Containment Alternative are described in the following subsections.

5.4.6.1 Archeological Resources

5.4.6.1.1 Construction

Completion of construction of the proposed DARHT Facility and the containment building, cleanout facility, or access road under any of the proposed containment options, would not be expected to have any direct or indirect impacts on known archeological sites eligible for the National Register. Existing TA-15 security measures that restrict general access would continue to provide protection for possible intentional or incidental impacts from human activities.

5.4.6.1.2 Operations

Any uncontained detonations conducted under the Vessel Containment or Phased Containment option would have impacts described under the DARHT Baseline Alternative in section 5.2.6.1.2. Potential impacts from contained detonations would be minimal, limited to vibratory ground motion.

5.4.6.2 Historical Resources

No direct or indirect impacts on historic structures are anticipated.

5.4.6.3 Native American Resources

There would be essentially no impacts on Native American cultural resources.

5.4.6.4 Paleontological Resources

Because of the nature of the soil and geological substrate, the occurrence of paleontological resources is not anticipated; no potential effects are postulated.

5.4.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Enhanced Containment Alternative are presented in the following subsections.

5.4.7.1 Demographic Characteristics

The Enhanced Containment Alternative would not have any significant impact on the existing demographic characteristics of communities in the region-of-interest, as described in section 4.7.1.

5.4.7.2 Economic Activities

The Enhanced Containment Alternative would involve construction and operation of the DARHT Facility but with some modification to contain airborne emissions of fragments or other debris _ either a containment vessel or a containment building. Under the Vessel Containment Option, the DOE would complete construction and begin operation of the dual-axis facility in FY 1999. At that time, DARHT operating costs would replace PHERMEX operating costs. Under the Building Containment Option, the DOE would complete construction and begin operation of the dual-axis facility in FY 2002, at which time DARHT operating costs would replace PHERMEX operating costs (table 5-13).

Table 5-13._***Capital-funded Construction and Operating Costs for the***

Enhanced Containment Alternatives (in millions of 1995 dollars)

Cost/Option	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Capital	6.6	29.6	32.4	41.1	24.9	0.6	0	0	135.2
Vessels	6.6	28.7	27.7	31.3	16.5	15.0	0.9	0	121.9
Building (150 lb)	6.6	29.5	41.7	34.7	16.5	15.0	0.9	0	139.5
Building (500 lb)	6.6	30.6	21.9	34.4	30.1	6.7	5.8	5.8	142
Phased									

Operations and MaintenanceVessels	4.2	4.1	4.1	4.0	9.7	9.6	9.5	9.4	54.7
Building (150 lb)	4.2	4.1	4.1	4.0	4.0	4.0	3.9	9.4	37.7
Building (500 lb)	4.2	4.1	4.1	4.0	4.0	4.0	3.9	9.4	37.7
Phased	4.2	4.1	4.1	4.0	6.3	6.1	5.8	5.6	40.3

For the purpose of estimating the regional economic impacts of the two containment alternatives, the analysis illustrates their respective levels of construction and operating expenditures relative to those associated with the No Action Alternative. These estimated costs do not include any site cleanup, nor D&D of the dual-axis facility at the end of its lifetime.

Over the period FY 1996 to FY 2002, the Vessel Containment Option is estimated to generate 321 full-time equivalent jobs in the regional economy, 137 directly related to project construction and operating expenditures, and 185 indirectly generated by consecutive rounds of spending and income generation within the regional economy. This alternative is also estimated to generate an annual average of $6.8 million of regional labor income, $2.9 million directly related to the project, and $3.9 million indirectly generated through consecutive rounds of spending in the regional economy. The alternative is estimated to add an annual average of $12.0 million of goods and services to the regional economy, $6.2 million directly generated by the project, and $5.8 million indirectly generated by consecutive rounds of spending within the regional economy.

Alternatively, the 150-lb (70-kg) Building Containment Option is estimated to generate 209 full-time equivalent jobs in the regional economy, and the 500-lb (230-kg) Building Containment Option is estimated to generate 238 full-time equivalent jobs. Of these totals, for the smaller and larger buildings, respectively, 87 and 99 jobs would be directly accounted for by project construction and operating expenditures. The other 122 or 139 jobs for the two building sizes would be indirectly accounted for by consecutive rounds of regional spending and income generation.

Correspondingly, the Building Containment Option is estimated to add annual averages of $4.5 million and $5.1 million in regional labor income, with $1.9 million and $2.1 million directly related to the project, and $2.6 million and $3.0 million indirectly generated by consecutive rounds of spending in the regional economy. Relative to these impacts, the Building Containment Option is estimated to generate annual averages of $7.6 million [150 lb (70 kg)] and $8.4 million [500 lb (230 kg)] of goods and services in the regional economy, $3.6 million [150 lb (70 kg)] or $4.0 million [500 lb (230 kg)] directly generated by the project, and $4.0 million [150 lb (70 kg)] or $4.4 million [500 lb (230 kg)] indirectly generated through consecutive rounds of spending in the regional economy.

The Phased Containment Option (preferred alternative) involves construction and operation of the DARHT Facility, but with modifications to phase in the containment of airborne emissions of fragments or other debris. The DOE would be expected to complete construction and begin operation of the dual axis facility in FY 1999. During this phase, construction and operations and maintenance costs are similar to the vessel containment option and reflect those of the DARHT Baseline Alternative (table 5-13). These estimated costs do not include any site cleanup, decommissioning, or decontamination of the dual axis facility at the end of its lifetime.

In the period FY 1996 to FY 2002 the preferred alternative is estimated to generate 253 FTE-equivalent jobs in the regional economy, 106 being directly related to project construction and O&M expenditures and the other 147 being indirectly generated by consecutive rounds of spending and income generation within the regional economy.

Corresponding to these employment impacts, the Phased Containment Option (preferred alternative) is estimated to generate an annual average of $5.4 million dollars of regional labor income in the period FY 1996 to FY 2002: $2.3 million being directly related to the project and the other $3.1 million being indirectly generated through consecutive rounds of spending in the regional economy.

Finally, the Phased Containment Option (preferred alternative) is estimated to generate an annual average of $9.0 million dollars of goods and services in the regional economy during the period FY 1996 to FY 2002: $4.4 million of these being directly generated by the project, and the other $4.6 million being indirectly generated by consecutive rounds of spending within the regional economy.

The underlying cost data were provided by LANL (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup nor D&D of either the proposed DARHT or PHERMEX facilities. Those relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.4.7.3 Community Infrastructure and Services

The Enhanced Containment Alternative would not have any significant impact on the existing community infrastructure in the region-of-interest, as described in section 4.7.3.

5.4.7.4 Environmental Justice

Referring to other sections of the EIS, the construction and operation of the DARHT Facility under any of the containment options of the Enhanced Containment Alternative would pose no significant environmental impacts. The foreseeable impacts include fugitive air and noise emissions during facility construction and operations (section 5.3.2), and potential surface or underground water contamination (section 5.3.4). No significant human health impacts appear to exist from either radioactive or hazardous material released or from exposing receptors onsite (workers) or offsite (section 5.1.8). Accordingly, DARHT Facility construction and planned operations under the Enhanced Containment Alternative options would not pose a disproportionate adverse health or environmental impact on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.4.8 Human Health

This section presents the impacts to the health of workers and the public from routine operations that would be conducted at the DARHT Facility under the Enhanced Containment Alternative. Impacts may potentially result from release and atmospheric transport of radioactive and hazardous material from the facility firing site as a result of planned detonations. Methods and assumptions used in calculating potential impacts are described in appendix H, Human Health.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the DARHT site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-7} the dose of depleted uranium for chronic releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose. Potential human health impacts may be *over estimated* by a factor of 100 because of the simplified, elevated point-source atmospheric dispersion model used rather than an explosive atmospheric dispersion model (see appendix H, Human Health). Potential impacts from any uses of plutonium would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.4.8.1 Public

Potential impacts to the MEI were evaluated at three locations in the vicinity of the DARHT site _ Los Alamos, White Rock, and Bandelier. These locations are representative of the neighboring residential clusters in close proximity to LANL. Potential impacts to the surrounding population were also calculated. Potential radiological and nonradiological impacts are presented in the sections below.

5.4.8.1.1 Radiological Impacts

Estimated radiological impacts to the public under the three options would be very similar. The maximum annual dose to any nearby resident under the Vessel Containment, Phased Containment, and Building Containment options would be about 2×10^{-5} rem. Using a risk conversion factor of 5×10^{-4} LCFs per person-rem for members of the public, the estimated maximum probability of a latent fatal cancer would be less than 1×10^{-8} for all three options. The estimated cumulative dose to an individual over the anticipated 30-year life of the project would be about 6×10^{-4} rem under the Phased Containment Option, and about 5×10^{-4} rem under the Vessel Containment and Building Containment options. The estimated maximum probability of a LCF from this cumulative exposure would be about 3×10^{-7} under the Phased Containment Option, and about 2×10^{-7} under the Vessel Containment and Building Containment options.

The annual collective dose to the population of 290,000 individuals living within 50 mi (80 km) of DARHT from the Vessel Containment, Phased Containment, and Building Containment options would be about 0.44, 0.57, and 0.27 person-rem, respectively. No LCFs would be expected among the population from these population doses (2×10^{-4}, 2×10^{-4}, and 1×10^{-4} LCFs, respectively). Over the anticipated 30-year operating life of DARHT, the potential impacts for the Vessel Containment, Phased Containment, and Building Containment options would be about 13, 17, and 8 person-rem, respectively. LCFs would not be expected (6×10^{-3}, 8×10^{-3}, and 4×10^{-3} LCFs, respectively).

5.4.8.1.2 Nonradiological Impacts

Members of the public might also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. Potential impacts from these exposures would be very small under all three options. The maximum probability of a beryllium-induced cancer would be about 1×10^{-11}. Toxicological effects from releases of uranium, beryllium, lead, or lithium hydride would not be expected (maximum Hazard Index of 5×10^{-8}). The probability of a beryllium-induced cancer over the anticipated 30-year life of the project would be about 3×10^{-10}. The maximum Hazard Index expected in the first year immediately after 30 years of operations, accounting for any toxicological effects from buildup of hazardous material in soil, would not exceed 4×10^{-8}. Toxicological effects would not be expected.

Cancers would not be expected in the population in the surrounding 50 mi (80 km) from exposure to beryllium released during a year of normal operations under any of the enhanced containment options. The estimated total incidence would be about 1×10^{-7} under the Vessel Containment and Phased Containment options, and about 5×10^{-8} under the Building Containment Option.

5.4.8.2 Noninvolved Workers

A noninvolved worker is defined as a LANL employee who works in TA-15, but would not be directly involved with the proposed facility operations. Nearby workers not involved with the proposed DARHT detonation process would not likely be affected by detonations occurring within containment. It was assumed that access control would still be in place for the Enhanced Containment Alternative. Uncontained detonations could still occur under this alternative [Vessel Containment and Phased Containment (preferred alternative) options], as well as potential breaches of the containment vessels or releases from the containment building. To evaluate potential impacts from these occurrences, a noninvolved worker is assumed to work continuously 2,500 ft (750 m) distant from the firing site. This distance is based on a hazard radius that would typically be put in place for hydrodynamic test. LANL implements this administrative exclusion area based on explosive safety principles (DOE 1994).

The annual dose to a noninvolved worker is estimated to be about 2×10^{-5} rem EDE under the Vessel Containment and Phased Containment Options and 1×10^{-5} rem under the Building Containment Option. The maximum probability of an LCF from these doses would be about 6×10^{-9} and 5×10^{-9}, respectively. Over the 30-year anticipated operating life of the facility, a noninvolved worker's cumulative dose would be about 5×10^{-4} rem and 4×10^{-4} rem, respectively. The maximum probability of LCF from these doses would be about 2×10^{-7} for both.

A noninvolved worker could also be exposed to heavy metals and other materials released during the detonation, including uranium, lead, beryllium, and lithium hydride. The maximum probability of a beryllium-induced cancer would be about 2×10^{-11} under the Vessel Containment and Phased Containment options and 1×10^{-11} under the Building Containment Option. The probability of a beryllium-induced cancer from exposure over the anticipated 30-year life of the project would be about 5×10^{-10} and 3×10^{-10}, respectively. Toxicological effects from exposure to releases of uranium, beryllium, lead, or lithium hydride would not be expected (maximum Hazard Indexes of 9×10^{-8} and 6×10^{-8}, respectively).

5.4.8.3 Workers

Impacts to workers under the Enhanced Containment Alternative could be somewhat higher than those observed under previous PHERMEX operating experience or projected for the uncontained alternatives because cleanup of contained space (vessels or buildings) could involve exposure to greater quantities and concentrations of materials. The average annual worker dose would probably not exceed 0.020 rem. The maximum probability of LCF from this dose would be 8×10^{-6}. The annual collective worker dose, assuming a maximum of 100 workers, would probably not exceed 2 person-rem. Latent cancer fatalities would not be expected from this dose (8×10^{-4} LCFs). The cumulative worker dose over the assumed 30-year lifetime of the facility would probably not exceed 60 person-rem. Latent cancer fatalities would not be expected from this dose (2×10^{-2} LCFs).

Involved worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable. Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

5.4.9 Facility Accidents

This section presents the impacts from postulated facility accidents involving depleted uranium to individual members of the public, noninvolved workers nearby, and workers at the facility. The bounding accident evaluated under the Enhanced Containment Alternative differed for the Vessel Containment, Phased Containment, and Building Containment options. Under the Vessel Containment and Phased Containment options, the bounding accident is the catastrophic failure of a containment vessel. Under the Building Containment Option, the bounding accident is the cracking and loss of integrity of the containment walls or major failure of the HEPA-filtered overpressure release system. Both of these bounding accidents would result in greater potential consequences to members of the public and noninvolved workers than inadvertent uncontained detonation of a test assembly. This is because the hypothetical release of materials would be at ground level rather than at a higher elevation, resulting in a more dense dispersion plume closer to the ground. The inadvertent detonation would be the bounding accident for workers at the facility. Accident initiation events were not addressed; accidents were simply evaluated on a "what if" basis even though the likelihood of occurrence is very small.

Radiological impacts may result from exposure to depleted uranium and tritium released to the atmosphere from detonations at the DARHT site. Depleted uranium would be the principal contributor to radiation dose; tritium would contribute about 1×10^{-8} the dose of depleted uranium for acute releases. The major exposure pathway would be inhalation of material released to the atmosphere, which would contribute more than 99 percent of the dose.

More detailed results, identification of postulated facility accidents, and methods of analysis are described in greater detail in appendix I, Facility Accidents. Much of the technical basis for the health impact of the accident analysis is included in appendix H, Human Health. Transportation-related accidents are described in section 5.7.

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Any future experiments with plutonium would always be conducted in double-walled containment vessels, and these experiments would not be expected to result in any release of plutonium to the environment. Potential impacts from facility accidents involving any use of plutonium would be essentially the same as for the No Action Alternative, described in section 5.1.9.

5.4.9.1 Public

As in the uncontained alternatives, potential impacts to members of the public were evaluated for three nearby points of public access: State Road 4, Pajarito Road, and the Bandelier National Monument. The MEI would be located at the State Road 4 location, approximately 0.9 mi (1.5 km) southwest of the site. An individual at this location under the assumed accident and exposure conditions would receive a radiation dose of about 0.01 rem EDE under the vessel containment failure scenario and about 0.001 rem under the building containment breach scenario. The maximum probability of a LCF from these doses would be about 6×10^{-6} and 6×10^{-7}, respectively. The maximum probability of beryllium-induced cancers would be about 8×10^{-9} and 8×10^{-10}, respectively. Toxicological effects would not be expected, as no more than 0.2 and 0.02 mg, respectively, of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled. The intakes are less than 2 percent of the IDLH equivalent intake values. Additional results are presented in appendix I, Facility Accidents.

Maximum population dose would occur under the containment vessel breach scenario, in the east-through-southeast direction, with a population dose of about 17 person-rem. Population dose under the building containment breach scenario would be about 1.7 person-rem. Latent cancer fatalities among the population would not be expected from either of these doses (9×10^{-3} and 9×10^{-4} LCFs, respectively). Cancer would not be expected among the population from exposure to beryllium (total incidence of 1×10^{-5} cancers and 1×10^{-6} cancers, respectively).

5.4.9.2 Noninvolved Workers

As in the No Action Alternative, nearby workers not involved with the detonation process would be affected to a lesser extent than involved workers because of their distance from the firing point. Under the Vessel Containment and Phased Containment (preferred alternative) options, access control and other area restrictions would be maintained for planned uncontained detonations that could take place. Other precautions taken under the No Action Alternative would also be maintained. However, for contained detonations, it was assumed that the hazard radius would be lessened, to 1,300 feet (400 m), and that a noninvolved worker would be at this distance and exposed to the material released from the detonation during the entire period of passage.

A noninvolved worker would receive a radiation dose of about 0.05 rem EDE under the vessel containment failure scenario and a dose of about 0.005 rem under the building containment breach scenario. The maximum probability of an noninvolved worker contracting a fatal latent cancer from these doses would be about 2×10^{-5} and 2×10^{-6}, respectively. The maximum probability of beryllium-induced cancers would be about 3×10^{-8} and 3×10^{-9}, respectively. Toxicological effects would not be expected, as no more than 0.7 mg of any of the released constituents (uranium, beryllium, lead, lithium hydride) would be inhaled. The inhalation intakes for LiH is the largest fraction of IDLH equivalent intake values at less than 8 percent. Additional results are presented in appendix I, Facility Accidents.

5.4.9.3 Workers

Impacts to involved workers would differ little from those described under the No Action Alternative in section 5.1.9.3. During completion of DARHT construction and the associated containment building or vessel cleanout facility, normal construction-type hazards would be encountered. During operations, the accident of greatest consequence would be the inadvertent detonation of high explosive on the firing site or in the containment building when workers are present. This accident is considered unlikely, but it could result in the deaths of all workers (a maximum of 15) in the immediate area.

Also, like the No Action Alternative, another possible accident on the firing site with serious consequences outside the scope of normal industrial or laboratory hazards would be the direct exposure of a worker to the ionizing radiation pulse produced by the DARHT accelerator. Although this accident would be extremely unlikely, a worker could receive a very high acute radiation dose, delivered over a fraction of a micro-second, to a localized portion of the body.

5.4.10 Waste Management

Under this alternative, debris from the majority of detonations at the facility would be contained either by vessels or inside a containment building. Volumes of nonhazardous solid waste, solid and liquid hazardous waste, mixed waste, and TRU waste generated under the Enhanced Containment Alternative for the Vessel Containment, Building Containment, and Phased Containment options would be essentially the same as those for the No Action Alternative, described in section 5.1.10. Wastes generated under the Enhanced Containment Alternative, as for other alternatives, would be subject to treatment, storage, and/or disposal in other LANL Technical Areas. Transportation of these wastes would be conducted following DOT guidelines and using DOE- or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

5.4.10.1 Vessel Containment Option LLW

Under the Vessel Containment Option, some uncontained detonations would be conducted, up to 25 percent of total annual depleted uranium expenditures of 1,540 lb (700 kg) or a maximum of 385 lb (175 kg) per year. The total estimated LLW generated and disposed from uncontained detonations would be less than 3,000 ft^3 (90 m^3), based upon a LLW generation rate of 1,800 ft^3 (50 m^3) LLW per 220 lb (100 kg) of depleted uranium used, as developed for the No Action Alternative (section 5.1.10). The bulk of this waste would be the gravel and soil that is removed with the detonation debris. Total volume of waste generated would depend on the number and frequency of the firing-site detonations and periodic cleanup.

For contained detonations, a reasonably predictable amount of waste would be generated each time. For contained major (hydrodynamic) detonation, the waste volume generated would be about 36 ft^3 (1 m^3) or up to five 55-gal drums. Some of the waste would be finely divided debris containing uranium, other metals, and occasionally lead. Much of this material would be separated out in the associated recovery facility and either recovered or disposed of separately, so that a reduced volume of LLW would remain for disposal. Assuming 50 percent recovery or separation of contained detonation material, and 20 major contained detonations per year, no more than 360 ft^3 (10 m^3) of LLW would be generated per year from contained detonations.

Total LLW generation is expected to be no more than 3,600 ft^3 (100 m^3) of LLW per year under the Vessel Containment Option. Assuming the total LANL LLW disposal volume in future years would be 180,000 ft^3yr (5,000 m^3/yr) (Bartlit et al. 1993), the Enhanced Containment Alternative, Vessel Containment Option would be projected to contribute no more than two percent of the total LANL LLW volume.

Given a bounding failure rate of five percent and 20 shots per year, one vessel may be projected to fail each year. The failed vessels would be decontaminated and decommissioned and reused as scrap metal so that they would not enter the waste management program.

5.4.10.2 Building Containment Option LLW

All detonations under the Building Containment Option would be conducted inside the containment building. Under this option, no uncontained detonations would occur, and therefore none of the large volumes of contaminated gravel and soil would be generated from cleaning the firing site of debris. LLW generation would be limited to that from contained detonations. As described above under the Vessel Containment Option, this would typically be no more than about 36 ft^3 (1 m^3) or up to five 55-gal drums per major hydrodynamic detonation. Assuming 50 percent recovery or separation of contained detonation material and 20 major contained detonations per year, no more than 360 ft^3 (10 m^3) of LLW would be generated per year under the Building Containment Option. Assuming the total LANL LLW disposal volume in future years would be 180,000 ft^3/yr (5,000 m^3/yr) (Bartlit et al. 1993), the Enhanced Containment Alternative, Building Containment Option would be projected to contribute no more than 0.2 percent of the total LANL LLW volume.

5.4.10.3 Phased Containment Option LLW

Under the phased Containment Option, the following three distinct phases would occur: 1) containment of 5 percent of the materials used during the first five years of operation, 2) containment of 40 percent of the materials used during the second five years of operation, and 3) beginning in the 11th year of operation, containment of at least 75 percent of the materials used. Under these distinct phases, there would be approximately 12,000 ft^3/yr (350 m^3/yr) of LLW generated during the first 5-year period, approximately 7,500 ft^3/yr (210 m^3/yr) in the second 5-year period, and 3,600 ft^3/yr (101 m^3/yr) during the last 20 years of the design life of the facility. The amount of LLW generated is reduced as the percentage of containment increases due to a lesser volume of soil removal.

Assuming the total LANL LLW disposed volume in future years would be 180,000 ft^3 (5,000 m^3/yr) (Bartlit et al. 1993) the volume of LLW generated under the Phased Containment Option would contribute 7 percent in each of the first five years, 4 percent in each of the second five years, and 2 percent in each of the last 20 years. Again, failed vessels would be decontaminated, decommissioned, and designated as scrap metal.

5.4.11 Monitoring and Mitigation

5.4.11.1 Monitoring

Monitoring under the Enhanced Containment Alternative would be essentially the same as that undertaken for the No Action Alternative, described in section 5.1.11.

5.4.11.2 Mitigation

Under normal operating conditions, two potential impacts would appear to warrant mitigation. Specific actions would be taken to minimize disturbance of the Mexican spotted owls inhabitating Cañon de Valle and Water Canyon near the DARHT site. Noise from construction equipment and activities would be minimized as much as possible. Operational noise from detonations would also be conducted to minimize disturbance. Facility lighting would be placed to direct illumination away from the canyons at night.

Protection of the Nake'muu archeological site may be necessary under certain uncontained detonation test configurations of the Vessel Containment and Phased Containment (preferred alternative) options. Mitigating measures similar to those of the other alternatives (e.g., blast shielding) may be necessary to avoid fragments reaching the site. No other archeological sites in the hazard radius have standing walls that would require mitigation activities. The containment structures used in this alternative would reduce the environmental consequences of operating DARHT and the need for mitigation for detonations performed in containment. Mitigation activities for cultural resources are presented in section 4.6 and 5.11.

5.4.12 Decontamination and Decommissioning

Decontamination and decommissioning under the Enhanced Containment Alternative would be essentially the same as described for the DARHT Baseline Alternative in section 5.2.12. In addition to those D&D activities and impacts, this alternative would result in decommissioning of a containment building and/or an undetermined number of vessels used for a 20- to 30-year design life. However, the amount of soil cleanup would be substantially less (25 to 90 percent) because of containment of wastes within the vessels or building.

5.5 PLUTONIUM EXCLUSION ALTERNATIVE

This section presents the expected environmental consequences associated with the Plutonium Exclusion Alternative.

5.5.1 Land Resources

Potential impacts of the Plutonium Exclusion Alternative on land resources would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.1.

5.5.2 Air Quality and Noise

Potential impacts of the Plutonium Exclusion Alternative on air quality essentially would be the same as those for the No Action Alternative for operations, described in section 5.1.2.1.2, and the DARHT Baseline Alternative for construction activities, described in section 5.2.1.1. Potential noise impacts would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.2.

5.5.3 Geology and Soils

Potential impacts of the Plutonium Exclusion Alternative on geology and soils would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.3.

5.5.4 Water Resources

Potential impacts of the Plutonium Exclusion Alternative on surface and ground water would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.4.

5.5.5 Biotic Resources

Potential impacts of the Plutonium Exclusion Alternative on biotic resources would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.5.

5.5.6 Cultural and Paleontological Resources

Potential impacts of the Plutonium Exclusion Alternative on cultural and paleontological resources would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.6.

5.5.7 Socioeconomic and Community Services

Environmental impacts of socioeconomics and community services for the Plutonium Exclusion Alternative are presented in sections 5.5.7.1 through 5.5.7.4.

5.5.7.1 Demographic Characteristics

The Plutonium Exclusion Alternative would not have any significant impacts on the existing demographic characteristics of communities in the region-of-interest, as described in section 4.7.1.

5.5.7.2 Economic Activities

Under the Plutonium Exclusion Alternative, the DOE would continue operating the PHERMEX Facility on a full-time basis while construction is completed on the DARHT Facility. Once construction of the dual-axis facility is completed, the DOE would begin operating the DARHT Facility on a full-time basis and operate the PHERMEX Facility on only a standby basis. The DOE expects to complete construction and begin operation of the DARHT Facility in FY 1999. At that time the present analysis assumes full-time operation of the DARHT Facility would begin, while full-time operation of the PHERMEX Facility would be scaled back to half time.

Table 5-14 illustrates the combined costs of operating and maintaining PHERMEX along with constructing, operating, and maintaining the DARHT Facility. These combined costs are expressed relative to ones that would be incurred under the No Action Alternative. The estimated costs do not include any site cleanup or D&D of the DARHT or PHERMEX Facilities at the end of their lifetimes. The economic impacts of these expenditures are described in terms of the number of regional jobs, labor income, and goods and services produced in the regional economy.

Table 5-14._*Capital-funded Construction and Operating Costs for*

the Plutonium Exclusion Alternative (in millions of 1995 dollars)

Year/Cost	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Capital	6.6	29.5	17.9	26.8	24.0	0.6	0	0	105.3
Operations and Maintenance	4.2	4.1	4.1	4.0	7.9	7.8	7.8	7.6	47.4

The Plutonium Exclusion Alternative would generate 233 FTE jobs in the regional economy. Of this total, 99 would be directly accounted for by project construction and varying levels of operation and maintenance of the PHERMEX and DARHT Facilities. The remaining 134 FTE jobs would be indirectly accounted for by consecutive rounds of regional spending and income generation.

Correspondingly, the Plutonium Exclusion Alternative is estimated to generate an annual average of $4.9 million in regional labor income. Of this total, $2.1 million is directly related to project construction and facility operation and maintenance. The remaining $2.9 million is indirectly generated by consecutive rounds of spending in the regional economy.

Meanwhile, the Plutonium Exclusion Alternative is estimated to generate a total of $8.6 million of goods and services in the regional economy, with $4.5 million directly accounted for by project construction and facility operations and maintenance. The remaining $4.1 million is indirectly accounted for by consecutive rounds of regional spending and income generation.

5.5.7.3 Community Infrastructure and Services

The Plutonium Exclusion Alternative would not have any significant impact on the existing community infrastructure in the region-of-interest, as described in section 4.7.3.

5.5.7.4 Environmental Justice

The construction and operation of the DARHT and PHERMEX facilities under the Plutonium Exclusion Alternative would pose no significant environmental impacts. The foreseeable impacts include fugitive air and noise emissions during facility construction and operations (section 5.2.2), and potential surface or underground water contamination (section 5.2.4). No significant human health impacts appear to exist from either radioactive or hazardous material release or from exposing receptors onsite (workers) or offsite (section 5.1.8). Accordingly, DARHT Facility construction and planned operations under the Plutonium Exclusion Alternative would not pose a disproportionate adverse health or environmental impacts on minority or low-income populations in the region-of-interest [populations residing within 50 mi (80 km) of the site].

5.5.8 Human Health

Potential impacts of the Plutonium Exclusion Alternative on human health would be essentially the same as for the No Action Alternative, described in section 5.1.8.

5.5.9 Facility Accidents

Potential impacts of facility accidents under the Plutonium Exclusion Alternative would be essentially the same as for the No Action Alternative, described in section 5.1.9.

5.5.10 Waste Management

Potential impacts of the Plutonium Exclusion Alternative on waste management would be essentially the same as for the No Action Alternative, described in section 5.1.10.

5.5.11 Monitoring and Mitigation

Potential impacts that would need to be monitored or mitigated under the Plutonium Exclusion Alternative would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.11.

5.5.12 Decontamination and Decommissioning

Impacts of D&D under the Plutonium Exclusion Alternative would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.12.

5.6 SINGLE AXIS ALTERNATIVE

This section presents the expected environmental consequences associated with the Single Axis Alternative.

5.6.1 Land Resources

Potential impacts on land resources in the Single Axis Alternative would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.1.

5.6.2 Air Quality and Noise

Potential impacts of the Single Axis Alternative on air quality essentially would be the same as the No Action Alternative for operations, described in section 5.1.2.1.2, and the DARHT Baseline Alternative for construction activities, described in section 5.2.1.1.

Potential noise impacts would be essentially the same as for the DARHT Baseline Alternative, described in section 5.2.2.

5.6.3 Geology and Soils

Potential impacts of the Single Axis Alternative on geology and soils would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.3.

5.6.4 Water Resources

Potential impacts of the Single Axis Alternative on surface and ground water would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.4.

5.6.5 Biotic Resources

Impacts on biotic resources in the Single Axis Alternative would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.5.

5.6.6 Cultural and Paleontological Resources

Impacts on cultural and paleontological resources from the Single Axis Alternative would be essentially the same as those for the DARHT Baseline Alternative, described in section 5.2.6.

5.6.7 Socioeconomic and Community Services

Environmental impacts on socioeconomics and community services for the Single Axis Alternative are presented in this section. Potential impacts on demographic characteristics, community infrastructure and services, and environmental justice would be essentially the same as the DARHT Baseline Alternative and are described in sections 5.2.7.1, 5.2.7.3, and 5.2.7.4, respectively. Potential impacts on economic activities are presented below.

5.6.7.1 Economic Activities

Under the Single Axis Alternative, the DOE is expected to complete construction of the facility by FY 1999. At that time, DARHT operating costs would replace PHERMEX operating costs (see table 5-15). For purposes of estimating the impacts of the Single Axis Alternative on the regional economy (employment, labor income, and output), the analysis shows the construction and operating expenditures under the Single Axis Alternative relative to those under the No Action Alternative. The estimated capital construction expenditures do not include any site cleanup nor D&D of the dual-axis facility at the end of its lifetime.

Table 5-15._*Capital-funded Construction and Operating Costs for*

the Single Axis Alternative (in millions of 1995 dollars)

Year/Cost	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**Total**
Capital	6.6	29.5	17.9	5.7	0	0	0	0	59.6
Operations and Maintenance	4.2	4.1	4.1	4.0	5.3	5.2	5.2	5.1	37.2

Over the period FY 1996 to FY 2002, the Single Axis Alternative is estimated to generate 104 FTE jobs in the regional economy, 44 directly related to project construction and operating expenditures, and the other 60 indirectly generated by consecutive rounds of spending and income generation within the regional economy. The Single Axis Alternative is also estimated to generate an annual average of $2.2 million of regional labor income, $0.9 million directly related to the project, and $1.3 million indirectly generated through consecutive rounds of spending. Finally, the Single Axis Alternative is estimated to generate an annual average of $3.8 million of goods and services in the regional economy, $1.9 million of these directly generated by the project, and $1.9 million indirectly generated by consecutive rounds of spending in the regional economy.

The underlying cost data were provided by LANL (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup, nor D&D of either the DARHT or PHERMEX facilities. These relevant data were adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994; Anderson 1995).

5.6.8 Human Health

Potential impacts of the Single Axis Alternative on human health would be essentially the same as those for the No Action Alternative, described in section 5.1.8.

5.6.9 Facility Accidents

Potential impacts of facility accidents under the Single Axis Alternative would be essentially the same as those for the No Action Alternative, described in section 5.1.9.

5.6.10 Waste Management

Potential impacts of the Single Axis Alternative on waste management would be the same as those for the No Action Alternative, described in section 5.1.10.

5.6.11 Monitoring and Mitigation

5.6.11.1 Monitoring

Potential impacts that would need to be monitored under the Single Axis Alternative would be the same as those for the No Action Alternative, described in section 5.1.11.

5.6.11.2 Mitigation

Mitigation measures taken under the Single Axis Alternative would be the same as those for the DARHT Baseline Alternative, described in section 5.2.11.2.

5.6.12 Decontamination and Decommissioning

Potential impacts of D&D under the Single Axis Alternative would be essentially the same as under the DARHT Baseline Alternative, described in section 5.2.12, except that there would be only one accelerator hall and support equipment for D&D evaluation.

5.7 TRANSPORTATION OF MATERIALS

This section presents the results of an analysis of incident-free (routine operations) and accident consequences associated with transportation of materials, details of which are given in appendix J, Transportation of Materials. For purposes of this EIS, one transportation analysis applies to the No Action Alternative and the Upgrade Alternative (associated with PHERMEX); another analysis applies to the remaining alternatives (associated with DARHT).

All transportation would be in LANL-controlled areas. The analysis presented in appendix J is based on the assumption that the test device would be secured to a flat-bed truck and transported to the receiving facility. The assembled test device would be transported from TA-16-410 to the PHERMEX or the DARHT Facility using roads internal to TA-16 and TA-15 (see figure 3-1). The truck would be loaded at TA-16-410 and transported nonstop approximately 4.7 mi (7.5 km) to the magazine (Building R_242). From the magazine, the test device would be transported nonstop approximately 1.2 mi (2 km) to the PHERMEX gate or 0.9 mi (1.5 km) to the DARHT gate. At each of the facilities, the test device would be transported approximately 1,000 ft (300 m) from the facility gate to the firing site. Because the total distances are so similar, less than 0.3 mi (0.5 km) difference, the longer distance to PHERMEX is used for data presented here.

For purposes of this analysis, 20 shipments per year were assumed. Although 150 lb (70 kg) high explosive is the normal maximum at the firing points, three hypothetical test devices were assumed for analysis to cover a range of high explosive content, including the maximum sizes for the firing points, 500 lb (230 kg) (see sections 3.4.2 and 3.5.2). The three hypothetical test devices are: Test Device 1 with 22 lb (10 kg) high explosive, Test Device 2 with 500 lb (230 kg) high explosive, and Test Device 3 with 1,010 lb (460 kg) high explosive.

Contrary to intuition, Test Device 1 would produce the worst-case worker doses because the device materials would be less dispersed in an accidental explosion. The worst-case results, Test Device 1, are presented in this section unless otherwise stated.

5.7.1 Incident-free Transportation

Potential impacts of routine transportation are discussed in the following sections.

5.7.1.1 Nonradiological Impacts

Nonradiological impacts of routine transportation would result principally from pollutants emitted from the vehicles. The estimated number of fatalities due to vehicle emissions from routine transportation was found to be essentially zero (2.4×10^{-4} LCFs over the life of the project).

5.7.1.2 Radiological Impacts

Radiological doses to the truck crew, onsite workers, and the public, resulting from transportation activities, were calculated using methods described in appendix J, Transportation of Materials. Results of the analysis are provided in table 5-16. The calculated dose is based on 20 shipments per year. The dose to truck crews over the life of the project would be about 1×10^{-4} person-rem. The calculated dose to the public over the life of the project would be less than 3×10^{-9} person-rem. The total dose to the onsite worker population over the life of the project for the No Action Alternative would be about 0.004 person-rem.

Table 5-16._*Summary of Analyses for Routine Transportation*

for the No Action Alternative and DARHT Baseline Alternative

Population Group[a]	**Per Shipment**		**Annually**	
	Radiological Dose (person-rem)	**Health Effects (LCFs)**	**Radiological Dose (person-rem)**	**Health Effects (LCFs)**

Radiological Impacts[b] Truck Crew Onsite Worker Total	6×10^{-6} 2×10^{-4} 2×10^{-4}	2×10^{-9} 7×10^{-8} 7×10^{-8}	1×10^{-4} 3×10^{-3} 4×10^{-3}	4×10^{-8} 1×10^{-6} 1×10^{-6}
Nonradiological Impacts Onsite Worker		4×10^{-7}		8×10^{-6}
Total Radiological and Nonradiological Impacts Truck Crew Onsite Worker	6×10^{-6} 2×10^{-4}	2×10^{-9} 5×10^{-7}	1×10^{-4} 3×10^{-3}	4×10^{-8} 9×10^{-6}

[a] The calculated dose to the public is less than 1×10^{-10} person-rem and for this analysis is considered essentially zero.

[b] The maximum individual in-transit dose is 6×10^{-9} person-rem per shipment. Truck crew doses

for the DARHT Baseline Alternative are slightly lower.

The potential LCFs were calculated using dose conversion factors given in ICRP 60 (ICRP 1991), i.e., 0.0004 LCFs/person-rem to the onsite worker and truck crew and 0.0005 LCFs per person-rem to the general public, respectively. Cancer would not be expected to occur for the life of the project (workers and crew, 2×10^{-6} LCFs; onsite worker, 5×10^{-5} LCFs; public, less than 4×10^{-11} LCFs).

5.7.2 Impacts of Transportation of

Materials Under Accident Conditions

Potential impacts of transportation of materials under accident conditions are discussed in the following subsections. If an accident occurs, the resulting debris and contamination, if any, would be removed and taken to appropriate LANL facilities as is done for firing-point debris.

5.7.2.1 Nonradiological Impacts

Transport vehicle speed is limited to 35 mph; therefore, vehicle collisions with other vehicles on the transportation route are not considered severe enough to cause fatalities to the truck occupants or occupants of the other vehicles involved in the accident. For the purposes of the analysis in appendix J, the transport vehicle is assumed to impact a stationary object with sufficient force to detonate the high explosive.

Impacts due to explosions are modeled based on accidental detonation of high explosive in each of the hypothetical test devices. Assuming that a peak overpressure of 30 psi (186 kpa) is fatal, all individuals within an approximate radius of 15 ft (5 m), 43 ft (13 m), and 53 ft (16 m) for test devices 1, 2, and 3, respectively, would be subjected to potentially fatal overpressures. The truck crews are assumed to be located within 30 ft (10 m) of the accident. Additionally, approximately 50 percent of the individuals at distances up to 80 ft (24 m) might be killed because of the blast wave. Injuries and fatalities to bystanders from flying shrapnel have not been estimated. There have been no such transportation accidents during more than 30 years of firing activities at TA-15.

In addition to evaluating the impacts from a detonation of the high explosives, an assessment of the consequences of a release of the hazardous materials associated with the devices was performed. It was assumed that 10 percent of the material released would be respirable (see appendix C). The results, based on the meteorological data for the LANL site, are shown in table 5-17. For comparison, although plume passage times are very short in duration, the IDLH exposure limits are also provided in table 5-17.

Table 5-17._*Nonradiological Transportation Accident Impacts to the Public*

Population Group	**Beryllium** (**mg/m^3**)	**Lead** (**mg/m^3**)	**Lithium Hydride** (**mg/m^3**)

Allowable Limit[a]	10	700	55
Onsite Worker[b]	1.2×10^{-4}	1.9×10^{-4}	1.2×10^{-3}
Offsite Individual[c]	1.1×10^{-4}	1.7×10^{-4}	1.1×10^{-3}

[a] IDLH limits taken from NIOSH 1990.

[b] Assumed to be located 0.5 mi (0.75 km) northwest.

[c] Assumed to be located 1 mi (1.5 km) southwest.

5.7.2.2 Radiological Impacts

The analyses of radiological impacts evaluates the impacts to MEI and the public because of a release of radioactive material. The analysis is based on the assumption that the transport vehicle would impact a stationary object, and the high explosive would be detonated. The accident rate used, about 4 accidents per 10 million mi (2 accidents per 10 million km) (Saricks and Kvitek 1994), is a combination of accident rates for rural and urban federally aided highway systems.

Radiological doses were calculated for two population densities of interest [i.e., laboratory open space, about 5 workers/0.4 mi^2 (1 km^2); and occupied buildings, about 360 workers/0.4 mi^2 (1 km^2)]. It was assumed that 10 percent of the material aerosolized was respirable. The calculated dose, on a per shipment basis, to the two populations is estimated to be 0.2 person-rem and 17 person-rem, respectively. The integrated risk to the public (i.e., consequences times accident frequency integrated over the entire shipping distance) was estimated to be less than 1×10^{-4} person-rem.

Table 5-18._***Radiological Accident Impacts***

to the Maximally Exposed Individuals

Receptor	**Radiological Dose per Accident (rem)**
Maximum Onsite Worker[a]	4.1×10^{-4}
Maximum Offsite Individual[b]	2.4×10^{-4}

[a] Assumed to be located 0.5 mi (0.75) km northwest.

[b] Assumed to be located 1 mi (1.5) km northwest.

Radiological doses were also calculated for the MEI, located about 300 ft (100 m) from the release, the onsite MEI, located at the nearest occupied facility, and the offsite MEI, located at the site boundary. For this analysis, based on the location of the site boundary and the nearest public roadway, and the meteorological data, the offsite MEI was assumed to be located approximately 0.9 mi (1.5 km) to the northwest. The onsite MEI is assumed to be located 2,500 ft (0.75 km) to the northwest. The results of the radiological analyses for the MEI are presented in table 5-18.

The largest dose among the groups investigated was calculated to be to the onsite worker and amounted to 4.1×10^{-4} rem. The dose to the offsite MEI would be 3.7×10^{-4} rem. The maximum probability of LCF from this dose would be about 2×10^{-7} for both the onsite worker and the offsite individual. The dose to the individual at 300 ft (100 m) was calculated to be essentially zero; the radioactive cloud was lofted well above and over the individual.

5.8 UNAVOIDABLE ADVERSE IMPACTS AND IRREVERSIBLE AND/OR IRRETRIEVABLE COMMITMENT OF RESOURCES

The following subsections address unavoidable adverse environmental impacts and irreversible and/or irretrievable commitment of resources.

5.8.1 Unavoidable Adverse Impacts

Potentially unavoidable adverse impacts associated with the No Action Alternative, DARHT Baseline Alternative, Upgrade PHERMEX Alternative, Plutonium Exclusion Alternative, and Single Axis Alternative were identified as follows:

_ Contaminating soils with various materials, including depleted uranium, beryllium, lead, copper, aluminum, and other metals within approximately 460 ft (140 m) of the firing point during testing

_ Disturbing wildlife as a result of blast noise from detonation of high explosives. DOE and the USFWS have negotiated to reduce noise impacts to any threatened or endangered species in the vicinity of the DARHT and PHERMEX facilities (see section 5.11).

_ Initiating small fires as a result of explosives testing.

Unavoidable adverse impacts identified with the Enhanced Containment Alternative would be limited to destruction of a small amount [about 0.25 ac (0.1 ha)] of piñon/ponderosa pine forest habitat for the construction of the cleanup/recycle facility. Any tests which are uncontained may result in the same unavoidable adverse impacts listed above.

5.8.2 Irretrievable and/or Irreversible Commitment of Resources

Irretrievable and/or irreversible commitment of resources associated with the various alternatives are presented in table 5-19.

Table 5-19.*_Irreversible and/or Irretrievable Commitment of Resources*

Factor	**No Action[a] Alternative**	**DARHT Baseline Alternative**	**Upgrade PHERMEX[e] Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative** **Single Axis Alternative**
				Vessels[b]	**Building[c]**	**Phased[d]**		
CONSTRUCTION	15,000	15,000	28,000	16,000	22,000	16,000	15,000	15,000
Construction Materials	4,500	4,500	9,000	5,100	7,100	5,100	4,900	4,900
Concrete (yd^3)	600	600	1,000	600	900	600	600	600
Cement (tons)	9,500	11,500	17,000	12,500	18,500	12,500	11,500	11,500
Rebar (tons)	9,500	11,500	17,000	12,500	18,500	12,500	11,500	11,500
Fuel	9,500	11,500	17,000	12,500	18,500	12,500	11,500	11,500
Diesel (gal)	365,000	365,000	750,000	365,000	450,000	365,000	365,000	365,000
Gasoline (gal)	50	59	120	74	140	74	59	59
Propane (lb)	12	14	29	18	26	18	14	14
Electricity (kWh)	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max. 15/day	max.	max. 15/day	max. 15/day
Work Force (worker years)	14.5	14.5	14.5	14.5	30.0	15/day	14.5	14.5
Craft						14.5		
Noncraft								
Project Management (people)								
Waste Disposal Costs								
($ thousands)								

TOTAL COSTS ($ millions)	49	123	145	154	159	154	123	85
(construction and equipment)								
OPERATIONS	40,000	70,000	70,000	110,000	110,000	100,000	100,000	60,000
Materials Used (Annual)	6,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Water (gal)	3,100	0	0	0	0	0	0	0
Helium (ft^3)	8,700	10,400	13,000	13,300	14,800	12,600	10,400	10,400
Sulfur Hexafluoride (ft^3)	550,000	2,250,000	2,500,000	2,600,000	2,900,000	2,520,000	2,250,000	1,350,000
Energy (Annual)								
Natural Gas (ft^3)								
Electricity (kWh)								

Table 5-19._*Irreversible and/or Irretrievable Commitment of Resources _ Continued*

Factor	**No Action[a] Alternative**	**DARHT Baseline Alternative**	**Upgrade PHERMEX[e] Alternative**	**Enhanced Containment Alternative**				**Plutonium Exclusion Alternative** **Single Axis Alternative**
				Vessels[b]	**Building[c]**	**Phased[d]**		
Work Force, (worker years)	9	15	15	24	24	22	20	13
Radiation-trained workers	5	5	5	5	5	5	5	5
Support staff	4.2	6.5	6.5	10.4	10.4	7.5[g]	6.5	5.4
Operating Costs per Year	1,540	1,540	1,540	1,540	1,540	9.5[h]	1,540	1,540
($ millions)	20	20	20	20	20	10.4[i]	20	20
Material Usage	30	30	30	30	30	1,540	30	30
Depleted Uranium (lb)	220	220	220	220	220	20	220	220
Beryllium (lb)	440	440	440	440	440	30	440	440
Lead (lb)	3,300	3,300	3,100	3,300	3,300	220	3,300	3,300
Copper (lb)	3	3	3	3	3	440	3	3
Other Metals (lb)[f]	220	220	220	220	220	3,300	220	220
High Explosive (lb)						3		
Tritium (Ci)						220		
Lithium Hydride (lb)								

[a] No construction at PHERMEX; however, construction at proposed DARHT site to complete building for nonhydrodynamic testing purposes.

[b] DARHT Facility plus vessel cleanout facility.

[c] DARHT Facility plus vessel cleanout facility and containment building.

[d] For operations, represents the annual average over the 30-year operating life. The Phased Containment Option of the Enhanced Containment Alternative is divided into three distinct phases of operation: 1) the first five years of operation are marked by 5 percent containment, 2) the second five years of operation are marked by 40 percent containment, and 3) the final phase beginning in the 11th year of operation is marked by 75 percent containment.

[e] New construction at PHERMEX plus DARHT construction noted in footnote a.

[f] When referring to PHERMEX, "other metals" means the sum of all aluminum, boron, brass, iron, inconel, niobium, nickel, silver, tin, tantalum, titanium, tungsten, and vanadium used during each year.

[g] FY 1999 _ 2002

[h] FY 2003 _ 2007

[i] FY 2008 and beyond

5.9 CUMULATIVE IMPACTS

The following discussion of cumulative impacts addresses the potential for impacts that are insignificant, when viewed separately, but may become significant when viewed together. Cumulative impacts include impacts on the affected environment of the proposed activities over the life of the project, in addition to past and reasonably foreseeable future activities, whether onsite or offsite and public or private. The only measurable cumulative impacts are those discussed in this section.

As currently projected for the foreseeable future, concentrations of metal contaminants (depleted uranium, beryllium, lead, and other metals) in soil would approximately double for the TA-15 PHERMEX test area under the No Action Alternative or the Upgrade PHERMEX Alternative. For the DARHT Baseline Alternative, Plutonium Exclusion Alternative, and the Single Axis Alternative, an area equivalent to that of the PHERMEX test area would be contaminated at the DARHT test site to approximately the current level of the PHERMEX test area. In the Enhanced Containment Alternative, if the vessel approach were used for uncontained tests, the DARHT test site would be contaminated to approximately 10 percent of the current contamination level of the PHERMEX test area. All of these areas could in time (centuries to millennia) contribute to contamination of ground water; however, the contamination levels were estimated through model simulations over 30 years and were found to be lower than drinking water standards. LANL has contaminated soils in other areas that might contribute to ground water contamination. Although these other potential sources have not been quantified, the contribution of any of the alternatives is not expected to increase the cumulative effects to ground water.

Collective worker dose for the LANL site for 1993 amounted to 239 person-rem, with approximately 0.3 person-rem attributable to testing at the PHERMEX Facility. Because the future testing program is expected to be roughly the same under all alternatives, and worker dose is related to operations, worker dose would be expected to be roughly the same 0.1 percent regardless of the alternative analyzed. Testing at PHERMEX or DARHT would be expected to contribute the same, about 0.1 percent, to LANL worker dose and would be inconsequential in terms of cumulative impacts.

Collective dose for the population within 50 miles (80 km) of the LANL site was 1.4 person-rem for 1992. Under the various hydrodynamic testing alternatives addressed here, the collective dose would be expected to range from 0.13 to 0.32 person-rem/yr. Thus, at a maximum for foreseeable conditions, hydrodynamic testing at TA-15 would continue to contribute roughly 10 to 25 percent of the reported collective population dose from LANL operations. Assuming the last 32 years of hydrodynamic testing to have resulted in about 10 person-rem and that an additional 30 years would double that, the cumulative collective dose from hydrodynamic testing at LANL would be about 20 person-rem out of an approximate 90 person-rem for all site sources (based on constant 1992 level). Cancer would not occur from such a cumulative collective dose since the calculated risk is 0.05 LCFs. The annual collective population dose for the same population from natural background radiation would be about 110,000 person-rem/yr. Hence, over the 30-year period, the collective population dose from natural background radiation would be about 3,200,000 person-rem, for which, using the same conversion factor, about 1,600 LCFs would be inferred.

5.10 IMPACTS ON LONG-TERM PRODUCTIVITY

This section addresses the relationship between short-term uses of the environment and the maintenance of its long-term productivity.

Based on the analyses performed in this EIS, impacts on long-term productivity at Area III of TA-15 would be limited to consequences of deposition of depleted uranium and other metals on the soils of the site from continued testing and the potential of such metals for affecting the piñon/ponderosa pine forest habitat. However, no adverse effects on the piñon/ponderosa pine forest habitat over the last 32 years of operations similar to those proposed have been observed. Therefore, no impacts are expected on long-term productivity of the site from implementation of any of the alternatives.

5.11 MITIGATION MEASURES

One purpose of an EIS is to identify measures that could be taken to mitigate any adverse impacts that are disclosed through the impact analysis. Mitigation measures can be those that are required by law or regulation, those that are built into a project from the start, or those that are developed in response to adverse effects identified in the impact analysis. This section summarizes the mitigation measures that might be applied for any alternative analyzed in this EIS. Mitigation measures required by law or regulation are not discussed in this section. Routine mitigation measures that would be taken as part of standard operating practices for construction or operation, such as providing silt fences around the construction site to reduce soil transport or operating sirens to warn personnel and wildlife of tests, are not included.

The mitigation measures discussed here are of three types. Some are common to all alternatives analyzed. Others are engineered design features that have been made part of the DARHT Facility, and would be common to all alternatives that would use that facility (all alternatives except the No Action and Upgrade PHERMEX alternatives). The third type are those that were identified for a specific alternative. Although these are included earlier in this chapter under each alternative, they are summarized here.

5.11.1 Mitigation Common to All Alternatives

Some mitigation measures would apply to all alternatives, regardless of what course of action the DOE would select. References to the DARHT Facility would apply to actions taken to complete the building for other uses as well as actions taken to complete the DARHT Facility for the proposed use.

_ DOE will continue to consult with the four Accord tribes (Cochiti, Jemez, Santa Clara and San Ildefonso Pueblos) to ensure protection of cultural resources in the vicinity of the DARHT and PHERMEX sites (section 4.6.3), and will periodically (at least once a year) arrange for Tribal officials to visit cultural resource sites within TA-15 that are of particular interest to the Tribes.

_ Evaluation of cultural resources in the vicinity of TA-15 will be coordinated with the New Mexico State Historic Preservation Officer for concurrence of eligibility determinations and potential effects (see section 4.6.1).

_ DOE will periodically (at least once a year) pick up metal fragments in the area, and will invite the local tribes to participate so that they can observe whether there has been damage to any cultural resource sites.

_ DOE will develop a way, possibly in conjunction with the State Historic Preservation Officer, the National Park Service, or the local Tribal governments, to periodically photograph or otherwise record the condition of the Nake'muu ruin to determine if activities at TA-15 are causing any structural changes to the ruin over time.

_ DOE and LANL have developed a Storm Water Pollution Prevention Plan for the DARHT Facility which was implemented before construction activities began. The plan includes measures for erosion control, sedimentation control, surface restoration and revegetation, storm water retention, and a general housekeeping plan (see appendix K).

_ DOE and LANL will develop a habitat management plan for all threatened and endangered species occurring throughout LANL. This plan would be used to determine long-range mitigation actions to protect the habitat for these species (see appendix K).

_ DOE and LANL will take specific mitigation actions to protect the nesting habitat of the Mexican spotted owl, such as not disturbing habitat within 0.25 mi (0.4 km) of known nesting habitat (see appendix K).

_ Construction activities will be restricted at the DARHT site during the breeding season for the Mexican spotted owl (March 1 to August 31). These measures include limits on light sources, noise, and restricted access for personnel and equipment (see appendix K).

_ To protect the habitat for many wildlife species, including Mexican spotted owls, raptors, and salamanders, DOE will not remove trees or dead snags without contacting the LANL ecological studies team (see appendix K).

_ To protect the habitat for many wildlife species, including threatened and endangered species, LANL ecological studies team will conduct field surveys to check for the presence of these species prior to site activities such as collecting metal fragments; an appropriate vegetation buffer zone will be maintained between facilities and the canyon rims to minimize erosion from site activities (see appendix K).

_ Native trees will be planted, as appropriate, for erosion control and landscaping to provide additional wildlife habitat (see appendix K).

_ Waterflow from the facilities will be monitored to ensure compliance with permitted outfalls (see appendix K).

_ Any permanent or temporary fencing or other barriers will be constructed so as to minimize the effects on large mammal and predator species movements (see appendix K).

_ The LANL ecological studies team will collect baseline data on any contaminants present, and will monitor contaminants by sampling soils, plants, animals, and roadkill at the TA-15 facilities.

_ Construction noise would be minimized as much as possible to mitigate adverse impacts to site workers and the general public.

5.11.2 Mitigation by Engineered Design Features

These mitigation measures have been engineered into the DARHT Facility. The facility was designed and (partially) constructed to incorporate many features that would limit potential adverse environmental impacts.

_ Orienting the two accelerator halls of the DARHT Facility to provide a "blast shadow" to minimize the possibility of flying fragments reaching the Nake'muu ruin.

_ Providing radiation shielding around the accelerators to limit radiation exposure to workers in the facility.

_ Construction of an earthen berm to limit radiation exposure beyond the firing site.

_ Providing spill containment (physical barriers or sills) inside the facility, with sufficient capacity to contain all hazardous material spills that could conceivably occur in the facility.

_ The DARHT site layout includes mitigation to specific cultural resource sites. The access road was routed to avoid two cultural resource sites, and the sites were fenced to protect them from disturbance during construction. At the request of the San Ildefonso Pueblo, a third site was capped and covered by the earthen radiation shielding berm instead of excavating the site. See section 4.6.1.

5.11.3 Mitigation By Alternatives

For the DARHT Baseline Alternative and all alternatives that would involve operating the DARHT Facility (all alternatives except the No Action Alternative and the Upgrade PHERMEX Alternative), glass plates, sandbags, or other shielding material would be used for mitigation during large uncontained shots to:

_ Deflect metal fragments and protect cultural resource sites from being reached by flying shrapnel

_ Break up fragments, buffer noise, and limit contaminant releases to the Mexican spotted owl habitat

For the Enhanced Containment Alternative the following mitigation measures would apply.

_ The method of enhanced containment, under the Building Containment, Vessel Containment, or Phased Containment options, would mitigate soils contamination and other adverse impacts from flying shrapnel for those tests that would be contained.

_ Under any option, the cleanout facility would mitigate adverse impacts from cleaning out the containment vessel or building by means of recycling materials and the processes used. See section 3.7.1.3.

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CHAPTER 6

REGULATORY REQUIREMENTS

This section discusses the significant Federal, State, and local permit and approval requirements required for construction and operation of the DARHT Baseline Alternative and the other analyzed alternatives. Names of outside agencies and individuals contacted during preparation of the draft EIS are also included.

6.1 RADIOACTIVE AIR EMISSIONS

Radioactive emissions from LANL facilities are subject to the Environmental Protection Agency (EPA) National Emission Standards for Hazardous Air Pollutants at 40 CFR Part 61. In particular, Subpart A, "General Provisions," and Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities," are applicable. Emissions of radionuclides to the ambient air from a DOE facility are not to exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr [40 CFR 61.92]. DOE submitted an application to construct the DARHT Facility, as described in the DARHT Baseline Alternative, to the Region VI Office of EPA in 1988. In a letter to DOE, dated August 2, 1988, that approved the construction, EPA determined the projected dose to the nearest offsite resident from DARHT operations and other activities conducted at LANL would be well within the 10 mrem/yr standard.

Subpart H of 40 CFR Part 61 [40 CFR 61.93] prescribes emission monitoring and test procedures to determine compliance with the 10 mrem/yr standard at DOE facilities. By letter dated June 25, 1991, DOE informed EPA that LANL was not in full compliance with Subpart H. Although DOE monitors LANL's radionuclide emissions, LANL's monitoring program does not meet the requirements of Subpart H. EPA subsequently issued a Notice of Noncompliance to DOE on November 27, 1991. Shortly thereafter DOE and EPA entered into discussions to execute a Federal Facilities Compliance Agreement to bring LANL into compliance. The EPA issued the draft agreement for public comments on June 5, 1995 [60 FR 29594]; the comment period closed on August 4, 1995. Although the Agreement has not yet been finalized, DOE has been working in the interim to bring sources which emit radionuclides into compliance. The source that emits 95 percent of the radionuclides at LANL, the Los Alamos Meson Physics Facility, is in full compliance, and DOE anticipates full compliance for all sources by the end of 1997. On September 13, 1994, the Concerned Citizens for Nuclear Safety brought a civil action against DOE under the Clean Air Act to enforce the 40 CFR Part 61 requirements at LANL. That matter is still in litigation.

6.2 NONRADIOACTIVE AIR EMISSIONS

Nonradioactive emissions from LANL facilities are subject to the regulatory requirements of the New Mexico Environment Department (NMED) established under the New Mexico Air Quality Control Act. The NMED Air Quality Control Regulation requires a permit for constructing stationary sources or modifying existing sources in the event that the source would have potential emission rates greater than 10 lb/h (4.54 kg/h) or 25 ton/yr (22.67 metric ton/yr) of any regulated air contaminant subject to a Federal or New Mexico ambient air quality standard [NMED Air Quality Control Regulations §702 Part Two.A(1)]. The PHERMEX Facility has not been subject to this requirement because its construction and operation preceded the effective date of §702 Part Two. The DARHT Baseline Alternative and the alternatives other than the No Action Alternative could be subject to the §702 Part Two permit requirement if they are classified as new stationary sources or modified stationary sources. The NMED regulations give a research facility, such as LANL, the opportunity to group its sources for the purposes of §702 at NMED's discretion [NMED Air Quality Control Regulations §702 Part One.33]. Consequently, the DARHT Facility could potentially be grouped with PHERMEX and not classified as a new stationary source. The DARHT Facility would be a "modification" to the PHERMEX Facility if 1) potential emissions of any regulated air contaminant increase in the event that DARHT became operational and PHERMEX were closed, or 2) new contaminants would be emitted by the DARHT Facility [NMED Air Quality Control Regulations §702 Part One.19].

NMED regulations also require a permit prior to the construction of new or modified sources with potential emissions of toxic air pollutants exceeding specified quantities [NMED Air Quality Control Regulations §702 Part Three.C]. The term *new source* is defined to be any source for which construction commenced after 1988, but not including any new source which is integrally related with and connected to the process of an existing source [NMED Air Quality Control Regulations §702 Part Three.B.(4)]. All alternatives analyzed except the No Action and PHERMEX Upgrade alternatives are, consequently, potentially subject to the permit requirement. However, the rule exempts from the permitting requirements activities such as those analyzed in this EIS (except for the Enhanced Containment Alternative) which are classified as "non-process fugitive emissions of toxic air pollutants from stationary sources" [NMED Air Quality Control Regulations §702 Part Two.C(3)(j)]. The Enhanced Containment Alternative, if implemented, would not be automatically exempt from the air toxic permit requirements since emissions from containment structures would pass through a vent and, therefore, not be classified as *fugitive emissions* under the definition of this term in §702 Part One.16. Appendix A to §702 Part Three of the NMED Air Quality Control Regulations contains the threshold quantity emission limits that would trigger the need for a toxic air emissions permit. The air pollutants from the alternatives under consideration with the greatest likelihood of triggering the permit requirement are uranium and lithium hydride. Appendix A specifies that a permit would be needed if emissions of natural uranium exceed 0.0133 lb/h (6 g/h) and emissions of lithium hydride exceed 0.00167 lb/h (0.76 g/h). (The DARHT Baseline Alternative and the alternatives use depleted uranium; however, the toxicity of depleted uranium is similar to natural uranium.)

If the Enhanced Containment Alternative were to be implemented, a vessel cleanout facility would be built to handle the debris resulting from cleaning the containment structure or vessels after each use. Air emissions for this facility are not currently defined. The need for an emissions permit under §702 will be evaluated when information becomes available.

NMED regulations require owners of sources with potential emissions greater than 10 ton/yr (9.1 metric tons/yr) of any regulated contaminant or 1 ton/yr (0.91 metric tons/yr) of lead to file a Notice of Intent with NMED, whether or not a permit is required, as a condition of construction [NMED Air Quality Control Regulations §703.1 Part Two.A]. Emissions from the DARHT Baseline Alternative or the other alternatives would be within these levels; consequently, a Notice of Intent would not be needed.

All of Los Alamos County has attainment status for the National Ambient Air Quality Standards listed at 40 CFR Part 50. Consequently, a written determination indicating that implementing any alternative analyzed in this EIS would conform to the New Mexico State Implementation Plan does not need to be prepared [20 New Mexico Administrative Code 2.98(2)]. Major new sources of pollutants in attainment areas are subject to prevention of significant deterioration (PSD) permit requirements. None of the alternatives analyzed would by themselves trigger the need for a PSD permit because they are not *major stationary sources* (as that term is defined in the NMED Air Quality Control Regulations §707.P.26) of regulated air pollutants. Projected emissions from any alternative selected for implementation would be combined with other emissions from LANL to determine whether total sitewide emissions would trigger the need for a sitewide PSD.

The DARHT Baseline Alternative and the other alternatives would not be included within the source categories subject to new source performance standards [NMED Air Quality Control Regulations §750].

Emissions of hazardous air pollutants from the DARHT Baseline Alternative or its alternatives would be less than 10 tons/yr (9.1 metric tons/yr) for a single hazardous air pollutant and 25 tons/yr (22.7 metric tons/yr) for any combination of two or more hazardous air pollutants. Consequently, the DARHT Baseline Alternative and the other alternatives would not be major sources of hazardous air pollutants subject to the requirements covering the construction or modification of major sources of hazardous air pollutants at 20 New Mexico Administrative Code 2.83.

Nonradioactive emissions from implementing the DARHT Baseline Alternative or another alternative would eventually be covered in an operating permit issued under NMED Air Quality Control Regulations §770 for the entire LANL site. DOE expects to submit an operating permit application to NMED in late 1995.

6.3 LIQUID DISCHARGES TO SURFACE WATER AND THE GROUND

The three sources of liquid discharges from the DARHT Baseline Alternative and all but the No Action Alternative are cooling tower blowdown, septic tank sanitary waste effluent, and storm water runoff. Although these sources would discharge to the ground, the discharges may enter Water Canyon, an ephemeral tributary to the Rio Grande. The State of New Mexico Environmental Improvement Division issued DOE a septic tank permit (number SF890589) for the DARHT Facility on October 30, 1989. Other septic tank permits have been issued for the Radiographic Support

Laboratory and the PHERMEX Facility. EPA issued to LANL on December 29, 1994, a National Pollutant Discharge Elimination System (NPDES) permit (number NMR10A236) covering storm water discharges from construction activity at the DARHT site. A storm water pollution prevention plan for the construction activity was completed and implemented. The cooling tower blowdown from the DARHT Baseline Alternative would have an average flow of 2,000 gal/d (7,600 L/d). This discharge is incorporated into the LANL sitewide NPDES permit (permit number NM0028355) issued to DOE and LANL by EPA Region VI on June 24, 1994.

6.4 CHEMICAL AND MATERIAL STORAGE

Chemical and material storage at a LANL facility would be conducted according to DOE Orders and Manuals. In particular, DOE Orders 5480.4 (Environmental Protection, Safety, and Health Protection Standards) and 5480.7A (Fire Protection) require compliance by DOE and its contractors with National Fire Protection Association Codes and Standards, the Occupational Safety and Health Standards at 29 CFR Part 1910 established by the Occupational Safety and Health Administration (OSHA), and the DOE Explosives Safety Manual. In addition, DOE rules in 10 CFR Part 835 establish radiation protection standards and program requirements to protect occupational workers at DOE facilities.

6.5 WASTE MANAGEMENT

If implemented, the DARHT Baseline Alternative or the other alternatives would produce five categories of regulated waste: solid waste, hazardous waste, mixed radioactive and hazardous waste (mixed waste), low-level radioactive waste, and TRU waste.

Solid waste that is not classified under Subtitle C of the Resource Conservation and Recovery Act (RCRA) as a hazardous waste would be disposed at the LANL Area J landfill in TA-54 or sent offsite to an approved disposal facility. The Area J landfill is operated according to the requirements in Subtitle D of RCRA, the New Mexico Solid Waste Act, and regulations issued under each Act.

Waste that is classified as hazardous waste under Subtitle C of RCRA would be taken to TA-54 for temporary storage. Ultimate treatment and disposal would occur at RCRA interim status or permitted facilities at LANL or offsite. Hazardous waste storage areas in TA-54 are operated according to the requirements of Subtitle C of RCRA, the New Mexico Hazardous Waste Act, and regulations issued under each Act.

Mixed waste would be treated and disposed according to the site treatment plan for LANL developed in response to the Federal Facility Compliance Act [42 U.S.C. 6939c(b)]. The availability of proposed site treatment plans for various DOE sites, including LANL, was announced April 5, 1995 [60 FR 17346].

Low-level radioactive waste would be disposed at the LANL low-level radioactive waste disposal site in TA-54. This site is operated according to the requirements in chapter III of DOE Order 5820.2A

(Radioactive Waste Management).

Materials required to be disposed as TRU waste would be size reduced, as appropriate, to minimize volumes of waste sent to the Waste Isolation Pilot Plant (WIPP). TRU waste would be stored at LANL Area G in TA-54 prior to packaging and certification for shipment to the WIPP.

6.6 NOISE

If implemented, the DARHT Baseline Alternative or the other alternatives would create substantial noise during those times when explosions occur as discussed in section 5.2.3.

Federal efforts to regulate noise largely derive from the Noise Control Act of 1972 [42 U.S.C. 4901-4918]. Under the Act, Federal agencies such as DOE are to carry out their programs to further the Act's purpose of promoting an environment for all Americans that is free from noise that jeopardizes health or welfare [42 U.S.C. 4903(a)]. DOE seeks to meet this obligation by placing high explosives test areas, such as PHERMEX or the DARHT Facility, away from populated areas, localizing the noise impacts to the extent practicable, and conducting operations involving explosives during hours when most people within hearing distance are not sleeping. Beyond the general obligation in the Noise Control Act, no specific requirements in the Noise Control Act or in any regulations implemented under the Act prohibit or regulate the activities conducted at the DARHT Baseline Alternative and its alternatives [42 U.S.C. 4309].

OSHA has established regulations to regulate the noise exposure of occupational workers [29 CFR 1910.95]. DOE Order 5480.4 specifies that DOE contractor operations, such as those to be conducted under the DARHT Baseline Alternative or an alternative, are to meet all OSHA standards in 29 CFR Part 1910.

The Noise Control Act requires Federal agencies to meet State and local requirements relating to the abatement of noise [42 U.S.C. 4903(b)]. No State requirements would prohibit or regulate the noise associated with operation of the DARHT Baseline Alternative or the other alternatives. The Los Alamos County Code does have noise restrictions. It is a violation of the code to cause noise levels exceeding 65 dBA in residential areas of the county between 7 a.m. and 9 p.m. and 53 dBA between 9 p.m. and 7 a.m. (Los Alamos County Code, Ch. 8.28.030). Between 7 a.m. and 9 p.m., the permissible noise level can be increased to 75 dBA in residential areas provided the noise is limited to 10 minutes in any 1 hour. Persons who cannot meet the preceding requirements can request a permit from the county for noise-generating activities of a temporary nature [Los Alamos County Code, Ch. 8.28.060(d)].

6.7 FLOODPLAINS AND WETLANDS

DOE's policy is to avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction of wetlands and the occupancy and modification of floodplains and wetlands [10 CFR 1022.3]. Executive Order 11988, issued by President Carter in 1977, requires Federal agencies to avoid direct or indirect support of floodplain development when there is a practicable alternative. Executive Order 11990, also issued by President Carter in 1977, directs Federal agencies to minimize the detrimental impact of their actions on wetland areas and avoid new construction on wetlands unless no practicable alternative exists. DOE has determined no floodplains or wetlands are present on land which would be affected by the DARHT Baseline Alternative or the other alternatives.

6.8 THREATENED AND ENDANGERED SPECIES

AND MIGRATORY BIRDS

The Endangered Species Act of 1973 requires that Federal agencies not take any action that is likely to jeopardize the continued existence of any endangered species or threatened species or result in destruction or adverse modification of their habitat [16 U.S.C. 1536]. Unless otherwise permitted by regulation, the Migratory Bird Treaty Act makes it unlawful to pursue, hunt, take, capture, kill (or to attempt any of the preceding) any migratory bird or nest or eggs of such bird [16 U.S.C. 703]. The Bald and Golden Eagle Protection Act [16 U.S.C. 668] protects bald and golden eagles. The Fish and Wildlife Coordination Act [16 U.S.C. 661] provides other requirements for protecting wildlife. DOE has reviewed the preceding authorities and has determined that construction and operation of the DARHT Baseline Alternative or another alternative would be consistent with the authorities through implementation of appropriate mitigating measures.

DOE has determined, and the U.S. Fish and Wildlife Service (USFWS) has concurred, that the preferred alternative analyzed in the EIS will not adversely affect any threatened or endangered species or their habitat. DOE and the USFWS have completed informal consultation under Section 7 of the Endangered Species Act; see appendix K. Mitigation measures have been negotiated and are discussed in section 5.11 and appendix K.

6.9 NATIVE AMERICAN, ARCHEOLOGICAL,

AND HISTORIC PRESERVATION

DOE's American Indian Tribal Government Policy is in DOE Order 1230.2, issued April 8, 1992. DOE commits in the Order to consult with Tribal governments to assure that Tribal rights and concerns are considered prior to DOE taking actions that may affect Tribes. DOE also has committed to avoiding unnecessary interference with traditional Tribal religious practices.

The August 11, 1978, American Indian Religious Freedom Act (AIRFA) [42 U.S.C. 1996] establishes that it is United States policy to protect and preserve for American Indians their inherent right of freedom to believe, express, and exercise their traditional religions, including access to sites, use and possession of sacred objects, and the freedom to worship through ceremonies and traditional rites. The Native American Graves Protection and Repatriation Act provides that Tribal descendants shall own Native American human remains and cultural items discovered on Federal lands after November 16, 1990 [25 U.S.C. 3002]. When items are discovered during an activity on Federal lands, the activity is to cease, and appropriate Tribal governments are to be notified. Work on the activity can resume 30 days after receipt of certification that notice has been received by the Tribal governments.

During the NEPA process for DARHT, DOE has consulted with local American Indian Tribes regarding sites in the vicinity of DARHT and PHERMEX. These consultations are summarized in section 4.6.3, and they are expected to continue in a similar manner through the life of testing activities at DARHT and PHERMEX.

During May, June, and July of 1995, DOE consulted with representatives of the four Accord Tribes, Cochiti, Jemez, Santa Clara and San Ildefonso Pueblos, which have identified themselves as the Tribes most affected by activities at LANL. Meetings included discussions concerning AIRFA matters, on a government-to-government basis following the publication of the draft EIS. Based on general and specific comments provided by Tribal government representatives, DOE has made changes in the content of the final EIS with respect to traditional cultural properties and mitigation measures to protect cultural resource sites. DOE will continue regular consultations with Tribal governments throughout the life of the DARHT project to ensure protection of traditional properties.

The Archaeological Resources Preservation Act prohibits the excavation of material remains of past human life that have archeological interest and are at least 100 years old without a permit from the appropriate Federal land manager or an exemption [16 U.S.C. 470bb, 470ee]. The Federal land manager for LANL is DOE.

The National Historic Preservation Act authorizes the Secretary of the Interior to maintain a National Register of Historic Places [16 U.S.C. 470a(a)(1)]. Federal agencies cannot approve projects that would affect properties listed, or eligible for listing, on the Register without considering the effect on the listed or eligible properties [16 U.S.C. 470f]. For proposed actions at LANL, DOE consults with the New Mexico State Historic Preservation Office and the Advisory Council on Historic Preservation, as necessary. DOE consulted with these offices and with the San Ildefonso Pueblo prior to initiating construction at the DARHT site, and employed the mitigation measures agreed to at that time to protect archeological sites.

DOE has reviewed the preceding authorities and has determined that construction and operation of the DARHT Baseline Alternative or another alternative would be consistent with the authorities through implementation of appropriate mitigating measures.

6.10 SITING AND PLANNING

All of the alternatives under consideration, including the No Action Alternative, involve land in TA-15 at LANL. The *LANL Site Development Plan* provides that existing and planned land uses for TA-15 are for high explosives research, development, and testing (LANL 1994). All alternatives analyzed in the EIS are consistent with the planned land uses for TA-15.

6.11 OTHER AGENCIES AND INDIVIDUALS CONSULTED

In addition to the agencies discussed above, during the preparation of the draft EIS the following outside governmental agencies and individuals were consulted:

> John L. Temple, Assistant Director, Bureau of Business and Economic Research, University of New Mexico, 1920 Lomas NE, Albuquerque, NM 87131-6021 (505-277-2216).
>
> Karma A. Shore, Economist, Bureau of Business and Economic Research Data Bank, University of New Mexico, 1920 Lomas NE, Albuquerque, NM 87131-6021 (505-277-8300).
>
> Gerry Bradley, Labor Economist Supervisor, New Mexico Department of Labor, Economic Research and Analysis, P.O. Box 1928, Albuquerque, NM 87103 (505-841-8645).
>
> Jim Greenwood, Los Alamos Economic Development Corporation, 901 18th St., Los Alamos, NM 87544 (505-662-0001).

6.12 REFERENCE CITED IN CHAPTER 6

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GLOSSARY

Access Control Office LANL office that monitors activities and controls access within TA-15.

aerosolize The process of converting a solid or a liquid into a gaseous suspension of fine particles (an aerosol).

air quality A measure of the quantity of pollutants in the air.

air quality standards The prescribed quantity of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified area.

alluvium Clay, silt, sand, and/or gravel deposits found in a stream channel or in low parts of a stream valley that is subject to flooding.

ambient air The surrounding atmosphere, usually the outside air, as it exists around people, plants, and structures. It is not the air in immediate proximity to emission sources.

aquifer Geologic material that contains sufficient saturated permeable material to conduct ground water and to yield worthwhile quantities of ground water to wells and springs.

aqueous Containing or dissolved in water.

atmosphere The layer of air surrounding the earth.

background radiation Normal radiation present in the lower atmosphere from cosmic rays and earth sources. Background radiation varies with location, depending on altitude and natural radioactivity present in the surrounding geology.

beryllium (Be) A rare metal (average atomic mass of about 9 atomic mass units) used most commonly in the manufacture of beryllium-copper alloys for numerous industrial and scientific applications. It is on the EPA's list of priority metals for hazardous air pollutants.

bound, bounding A description of the evaluation process that provides a reasonable upper limit to potential consequences or impacts.

breccia A coarse-grained rock composed of angular broken rock fragments held together by a naturally occurring mineral cement.

ºC Degree Celsius. ºC = 5/9 x (ºF - 32).

cancer Any malignant new growth of abnormal cells or tissue.

capable (fault) A term defined by the Nuclear Regulatory Commission to indicate that a fault is a hazard to be considered in safety analyses.

carcinogenic Adjective describing an agent that is capable of producing or inducing cancer.

cavate A hand-dug cavity in the tuff cliff face.

collective dose The sum of the individual doses to all members of a specific population.

community A group of people or a site within a spatial scope exposed to risks that potentially threaten health, ecology, or land values, or exposed to industry that stimulates unwanted noise, smell, industrial traffic, particulate matter, or other nonaesthetic impacts (environmental justice definition).

concentration The amount of a substance contained in a unit quantity (mass or volume) of a sample.

conglomerate A coarse-grained sedimentary rock composed of rounded fragments larger than 2 mm in diameter set in fine-grained sand or silt. It is commonly cemented naturally by a mineral cement.

control and accountability Continuing control and accountability, particularly of special nuclear materials such as plutonium and highly enriched uranium.

criteria pollutants Six pollutants (ozone, carbon monoxide, total suspended particulates, sulfur dioxide, lead, and nitrogen oxide) known to be hazardous to human health and for which the EPA sets National Ambient Air Quality Standards under the Clean Air Act.

criticality A state in which a self-sustaining nuclear chain reaction is achieved.

cumulative effects Additive environmental, health, and socioeconomic effects that result from a number of similar activities in an area or over time.

cumulative impacts The sum of environmental, health, and socioeconomic impacts that result from a number of activities in an area or over time.

curie (Ci) A unit of radioactivity equal to 37,000,000,000 (3.7×10^{10}) decays per second.

dBA Decibel on the A-weighted scale (*see also decibel and decibel, A-weighted*).

decay, radioactive The spontaneous transformation of an unstable atom to a lower, more stable energy state, often with the emission of particulate or electromagnetic radiation (alpha, beta, gamma, or x-radiation).

decibel An expression of sound pressure level that is referenced to a pressure of 20 micropascals expressed on a logarithmic scale, 1 dB = 20 $\log_{10}$ (p/20) where p is the sound pressure in micropascals. Twenty micropascals approximates the minimum audible sound pressure level in humans (*see also decibel, A-weighted*).

decibel, A-weighted

(dBA) The A-weighted decibel (dBA) is an expression of adjusted pressure levels by frequency that accounts for human perception of loudness. Consequently, dBA is most often used when evaluating human noise disturbance. For example, at a frequency of 500 Hz, 60 dB are reduced by 3.2 dB to give an A-weighted pressure level of 56.8 dBA. Lower frequencies are reduced more because they are less of an annoyance to humans, and higher frequencies are reduced less because they are more of an annoyance (*see also decibel*).

decommissioning The removal from service of facilities such as processing plants, waste tanks, and burial grounds, and the reduction or stabilization of radioactive contamination, if present.

depleted uranium A mixture of uranium isotopes where uranium-235 represents less than 0.7 percent of the uranium by mass.

design life The estimated period of time that a component or system is expected to perform within specifications before the effects of aging result in performance deterioration or a requirement to replace the component or system.

detonation *See explosion*.

disablement A means to render a nuclear weapon so that it cannot be detonated.

dose rate The radiation dose delivered per unit time (e.g., rad/h).

dynamic experiment An experiment to provide information regarding changes in materials under conditions caused by the detonation of high explosives.

E/Q (E over Q) A measure of atmospheric dispersion for short-term (acute) atmospheric releases using Gaussian dispersion plume modeling, with units of s/m^3. For a given point or location at some distance from the source, it represents the time-integrated air concentration ($Ci \cdot s/m^3$) divided by the total release from the source (Ci). Integrated air concentrations used are usually plume centerline values. E/Qs are typically used for release lasting no longer than 8 to 24 hours.

ecology The science dealing with the relationship of all living things with each other and with the environment.

ecosystem A complex of the community of living things and the environment forming a functioning whole in nature.

ecotone A transition zone that exists between two ecologic communities.

Ector An existing x-ray diagnostic machine scheduled to be moved to PHERMEX in mid-1995.

effective dose equivalent A concept used to estimate the biological effect of ionizing radiation. It is the sum over all body tissues of the product of absorbed dose, the quality factor (to account for the different penetrating abilities of the various types of radiation), and the tissue weighing factor (to account for the different radiosensitivity of the various tissues of the body).

effluent Liquid or airborne material released to the environment. In common usage, however, the term "effluent" implies liquid release.

effluent standards Defined limits of effluent in terms of volume, content of contaminants, temperature, etc.

EIS Environmental impact statement; a document required by the National Environmental Policy Act (NEPA) of 1969, as amended, for proposed major Federal actions involving potentially significant environmental impacts.

electron accelerator A device which uses intense electrical and magnetic energy to increase the velocity of electrons, thereby increasing their energy.

element One of the known chemical substances that cannot be divided into simpler substances by chemical means. All isotopes of an element have the same atomic number (number of protons) but have a different number of neutrons, and thus different atomic weights.

emission standards Legally enforceable limits on the quantities and kinds of air contaminants that can be emitted into the atmosphere.

endangered species Plants and animals that are threatened with extinction, serious depletion, or destruction of critical habitat. Requirements for declaring a species endangered are contained in the Endangered Species Act.

energy The capacity to produce heat or do work.

enhanced radiography A radiography technique for producing extremely high-resolution, time-phased, photographic images of an opaque object (*see also radiography*).

environment The sum of all external conditions and influences affecting the life, development, and ultimately the survival of an organism.

environmental monitoring The act of measuring, either continuously or periodically, some quantity of interest, such as radioactive material in the air.

ephemeral stream A stream channel which carries water only during and immediately after periods of rainfall or snowmelt.

epicenter The point on the earth's surface directly above the focus of an earthquake.

equation-of-state A mathematical expression which defines the physical state of a homogeneous substance by relating volume to pressure and absolute temperature for a given mass of the material.

erosion A general term for the natural processes by which earth materials are loosened, dissolved, or worn away and moved from one place to another. Typical processes are wind and water as they carry away soil.

evapotranspiration Loss of water from the earth's surface to the atmosphere by evaporation from the soil, lakes, streams, and by transpiration from plants.

exclusion zone The area surrounding the firing point that is cleared of all personnel for a test shot. The radius of this area is determined by the size of the shot.

explosion An extremely fast chemical reaction producing high temperatures and a large amount of gas. The terms explosion and detonation (also explode and detonate) are used interchangeably here; but to a specialist, they are distinct terms and depend on reaction rates.

exposure to radiation The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that occurs during a person's working hours. Population exposure is the exposure of a number of persons who inhabit an area.

ºF Degree Fahrenheit. F = (ºC x 9/5) + 32.

fallout Radioactive material that has been produced and distributed through the atmosphere as a result of aboveground testing of nuclear devices.

fault A fracture or a zone of fractures within a rock formation along which vertical, horizontal, or transverse slippage of the earth's crust has occurred in the past.

fissionable Atoms capable of being split or divided (fissioned) by the absorption of thermal neutrons. The most common fissionable materials are uranium-233, uranium-235, and plutonium-239.

fission The splitting of a heavy nucleus into two approximately equal parts, which are nuclei of lighter elements, accompanied by the release of energy and generally one or more neutrons. Fission can occur spontaneously or can be induced by nuclear bombardment.

forb A general term for a weed or broad leaf flowering plant as distinguished from grasses and sedges.

formation A body of rock identified by lithic characteristics and stratigraphic position. Formations may be combined into groups or subdivided into members.

fugitive emission Those emissions which could not reasonably pass through a stack, chimney, vent, or other fundamentally equivalent opening.

GENII A computer program used to estimate doses to individuals and populations from releases of radioactive materials.

geology The science that deals with the earth; the materials, processes, environments, and history of the planet, especially the lithosphere, including the rocks, their formation, and structure.

ground water All subsurface water, especially that part that is in the zone of saturation.

group The geological term for the rock layer next in rank above formation.

habitat The part of the physical environment in which a plant or animal lives.

half-life (radiological) The time in which half the atoms of a radioactive substance disintegrate to another nuclear form. Half-lives vary from millionths of a second to billions of years.

Hazard Index (HI) An indicator of the potential toxicological hazard from exposure to a particular substance. The HI is equal to an individual's estimated exposure divided by the U.S. EPA's substance-specific reference dose. An HI of 1.0 would indicate an expectation of the health effect upon which the reference dose is based. No toxicological effects would be expected where the HI is less than 1.0.

hazard zone A circular area in which personnel are not allowed outside the control rooms during tests involving high explosives. The area is centered on the firing point and its radius is determined from the amount of explosives to be used.

He-Ne Laser A device which uses a gaseous mixture of helium (He) and Neon (Ne) to produce an intense beam of light.

HEPA filter High-efficiency particulate air filter designed to remove greater than 99.9 percent of particles from a flowing air stream. Efficiency is determined at 0.3 μ; efficiency increases for particles larger and smaller than 0.3 μ.

historic resources The sites, districts, structures, and objects considered limited and nonrenewable because of their association with historic events, persons, or social or historic movements.

Horizon A (soil) The top-most layer of soil distinguishable by color, texture, or structure.

hydrodynamic test A dynamic integrated systems test of a mock-up nuclear package during which the high explosives are detonated and the resulting motions and reactions of materials and components are measured. The explosively generated high pressures and temperatures cause some of the materials to behave hydraulically (like a fluid).

hydrodynamic testing

facility A facility in which to conduct dynamic and hydrodynamic testing for nuclear and conventional weapons research and assessment. Fast diagnostic systems that are available include radiographic, electrical, optical, laser, and microwave.

hydronuclear experiment Very-low-yield experiment (less than a few pounds of nuclear energy released) to assess primary performance and safety with normal detonation.

intensity (earthquake) A numerical rating used to describe the effects of earthquake ground motion on people, structures, and the earth's surface. The numerical rating is based on an earthquake intensity scale such as the modified Mercalli Scale commonly used in the United States.

interbed A typically thin bed of one kind of rock material occurring between or alternating with beds of another material.

interfingers The combination of markedly different rocks through vertical succession of thin interlocking or overlapping of wedge-shaped layers.

interflow breccias A breccia that occurs in or between volcanic flows.

ion An atom or molecule that has gained or lost one or more electrons to become electrically charged.

ionization The process that creates ions. Nuclear radiation, x-rays, high temperatures, and electric discharges can cause ionization.

ionizing radiation Radiation capable of displacing electrons from atoms or molecules to produce ions.

irradiation The process of exposing a material to radiation.

ISC2 A computerized dispersion program used to calculate ground-level concentrations of air pollutants.

isotope An atom of a chemical element with a specific atomic number and atomic weight. Isotopes of the same element have the same number of protons but different numbers of neutrons. Isotopes are identified by the name of the element and the total number of protons and neutrons in the nucleus. For example, uranium-238 is a uranium atom with 238 protons and neutrons.

laser An active electronic device that converts input power into a very narrow, intense beam of light.

latent cancer fatalities

(LCFs) Deaths that were ultimately caused by a radiation-induced cancer. The cancer became evident years after the radiation exposure. LCFs can be calculated for the public by using the risk conversion factor of 5×10^{-4} deaths per person-rem and for the worker by using the risk conversion factor of 4×10^{-4} deaths per person-rem.

lineament A geological term for straight or gently curved alignments of topographic features such as depressions, streams, or changes in surface slope.

linear accelerator A device in which atomic particles travel in a straight line as their velocity is increased. A particle accelerator that accelerates electrons, protons, or heavy ions in a straight line by the action of alternating voltages.

lithic The description of rocks on the basis of such characteristics as color, mineralogic composition, and grain size.

low-income communities A community where 25 percent or more of the population is identified as living in poverty.

low-level waste Radioactive waste not classified as high-level waste or TRU waste; for DARHT and PHERMEX it would consist mainly of solid material contaminated with low levels of depleted uranium.

lystric fault The fault that is steep at the ground surface and becomes less and less steep as its depth increases. It eventually becomes horizontal or nearly horizontal.

mass balance error The difference between two estimates of the change in water stored; the difference between influent and effluent, and the difference between initial and final stored water.

maximum contaminant

levels (MCLs) The maximum permissible level of a contaminant in water that is delivered to a user of a public water system.

maximally exposed

individual (MEI) A real or hypothetical person located to receive the maximum possible dose from a given hazardous material release.

member A geological term for a layer of rock that includes some specially developed part of a formation.

MEPAS Computer code used to estimate the toxicological hazards resulting from releases of hazardous materials.

migration The movement of a material through the soil or ground water.

mitigate To take practicable means to avoid or minimize environmental harm from a selected alternative.

National Register

of Historic Places A list maintained by the National Park Service of architectural, historic, archeological, and cultural sites of local, State, or national importance.

natural background

radiation Radiation that is ubiquitous and generated in naturally occurring materials or through naturally occurring processes. Principal sources of background radiation are primordial radionuclides such as uranium, thorium, and potassium-40 and cosmic radiation. In contrast, radiation may be produced or enhanced by man-made means such as activation or nuclear fission.

noninvolved worker For this EIS, a worker who is not involved in the operation of a facility when a radioactive release occurs, and who is assumed to be 2,500 ft (750 m) or 1,300 ft (400 m) from the point of release, depending on the exposure scenario and alternative.

NEPA National Environmental Policy Act of 1969 as amended; it requires the preparation of an EIS for Federal projects that could present significant impacts to the environment.

nonproliferation The restriction of ability to easily access fissile material in concentrations sufficient to assemble a nuclear weapon.

NO_x Oxides of nitrogen, primarily nitrogen oxide (NO) and nitrogen dioxide (NO_2). These are produced in the combustion of fossil fuels, and can constitute an air pollution problem.

nuclear radiation *See radiation.*

nuclear reaction An interaction between a photon, particle, or nucleus and a target nucleus, leading to the emission of one or more particles and photons.

nuclear stockpile The total aggregation of the Nation's nuclear weapons that are in the custody of the Department of Defense. This quantity is defined in the nuclear weapons stockpile memorandum.

nuclear weapon The general name given to any weapon in which an explosion can result from the energy released by reactions involving atomic nuclei, either fission, fusion, or both.

nuclear weapons primaries Those components of a nuclear weapon involved in the reaction up to the point where nuclear criticality is achieved.

nuclide A species of atom, characterized by its nuclear constitution (number of protons and number of neutrons).

organic compounds Carbon compounds which are, or are similar to, compounds produced by living organisms.

outfall Place where liquid effluents enter the environment and are monitored.

oxide A compound in which an element chemically combines with oxygen.

ozone A molecule of oxygen in which three oxygen atoms are chemically attached to each other.

particulates Solid particles and liquid droplets small enough to become airborne.

passive safety system A system that provides safety features requiring no human intervention or adverse condition to actuate.

perennial stream A stream that contains water at all times except during extreme drought.

perched aquifer A body of ground water separated from an underlying body of ground water by an unsaturated zone.

people of color communities A population classified by the U.S. Bureau of the Census as Black, Hispanic, Asian and Pacific Islander, American Indian, Eskimo, Aleut, and other nonwhite persons, the composition of which is at least equal to or greater than the state minority average of a defined area or jurisdiction.

permeability Ability of liquid to flow through rock, ground water, soil, or other substance.

person-rem Unit of radiation dose to a given population; the sum of the individual doses received by a collection of individuals.

pH A measure of the hydrogen ion concentration in aqueous solution. Pure water has a pH of 7, acidic solutions have a pH less than 7, and basic solutions have a pH greater than 7.

physiographic Pertaining to the physical features of the earth's surface, such as land forms or bodies of water.

plutonium (Pu) A transuranic, heavy (average atomic mass ranging from about 237-244 atomic mass units), silvery metallic element with 15 isotopes that is produced by the neutron irradiation of natural uranium.

PM_{10} Particulate matter with a 10 micron or less aerodynamic diameter.

pollution The addition of an undesirable agent to the environment in excess of the rate at which natural processes can degrade, assimilate, or disperse it.

progeny Stable or radioactive elements formed by the radioactive decay of another nuclide, which is the "parent."

pulse width The duration of a brief burst of energy, such as x-rays or direct current electricity.

Puye Formation A stratigraphic unit composed of basalts, interflow breccias, conglomerates, sandstones, and siltstones that underlies Los Alamos National Laboratory.

radiation The emitted particles or photons from radioactive atoms.

radioactive waste Materials from nuclear operations that are radioactive or are contaminated with radioactive materials and for which there is no practical use or for which recovery is impractical (*see low-level waste*).

radioactivity The process of radioactive decay (*see decay*, *radioactive*)

radiography The technique of producing a photographic image of an opaque specimen by transmitting a beam of x-rays or gamma rays through it onto an adjacent photographic film; the image results from variations in thickness, density, and chemical composition of the specimen.

radionuclide A nuclide that emits radiation.

reach A continuous and unbroken expanse or surface of water (used in hydrologic contexts).

recharge The processes involved in the absorption and addition of water to an aquifer.

rem The unit of effective dose equivalent.

render safe A means to make a nuclear weapon secure from unwanted detonation.

Richter Scale A numerical scale of earthquake magnitude that represents the size of an earthquake at its source.

risk In accident analysis, the probability weighted consequence of an accident, defined as the accident frequency per year multiplied by the dose. The term "risk" is also used commonly to describe the probability of an event occurring.

runoff The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and eventually returns to streams.

Santa Fe Group The name applied to a sequence of geologic formations that have been deposited mostly in the Rio Grande rift. These deposits are primarily sediments with some limestones, volcanic tuffs, and basalts.

Stockpile Stewardship and

Management Program The DOE program to develop a new approach, based on scientific understanding and expert judgement, to ensure continued confidence in the safety, performance, and reliability of the nuclear weapons stockpile.

seismicity The way earthquakes of various sizes occur geographically and temporally.

shield Material used to reduce the intensity of radiation that would irradiate personnel or equipment.

short-lived A designation for radionuclides with relatively short half-lives.

solid state laser A device which uses a semiconductor to produce an intense beam of light. This term is often used to distinguish a device from gas lasers.

spallation products Products that result from a nuclear reaction in which the energy of the incident particle is so high that more than two or three particles are ejected from the target nucleus, and both its mass number and atomic number are changed.

stabilization The action of making a nuclear material more stable by converting its physical or chemical form or placing it in a more stable environment.

static testing Using radiographic equipment to make an x-ray image of a test assembly before other testing is done.

stockpile management Maintenance, evaluation, repair, or replacement of weapons in the existing stockpile.

stockpile stewardship A program of activities to maintain the technical competence and capability for the Nation to continue to have confidence in the safety, reliability, and performance of our nuclear weapons.

strata Layers of rock usually in a sequence.

stratum A single layer of rock, usually one of a sequence.

stratigraphy The science of rock strata, or the characteristics of a particular set of rock strata.

surface water All bodies of water on the Earth's surface (e.g., streams, lakes, reservoirs), as distinguished from ground water.

threatened species Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

transuranic elements Elements that have atomic numbers greater than 92; all are radioactive, and are products of artificial nuclear changes.

tritium A radioactive isotope of hydrogen; its nucleus contains one proton and two neutrons.

TRU waste Material contaminated by alpha-emitting radionuclides, which are heavier than uranium, with half-lives greater than 20 years and in concentrations greater than 100 nCi/g of material.

Tshirege member Layer of volcanic rock that is a member of the Bandelier tuff. It is composed of multiple flow units of tuff.

tuff A type of rock formed of compacted volcanic fragments.

uranium (U) A heavy (average atomic mass of about 238 atomic mass units), silvery-white metal with 14 radioactive isotopes.

welding Consolidation of sediments by pressure resulting from weight of material or from earth movement.

__/Q´ (*Chi-bar over Q-prime*) A measure of the average atmospheric dispersion for long-term (chronic) atmospheric releases using gaussian dispersion plume modeling, with units of s/m^3. For a given point or location at some distance from the source, it represents the average air concentration in Ci/m^3 divided by the release rate in Ci/s. Typically the concentration used __/Q´ is the average centerline value for individuals and is averaged over a specific sector of a polar grid surrounding the release point for populations. is used for long-term (chronic) releases, often on the order of months or years.

x-ray A penetrating electromagnetic radiation, which may be generated by accelerating electrons to high velocity and suddenly stopping them by collision with a target material.

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APPENDIX A

LIST OF PREPARERS AND CONTRIBUTORS

This list identifies individuals who were principal preparers and contributors to this environmental impact statement (EIS). Many other individuals contributed to the preparation and review of the EIS. M. Diana Webb of the Los Alamos Area Office of the Department of Energy (DOE) directed the preparation of the EIS. David E. Rosson, Jr., of DOE's Albuquerque Operations Office is the Director of the DOE/AL *Environmental Impact Statement* Program Office. Glen T. Hanson of Battelle's Albuquerque Office provided overall project management, as well as technical and document preparation support. E. B. Moore provided management of the technical support from participating staff from DOE's Pacific Northwest Laboratory (managed and operated by Battelle).

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· M.S., Limnology, Colorado State University, 1956

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· B.S., Plant and Soil Science, University of Maine, 1976

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Name: NANCY FOOTE

Affiliation: Battelle - Pacific Northwest Laboratory

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Technical Experience: Twenty-four years of experience in environmental and resource management, regulatory compliance, environmental assessment and impact analyses for NEPA documentation, facility siting, site characterization, cultural resource assessment and management, and environmental program management.

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· M.S., Seismology, California Institute of Technology, 1971

· Geophysical Engineer, Colorado School of Mines, 1960

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Education: · Ph.D., Geology, Johns Hopkins University, 1989

· M.S., Geology, University of New Mexico, 1985

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Education: · M.S., Civil Engineering, Oregon State University, 1990

· B.S., Agricultural Engineering, Oregon State University, 1987

Technical Experience: Five years of experience in hydrologic and hydrothermal vadose zone modeling for performance assessment of waste isolation and disposal issues.

EIS Responsibility: Prepared ground water transport modeling for water resources section of chapter 5.

Name: PAUL NICKENS

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Anthropology, University of Colorado, 1974

· M.A., Anthropology, University of Colorado, 1972

· B.A., Anthropology, University of Colorado, 1969

Technical Experience: Twenty-one years of experience in southwestern archeology and cultural site protection and preservation.

EIS Responsibility: Prepared the cultural resources sections of chapter 5.

Name: ROBERT T. NIEHOFF

Affiliation: Battelle - Columbus

Education: · B.S., Chemistry, Xavier University, 1960

Technical Experience: Thirty-one years of experience in information research, document management, and technical editing.

EIS Responsibility: Technical editor/writer.

Name: YASUO ONISHI

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Mechanics and Hydraulics, University of Iowa, 1972

· M.S., Mechanical Engineering, University of Osaka Prefecture, 1969

· B.S., Mechanical Engineering, University of Osaka Prefecture, 1967

Technical Experience: Twenty years of experience in fluid mechanics and hydrology with expertise in transport and chemical interactions of sediment and contaminants.

EIS Responsibility: Obtained solubility and adsorption properties of potential contaminants for water resources section of chapter 5.

Name: TED M. POSTON

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · M.S., Fisheries, Central Washington University, 1978

· B.A., Fisheries, Central Washington University, 1973

Technical Experience: Twenty years of experience in research, environmental assessment, and noise analysis.

EIS Responsibility: Prepared noise analysis sections of chapter 5 and appendix C2.

Name: RANDY F. REDDICK

Affiliation: Battelle - Albuquerque

Education: · M.S., Environmental Health Engineering, University of Kansas, 1983

· B.S., Civil Engineering, University of Kansas, 1982

Technical Experience: Twelve years of experience with NEPA compliance, NEPA document preparation, and safety studies.

EIS Responsibility: Deputy Project Manager - Battelle - Albuquerque. Prepared portions of chapters 3 and 4.

Name: MARSHALL C. RICHMOND

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Civil and Environmental Engineering, University of Iowa, 1987

· M.S., Civil and Environmental Engineering, Washington State University, 1983

· B.S., Civil and Environmental Engineering, Washington State University, 1982

Technical Experience: Eight years of experience in the development and application of hydrodynamic and contaminant transport models for surface water flow systems.

EIS Responsibility: Modeled water transport for chapter 5 and appendix E.

Name: DEBORAH RISBERG

Affiliation: Los Alamos National Laboratory

Education: · B.S., Biology, University of New Mexico, 1990

Technical Experience: Ten years of experience in many areas of environmental biology, including research, environmental compliance, and environmental protection.

EIS Responsibility: Conducted endangered species surveys and prepared the biological assesment for DARHT.

Name: ALAN C. ROHAY

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Geophysics, University of Washington, 1982

· B.S., Geology, Massachusetts Institute of Technology, 1974

Technical Experience: Fifteen years of experience in seismic and volcanic hazards, structure of the earth, earthquake, explosion, and noise signal analysis.

EIS Responsibility: Supported the sections on seismic hazard and facility noise consequences in chapter 5.

Name: STEVEN B. ROSS

Affiliation: Battelle - Albuquerque

Education: · M.S., Nuclear Engineering, University of New Mexico 1987

· B.S., Nuclear Engineering, University of New Mexico 1985

Technical Experience: Nine years of experience in safety analysis, risk assessment, regulatory analysis, and fire risk assessment.

EIS Responsibility: Provided technical review of chapters 3, 4, 5, and appendixes.

Name: DAVID E. ROSSON, JR.

Affiliation: U.S. Department of Energy

Education: · B.S., Metallurgical Engineering, University of Tennessee, 1963

Technical Experience: Thirty-five years of government service with increasing responsibilities in program and project management, including five years' experience in the safety and environmental area.

EIS Responsibility: Director, DOE/Albuquerque Operations, EIS Project Office.

Name: NANCY N. SAUER

Affiliation: Los Alamos National Laboratory

Education: · Ph.D., Inorganic Chemistry, Iowa State University, 1986

· B.S., Chemistry, University of Idaho, 1981

Technical Experience: Twelve years of experience in metal ion coordination chemistry and four years' experience in development of waste treatment technologies.

EIS Responsibility: Contributed to development of Enhanced Containment Alternative in chapter 3.

Name: SANDRA F. SNYDER

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · M.S.P.H., Radiological Hygiene, University of North Carolina, 1991

· B.S., Environmental Resource Management, Pennsylvania State University, 1986

Technical Experience: Seven years of experience in modeling of environmental releases of radioactive materials.

EIS Responsibility: Prepared human health section of chapter 5. Prepared appendixes H and I.

Name: LISSA STAVEN

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · M.S., Health Physics, Colorado State University, 1990

· B.S., Environmental Conservation, University of New Hampshire, 1984

Technical Experience: Five years of experience in environmental health physics and low-level waste disposal management practices.

EIS Responsibility: Contributed to decontamination and decommissioning sections and prepared waste management sections of chapter 5.

Name: T. J. TRAPP

Affiliation: Los Alamos National Laboratory

Education: · Ph.D., Nuclear Engineering, Oregon State University, 1977

· M.S., Nuclear Engineering, Mississippi State University, 1974

· B.S., Nuclear Engineering, Mississippi State University, 1973

Technical Experience: Twenty years of experience in plutonium science and nuclear technology.

EIS Responsibility: Provided information for chapter 3 and classified supplement to the EIS.

Name: CARLOS A. ULIBARRI

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Economics, University of New Mexico, 1992

· B.A., Economics and Spanish Literature, University of New Mexico, 1984

Technical Experience: Five years of experience in natural resource and environmental economics.

EIS Responsibility: Prepared sections on socioeconomics and environmental justice in chapters 4 and 5. Prepared appendix G.

Name: JANIS L. VOMACKA

Affiliation: Battelle - Albuquerque

Education: · Graduate, American Business College, 1964

Technical Experience: Twenty-eight years of experience in publication preparation and management, including technical editing, graphics design and production, desktop publishing, and printing.

EIS Responsibility: Technical editor, graphics designer, and production coordinator.

Name: DAVE WARD

Affiliation: Battelle -Albuquerque

Education: · B.S., Engineering Physics, University of Maine, 1957

Technical Experience: Thirty-eight years of nuclear engineering and safety analysis experience.

EIS Responsibility: Assisted in data collection for chapter 3.

Name: M. DIANA WEBB

Affiliation: Department of Energy, Los Alamos Area Office

Education: · M.L.A., Landscape Architecture, University of Illinois, 1975

· B.F.A., Fine Arts, University of Illinois, 1966

Technical Experience: Twenty-eight years of experience in the areas of environmental planning and NEPA compliance.

EIS Responsibility: DOE NEPA Document Manager and contributed to various sections of the EIS.

Name: MARK WIGMOSTA

Affiliation: Battelle - Pacific Northwest Laboratory

Education: · Ph.D., Environmental Engineering, University of Washington, 1991

· M.S., Geological Sciences, University of Washington, 1983

· B.S., Geological Sciences, University of Washington, 1981

Technical Experience: Twelve years of experience in the areas of surface water hydrology, erosion processes, and sediment transport.

EIS Responsibility: Contributed to water resources section of chapter 5 in areas of surface runoff and sediment and contaminant transport in chapter 5 and appendix E.

Name: SANDRA K. WISE

Affiliation: Battelle - Albuquerque

Education: · B.S., Environmental Health, Colorado State University, 1995

Technical Experience: Eight years of experience in data management, quality assurance and one year experience in NEPA compliance.

EIS Responsibility: Prepared sections of appendix K.

Name: DONALD C. WOLKERSTORFER

Affiliation: Los Alamos National Laboratory

Education: · Ph.D., Applied Physics, Stanford University, 1971

- M.S., Applied Physics, Stanford University, 1967

- B.S., Physics, Marquette University, 1965

Technical Experience: Twenty-two years of experience in nuclear design and nuclear weapons program management.

EIS Responsibility: Provided information for chapter 2 and the classified supplement to the EIS.

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APPENDIX B

PHERMEX BASELINE

This section describes the current condition of the PHERMEX firing site and summarizes the materials used to conduct current operations and the materials that have been released to the immediate environment of the firing point. This baseline represents PHERMEX conditions before any decision is made on the hydrodynamic testing alternatives. This baseline information was compiled to develop reasonable testing activities which are analyzed under each alternative in this EIS in order to determine valid impacts and to establish a comparative analysis of alternatives with respect to current conditions. Historically, numbers of tests and quantities of various materials have varied by year, in accordance with program needs. Material usage over the past five years has been used in this EIS to establish the baseline for material usage. This baseline does not reflect projected future changes in the activities at PHERMEX under various alternatives. The current levels of migration of materials by air and water pathways are discussed, as well as the disposition of materials removed from the site during periodic cleanup activities. Waste streams resulting from the current operation are also discussed.

B.1 AIR QUALITY AND NOISE

This section describes the nonradioactive ambient air criteria pollutants emitted from PHERMEX operations as well as the noise impacts from PHERMEX experiments.

B.1.1 Air Quality

The ambient air criteria pollutants potentially released due to PHERMEX operations include nitrogen dioxide, PM_{10} (aerosolized material assumed to be respirable), beryllium, heavy metals (depleted uranium and lead), and lead (the concentration of pollutants is similar to those presented in section 5.1.2; see related discussion in section 4.2.4). Cleaning chemicals are not used on a scale large enough to produce measurable releases. Materials used are rags dampened with acetone, chlorinated hydrocarbons, toluene, xylene, or 1,1,1-trichloroethane.

Since the PHERMEX operations are classified as intermittent fugitive emission sources, no stations are established to directly monitor potential emissions from PHERMEX (see related discussion in section 4.2.5 and figure 4-6). A sitewide sampling network is available at LANL to provide air monitoring data for the site. The radiological dose from TA-15 operations has been estimated at 1 percent or less of the total LANL dose to the public.

Waste wood from the platforms used to support the experiments is taken to TA-36 for disposal in an open burn. An existing open burn permit from the NMED indicates approximately four to five burns per year are required to reduce the fire and safety hazards due to the accumulation of wood. Some of the wood waste may be contaminated with small quantities of high explosives and/or depleted uranium.

In support of the open burn permit application, the DOE Los Alamos Area Office submitted dose dispersion estimates. The nearest residential community, White Rock 1.8 mi (3 km) from the burn site,was estimated to receive 1.1×10^{-8} rem using the HOTSPOT 6.5 modeling program and 2.9×10^{-8} rem using the DISPERSION modeling program (DOE 1993). The NMED Air Quality Bureau reviewed the dose estimates and concluded that the results indicate reasonable assurance of no health effects in White Rock from this source (NMED 1993).

B.1.2 Noise

Noise from a 150-lb (70-kg) test explosion, the largest in normal operation at PHERMEX, was measured March 11, 1995, at several locations in and around LANL (Burns 1995; Vigil 1995; Vibronics 1995). Peak overpressure in the air, reported in dB, is the important measurement for assessing the potential effects of an air wave but is not the same as a dBA noise measurement (see section 4.2.6). These peak overpressure measurements showed 138 dB at a distance of 2,150 ft (655 m) from the 150-lb (70-kg) shot, and 137 dB at the Nake'muu ruin site, a distance of 3,880 ft (1,180 m). If the largest explosive charge for PHERMEX, 1,000 lb (450 kg), were fired, the expected pulse would be about 6 dB higher than for the 150-lb (70-kg) explosion.

Two types of instrumentation were used for the noise measurements recorded during the tests conducted at PHERMEX on March 11, 1995. A sound level meter set up for a broad frequency range (about 20 to 12,000 Hz), slow time response, and frequency sensitivity corresponding to human hearing (A scale, ANSI-S1.4-1971) was used. The results are reported in decibels weighted for hearing response, dBA. The peak overpressure was measured in the air with a microphone sensitive to low frequencies (2 to 200 Hz) and having fast time response. These results are reported in decibels (dB) and are important for assessing potential effects of an air wave but are not the same as "noise" measurements.

Both types of instruments were used at only one location, on State Highway 4, which is the closest possible public approach to the firing point [1.3 mi (2 km) to the south]. The slow time response and frequency sensitivity corresponding to human hearing measured 71 dBA while the fast time response instrument measured 120 dB; the peak pulse energy was at about 20 Hz. These two values are comparable because the A-scale weighing at 20 Hz is about -50 dB (ANSI-S1.4-1971). Using the sound level meter, 60 dBA was measured near the entrance to Bandelier National Monument [closest permanent residences, 2.6 mi (4.3 km)], and about 70 dBA in White Rock [a nearby residential community, 4 mi (6.4 km)]. At these levels and distances, variations in local atmospheric conditions may account for the louder noise at the more distant site, but measurements under a range of known atmospheric conditions have not been made. These measured levels can be used to estimate a sound level of 61 to 68 dBA in southern Los Alamos, the closest residential area to PHERMEX at a distance of 3 mi (5 km).

B.2 SOILS

In 1993, LANL collected and analyzed over 20 surface soil samples and 2 sediment samples at the PHERMEX firing site (Fresquez 1994). These soil sampling surveys indicated that no lead, beryllium, or mercury were observed beyond 200 ft (60 m) of the firing point. The samples were analyzed for RCRA-regulated metals (silver, arsenic, barium, cadmium, chromium, lead, mercury, beryllium, selenium) using the Toxicity Characteristics Leaching Procedure (TCLP); total beryllium, gallium, lead, thorium, and uranium; semivolatile organic compounds (SVOCs); and high explosive residues. The sampling plan and the results for uranium, beryllium, and lead are described in appendix D. Most TCLP metals in surfacesoil samples were detected below proposed U.S. Environmental Protection Agency (EPA) action levels; however, two soil samples contained lead above the EPA action level of 5 ppm. Among the other metals analyzed, most beryllium values were above the EPA action level (see appendix D). No sediment samples from drainage channels leading away from the PHERMEX site contained TCLP metals above EPA action levels or other metals above their background level. The PHERMEX area soils contained traces of 21 SVOCs, but no detectable high explosive residues.

B.3 HUMAN HEALTH

The average dose received for 92 workers who were assigned dosimetry badges in 1993 and who worked regularly or occasionally at PHERMEX was 0.003 rem/person. LANL has established an administrative dose limit of 2 rem/year, which is below the DOE limit of 5 rem/year.

The PHERMEX facility operated an internal dosimetry program for three years beginning in 1992. No dose equivalent greater than 0.003 rem was detected, and over 50 percent of the participants registered doses at or below natural background levels. It was concluded that no radiological hazard exists for PHERMEX and the program was discontinued except for suspected exposures. Chemical toxicity has also been evaluated, and calculated fractions of nephrotoxic limits have not approached any levels of concern (Kottmann 1994).

B.4 ACCIDENTS

Operations at PHERMEX pose accident hazards expected at industrial sites. In addition, there are unique hazards associated with high explosives, high voltages, high densities for energy stored in capacitor banks, intense x-rays, and test materials. Hazards that have the potential to lead to accidents at a hydrodynamic test facility are summarized in table B-1**Table B-1.-*Hazards at Hydrodynamic Test Facilities***

Hazard	Location	Comments
Ionizing Radiation Exposure Personnel inside exclusion areas during beam pulsing	Accelerator bay, optical room, and firing pad	Beam pulse with up to 2,000 rad x-rays at one meter on axis
NonIonizing Radiation Operating personnel intersect laser beam	Laser room	
Electrical Personnel in contact with the power supplies or capacitor banks Personnel in contact with laser power supplies	Accelerator room and power supply rooms Accelerator bay and laser rooms	Power supplies with voltages up to 4MV, high energy-densities in capacitor banks Power supplies with voltages up to 35 kV
High Explosives Blast Personnel in the hazard radius exclusion area during testing Accidental detonation of explosive	Firing site exclusion area Firing pad	Area radius is 2,500 ft (750 m), personnel OK in R-184 and R-310
Mechanical Crane maintenance and operation	Accelerator bay, power supply rooms, equipment and assembly rooms	Potential for misuse
Occupational Slippery surfaces due to fluids	Accelerator bay, power supply rooms, equipment room	Leaks or spills from tanks, valves, or connections

Gases Helium Sulfur hexafluoride	Firing pad, diagnostics area Accelerator hall, power supply room	Used to drive high-speed cameras Leaks from spark gaps
Chemicals/Solvents Acetone, ethanol	Accelerator bay and assembly room	Inhalation hazards
Fire Insulating oil Wicking of insulating oil Acetone, ethanol Electrical control cables, high-voltage cables, and components Fire from parked vehicles Natural gas Trash and rag accumulation Forest or brush fire	Accelerator bay and power supply rooms Power supply rooms Accelerator bay and assembly room Accelerator bay, power supply rooms, equipment room Parking and delivery area Equipment room Accelerator bay, power supply rooms, equipment room External to building	EXXON 1830 type insulating oil has a flash point above 149ºC (330ºF) Oil-soaked rags Volatile cleaning solvents Faulty items may cause sparks to ignite oil, etc. Gasoline in fuel tanks Hot water boiler Ignition source for oil May arise from explosives or natural causes
Natural Phenomena High winds Lightning Earthquake	TA-15 TA-15 TA-15	Damage to utilities Damage to utilities Damage to any of LANL infrastructure, design level is 0.22 G for DARHT, current expectation is 0.5 to 0.6 G for maximum earthquake.

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The accident hazards in table B-1 are addressed by physical barriers, interlock systems, and administrative controls. The accidents with the most serious potential consequences (i.e., radiation exposure, high explosive detonation, and electrical discharges) were analyzed for likelihood of occurrence. An annual probability of less than 10^{-4} was estimated for each of these accidents, with no likely common-mode accidents identified. Probabilities for the other hypothetical accidents are based on commercial industry experience. All these accident probabilities are shown in table B-2**Table B-**

2.-*Hypothetical Accidents and Probabilities*

Accident	**Levels**[a]	**Probability**
Unplanned exposure to radiation	III-IV	$< 10^{-4}$
Laser hazards	III	$< 10^{-4}$
Electrical energy hazards	III-IV	$< 10^{-4}$
Blast hazards	II	$< 10^{-4}$
Accidental detonation	II	$< 10^{-4}$
Mechanical hazards	IV	$< 10^{-2}$
Occupational hazards	IV	$< 10^{-2}$
Confined space	IV	$< 10^{-4}$
Pressurized containers and distribution systems	IV	$< 10^{-4}$
Toxic gases and vapors	IV	$< 10^{-4}$
Chemicals/solvents	IV	$< 10^{-2}$
Fire hazards	IV	$< 10^{-4}$
Natural phenomena	IV	$< 10^{-4}$

[a] System failure level categories are as follows:

II - Critical: May cause severe injury, severe occupational illness, major damage to a facility operation, or major environmental damage.

III - Marginal: May cause minor injury, minor occupational illness, or minor environmental damages.

IV - Negligible: Will not result in a significant injury or occupational illness, or have a significant environmental effect.

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During the most recent 10-year period (1985 to 1994), the accident statistics for PHERMEX indicate that there were a total of 19 lost-work days due to injury. None of these injuries were considered serious; they consisted of a contusion, a concussion, and numerous back strains. The most recent incident that resulted in lost time occurred in 1991 when an employee who suffered a strain injury as a result of a lifting activity lost three workdays. There have been no reported accidents that were initiated by the detonation of explosives.

B.4.1 Radiation Exposure

The safety system associated with radiation protection provides controls and barriers to prevent radiation exposure. This system consists of positive interlocks, alarms, warning lights, television monitors, and personnel accountability sweeps of the area prior to testing. These functions can be monitored from the control room. Extensive operator training, personnel radiation dosimetry, and use of thermoluminescent dosimeter (TLD) surveys for facility radiation monitoring are integral parts of facility operations to monitor exposures and prevent accidental overexposure. The following two accident scenarios have been analyzed to provide the unplanned exposure to radiation probability in table B-2:

- The walk-through clearance plan fails to detect personnel in the exclusion areas

- The interlock safety system fails, and the accelerator is pulsed while personnel are in the accelerator hall

B.4.2 Electrical Discharge

Controls and barriers associated with electrical energy hazards are designed into the PHERMEX facility. Physical barriers, such as cabinets around power supplies and capacitor banks and the injector power supplies, along with an interlocked high-voltage safety system, prevent entry during pulsing orhydrodynamic testing. Only experienced, trained personnel are allowed to perform the operations at the firing point. Potential accident scenarios include personnel contact with power supplies, charged capacitor banks, or laser power supplies.

B.4.3 Explosives

The most serious hazard to operation personnel is from firing high explosives during a hydrodynamic test. The buildings and structures at the firing site are designed to withstand repetitive explosions, but only R-184 and R-310 may be occupied during a test. Safety interlocks prevent firing the high explosives if personnel exit these buildings during the firing sequence. Hazards involved with handling explosives are well recognized and are based on long experience. The hazard radius around the firing site varies from test to test depending on the size of the shot. Two main accident scenarios have been analyzed to provide the blast hazards and accidental detonation probabilities in table B-2.

- By error, some personnel are within the hazard radius during a test.

- Predetonation of the explosives occurs during test setup.

Occupational injuries at PHERMEX have primarily dealt with injuries such as strains, lacerations, and contusions that have resulted from the movement of equipment and materials associated with the experiments.

B.5 MITIGATION AND MONITORING

B.5.1 Mitigation

The PHERMEX facility employs mitigation systems and administrative controls in a defense-in-depth approach to facility safety. Physical barriers consisting of passive shielding for radiation control and blast protection form the first level of barrier to prevent injury to personnel. Active barriers are in place, consisting of locked and interlocked gates and roadblocks or passageway closures to prevent entry to radiation areas or explosives areas. Audible and visual warning systems are in place which are activated whenever the imminent exposure to radiation or explosive blast is possible. Red stop or scram buttons are placed near visual alarms to allow any personnel inadvertently left in the area to abort the test or hazardous condition. In-place administrative procedures control the transportation and movement of explosives and hazardous materials and limit the number of personnel who might be exposed to a given hazard. Trucks and cranes may be operated only by personnel who are trained and experienced in the operation being conducted.

Access is controlled to ensure that no personnel are within the hazard area for each shot. Clearance personnel maintain radio contact with each other, and the access control office visually checks the hazard area from the firing point to the clearance radius before each test and then establishes road blocks to prevent inadvertent entry to the area until the test has completed. Small fires after a test are not unusual, and the fire suppression personnel are available at the boundary to the hazard area for each explosive shot. Fire suppression personnel, trained for the hazards to be expected when fighting fires immediately following explosives tests, are allowed access to the firing point immediately after the all-clear is sounded to extinguish any resulting fires.

B.5.2 Monitoring

Monitoring consists of radiological area monitors and visual television monitoring of critical areas. The accelerator hall and firing point are monitored annually for radioactivity. TLDs are placed at potential exposure areas in and around the facility and are read annually to monitor cumulative doses. Except for the expected high dose observed at the firing point and on the axis of the PHERMEX beam, all recorded doses are in the mrem/year range.

Environmental Surveillance at Los Alamos during 1992 describes LANL's surveillance and monitoring program (LANL 1994). LANL routinely monitors radioactive and nonradioactive pollutants in environmental media (air, water, soil) on the LANL site and in the surrounding region.

Three air-monitoring networks are operated or accessed by LANL. Nonradiological ambient air monitors are used to measure criteria pollutants, beryllium, acid precipitation, and visibility. A network of continuously operating sampling stations measures ambient airborne radioactivity. Thermoluminescent dosimeters are used to monitor doses of external penetrating radiation. LANL's air-monitoring program is discussed in detail in section 4.2.5.

Surface waters and ground water are monitored to detect any contaminants from LANL operations. Water monitoring is discussed in detail in section 4.4.3.

B.6 MATERIALS USED

The materials used at the PHERMEX site include water, industrial chemicals, and materials comprising the test assemblies. Water at the PHERMEX site is not separately metered, but is supplied through an 8-in (20-cm) line from a 250,000-gal (946,000-L) tank located near TA-15. Water is used in a cooling tower, and deionized water is used in a closed cycle for magnet cooling. Sulfur hexafluoride is used as an insulating material. The major uses of industrial chemicals on an annual basis for the No Action Alternative are:

- Helium - 6,000 ft^3 (170 m^3)

- Sulfur hexafluoride - 3,100 ft^3 (90 m^3)

- Acetone - 3 gal (11 L)

- Ethanol - 6 gal (23 L)

The tests themselves contain materials that are released to the environment during uncontained tests. Table B-3**Table B-3.**-***Number and Type of Tests at PHERMEX (P) and FXR (F) for CY 1990 to CY 1994***

Area of Research	**CY90**		**CY91**		**CY92**		**CY93**		**CY94**	
	P	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**	**F**
Weapon Development	2	3	2	13	6	5	0	0	0	0
Stockpile Support	9	12	8	48	5	23	6	14	4	8
Predictive Capability	10	-[a]	12	-[a]	8	-[a]	26	-[a]	11	-[a]
Proliferation Assessment and Disablement	0	4	0	4	1	3	1	1	5	11
Conventional Munitions	70	5	0	22	0	22	7	18	3	3
Measurement Technique Development	0	0	0	0	10	0	5	0	15	0
Other Applications	6	5	3	10	1	20	0	0	0	0
TOTALS	97	30	25	97	31	73	45	33	38	22

[a] Due to record-keeping differences, the FXR totals under Stockpile Support include both Stockpile Support and Predictive Capability.

Definition of research areas:

1. **Weapon Development** - This type of testing supported engineering development of new weapon systems.

2. **Stockpile Support** - This type of testing was directed to stockpile surveillance, benchmarking against the underground nuclear test database, stockpile life extension, and nuclear safety. Experiments included large, full-scale mock-ups of weapons systems to observe integrated operation and smaller-scale mock-ups of weapons systems to observe integrated operation and smaller-scale experiments dedicated to observing selected phenomena isolated as much as possible from other effects. Each large-scale test was accompanied by a smaller test used to calibrate experimental timing and recording instruments and this smaller test is also counted in this category.

3. **Predictive Capability** - This type of testing included smaller-scale experiments to validate or develop parts of computer simulations and to gather data for computer models of equations-of-state, turbulence, high-explosive detonation, etc. This type of testing was also meant to explore new or poorly understood phenomena. Large tests were done of weapons geometries to benchmark three-dimensional or other advanced computer simulation tools that integrated several complex models.

4. **Proliferation Assessment and Disablement** - Tests done to evaluate actual or potential foreign, proliferant, or terrorist nuclear devices. This included tests to develop and evaluate disablement technologies.

5. **Conventional Munitions** - Tests done to develop and evaluate non-nuclear, conventional munitions, usually for the Department of Defense.

6. **Measurement Technique Development** - Tests done to develop and evaluate new diagnostics and techniques for radiographic hydrodynamics and other high-explosives experiments.

7. **Other Applications** - Experiments not covered by the other categories.

shows the number of separate tests conducted at both PHERMEX and FXR during CY 1990 to 1994. The tables include all tests at the facility, not only those using the accelerator radiographic diagnostics. A large range of complexity exists among high-explosives tests, and simply counting the number of tests serves only as a broad summary of the testing efforts at each facility. Table B-4**Table B-4.-*Materials Released to the Environment Before Regular Firing-site Cleanup***

at PHERMEX and FXR for CY 1990 to CY 1994

Year	DU (kg)	Be (kg)	Pb (kg)	Cu (kg)	Other Metals	HE (kg)	Tritium (Ci)	LiH (kg)	Fluoride Salts (kg)
PHERMEX	66	4	12	7	77	148	0[b]	9	-[a]
CY94	251	4	20	75	91	269	0[b]	12	-[a]
CY93	244	2	48	0[b]	29	146	0.8	17	-[a]
CY92	245	2	0[b]	0[b]	156	340	0[b]	21	-[a]
CY91	71	-[a]	0[b]	11	75	301	0[b]	-[a]	-[a]
CY90									
FXR	204	4	0	14	4	371	0	5	0
CY94	186	2	0	20	3	413	0	9	0
CY93	154	10	10	22	19	1,744	0	13	0
CY92	214	6	0	41	14	1,466	0	14	0
CY91	315	16	0	19	15	411	0	15	9
CY90									

[a] None reported.

[b] The material was reported as 0.

Notes: "DU," short for depleted uranium, refers to uranium in which the isotope uranium-235 has been depleted below the content of 0.7 percent found in naturally occurring uranium. The majority isotope in the material is uranium-238.

When referring to PHERMEX, "other metals" means the sum of all aluminum, boron, brass, iron, inconel, niobium, nickel, silver, tin, tantalum, titanium, tungsten, and vanadium used during each year. For FXR, "other metals" includes those metals listed above, plus barium, chromium, cobalt, and molybdenum.

Standardized symbols are used for the following materials: beryllium (Be), lead (Pb), copper (Cu), high explosives (HE), and lithium hydride (LiH).

shows the corresponding materials released as a result of these tests, prior to regular firing-point cleanups.

For this EIS, DOE averaged the amount of material used at PHERMEX over the past five years to estimate the expected amounts of material that will be used in the future. However, operations at PHERMEX during the last five years underrepresent the facility's use of depleted uranium. For thisestimate, DOE looked at use over the past 30 years. For example, the average annual release of depleted uranium during the mid-1980s was approximately 450 lb (200 kg) per year. Earlier use expended even greater amounts of material. Based on the known use of depleted uranium during the period from 1963 until 1994, DOE estimates that the expected use of depleted uranium would be higher than the average of the past five years, as shown in table B-4.

For this EIS, DOE estimates that the average annual releases over the past 32 years to the environment as a result of high-explosives testing, prior to regular firing-point cleanups, were:

· Depleted uranium - 1,100 lb (500 kg)

· Beryllium - 15 lb (7 kg)

· Lead - 22 lb (10 kg)

· Copper - 155 lb (70 kg)

· Other metals - 310 lb (140 kg): consists of 50 percent aluminum, 35 percent stainless steel, and 15 percent other metals and alloys, including tantalum, brass, nickel, silver, tin, and very small quantities of others.

· Tritium - 2 Ci

· Lithium hydride - 155 lb (70 kg)

· High explosives - 2,400 lb (1,100 kg)

The alternatives analyzed in this EIS predict an increase in hydrodynamic testing and dynamic experiments. This predicted increase incorporates conservative estimates for the purpose of analyzing impacts in this EIS. It reflects the increased use of radiographic hydrodynamic testing and dynamic experiments over the next few years for reasons such as: the cessation of underground nuclear testing and the pursuit of a Comprehensive Test Ban treaty, the need for stewardship of the nuclear weapons stockpile, benchmarking computer simulations of the stockpile that will be compared to the past data obtained from underground nuclear tests, increases in proliferation assessment and disablement, and the need for tests to improve nuclear weapons safety, security, and reliability.

B.7 WASTE MANAGEMENT

During more than 30 years of PHERMEX operations, a total of about 35,000 lb (16,000 kg) of depleted uranium has been used. This amount of depleted uranium represents a total volume of about 35 ft^3 (1 m^3). LANL has estimated that at least 70 percent of the depleted uranium remained on or near the firing point after test assembly detonations and has been removed during routine operational cleanup of the firing site. The depleted uranium and other firing-site debris are handled as low-level radioactive waste. Approximately 10 to 12 truck loads, each having an average weight of 7 tons (6,400 kg) are sent to TA-54 Area G for disposal each year, totaling about 160,000 lb (70,000 kg). This material consists mainly of firing-site soil, wood, metal, glass, plastic, rubber, and cabling used to set up a test assembly detonation. The average quantity of depleted uranium in this waste would be about 770 lb (350 kg), less than 1 percent of the total waste mass.

Lead has been a constituent of a small number of test assemblies fired at the site; however, when lead is present in a test assembly, the site is cleaned both before and after the test so that the site is cleared of lead before the next test. The firing-site debris (including soil on and around the firing site) is characterized periodically for the presence of RCRA-controlled metals. The negative findings of these characterizations have always resulted in the firing-site debris being classified as low-level radioactive waste (not mixed waste). Other lead is used for shielding (rather than as part of a test assembly) which may become contaminated with radioactive material and is kept onsite for reuse. Approximately 10 percent, less than one 55-gal drum or 220 lb (100 kg) per year, of the lead shielding that is potentially radioactively contaminated is considered unusable, becomes waste, and is transferred to the established LANL mixed-waste program.

As shown in table 3-1, plastics, glues, foams, binders, and other organic materials are used in constructing test assemblies. However, only small quantities, less than a few pounds total for each assembly, are used, and these are mostly destroyed when the assembly is detonated. What little remains would be part of the shot-point debris described above.

A small amount of industrial chemicals and solvents are routinely used to support normal operations at PHERMEX. The major industrial chemicals used on an annual basis are solvents: 3 gal (11 L) of acetone and 6 gal (23 L) of ethanol. Other solvents, which are used on rags for cleaning and are used in very small quantities, are chlorinated fluorocarbons, toluene, 1,1,1-trichloroethane, and xylene. The cleaning rags are collected and disposed as solid potentially hazardous waste following laboratory guidelines. Historically, no more than 220 lb (100 kg) of solid hazardous waste and 1,800 lb (800 kg) of liquid hazardous waste have been disposed for every 1,000 lb (450 kg) of depleted uranium used at PHERMEX firing site.

Nonhazardous solid waste from the building is sent to the county landfill. Approximately one dumpster of nonhazardous solid waste is generated per week.

Wastes generated under current operations and under the proposed alternatives would be subject to treatment, storage, and disposal in other LANL Technical Areas. Transportation of these wastes is conducted using DOE- or DOT-approved containers carried on government vehicles using public roads between LANL facilities, as needed.

The PHERMEX facility has sanitary and storm water management systems. The sanitary system employs a septic tank and leach field. The storm system directs rainwater away from buildings. The sanitary system is registered with Los Alamos County and the storm system has an EPA authorization to discharge. Cooling tower blowdown consisting of a few gallons per year is discharged into the sanitary system.

When containment was used for a test shot, the containment vessel was taken to another LANL facility for cleaning and refurbishing. The blast debris removed was taken to appropriate LANL facilities for processing and disposition.

B.8 DISTRIBUTION OF MATERIAL RELEASED TO THE ENVIRONMENT

For the purposes of this EIS, DOE has estimated the distribution of test assembly material released to the environment to support evaluation of potential impacts for the proposed alternatives. Approximately 50 percent of the depleted uranium in test assemblies at the PHERMEX site is contained in simulated secondaries and blast pipes of pin experiments. During detonation this fraction of the depleted uranium is ejected as relatively large fragments (see figure B-1) that remain in the immediate vicinity of the firing point and are collected during routine cleanup operations. Another approximately 40 percent of the total depleted uranium may be dispersed as relatively small, platelet-shaped fragments having surface areas ranging from 0.08 to 1.1 in^2 (0.5 to 7 cm^2). About half of this material remains in the immediate vicinity of the firing point and is also collected during routine cleanup. Therefore, about 70 percent of the total depleted uranium used on the firing site is collected during cleanup operations. The remaining depleted uranium (about 10 percent of the total) may be released as an aerosol, all of which was considered respirable for the EIS analyses. Respirable particles are those with an activity median aerodynamic diameter (AMAD) of 3.94×10^{-4} inches (10 μ) or less.

The other half of the small depleted uranium fragments (20 percent of the total depleted uranium) dispersed as a result of detonation typically falls within a 4,100-ft (1,250-m) circle. Larger particles of the aerosolized fraction may also fall out from the plume of released material and be deposited near the firing point. These two fractions constitute the majority of depleted uranium contamination that has been detected in the soil (McClure 1995).

The release and aerosolization fractions described above are also used to estimate the dispersion of other constituents in test assemblies detonated on the PHERMEX firing site. Thus, the other metals (beryllium, lead, copper, and "other metals" in table B-4) are presumed to distribute in ways similar to depleted uranium. Lithium hydride converts to the hydroxide and is not an environmental problem. The high explosives convert to water, NO_2, and CO_2; any residues are extremely minor.

B.9 TRANSPORTATION

Test assemblies that include high explosives are shipped using DOE and LANL trucks, containers, and tie-down techniques from the assembly area at TA-16 to the PHERMEX site. This is a total distance of about 3.5 miles under a speed limit of 35 miles per hour. This shipment is conducted on LANL secure roads and is not conducted on public roads. Transportation requirements consist of one trip for each assembly and up to three trips for shipment of support materials. Support shipments might include high explosives or surrogate materials, but not both simultaneously. Shipments of radioactive surrogate materials exhibit no external radiation exposure characteristics either because of the nature or the characterization of the shipping container.

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APPENDIX C

AIR QUALITY AND NOISE

This appendix presents the methods used for analyzing potential impacts to air quality and potential noise impacts. Appendix C1, Air Quality, addresses routine emission of nonradiological air pollutants from the DARHT and PHERMEX sites from construction activities and normal operations. Pollutants addressed in this appendix include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), respirable particulate matter (PM_{10}), heavy metals, beryllium, and lead.

Appendix C2, Noise, provides methods and information on potential noise impacts from explosive detonation activities, construction, and traffic that would be associated with the DARHT or PHERMEX facilities.

APPENDIX C1: AIR QUALITY

Emission of nonradiological air pollutants into the atmosphere is regulated by Federal and State ambient air quality standards. Nonradioactive air pollutants at LANL are summarized in chapter 4. Estimates of the air quality impacts that would result from the emission of nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter with a 10-µ or less aerodynamic diameter (PM_{10}) were presented in chapter 5. Other criteria pollutants are carbon monoxide (CO) and ozone (O_3), but these pollutants are not emitted in any significant quantities by the operation of the facilities. Modeling tools and assumptions used to estimate impacts on air quality are presented in this appendix. In formulating inputs for air quality modeling, a series of conservative assumptions was made (i.e., assumptions which tended to maximize air quality impacts).

C1.1 MODELS

The Industrial Source Complex (ISC2) computer code was used to estimate the annual air quality impacts, as well as some of the short-term air quality impacts of criteria pollutants. The ISC2 model consists of the ISC2 short-term model (ISCST2) and the ISC2 long-term model (ISCLT2). The two models use steady-state Gaussian plume algorithms to estimate pollutant concentrations from a wide variety of sources associated with industrial complexes (EPA 1992a). The models are appropriate for flat or rolling terrain, modeling domains with a radius of less than 31 mi (50 km), and urban or rural environments. The ISC2 models are approved by the EPA for specific regulatory applications and designed for use on personal computers. Input requirements for the ISC2 model include a variety of information that defines the source configuration and pollutant emission parameters. The user may define point, line, area, or volume sources. The ISCST2 model uses hourly meteorological data to compute straight-line plume transport and diffusion, while the ISCLT2 model uses a joint frequency distribution of wind direction, wind speed, and atmospheric stability data to compute the transport and diffusion. Plume rise, stack tip downwash, and building wake can be computed and deposition taken into account. The ISC2 models compute a variety of short- and long-term averaged products (concentrations and depositions) at user-specified receptor locations. Tables C1-1**Table C1-1.-*Input Parameters for Modeling Short-term Releases***

of NO_2 Emissions from Natural Gas Boiler, ISCST2 Model

Parameter	Value

Pollutant Type	NO_2
Averaging Time	24 h
X-coordinate of Source on Grid	0.0
Y-coordinate of Source on Grid	0.0
Release Height of Source	0.0 m
Emission Rate of Source	4.53×10^{-3} g/s
Exit Temperature of Source	373 K
Exit Velocity of Source	0.0 m/s
Exit Diameter of Source	0.0 m
Origin of Receptor Rings: x-coordinate y-coordinate	0.0 0.0
Radii of Polar Rings (m)	100. 200. 400. 800. 1000. 1200. 1500. 1800. 2000. 2500. 2700. 3000. 4000. 4400. 5000. 5500. 6000. 7000.
Number of Receptors per Ring	16
Height of Receptors	0.0 m
Starting Angle at each Ring	0.0 deg
Angle between Receptors on Ring	22.5 deg
Meteorological Input File	TA61994.MET
Anemometer Height	10 m

and C1-2**Table C1-2.-*Input Parameters for Modeling Long-term NO_2 Emissions***

from Natural Gas Boiler, ISCLT2 Model

Parameter	**Value**
Pollutant Type	NO_2
Averaging Time	24 h
X-coordinate of Source on Grid	0.0
Y-coordinate of Source on Grid	0.0
Release Height of Source	0.0 m
Emission Rate of Source	4.53×10^{-3} g/s
Exit Temperature of Source	373 K
Exit Velocity of Source	0.0 m/s
Exit Diameter of Source	0.0 m
Origin of Receptor Rings: x-coordinate y-coordinate	0.0 0.0
Radii of Polar Rings (m)	100. 200. 400. 800. 1000. 1200. 1500. 1800. 2000. 2500. 2700. 3000. 4000. 4400. 5000. 5500. 6000. 7000.
Number of Receptors per Ring	16
Height of Receptors	0.0 m
Starting Angle at each Ring	0.0 deg
Angle between Receptors on Ring	22.5 deg

Meteorological Input File	LANLTA6.JFD
Anemometer Height	10 m
Average Wind Speed for Six Wind Speed Categories (m/s)	1.23 2.40 4.08 6.46 9.30 13.28
Average Temperature for Six Stability Classes	282 K
Averaging Mixing Height for: Stability A Stability B Stability C Stability D Stability E Stability F	2600.0 m 2170.0 m 1740.0 m 1310.0 m 880.0 m 450.0 m

present input parameters for the short-term and long-term models, respectively.

To calculate some of the short-term (24-h or less) criteria pollutant impacts, the SCREEN2 model was used. SCREEN2 is a screening model used to estimate short-term air pollutant concentrations, including estimates of maximum ground-level concentrations from a single source (EPA 1992b). The model uses a steady-state Gaussian plume algorithm to calculate the concentration from a single point, area, or simple volume source. The model can be applied to both simple and complex terrain for modeling domains out to 62 mi (100 km). Input requirements for SCREEN2 include information about the source configuration and pollutant emission parameters. Plume rise, building wake downwash, fumigation, and plume impaction on complex terrain can be computed. While specific meteorological values of wind speed and stability can be input to calculate pollutant transport and diffusion, the model can also calculate a worst-case maximum concentration, in which the model examines a range of stability classes and wind speeds to identify the "worst-case" meteorological conditions. Output of the SCREEN2 model is 1-h maximum concentration at specified distances. Adjustment factors can be applied to estimate concentrations for longer averaging periods (i.e., up to 24 h). The SCREEN2 model is approved by the EPA for specific screening procedures and is designed to run on personal computers.

C1.2 RECEPTORS

Maximum ground-level pollutant concentrations for regulatory-significant time periods are reported at the maximally impacted receptor location. To capture this impact, ISC2 model runs have at least one receptorlocation in each of the 16 transport directions (north, north-northeast, etc.) used by the model. Receptors are positioned at points of public access along publicly accessible roads within the boundaries of LANL, along the LANL fenceline, and in existing residential areas (figure C1-1).

To determine maximum short-term (i.e., exposure periods from 1 to 24 h) impacts, pollutant concentrations are reported for the maximally impacted point of public access. This involves assessing impacts at receptors located within, along, and outside of the LANL fenceline. For long-term impacts (i.e., annual exposures), pollutant concentrations are reported for the maximally impacted point of unrestricted public access. This involves the assessment of impacts at receptor locations along and outside of the LANL fenceline. Onsite points of public access are not considered because of the limited time any member of the public would spend at an onsite location over the course of an entire year; however, receptor locations along large segments of the LANL fenceline are considered even though current land-use restrictions do not allow permanent residents in these areas.

ISC2 model runs indicate that the maximum short-term (i.e., 1, 3, 8, and 24 h) pollutant concentrations would occur along the LANL fenceline at a point 1.0 mi (1.5 km) southwest of the proposed DARHT Facility (receptor 18 on figure C1-1). Maximum long-term (annual) pollutant concentrations would occur along the LANL fenceline at a point 1.1 mi (1.8 km) south of the DARHT Facility (receptor 16 on figure C1-1). Because of the close proximity of the DARHT and PHERMEX sites, emissions from both facilities are conservatively assumed to occur at the DARHT Facility.

C1.3 SOURCE TERM AND IMPACTS

The increases in the airborne concentration of criteria pollutants, as described for each alternative in chapter 5, is assumed to result from construction activities and routine operation of the DARHT or PHERMEX facilities. Construction activities release NO_2, SO_2, and PM_{10} as a result of the operation of diesel- and gasoline-powered construction equipment. PM_{10} emissions also occur, in the form of fugitive dusts, as a result of the movement of construction equipment over the disturbed ground. Operations activities release NO_2 and PM_{10} as a result of emissions during hydrodynamic testing and NO_2, SO_2, and PM_{10} as a result of the operation of the natural gas boiler used in heating the DARHT Facility.

In all but one case, pollutants were assumed to be released from a ground-level point source located on flat terrain; the only exception to this is that fugitive dust emissions during construction are assumed to come from an area source. The use of more realistic pollutant release heights, accounting for buoyant and mechanical plume rise, and the consideration of initial plume spreading (e.g., as would result from

hydrodynamic testing) are factors that would tend to reduce maximized ground-level impacts, but were not included in this analysis.

To calculate annual pollutant concentrations using the ISCLT2 model, a joint frequency distribution of wind speed, wind direction, and atmospheric stability data from tower TA-6 was used (exhibit C1-1). The TA-15 area, where the proposed DARHT and PHERMEX facilities are located, does not have routine meteorological monitoring. As described in appendix H, meteorological data from TA-6 were also used to compute human health impacts from the airborne transport of pollutants.

The ISCLT2 model also required estimations of average mixing layer depth for the six stability classes (A-F). Because no mixing height data is available from Los Alamos, the annual morning mixing height of Albuquerque, 1,500 ft (450 m), is assumed to be the average mixing layer depth for stability class F (very stable), and the annual afternoon mixing height of Albuquerque, 8,500 ft (2,600 m), is assumed to be the average mixing layer depth for stability class A (very unstable) (Holzworth 1972). The mixing layer depths at stability classes between A and F are estimated by linear interpolating between the mixing heights at stability class A and F.

To calculate the short-term averaged concentration using the ISCST2 model requires hourly meteorological data of wind speed, wind direction, atmospheric stability, air temperature, and mixing heights. The hourly meteorological data for 1994 at tower TA-6 were used as meteorological input in the ISCST2 model. Because mixing layer depth is not measured at Los Alamos, a conservative estimate of the morning mixing height for Albuquerque for all stability classes was used (Holzworth 1972). The morning mixing height varied by season.

For estimating the short-term averaged concentration using the SCREEN2 model, no meteorological input is required. The worst-case maximum concentration option is used in which the SCREEN2 model estimates the maximum concentration by examining a range of wind speed and stability classes to find the worst-case meteorological conditions. For a ground-level release, the worst-case meteorological variables are a 2 mi/h (3.6 km/h or 1 m/s) wind speed and a stability class of F (very stable).

C1.3.1 Fugitive Dust

Because it is nearly impossible to accurately predict the amount of dust emitted during construction, a default value of 1.2 ton/ac/mo of total suspended particulates is assumed (EPA 1993). This value was based on EPA measurements of suspended particulates (with aerodynamic diameters = 30 µ) made during the construction of apartments and shopping centers. It takes into account emissions during land clearing, blasting, ground excavation, cut and fill operations, and facility construction (EPA 1993).

The amount of PM$_{10}$ emitted from the construction at the DARHT site should be less than

1.2 ton/ac/mo because many of the particulates suspended during construction are at the larger end of the 30-µ size range and will tend to rapidly settle out of the atmosphere at locations very close to the source (Seinfeld 1986). Experiments on dust suspension due to construction found that at 160 ft (50 m), a maximum of 30 percent of the remaining suspended particulates in the atmosphere were in the PM$_{10}$ size range (EPA 1988). Thus, only 30 percent of 1.2 ton/ac/mo of total suspendable particulates or 0.4 ton/ac/mo are assumed to be emitted as PM$_{10}$ from the construction site. Any active dust suppression activities at the DARHT construction site would further reduce PM$_{10}$ emissions; however, no dust suppression activities are assumed in our analysis.

To estimate the annual and 24-h average PM$_{10}$ concentration requires both the size of the area disturbed and the unit-area emission rate (0.4 ton/ac/mo). For all alternatives except the No Action, a square-shaped area of 8 ac (3 ha) is assumed to be disturbed. For the No Action Alternative, the construction impacts

Table C1-3.-*Source Term for Calculating Fugitive Dust Impacts*

for All Alternatives Except the No Action Alternative

Pollutant	**Averaging Time**	**Mass of Pollutant per Time Period per Area**	**Area of Source (ac)**	**Maximum Emission Rate (g/(m^2-s))**
PM$_{10}$	Annual	4.4×10^3 kg/(yr-ac)	8	3.4×10^{-5}
	24-h	12 kg/(24-h-ac)	8	3.4×10^{-5}

Table C1-4.-*Impacts on Air Quality from Fugitive Dust*

from Completing Construction for the DARHT Facility

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access (μg/m^3)	**Percent of Regulatory Limit[a]**
PM$_{10}$	Annual 24-h	0.8 17	1.6% 11%

[a] Uses the applicable regulatory limit from table 4-3.

Note: No Action Alternative construction impacts were estimated to be no more than one-half those of other alternatives.

Table C1-5.-*Estimated Average Monthly and Peak Daily Consumption*

of Diesel and Gasoline for Construction of the DARHT Facility

Fuel	**Average Monthly Consumption (gal/mo)**	**Daily Peak Consumption (gal/day)**
Diesel	500	135
Gasoline	500	17

Table C1-6.-*Amount of Pollutant Released per m^3 of Fuel Consumed*

by Construction Equipment with Highest Emissions

Pollutant	**Diesel** **(kg of pollutant/m^3)**	**Gasoline** **(kg of pollutant/m^3)**
NO$_2$	52.4	17.5
SO$_2$	3.7	0.6
PM$_{10}$	5.6	1.0

are assumed to be no more than one-half of those from the other alternatives, as some construction occurs on the existing DARHT structure to ready it for other uses. Table C1-3 presents the source term used to calculate the air quality impacts from fugitive dust emissions. Both the annual and 24-h maximum average concentrations are calculated using the ISC2 models. Estimated impacts on air quality from fugitive dust emissions are shown in table C1-4. These impacts apply to all alternatives except the No Action Alternative.

C1.3.2 Construction Equipment

The other major source of criteria pollutant emissions from construction is the operation of diesel- and gasoline-powered construction equipment. To obtain the emission rate for each pollutant from the construction equipment, it is assumed that all the diesel and gasoline are consumed by the heavy-duty construction equipment that emits the maximum amount of each pollutant for the given equipment type. The pollutant emission rate for heavy-duty construction equipment is found in EPA's AP-42 tables 2-7.1 and 2-7.2 (EPA 1991). Table C1-5 presents the estimated average monthly and the peak daily consumption of diesel and gasoline for construction of DARHT. Table C1-6 presents the kilograms of pollutant emitted per cubic meter (m^3) of fuel consumed by the construction equipment. For all pollutants but SO_2, the largest emitter is a wheeled tractor; the motor grader and the wheeled dozer are the largest emitters of SO_2 for diesel- and gasoline-powered equipment, respectively.

The emission rate for the annual concentration is calculated from the average monthly emissions, assuming that the construction is year round. Annual concentrations are calculated using the ISCLT2 model.

The 3-h average emission rate assumes that all of the full workday ration of fuel is consumed in a 3-h period [i.e., 135 gal (0.5 m^3) of diesel fuel per 3 h]. The 24-h average emission rate assumes that the same workday ration of fuel is consumed over a 24-h period. The short-term average concentrations are calculated using the SCREEN2 model. Because there is no specific information on different fuel consumption rates for the various alternatives, the same annual, 24-h, and 3-h consumption rates are used for all the alternatives except the No Action Alternative.

Table C1-7.-*Source Term for Construction Equipment Emissions*

for All Alternatives Except the No Action Alternative

Pollutant and Averaging Time	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
PM_{10}	Annual	150 kg/yr	4.7×10^{-3}
	24-h	2.9 kg/24 h	3.4×10^{-2}
NO_2	Annual	1,600 kg/yr	5.0×10^{-2}
	24-h	28 kg/24 h	3.2×10^{-1}
SO_2	Annual	99 kg/yr	3.2×10^{-3}
	24-h	1.9 kg/24 h	2.3×10^{-2}
	3-h	1.9 kg/3 h	1.8×10^{-1}

Table C1-8.-*Impacts on Air Quality from Construction Equipment Emission*

for All Alternatives Except the No Action Alternative

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit[a]
NO_2	Annual	0.04	0.06%
	24-h	4.8	3.3%
PM_{10}	Annual	0.004	0.008%
	24-h	0.06	0.04%
SO_2	Annual	0.003	0.007%
	24-h	0.3	0.2%
	3-h	22	2.2%

[a] Uses the applicable regulatory limit from table 4-3.

Note: No Action Alternative construction-related impacts assumed to be no more than one-half those of other alternatives.

Table C1-7 presents the source term for the construction equipment emissions used for all alternatives except the No Action Alternative.

Estimated impacts on air quality from construction equipment emissions are shown in table C1-8. These impacts apply to all alternatives except the No Action Alternative, which is estimated to have air quality impacts no more than one-half of the other alternatives for construction-related activities.

C1.3.3. Hydrodynamic Testing

Five ambient air pollutants - NO_2, PM_{10}, beryllium, heavy metals (uranium and lead), and lead - are assumed to be emitted during hydrodynamic testing. These are products of detonation of high explosives and the resultant aerosolization of metals. It is assumed that the high explosives do not contain any significant amounts of sulfur; thus, they are not a source of sulfur dioxide.

For purposes of this analysis, it was assumed that 10 percent of the metals in a device become respirable (PM_{10}) following a test. The remaining materials, detectable above background levels, stay within 460 ft (140 m) of the firing point (see appendix B). Table C1-9**Table C1-9.-*Estimated Material Released to the Environment During a Year***

of Testing for the No Action and Enhanced Containment Alternatives

Alternative	**DU (kg)**	**Be (kg)**	**Pb (kg)**	**Cu (kg)**	**Other Metal (kg)**	**HE (kg)**	**LiH (kg)**	**Total (kg)**
No Action[a]	700	10	15	100	200	1,500	100	_2,600
Enhanced Containment								
Vessel	210	3	4	30	60	1,500	30	_1,800
Building	42	1	1	6	12	1,400	6	_1,500
Phased	330[b]	5[b]	7[b]	50[b]	90[b]	1,500[b]	50[b]	_2,000[b]

DU = Depleted uranium Be = Beryllium

Pb = Lead Cu = Copper

HE = High explosives LiH = Lithium hydride

[a] Other alternatives are the same as the No Action Alternative.

[b] Annual average over 30-year operating life.

gives the estimated maximum amount of material used each year in the No Action and the Enhanced Containment alternatives. With the exception of the Enhanced Containment Alternative, all the alternatives involve the same amount of material. Under the Enhanced Containment Alternative, the containment building or vessel limits the release of gases, fine particles, and fragments to 6 percent of the values estimated for the other alternatives. The 6 percent release factor is a highly conservative assumption that accounts for potential leakage of the containment structure and vessel/ building failure. Annual concentrations are calculated using the ISCLT2 model.

For the 24-h concentration of PM_{10}, an estimate of the largest amount of material to be expended in a 24-h period is needed. To provide a rough estimate of the maximum amount of material that could be detonated in a 24-h period, the largest test device detonation was used for all alternatives, assuming detonation of 500 lb (230 kg) of material in a 24-h period. The same emission rate was used for all alternatives except the Enhanced Containment Alternative, for which the emission rate is assumed to be 6 percent of the No Action Alternative. The 24-h PM_{10} concentrations are calculated using the SCREEN2 model.

Nitrogen dioxide can be produced from the detonation of high explosives. Because the type of high explosives to be used during testing is variable, a bounding case is used. The high explosive used in thisassessment was nitroglycerine (even though this specific explosive would not be used in hydrodynamic testing) because it has the highest emission rate of nitrogen dioxide, 53 lb/ton (26 kg/MT), of any of the explosives listed by the U.S. Environmental Protection Agency for stationary point and area sources (EPA 1993). Table C1-9 shows the yearly amount of high explosives to be used for the No Action and Enhanced Containment alternatives. All alternatives except the Enhancement Containment Alternative use the same amount of explosives as the No Action Alternative.

The annual emission rate for nitrogen dioxide from hydrodynamic testing is the product of the number of tons of high explosive used per year and the amount of nitrogen dioxide released per ton of explosive. The emission rate for nitrogen dioxide is the same for all alternatives except the Enhanced Containment Alternative, which uses a smaller quantity of high explosives. The annual concentrations are calculated using the ISCLT2 model.

For the 24-h emission rate of nitrogen dioxide from hydrodynamic testing, the largest amount of high explosive expended in a 24-h period is needed. This quantity is not known. It is assumed that 500 lb (230 kg) of high explosive (nitroglycerine for purposes of nitrogen dioxide emission) will be the maximum amount detonated in a 24-h period. The same emission rate is used for all alternatives. (In the Enhanced Containment Alternative, nitrogen dioxide emissions might initially be contained, but they are soon vented from the building or vessel.) The 24-h concentrations are calculated using the SCREEN2 model.

Table**Table C1-10.-*Source Term for Hydrodynamic Testing for the No Action***

and Enhanced Containment Alternatives

Alternative	Pollutant	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
No Action[a]	PM_{10} NO_2	Annual 24-h Annual 24-h	260 kg/yr 23 kg/24-h 39 kg/yr 5.9 kg/24-h	8.3×10^{-3} 2.6×10^{-1} 1.2×10^{-3} 6.8×10^{-2}
Enhanced Containment	PM_{10}[b] NO_2	Annual 24-h Annual 24-h	8.8 kg/yr 1.4 kg/24-h 36 kg/yr 5.9 kg/24-h	2.8×10^{-4} 1.6×10^{-2} 1.1×10^{-1} 6.8×10^{-2}

[a] Other alternatives are the same as the No Action Alternative.

[b] Values shown are for the Building Containment Option. Values for the Vessel Containment Option and Phased Containment Option would be between the No Action Alternative and Building Containment Option values.

Table C1-11.-*Data Used to Estimate Ambient Air Concentrations*

of Metals from Hydrodynamic Testing

Parameter	Uncontained Detonation	Containment Release
Release height	elevated (99 m)	ground level (<10 m)
__/Q´	6.8 x 10^{-8} s/m^3	5.3 x 10^{-7} s/m^3
Release fraction	1.0	0.06
Respirable fraction	0.1	1.0

· Comparison point was at State Road 4, approximately 0.9 mi (1.5 km) southwest of the DARHT site.

· Comparisons to 30-day air quality standards for heavy metals and beryllium assumed 25 percent of the annual usage of materials; assumed quantities used were 175 kg uranium, 2.5 kg beryllium, and 3.75 kg lead.

· Comparison to the calendar quarter air quality standard for lead assumed 50 percent of the annual usage of material; assumed quantity used was 7.5 kg lead.

· Uncontained detonation characterized the No Action, DARHT Baseline, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis alternatives.

· The Building Containment Option of the Enhanced Containment Alternative was characterized as 100 percent containment use.

· The Vessel Containment Option of the Enhanced Containment Alternative was characterized as 25 percent uncontained detonation, 75 percent containment use.

· The Phased Containment Option (preferred alternative) of the Enhanced Containment Alternative was evaluated as 1) 5 percent containment release and 95 percent uncontained detonation; 2) 40 percent containment release and 60 percent uncontained detonation; and 3) same as the Vessel Containment Option of the Enhanced Containment Alternative.

C1-10 gives the source term used to estimate the air quality impacts from PM_{10} and NO_2 due to hydrodynamic testing for the No Action and Enhanced Containment alternatives. As stated before, all alternatives except the Enhanced Containment Alternative are assumed to be the same as the No Action Alternative.

Ambient air concentrations for beryllium, heavy metals (uranium and lead), and lead were estimated using information presented in table C1-11. Twenty-five percent of the annual usage of metals was assumed to be released during the 30-day averaging time for beryllium and heavy metals, and 50 percent was assumed released during the calendar quarter averaging time for lead. Estimated impacts on air quality from releases of metals during hydrodynamic testing are shown in table C1-12.**Table C1-12.-*Impacts on Air Quality from Hydrodynamic Testing***

for the Enhanced Containment Alternative

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access (μg/m^3)	Percent of Regulatory Limit[a]
NO_2	Annual 24-h	8×10^{-4} 0.9	0.001% 0.6%
PM_{10}	Annual 24-h	0.003 0.2[c] 3.2[d]	0.006% 0.1%[c] 2.1%[d]
Beryllium	30 days	2×10^{-5}	0.0002%
Heavy Metals[b]	30 days	0.002	0.02%
Lead	Calendar Quarter	1×10^{-4}	0.007%

[a] Uses the applicable regulatory limit from table 4-3.

[b] Sum of the air concentration of uranium and lead.

[c] Building Containment Option.

[d] Vessel Containment and Phased Containment options.

Air quality impacts from uncontained detonations are lower than those from containment releases. There are three major reasons for this.

· Atmospheric Dispersion: There is more atmospheric dispersion from uncontained detonations than from containment releases. Greater dispersion results in lower contaminant concentrations in air. Dispersion of ground-level releases is considerably less than for elevated releases, particularly for nearby locations. In general, ground-level releases impact closer individuals much more than elevated releases, which have greater impact on distant individuals and populations because of the greater dispersion. Thus, even though less material is released via the enhanced containment alternative, the potential for exposure is greater because of the decreased dispersion of ground-level releases.

· Source Term: It is conservatively assumed that 6 percent of the material used inside containment would be released. These releases from containment would be ground-level [< 30 ft (< 10-m high)] releases occurring as part of normal operations (1 percent) or small failures (5 percent) of the containment structure (building or vessel), rather than elevated releases as for uncontained detonations.

· Receptor Location: The point where a member of the public could receive the maximum offsite exposure is only 0.9 mi (1.5 km) from the firing point, southwest to State Road 4. This relatively short distance to the receptor and point of air quality determination tends to maximize the issues raised in items 1 and 2 above.

Item 1 above relatively decreases the impact of uncontained detonations, item 2 relatively decreases the impact of contained releases, and item 3 relatively increases the impact of contained releases. Taking all these issues into consideration, 100 percent containment releases have an air quality impact about five times those of 100-percent uncontained detonation releases.

Estimated impacts on air quality from uncontained detonations during hydrodynamic testing are shown in table C1-13**Table C1-13.-*Impacts on Air Quality from Hydrodynamic***

Testing for All Uncontained Alternatives

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access (μg/m^3)	Percent of Regulatory Limit[a]
NO_2	Annual 24-h	0.001 0.9	0.001% 0.6%
PM_{10}	Annual 24-h	0.007 3.2	0.01% 2.1%
Beryllium	30 days	5×10^{-6}	0.00005%
Heavy Metals[b]	30 days	5×10^{-4}	0.005%
Lead	Calendar Quarter	2×10^{-5}	0.001%

[a] Uses the applicable regulatory limit shown in table 4-3.

[b] Sum of the air concentration of uranium and lead.

Table C1-14.-*Emission of Primary Pollutants from Natural Gas*

Combustion, Heating Value, and Hourly Gas Input for an 80-hp

Commercial Boiler for All Alternatives

Pollutant	Pollutant Emitted (kg of pollutant per 10^6 m^3 of fuel)	Heating Value (kcal/m^3)	Hourly Gas Input (10^3 Btu/hr)

NO_2	1,600	8,270	3,348
SO_2	9.6	8,270	3,348
PM_{10}	192	8,270	3,348

. These impacts apply to all alternatives except the Enhanced Containment Alternative. Impacts from the Enhanced Containment Alternative are shown in table C1-12.

C1.3.4. Boiler Emissions

The only other primary pollutant source from operation of the facility is emissions from the natural gas boiler used for heating. The natural gas boiler is assumed to be a commercial boiler (80 hp) with an hourly gas input rate of 3,348,000 Btu/hr. The emission rate of each pollutant can be calculated from the emission factors for commercial natural gas boilers given in EPA's AP-42 document (EPA 1993). Table**Table C1-15.-*Source Term for Emissions from the Natural Gas Boiler***

Used in Heating the Facilities for All Alternatives

Pollutant	Averaging Time	Mass of Pollutant per Time Period	Maximum Emission Rate (g/s)
PM_{10}	Annual 24-hr	170 kg/yr 4.7×10^{-1} kg/24-h	5.4×10^{-3} 5.4×10^{-3}
NO_2	Annual 24-hr	1,400 kg/yr 3.8 kg/24-h	4.5×10^{-2} 4.5×10^{-2}
SO_2	Annual 24-hr 3-hr	8.6 kg/yr 2.4×10^{-2} kg/24-h 2.9×10^{-3} kg/3-h	2.7×10^{-4} 2.7×10^{-4} 2.7×10^{-4}

Table C1-16.-*Impacts on Air Quality from Emissions*

from the Natural Gas Boiler for All Alternatives

Pollutant	Averaging Time	Maximally Impacted Point of Unrestricted Public Access ($\mu g/m^3$)	Percent of Regulatory Limit[a]
NO_2	Annual	0.04	0.06%
	24-h	1	0.7%
PM_{10}	Annual	0.004	0.008%
	24-h	0.1	0.07%
SO_2	Annual	0.0002	0.0005%
	24-h	0.006	0.003%
	3-h	0.03	0.003%

[a] Uses the applicable regulatory limit from table 4-3.

Note: Air quality impacts are identical for all alternatives.

C1-14 gives these emission rates in units of kilograms of primary pollutant (nitrogen dioxide, sulfur dioxide, and PM_{10}) per million m^3 of natural gas. The rates are computed assuming a heating rate of 8,270 kcal/m^3 of natural gas (EPA 1993). To be conservative, the boiler is assumed to run continuouslythroughout the year. It is also assumed that the boiler has no emissions controls for nitrogen dioxide. Since the hourly gas input rate is known, there is no special requirement for finding the short-term emission rates compared to annual emission rates. The emission rate is the same for all alternatives. Table C1-15 presents the source term used to estimate the air quality impacts due to emissions from the natural gas boiler. All the concentrations are calculated using the ISC2 models.

Estimated impacts on air quality from boiler emissions are shown in table C1-16. These impacts apply to all alternatives.

APPENDIX C2: NOISE

This evaluation of noise impacts focuses on three sources of noise: construction noise associated with each alternative, increases or decreases in traffic and resulting noise propagation in adjacent communities based on facility construction and operation, and effects of noise from the firing of test shots at the facilities. In support of the evaluation, this appendix reviews how meteorological conditions and terrain influence sound travel, summarizes noise measurements made at a series of testing firings at PHERMEX on March 11, 1995, and documents the tests or methods employed in the noise analysis.

C2.1 GENERAL INFORMATION

Noise is defined as sound that is loud, harsh, or confusing to humans. The standard unit of sound pressure level is the decibel (dB). The decibel (dB) is an expression of sound pressure level that is referenced to a pressure of 20 micropascals expressed on a logarithmic scale,

$1\ \text{dB} = 20 \log_{10} (p/20)$

where p is the sound pressure in micropascals. Twenty micropascals approximates the minimum audible sound pressure level in humans and is routinely used for noise levels. The dB(A) is an expression of adjusted pressure levels by frequency that accounts for human perception of loudness; consequently, dB(A) is most often used when evaluating human noise disturbance. For example, at a frequency of 500 Hz, 60 dB are reduced by 3.2 dB to give an a-weighted pressure level of 56.8 dB(A). Frequencies lower than 500 Hz sustain a larger adjustment (from -8.6 to -26.2 dB compared to frequencies greater than 500 Hz (-1.1 to 1.2).

For this assessment, noise is expressed in two forms. A-weighted sound pressure levels (dBA) are adjusted values that are most indicative of adverse community responses to noise. Firing noise levels are reported as peak dBA levels. Noise derived from traffic estimates are reported as 1-h equivalent sound levels (L_{eq}). The L_{eq} (in dBA) is the equivalent steady-state sound level that, if continuous during a specified time period, would contain the same energy as the actual time-varying sound over the monitored or modeled time period (in this case, 1 h). Except for vehicles exceeding 10,000 lb (4,540 kg) Gross Vehicle Weight (GVW), vehicle noise on public thoroughfares is exempted from residential noise standards.

C2.2 NOISE ANALYSIS MARCH 1995 TEST SHOTS

On March 11, 1995, at the PHERMEX pad, a series of test shots was fired to obtain seismic and acoustic measurements at selected locations. The coordinates at the PHERMEX firing point were North 35_49.957´ and West 106_17.739´. Acoustic (sound pressure) readings were taken by instruments fitted with wind screens at three locations: Technical Area 49 (TA-49), Bandelier National Monument entrance, and the community of White Rock.

C2.2.1 TA-49

The sampling location was located approximately 3/4 mi (1 km) east of the TA-49 Gate along State Route 4 (coordinates for this site were North 35_49.133´ and West 106_18.518´). A multi-spectral IVIE sound-level meter (IVIE #677) was used to record maximum sound pressure levels at nine standard frequencies. This location was the shortest distance between the firing site and the site boundary.

C2.2.2 Bandelier National Monument Entrance

This sampling location was located just off State Route 4 in a turn-off on the east side of the highway about 100 yards west of the entrance to Bandelier National Monument. The coordinates were North 35_47.797´ and West 106_16.545´. A multi-spectral IVIE sound-level meter (IVIE #436) was used to record maximum sound pressure levels at nine standard frequencies. This location represents the closest residence to the PHERMEX firing site.

C2.2.3 White Rock Community

This station was located about 100 to 150 ft (30 to 45 m) east of the intersection of State Route 4 and Karen Circle Road on LANL property just off State Route 4. The mean coordinates of two readings were North 35_82.026´ and West 106_22.182´. A-weighted sound levels were measured with a GenRad Precision Sound Level Meter at 250 Hz. On March 11, 1995, White Rock, which is generally ENE of PHERMEX, was not directly downwind of PHERMEX. Because of terrain and anticipated wind patterns, this location represents the community that is most likely to have the greatest noise levels resulting from blasts.

Acoustic measurements collected on March 11, 1995, measured air over pressure signals (frequencies from 2 to 200 Hz) with a microphone equipped with a wind screen. Measurements were collected at the TA-49 location from two duplicate sensors (Station B1 and Station B2), as shown in table C2-1**Table C2-1.-*Acoustic (Airblast) Measurement at***

TA-49 Seismic

and Acoustic Monitoring Stations, March 11, 1995

Shot #	Load[a]	Time	Station B1			Station B2		
			AOP[b]	dB	Hz	AOP[b]	dB	Hz
0942	10	12:15	<0.04	NS	NS	<0.04	NS	NS
0943	25	12:38	<0.04	NS	NS	<0.04	NS	NS
0944	50	13:01	0.17	119	6.6	0.14	117	6.9
0945	50	13:33	<0.04	NS	NS	<0.04	NS	NS
0946	100	13:54	0.11	116	6.0	0.12	116	6.2
0958	150	14:16	0.21	121	7.1	0.20	120	5.0

[a] lb TNT used

[b] Air overpressure in millibars

dB = decibel

Hz = frequency, in Hertz

NS = not sampled

Table C2-2.-*Estimated Distances Between PHERMEX*

Firing Site and Sound Measurement Locations

Location	Distance
TA-49 (off Route 4)	1.3 mi (2 km)
Bandelier National Monument Entrance	2.6 mi (4 km)
White Rock	4.0 mi (6 km)

Los Alamos	3.0 mi (5 km)

. Air blast measurements were measured at frequencies (5 to 15 Hz) which do not contribute to the A-weighted measurements for evaluation of human noise impacts. Consequently, air blast measurements are not addressed further.

Meteorological and environmental factors significantly affected the March 11, 1995, noise measurements. Terrain and wind are discussed below.

C2.2.4 Terrain

LANL is situated on the Pajarito Plateau and supports a mixture of conifers, trees, and shrubs. This ground cover will attenuate sound as it travels over land. Generally, the higher frequency sound is more

effectively attenuated than lower frequencies. The rate of attenuation through medium-dense woods at 250 Hz is 0.06 dB/m (EEI 1978); hence, attenuation in low-frequency bands that characterize blast noise is significant. The mesas, which run in an east-southeasterly direction, are separated by valleys that may also channel and influence offsite noise measurements.

Portions of the community of Los Alamos are closer to PHERMEX than White Rock (table C2-2), but they are located uphill over heavily forested terrain and beyond a hill. These factors would tend to significantly reduce noise levels at locations north and northwest of PHERMEX. Communities located to the east of LANL are lower in elevation and may have noise channeled into the community down through the valleys.

C2.2.5 Wind

Wind measurements are summarized from data collected at the TA-49 weather station (table **Table C2-3.-*Summary of Meteorological Data Collected***

at TA-49 Weather Station March 11, 1995

Shot #	Approximate Time	Time	Wind Speed (mi/h)	Wind Direction (Degrees N=0)	Temperature (_F)	Relative Humidity (percent)
		12:00	9.7	183	54.1	37
942	12:16	12:15	12.1	182	57.0	33
		12:30	13.0	182	57.7	31
943	12:39	12:45	15.4	187	56.8	31
944	13:02	13:00	13.9	177	58.6	31

		13:15	16.1	180	59.0	30
945	13:33	13:30	17.4	190	58.1	30
		13:45	13.9	194	57.4	30
946	13:55	14:00	15.4	187	7.0	31
958	14:17	14:15	14.5	189	57.0	31
		14:30	11.0	183	56.5	32

C2-3). As the firings progressed, wind velocity steadily increased; however, the winds varied and were gusty. The wind measurements do not indicate gusts of possible greater speed that may have occurred at the time of firing. Sound moving into the wind is bent upwards, producing a shadow zone and generally reducing sound levels measured at ground level in an upwind location (EEI 1978). The Bandelier location is located to the south of the firing site and the TA-49 location is located to the SW. The prevailing winds would, therefore, reduce the measurements recorded at these two upwind locations. Sound traveling with the wind is forced downward, which effectively negates any ground-level attenuation that may result from trees, shrubs, terrain, or other sound-attenuating obstructions. This situation is further exacerbated by thegeneral decrease in slope from the PHERMEX firing site to the White Rock location. Because White Rock is located generally east of PHERMEX, the prevailing wind conditions would tend to increase noise levels there. Daytime winds are generally westerly during the months of March, April, and May (Bowen 1990), hence the selection of the White Rock location. However, during the March 11, 1995, testing, the winds came from the south.

Temperatures and relative humidity varied little over the duration of the firings (table C2-3). The differential effects on noise travel would not significantly affect measured noise levels during the March 11, 1995, tests.

C2.2.6 Measured Sound Levels at White Rock, Bandelier Entrance, and TA-49

During the testing, sound pressure recording generally increased with blast intensity (table C2-4**Table C2-4.-*Noise Measurements Conducted at LANL on March 11, 1995***

		Frequency, in Hertz									
Firing No.	**Load (lb TNT)**	**31.5**	**63**	**125**	**250**	**500**	**1,000**	**2,000**	**4,000**	**8,000**	**dBA**

TA-49 (I) 942 943 944 945 946 958	10 20 50 50 100 150	32 <46 48 **NR** 48 **NR**	42 52 52 54 50 62	54 58 62 56 60 68	52 58 62 54 64 64	50 46 60 54 62 64	46 52 58 50 60 58	42 46 48 48 50 54	44 **NR** **NR** **NR** 50 48	48 **NR** **NR** **NR** **NR** **NR**	**NR** 66 68 64 70 71
Bandelier (II) 943 944 945 946 958	20 50 50 100 150	**NR** 38 36 40 40	**NR** 52 42 46 48	**NR** 56 50 54 54	**NR** 54 50 52 56	**NR** 52 54 48 52	**NR** 48 56 42 54	**NR** 42 48 38 52	**NR** 40 40 36 36	**NR** 36 42 40 <36	**NR** **NR** 62 61 60
White Rock 942 943 944 945 946 958	10 20 50 50 100 150	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	60.9 65.3 69.1 63.1 71.6 68.6	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**	**NR** **NR** **NR** **NR** **NR** **NR**

Background Measurements		31.5	63	125	250	500	1,000	2,000	4,000	8,000	dBA
BKG1-67749		49	41	34	30	31	25	25	**NR**	**NR**	31
BKGII-436		42	40	38	34	32	30	28	30	28	35
White Rock		**NR**	**NR**	**NR**	38	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**
White Rock (car noise)		**NR**	**NR**	**NR**	51	**NR**	**NR**	**NR**	**NR**	**NR**	**NR**

NR = data not recorded or lost

BKG1-67749 taken at TA-49

BKGII-436 taken at Bandelier entrance

). The noise variation observed by frequency and intensity is caused by the fluctuating wind that changed, not only in direction, but in speed. Under ideal conditions of calm and optimum temperature and humidity, it is possible for sound pressure levels at the TA-49 Site boundary location to exceed 70 dBA with the larger blasts. The lower power firings will have a lower probability of exceeding the 75-dBA Los Alamos County daytime guideline. The nighttime standard imposed from 9:00 p.m. to 7:00 a.m. of 53 dBA can be exceeded at the closest site boundary locations. The diverse terrain and the frequency and directional variability of winds complicate routine noise estimation procedures and introduce a high level of uncertainty.

With a base schedule of 20 shots per year, blast noise impacts are considered equivalent for all alternatives except the Enhanced Containment Alternative. In this option, containment may reduce blast noise by as much as 80 percent; however, uncertainties in the choice of a vessel or a building and the design of containment prevent a more specific evaluation of blast noise impacts. The county noise regulations restrict maximum noise levels to 75 dBA for a period of not more than 10 minutes in a single hour during daylight hours (7:00 a.m. to 9:00 p.m.). Monitoring results indicate that it would be extremely unlikely for this guideline to be exceeded as an instantaneous measurement of more than 75 dBA or for 10 min of blast-associated noise to exceed 65 dBA in a given hour. (Under test shot operating procedures, it is not possible for more than three shots to be fired in one hour.) However, the likelihood of exceeding the 53-dBA county limit for nighttime noise imposed from 9:00 p.m. to 7:00 a.m. is high.

C2.3 WORKER PROTECTION

Construction workers are protected by administrative procedures and protective devices (such as ear plugs or muffs). Threshold limit values (ACGIH 1993) for impulse noise are 100 impulses per day at 140 dB. The maximum number of firings in an 8-h period, assuming 20 minutes between shots, is 25, well below the limit. Safety procedures implemented during firing create an exclusion zone that would protect staff from excessive impulse noise due to intensity and frequency.

C2.4 WILDLIFE

Firing noise may potentially impact sensitive wildlife, such as nesting birds. A group of deer observed during the first test shot on March 11, 1995, had an unhabituated startle response to the first firing. This observation suggests that local wildlife have not habituated to routine firings. However, the general health and well-being of deer and elk herds in the area suggest that testing programs involving firings have not had an adverse effect on ungulate populations at LANL or Bandelier National Monument.

C2.5 ESTIMATION OF TRAFFIC NOISE

Traffic noise is exempted under Los Alamos County noise regulations; however, increases in traffic can result in complaints about associated noise or congestion. A regression equation was developed from modeled data of traffic volume (vehicles/h) and estimated noise levels (1-h L_{eq} in dBA). The modeled data was developed to assess traffic noise associated with the New Production Reactor Environmental Impact Statement (DOE 1991). The regression equation was:

$$Y = 48.35549 + 7.25929X$$

where Y is the predicted noise level in 1 h L_{eq} (dBA) and X is the log of the hourly traffic volume.

For the analysis, three baseline levels of traffic volume were used: 10, 100, and 1,000 vehicles/h. The 10-vehicle/h limit might approximate early morning traffic. The 1,000-vehicle/h value is a conservative estimate of rush hour traffic volume. The larger the baseline traffic volume, the less significant the potential impact on overall traffic noise in the community. Incremental increases of traffic for each of these standard traffic volumes were raised by the full-time equivalents (FTEs) associated with each alternative. The impact was then related to the base flow to define the range of impact [the change (·) in table C2-5]. The same approach was used to estimate increases in traffic due to construction. Mean and maximum construction forces of 50 and 75 staff, respectively, were used in the assessment and the differences between alternatives resulting from the length of the construction phase.

Table C2-5.-*Estimated Traffic Noise Increases by Alternative for Operation and Construction*

Volume (Vehicles/hr)	**Log Volume**	**Estimated L_{eq}**	**Baseline L_{eq}**	**Change in L_{eq} ($\cdot L_{eq}$)**
OPERATIONS				
Analysis Baseline Traffic Flow				
10				
100				
1000				
No Action Alternative				
(based on 13.4 FTEs)				
23				

113	1	56	NA	NA
1013	2	63	NA	NA
DARHT Baseline Alternative	3	70	NA	NA
(based on 19.9 FTEs)	1.4	58	56	2.7
30	2.1	63	63	0.4
120	3.0	71	70	0.04
1020	1.5	59	56	3.5
Enhanced Containment Alternative	2.1	63	63	0.6
(based on 28.5 FTEs)	3.0	70	70	0.06
39	1.6	60	56	4.3
129	2.1	64	63	0.8
1029	3.0	70	70	0.09
Plutonium Exclusion Alternative (based on 19.9 FTEs)	1.5	59	56	3.4
30	2.1	63	63	0.6
120	3.0	70	70	0.06
1020	1.4	59	56	3.2
Single-Axis Alternative	2.1	63	63	0.5
(based on 17.34 FTEs)	3.0	70	70	0.05
27	1.5	60	56	3.4
117	2.1	63	63	0.6
1017	3.0	70	70	0.06
PHERMEX Upgrade Alternative (based on 19.9 FTEs)	1.9	62	56	6.8
	2.2	65	63	1.8
30	3.0	70	70	0.2
120	1.8	61	56	5.7

1020	2.2	64	63	1.3
CONSTRUCTION	3.0	70	70	0.2
Maximum				
85				
175				
1075				
Mean				
60				
150				
1050				

L_{eq} is the one-hour equivalent sound level.

The increases in traffic noise associated with all alternatives, compared to the No Action Alternative, are inconsequential because, in the modeled assumptions, the expected increases in traffic noise would not increase residential noise levels above 5 dBA. Within Los Alamos County noise standards, operation of motor vehicles on public thoroughfares is exempted from the county noise code.

C.3 REFERENCES CITED IN APPENDIX C

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Exhibit C1-1.-*Joint Frequency Distribution of Atmospheric Stability, Wind Direction,*

and Wind Speed for Los Alamos National Laboratory at Tower TA-6

Wind measurements were made on-site at 32 ft (10 m) above ground level. Data are

based on measurements made from 1990 through 1993.

WIND DIRECTION

STAB FROM WHICH THE WIND SPEED CLASS (m/s)

CLASS WIND IS BLOWING 0 - 1.8 1.8 - 3.3 3.3 - 5.5 5.5 - 8.5 8.5 - 11.5 > 11.5

A	NORTH	0.0014	0.0005	0.0000	0.0000	0.0000	0.0000
A	NORTH-NORTHEAST	0.0022	0.0006	0.0000	0.0000	0.0000	0.0000
A	NORTHEAST	0.0048	0.0019	0.0000	0.0000	0.0000	0.0000
A	EAST-NORTHEAST	0.0086	0.0023	0.0000	0.0000	0.0000	0.0000
A	EAST	0.0096	0.0031	0.0000	0.0000	0.0000	0.0000
A	EAST-SOUTHEAST	0.0081	0.0044	0.0000	0.0000	0.0000	0.0000
A	SOUTHEAST	0.0086	0.0076	0.0001	0.0000	0.0000	0.0000

A	SOUTH-SOUTHEAST	0.0066	0.0074	0.0002	0.0000	0.0000	0.0000
A	SOUTH	0.0038	0.0039	0.0003	0.0000	0.0000	0.0000
A	SOUTH-SOUTHWEST	0.0017	0.0013	0.0001	0.0000	0.0000	0.0000
A	SOUTHWEST	0.0010	0.0007	0.0001	0.0000	0.0000	0.0000
A	WEST-SOUTHWEST	0.0007	0.0005	0.0000	0.0000	0.0000	0.0000
A	WEST	0.0007	0.0004	0.0001	0.0000	0.0000	0.0000
A	WEST-NORTHWEST	0.0007	0.0003	0.0001	0.0000	0.0000	0.0000
A	NORTHWEST	0.0009	0.0006	0.0001	0.0000	0.0000	0.0000
A	NORTH-NORTHWEST	0.0007	0.0006	0.0001	0.0000	0.0000	0.0000
B	NORTH	0.0005	0.0004	0.0001	0.0000	0.0000	0.0000
B	NORTH-NORTHEAST	0.0008	0.0012	0.0002	0.0000	0.0000	0.0000
B	NORTHEAST	0.0019	0.0031	0.0004	0.0000	0.0000	0.0000
B	EAST-NORTHEAST	0.0029	0.0032	0.0001	0.0000	0.0000	0.0000
B	EAST	0.0029	0.0032	0.0000	0.0000	0.0000	0.0000
B	EAST-SOUTHEAST	0.0020	0.0041	0.0001	0.0000	0.0000	0.0000
B	SOUTHEAST	0.0019	0.0055	0.0005	0.0000	0.0000	0.0000
B	SOUTH-SOUTHEAST	0.0021	0.0085	0.0022	0.0000	0.0000	0.0000
B	SOUTH	0.0016	0.0066	0.0035	0.0000	0.0000	0.0000
B	SOUTH-SOUTHWEST	0.0008	0.0026	0.0019	0.0000	0.0000	0.0000
B	SOUTHWEST	0.0005	0.0011	0.0010	0.0000	0.0000	0.0000

B	WEST-SOUTHWEST	0.0002	0.0008	0.0004	0.0000	0.0000	0.0000
B	WEST	0.0002	0.0007	0.0002	0.0000	0.0000	0.0000
B	WEST-NORTHWEST	0.0002	0.0007	0.0002	0.0000	0.0000	0.0000
B	NORTHWEST	0.0002	0.0008	0.0004	0.0000	0.0000	0.0000
B	NORTH-NORTHWEST	0.0002	0.0005	0.0003	0.0000	0.0000	0.0000
C	NORTH	0.0008	0.0013	0.0005	0.0000	0.0000	0.0000
C	NORTH-NORTHEAST	0.0016	0.0037	0.0019	0.0000	0.0000	0.0000
C	NORTHEAST	0.0026	0.0058	0.0021	0.0000	0.0000	0.0000
C	EAST-NORTHEAST	0.0035	0.0031	0.0002	0.0000	0.0000	0.0000
C	EAST	0.0040	0.0041	0.0001	0.0000	0.0000	0.0000
C	EAST-SOUTHEAST	0.0021	0.0046	0.0004	0.0000	0.0000	0.0000
C	SOUTHEAST	0.0018	0.0030	0.0007	0.0000	0.0000	0.0000
C	SOUTH-SOUTHEAST	0.0022	0.0087	0.0076	0.0000	0.0000	0.0000
C	SOUTH	0.0026	0.0141	0.0160	0.0000	0.0000	0.0000
C	SOUTH-SOUTHWEST	0.0014	0.0073	0.0090	0.0000	0.0000	0.0000
C	SOUTHWEST	0.0009	0.0039	0.0053	0.0000	0.0000	0.0000
C	WEST-SOUTHWEST	0.0004	0.0021	0.0046	0.0000	0.0000	0.0000
C	WEST	0.0004	0.0014	0.0026	0.0000	0.0000	0.0000
C	WEST-NORTHWEST	0.0003	0.0013	0.0019	0.0000	0.0000	0.0000
C	NORTHWEST	0.0004	0.0016	0.0026	0.0000	0.0000	0.0000

Exhibit C1-1.-*Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Los Alamos National Laboratory at Tower TA-6 - Continued*

WIND DIRECTION

STAB FROM WHICH THE WIND SPEED CLASS (m/s)

CLASS WIND IS BLOWING 0 - 1.8 1.8 - 3.3 3.3 - 5.5 5.5 - 8.5 8.5 - 11.5 > 11.5

C	NORTH-NORTHWEST	0.0004	0.0009	0.0007	0.0000	0.0000	0.0000
D	NORTH	0.0098	0.0083	0.0011	0.0003	0.0000	0.0000
D	NORTH-NORTHEAST	0.0079	0.0081	0.0031	0.0010	0.0000	0.0000
D	NORTHEAST	0.0067	0.0041	0.0007	0.0001	0.0000	0.0000
D	EAST-NORTHEAST	0.0046	0.0010	0.0001	0.0000	0.0000	0.0000
D	EAST	0.0055	0.0020	0.0001	0.0000	0.0000	0.0000
D	EAST-SOUTHEAST	0.0046	0.0024	0.0003	0.0000	0.0000	0.0000
D	SOUTHEAST	0.0040	0.0012	0.0000	0.0000	0.0000	0.0000
D	SOUTH-SOUTHEAST	0.0060	0.0044	0.0022	0.0002	0.0000	0.0000
D	SOUTH	0.0098	0.0131	0.0041	0.0013	0.0000	0.0000
D	SOUTH-SOUTHWEST	0.0099	0.0221	0.0101	0.0027	0.0000	0.0000
D	SOUTHWEST	0.0085	0.0204	0.0084	0.0019	0.0002	0.0000
D	WEST-SOUTHWEST	0.0065	0.0120	0.0089	0.0038	0.0001	0.0000
D	WEST	0.0062	0.0095	0.0145	0.0090	0.0012	0.0001
D	WEST-NORTHWEST	0.0058	0.0092	0.0147	0.0101	0.0020	0.0012
D	NORTHWEST	0.0080	0.0130	0.0095	0.0030	0.0002	0.0000

D	NORTH-NORTHWEST	0.0079	0.0071	0.0011	0.0002	0.0000	0.0000
E	NORTH	0.0056	0.0027	0.0000	0.0000	0.0000	0.0000
E	NORTH-NORTHEAST	0.0028	0.0011	0.0000	0.0000	0.0000	0.0000
E	NORTHEAST	0.0016	0.0003	0.0000	0.0000	0.0000	0.0000
E	EAST-NORTHEAST	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
E	EAST	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000
E	EAST-SOUTHEAST	0.0008	0.0001	0.0000	0.0000	0.0000	0.0000
E	SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
E	SOUTH-SOUTHEAST	0.0015	0.0004	0.0000	0.0000	0.0000	0.0000
E	SOUTH	0.0026	0.0013	0.0000	0.0000	0.0000	0.0000
E	SOUTH-SOUTHWEST	0.0047	0.0036	0.0001	0.0000	0.0000	0.0000
E	SOUTHWEST	0.0063	0.0076	0.0001	0.0000	0.0000	0.0000
E	WEST-SOUTHWEST	0.0047	0.0151	0.0007	0.0000	0.0000	0.0000
E	WEST	0.0039	0.0093	0.0029	0.0001	0.0000	0.0000
E	WEST-NORTHWEST	0.0038	0.0096	0.0050	0.0005	0.0000	0.0000
E	NORTHWEST	0.0062	0.0231	0.0010	0.0000	0.0000	0.0000
E	NORTH-NORTHWEST	0.0063	0.0070	0.0000	0.0000	0.0000	0.0000
F	NORTH	0.0058	0.0011	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHEAST	0.0031	0.0005	0.0000	0.0000	0.0000	0.0000
F	NORTHEAST	0.0019	0.0001	0.0000	0.0000	0.0000	0.0000

F	EAST-NORTHEAST	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
F	EAST	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
F	EAST-SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTHEAST	0.0009	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTH-SOUTHEAST	0.0011	0.0001	0.0000	0.0000	0.0000	0.0000
F	SOUTH	0.0020	0.0002	0.0000	0.0000	0.0000	0.0000
F	SOUTH-SOUTHWEST	0.0032	0.0003	0.0000	0.0000	0.0000	0.0000
F	SOUTHWEST	0.0058	0.0013	0.0000	0.0000	0.0000	0.0000
F	WEST-SOUTHWEST	0.0078	0.0068	0.0000	0.0000	0.0000	0.0000
F	WEST	0.0101	0.0307	0.0028	0.0000	0.0000	0.0000
F	WEST-NORTHWEST	0.0100	0.0308	0.0035	0.0000	0.0000	0.0000
F	NORTHWEST	0.0111	0.0149	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHWEST	0.0078	0.0030	0.0000	0.0000	0.0000	0.0000

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APPENDIX D

GEOLOGY AND SOILS (SOILS CONTAMINATION)

This appendix describes the soils contamination resulting from firing-site activities. The description is presented both in terms of the level of soils contamination evident at firing sites, and in terms of the distance from the firing point (i.e., the soil contamination circle radius) at which levels of contamination cannot be distinguished from known background concentrations of metals.

Observed contamination of the soils surrounding the PHERMEX firing point provides the basis for a reasonable estimate of future soil contamination levels at the PHERMEX or DARHT sites and the soil contamination circle radius applicable to either site. Data from the E-F firing sites, located on the watershed for Potrillo Canyon and also within TA-15, provide additional insight into the maximum soil contamination levels and the levels of contamination as a function of soil depth. Results from an aerial radiological survey provide an integrated assessment of surface soil contamination levels and show that the land area surrounding the PHERMEX firing point exhibits uranium-238 contamination above background levels. Finally, operational aspects of the cleanup of depleted uranium are summarized.

D.1 ABSTRACT

With respect to the soils environment, the existing PHERMEX firing site is an appropriate analogue for future contamination of firing sites located at either the PHERMEX or DARHT sites. PHERMEX is located approximately 2,000 ft (610 m) southeast of DARHT in TA-15 on Threemile Mesa. Soils, precipitation, and vegetation of the two sites are similar. A similar inventory of depleted uranium, i.e., 35,000 lb (~16,000 kg) depleted uranium (Anderson 1995), has been used at PHERMEX, as is planned for the No Action or DARHT Baseline alternatives, i.e., 46,000 lb (~21,000 kg) depleted uranium. Lesser amounts of beryllium and lead are forecast to be used in future tests than have been used in the past 32 years of testing at the PHERMEX firing site (Anderson 1995). Soils contamination observed at the E-F firing sites provides an upper bound to what might be expected under either the No Action Alternative (implying continued use of the PHERMEX site) or DARHT Baseline Alternative (implying use of the DARHT site) because of the higher inventory used at the E-F firing sites between 1943 and 1973. Based on soils contamination data from PHERMEX and E-F firing sites and the ratio of inventory planned for use versus that used at PHERMEX, the maximum average soil contamination level for depleted uranium at the firing point of the DARHT site is not anticipated to be greater than 5,300 ppm. Similarly, the maximum average soil contamination level observed at PHERMEX in the vicinity of the firing point under either the No Action or Upgrade alternatives would be approximately double that observed currently at PHERMEX or 9,300 ppm.

The amount of explosive used in individual tests would be no greater than that used at PHERMEX in the past 32 years. The general pattern and number of tests (i.e., large and small explosives amounts) would be virtually the same over the next 30 years (under any of the proposed alternatives) as that used during the past 32 years. Thus, the radius of a circle defining the area with soils contamination above background (soils contamination circle) at PHERMEX should be virtually the same for either continued operation at PHERMEX or operation of DARHT. That soil contamination circle radius at the PHERMEX site is approximately 460 ft (140 m).

Approximately 70 percent of the depleted uranium used at PHERMEX in open-air experiments is removed from the firing point and disposed during periodic cleanup operations. However, all beryllium, lead, copper, and aluminum used at the firing point in each alternative is assumed to be released to and remain in the environment within the soil contamination circle. Cleanup of these materials has not been documented. Surface soil concentrations of beryllium and lead indicate they drop to background levels within 200 ft (61 m) of the firing point, well within the soil contamination circle radius of 460 ft (140 m). No information was found on the distribution of copper and aluminum in firing site soils; however, it is assumed that they, like the other metals, remain initially within the soil contamination circle.

D.2 PHERMEX FIRING SITE SOIL CONTAMINATION

Results of a soil sampling survey conducted at the PHERMEX firing site have been reported (Fresquez 1994). Over 20 soil surface samples were collected from the 0- to 3-in (0- to 7.6-cm) depth at six distances along the length of four transects radiating outward from the center of the detonation area towards the NE, E, SE, and SSE. Two sediment samples were also collected: one located in a drainage channel about 240 ft (73 m) northeast of the detonation pad and the other located approximately 200 ft (61 m) south of the pad. Results of this sampling effort are summarized in table D-1**Table D-1.-*Average Uranium, Beryllium, and***

Lead Concentrations in Surface Soils at PHERMEX

Sample Locations or Description - Distance ft (m)	Mean Concentrations (ppm)		
	Total Uranium	Beryllium	Lead
0	161.5	0.6	230.0
20 (6.1)	1746.9	18.5	93.9
40 (12.2)	3789.8	1.6	68.4

80 (24.4)	315.4	3.0	24.5
160 (48.8)	165.7	73.3	39.0
200 (61)	26.8	1.0	13.7
Simple Average	1210	18	52
NE Drainage Channel	105	3.1	16
S Drainage Channel	11.5	1.2	9.5
Background (mean + 2 std dev)	3.4	2.88	54
Source: Fresquez 1994			

, showing mean values at various distances from the firing point. Note, the data contained in table D-1 include background and, therefore, are not net values. Note also that the maximum average values, referred to later as the maximum average, does not occur at the same distance from the firing point for the different metals.

Total uranium (i.e., the sum of all uranium mass regardless of the isotope mix) in individual soil samples ranged in concentration from 0.8 to 13,398 ppm. The highest concentration, 13,398 ppm, is well above the other observations and resulted from a soil sample taken at the base of a building wall very near the firing point. The wall was exposed to fragments and aerosolized fractions during shots and apparently acts to concentrate depleted uranium in the soils immediately beneath the wall. Most samples were above the upper limit background (mean + 2 standard deviation) uranium concentration of 3.4 ppm for the firing site. Total beryllium (i.e., the sum of all beryllium mass regardless of the isotope mix) in individual surface soil samples ranged from 0.2 to 218 ppm, and total lead (i.e., the sum of all lead mass regardless of the isotope mix) concentrations ranged from 2.9 to 230 ppm. Most beryllium and lead data were also above the upper limit background concentrations of 2.88 and 54 ppm, respectively. However, soil concentrations of both beryllium and lead dropped to background levels at the maximum sampling radius of ~200 ft (~61 m). Simple averages of uranium, beryllium, and lead samples were 1,210, 18, and 52 ppm.

Using the radial measurement point as the center of an annulus having constant contaminant concentration, an area-weighted integration of total uranium concentration was performed. The integration considered only the upper 3 in (7.6 cm) of soil and assumed a dry bulk soil density of 1.4 g/cm^3. If measured surface soil depleted uranium contamination levels were applied to a full circle of radius 200 ft (61 m), the total uranium inventory in the soil would be 1,300 lb (568 kg) uranium. The area-weighted average total-uranium concentration, which takes into account the radial pattern of material deposition, was 456 ppm.

While measured values of beryllium and lead fell to background levels within the ~200 ft (~61 m) radial distance sampled, the total uranium levels did not. A regression analysis on the full (natural log-transformed) total uranium data set (Fresquez and Mullen 1995) showed the distance from the detonation pad to a point where total uranium concentrations would drop to upper limit background levels (i.e., 3.4 ppm) was 279 ± 83 ft (85 ± 25.3 m). The 95 percent upper confidence level of this one-sided estimate was 422 ft (128.6 m). This is an estimate of the soil contamination circle radius enclosing total uranium soil concentrations above background levels.

The drainage channel located northeast of the detonation pad yielded sediments containing 105 ppm total uranium. The channel to the south of the firing pad yielded sediments with only 11.5 ppm total uranium. No TCLP or total heavy metals were detected above EPA or background concentrations in any of the drainage channels. No traces of high explosive materials were detected in any of the soil or sediment samples.

A previous sampling study conducted at the PHERMEX site in 1987 (Fresquez 1995) showed levels of total uranium up to 3,593 ppm and of beryllium up to 470 ppm. A simple average concentration of surface soil samples yielded average uranium and beryllium concentrations for the site of 432 (± 647) ppm and 31.7 (± 83) ppm. Note, these are simple averages of all data and are not area-weighted mean values that would take into account the radial pattern of contaminant distribution.

D.3 E-F FIRING SITES SOIL CONTAMINATION

The E-F firing sites are located within TA-15, in the watershed for Potrillo Canyon. It has been estimated that between 1943 and 1973 up to 150,000 lb (66,500 kg) of uranium (a combination of natural and depleted uranium) were used in tests at the E-F firing sites (Hanson and Miera 1977). This is nearly fourtimes the inventory used at PHERMEX. The amount of explosive charge in individual tests at the E-F firing sites exceeds that proposed under the DARHT EIS. This implies that both the level of soil contamination and the spatial spread of debris at the E-F firing sites would be greater than has occurred at PHERMEX and is expected to occur under the alternatives examined in this EIS.

In 1976 a polar coordinate sampling pattern was used to collect soil samples at the E-F site for total uranium analysis (Hanson and Miera 1976; Hanson and Miera 1977; Hanson and Miera 1978). Samples were taken at nine distances from 33 to 660 ft (10 to 200 m) on transects that extended outward from the detonation pad every 45 degrees. Total uranium concentrations were determined for six depth increments ranging from 0 to 1 in to 0.66 to 1 ft (0 to 2.5 cm to 20 to 30 cm) depths. The variation in total uranium concentration with horizontal distance from the firing point for the surface soils [0 to 1 in (0 to 2.5 cm)] is presented in table**Table D-2.-*Uranium Distribution in E-F Firing Site***

Surface Soils [0 to 1 in (0 to 2.5 cm)]

Distance ft (m)	Mean Concentration (ppm)
0	4,650
33 (10)	4,520
66 (20)	1,000
98 (30)	1,800
130 (40)	745
160 (50)	395
250 (75)	350
330 (100)	520
490 (150)	725
660 (200)	165
Source: Hanson and Miera 1977	

Table D-3.-*Distribution of Total Uranium with Depth*

in Surface Soils at the E-F Firing Site

Distance ft (m)	Percent of total uranium in top 2 in (5 cm) of the column	Lowest Reported Depth [ft (cm)][a]	Concentration[b] (ppm)

0	86	0.33-0.5 (10-15)	650
33 (10)	48	0.66-1 (20-30)	~5000[c]
66 (20)	86	0.33-0.5 (10-15)	80
98 (30)	71	0.33-0.5 (10-15)	250
130 (40)	62	0.33-0.5 (10-15)	450
160 (50)	43	0.66-1 (20-30)	100
[a] Lowest depth presented in figure 5 of the Hanson and Miera report. [b] Estimate from figure 5 of the Hanson and Miera report. [c] Includes a value of 22,000 ppm. Source: Hanson and Miera 1977			

D-2. The area-weighted mean uranium concentration for surface soils in the sampling area was 542 ppm.

Data on the vertical distribution of uranium in site soils were presented in Hanson and Miera (1977). Data collected at the E-F firing sites indicated that uranium had migrated into the soil to the maximum sampling depth; however, sample analyses were incomplete when Hanson and Miera published their work in 1977 and samples from 0.66 to 1 ft (20 to 30 cm) were not reported for all sample distances. Available results are presented in table D-3. The anomaly observed in the 33-ft (10-m) sample from 0.6 to 1 ft (20 to 30 cm) was attributed to a single observation of 22,000 ppm. Deletion of this datum from the mean value calculation resulted in a decreasing uranium concentration with increasing depth for all profiles. Extending the slope of the 33-ft (10-m) sample line in figure 5 Hanson and Miera (1977) results in an approximate value of 1,000 ppm total uranium in the 0.66- to 1-ft (20- to 30-cm) depth interval 33 ft (10 m) from the firing point.

The uranium in the top 2 in (5 cm) ranges between 86 and 43 percent of the total uranium at a sample point, with a regular decrease beyond 66 ft (20 m). Total uranium concentrations presented by Hanson and Miera (1977) show a general decrease with increasing depth. However, even at the maximum sample depths reported, total uranium concentrations were above background.

The E-F firing sites operated over a 30-year period and used on the order of 150,000 lb (66,500 kg) of uranium. The estimate of depleted uranium used at PHERMEX during the past 32 years is 35,000 lb (16,000 kg). The forecasted depleted uranium usage over the next 30 years is 46,000 lb (21,000 kg). Thus, if the No Action Alternative is implemented, the quantity of depleted uranium used at PHERMEX would increment from 35,000 lb (16,000 kg) to 82,000 lb (37,000 kg) depleted uranium over a 30-year period. This represents slightly more than half (57 percent) of the inventory used at E-F during its 30-year operation. Thus, future soil-contamination levels at PHERMEX firing site should not exceed and would likely be less than those observed at the E-F firing sites. If deposition is a linear function of inventory, soil contamination at PHERMEX would be approximately double the levels currently observed at the PHERMEX firing point, [e.g., 9,300 ppm = 4,000 ppm x 82,000 lb (37,000 kg)/35,000 lb (16,000 kg)].

The maximum explosive charge used in tests at the E-F firing sites exceeds that forecast for testing under any DARHT EIS alternative. As a result of tests involving larger explosive charges, uranium contamination in soils is spread over a larger area at the E-F firing sites than is observed at PHERMEX. The amount of explosive used in individual tests under any DARHT EIS alternative would be no greater than that used at PHERMEX in the past 32 years. Additionally, the general pattern and number of tests(i.e., large and small explosives amounts) would be virtually the same over the next 30 years (under any of the proposed alternatives) as that used during the past 32 years at PHERMEX. Based on the size of explosive forecast for use in the DARHT EIS alternatives, the current areal extent of contamination atPHERMEX is a better analogue than the E-F firing sites for estimating the areal extent of future soils contamination at either PHERMEX or DARHT.

The E-F firing sites data does reveal that surface soil contamination levels at the PHERMEX firing point can be expected to increase for alternatives that involve continued use of the PHERMEX firing site. Still, average surface-soil total-uranium concentrations local to the firing point do not exceed 5,000 ppm at the E-F firing sites. The depth profile data suggest that uranium concentrations in soil ~1 ft (30 cm) or more below the surface can be expected to exceed background levels within 160 ft (50 m) of the firing point. However, contaminant concentrations at depth were measured to be a factor of 2 to 10 below surface soil contamination levels. Thus, with regard to soils contamination levels, average surface-soil total-uranium concentration levels at the E-F firing sites represent maximums.

D.4 AERIAL RADIOLOGICAL SURVEY

An aerial radiological survey of TA-15 was conducted in 1982 to estimate the extent of uranium (uranium-238) contamination in the vicinity of firing sites (Fritzsche 1989). The survey monitored levels of protactinium (protactinium-234m), a radioactive daughter of uranium-238. Surface contamination was seen to decrease radially as the distance from the test-firing area increased. A surface area of 630,000 ft^2 (58,600 m^2) around PHERMEX was estimated to be contaminated above background. The contaminated area can be represented by a circular area with radius of 450 ft (137 m) centered at the PHERMEX firing point (LATA 1992). The 450-ft (137-m) radius circle is rounded to 460 ft (140 m) for convenience.

D.5 MATERIAL RELEASES AND SITE CLEANUP DURING OPERATIONS

During the 32 years of PHERMEX operations, a total of about 35,000 lb (16,000 kg) of depleted uranium has been used. This amount of depleted uranium represents a volume of about 35 ft^3 (1 m^3). Most of the depleted uranium was used in the form of experimental assemblies of simulated nuclear weapons. Approximately 50 percent of the depleted uranium was contained in simulated secondaries and blast pipes of pin experiments. This depleted uranium is ejected as relatively large fragments. These large fragments remain in the immediate vicinity of the firing point. An estimated 40 percent of the total was dispersed as relatively small, platelet-shaped fragments having surface areas ranging from 0.08 to 1.1 in^2 (0.5 to 7 cm^2). An estimated 10 percent of the depleted uranium was released as an aerosol (McClure 1995).

LANL has estimated that at least 70 percent of the depleted uranium remains on or near the firing point and is removed and disposed of (see Waste Management in appendix B) during routine housekeeping. This 70 percent consists of all of the large fragments, half of the small fragments (i.e., those ejected downward), and some portion of the aerosol. Most of the other half of the small fragments would fall within a 4,100-ft (1,250-m) circle (McClure 1995).

In addition to depleted uranium, the only other materials of regulatory concern for the firing area are beryllium and lead. Materials released during open-air tests at the PHERMEX facility have resulted in observable quantities of beryllium and lead on or near the firing site. The soil sampling mentioned above indicates that no beryllium or lead are observed at levels above background beyond 200 ft (60 m) from the firing point.

Under the Enhanced Containment Alternative, three options are explored: the Vessel Containment Option, the Building Containment Option, and the Phased Containment Option. Normally, when containment would be used for a test shot, the blast products would remain in the containment vessel or building element designed to contain the test. Hence, a containment vessel would contain the blast debris; the debris would be taken to appropriate LANL facilities according to the nature of the debris. For the containment options, potential releases from containment vessels or the containment building are described by two conservative performance assumptions: no more than 1 percent of the blast byproducts could escape a normal test, and no more than 5 percent of the tests could cause a rupture of the containment vessel or building. While containment vessels and buildings would be designed not to fail and are not expected to fail, these assumptions address the possibility of failure. A rupture of a containment vessel means the development of a crack, not a catastrophic explosion of the entire containment vessel. Thus, a 6 percent release of inventory as blast byproducts for all contained test shots represents a highly unlikely result. To be conservative, it is also assumed that all blast byproducts that escape contained tests (i.e., in Vessel Containment, Building Containment, and Phased Containment options) would be in the soils surrounding the firing point and not removed from the site by any routine cleanup activity.

Under the Vessel Containment and Phased Containment options, some uncontained experiments would be conducted. In the case of the vessel containment option, up to 25 percent of the inventory would be shot in uncontained tests. In the case of the phased containment option, three phases would occur in the uncontained-to-contained percentages: 95 percent uncontained and 5 percent contained for 5 years, 60 percent uncontained and 40 percent contained for 5 years, and finally 25 percent uncontained and 75 percent contained for 20 years. All uncontained testing would be conducted under site cleanup protocols similar to those used today, and consequently only 30 percent of the depleted uranium inventory expended in uncontained tests would remain in the soil at the firing site. However, all beryllium and lead released in uncontained tests is assumed to remain in the soils at the firing site.

D.6 SOIL CONTAMINATION CIRCLE RADIUS AND SOIL CONTAMINATION LEVELS

The estimate of the soil contamination circle radius from the aerial radiological survey (i.e., 460 ft or 140 m) is comparable to the 420-ft (128-m) radius calculated by Fresquez and Mullen (1995) as defining the 95 percent upper-confidence level of enclosing all above-background total-uranium soil contamination. The soil survey conducted by Fresquez (1994) only characterized an ~200-ft (~61-m) radius circle centered on the firing point and may reflect only a portion of the fragment and aerosol size fractions. However, the aerial radiological survey takes into account uranium (uranium-238) concentration levels associated with the complete range of fragment sizes as well as the aerosol fraction. Based on the similarity of tests to be run in the future as compared to past PHERMEX operations (e.g., explosive charges, the range and pattern of large and small tests), we conclude that the soil contamination area around PHERMEX [defined approximately by a circle with radius 460 ft (140 m) centered on the firing point] is appropriate for application to alternatives involving either PHERMEX or DARHT sites.

The inventory of depleted uranium used at PHERMEX over the last 32 years is ~35,000 lb (~16,000 kg). Of this, 30 percent, or 11,000 lb (4,800 kg) of depleted uranium, is estimated to remain within the soil contamination circle. Clearly, this is greater than the estimated 1,300 lb (568 kg) of uranium accounted for in the surface soils (i.e., to 3 in or 7.5 cm depth) within 200 ft (61 m) of the firing point at PHERMEX. However, a circle of radius 200 ft (61 m) represents only ~20 percent of the area of the soil contamination circle that has a radius of 460 ft (140 m). If 11,000 lb (4,800 kg) of depleted uraniumwere uniformly distributed in the upper ~1 ft (~30 cm) of soil within an ~460-ft (~140-m) radius soil contamination circle, the resulting uranium concentration would be ~190 ppm.

Under the No Action Alternative, the total inventory of depleted uranium used at PHERMEX after an additional 30 years would be 82,000 lb (37,000 kg) of depleted uranium. Of this, 30 percent, or ~24,000 lb (~11,000 kg), of depleted uranium would remain onsite within the soil contamination circle and contribute to soil contaminant concentrations. If initially distributed uniformly in the upper ~1 ft (30 cm) of the soil contamination circle, the resulting uranium concentration would be 430 ppm.

While total uranium concentration in soils in the immediate vicinity of firing points is known to be significantly higher (e.g., average values of 3,789 and 4,650 ppm values calculated for PHERMEX and E-F firing sites), these areas represent a relatively small fraction of the overall soil contamination circle in an area-weighted average. Area-weighted average concentrations calculated at E-F (542 ppm for a 660-ft or 200-m radius) and PHERMEX (456 ppm for a 200-ft or 61-m radius) are comparable to those calculated for the uranium inventory forecast to be within the soil contamination circle of PHERMEX operations (i.e., 190 ppm current and 430 ppm future).

The soil contamination circle radius of current PHERMEX operations, 460 ft (140 m), is assumed to apply to alternatives involving either the PHERMEX or DARHT sites. Based on soils contamination data from PHERMEX and E-F firing sites and the ratio of inventory planned for usage versus that used at PHERMEX, the maximum average soil contamination level for depleted uranium at the firing point of the DARHT site is not anticipated to be greater than 5,300 ppm (i.e., 4,000 ppm x 46,000 lb (21,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium). Similarly, the maximum average soil contamination level observed at PHERMEX in the vicinity of the firing point under either the No Action or Upgrade PHERMEX alternatives is not anticipated to be greater than double that observed currently at PHERMEX or 9,300 ppm [i.e., 4,000 ppm x 82,000 lb (37,000 kg) depleted uranium/35,000 lb (16,000 kg) depleted uranium].

It is apparent from the recent surface soil survey of PHERMEX (Fresquez 1994) that beryllium and lead contamination drops to background levels inside of the soil contamination circle for depleted uranium. However, no information is available on site cleanup and removal of beryllium and lead. Therefore, the entire original inventory of both beryllium and lead is assumed to be dispersed within the soil contamination circle and available for migration in hydrologic pathways.

There is no information on the distribution of copper and aluminum in the soils surrounding the PHERMEX firing point. Nor is there information about periodic cleanup activities at the firing point removing either copper or aluminum. Consequently, total inventories of copper and aluminum are assumed to be in the soils and available for migration via surface water and ground water pathways.

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APPENDIX E

WATER RESOURCES

This appendix provides background information on 1) estimates of recharge at the mesa top (i.e., firing sites), 2) the solubilities and distribution coefficients associated with the metals of interest when associated with LANL site sediments, 3) the approach taken to model surface water pathway, and 4) the approach taken to model the vadose zone and ground water pathways.

APPENDIX E1: DEEP DRAINAGE BENEATH THE

DARHT AND PHERMEX SITES

E1.1 ABSTRACT

Meteoric water that drains well below the lowest level of plant roots is called deep drainage and can transport solubilized contaminants through vadose zone deposits to ground water. This pathway for contaminant migration to the accessible environment must be evaluated to understand the potential for surface soil contamination to migrate through the mesa and underlying vadose zone to ground water. The objective of this study was to estimate the deep drainage rates at two locations, the DARHT and PHERMEX sites. Estimates of deep drainage were performed using the UNSAT-H computer code, daily weather data from 1980 to 1994, and, in lieu of site-specific data, surrogate information for the hydrologic properties of vegetation and soils. Drainage rates were determined for a variety of soil and vegetation scenarios; the actual rates depend explicitly on the site-specific surface conditions. For the scenarios studied, the drainage rates ranged from 4.7 to 520 mm/yr. For the center of the DARHT site, the rates for an unvegetated surface were 265 and 360 mm/yr depending on the soil type. Modifying the surface with a gravel cover increased the drainage rate to 520 mm/yr. For the center of the PHERMEX site, the rate was 124 mm/yr for the unvegetated surface. Allowing shrubs and grasses to grow on the sites reduced, but did not eliminate, deep drainage. The potential exists for deep drainage at both sites. Whether deep drainage actually exists can only be determined with site-specific measurements.

E1.2 INTRODUCTION

One component of the DARHT EIS is an analysis of the potential for deep drainage beneath the DARHT and PHERMEX sites to carry contaminants to the main aquifer. At other DOE sites, deep drainage has transported solubilized contaminants to underlying ground water systems. While such transport is not apparent beneath Threemile Mesa on which DARHT and PHERMEX are located, it does represent a pathway of interest and must be evaluated. The objective of this portion of the EIS was to estimate the deep drainage rate beneath the DARHT and PHERMEX sites.

E1.3 PRIOR ESTIMATES

Information on the rates of deep drainage beneath the DARHT and PHERMEX sites was unavailable. However, occasional monitoring at other locations at LANL indicates that deep drainage rates are highly variable, ranging from near zero to more than the annual precipitation rate, depending on the surface conditions at each of the specific locations.

Abeele et al. (1981) and Nyhan (1989a) reported water content profiles measured with neutron probes in several deep access wells. Some wells had low water contents in the tuff, indicating little, if any, deep drainage. Other wells had high water contents, particularly in the upper zones of tuff, possibly indicative of recent deep drainage. In one well, the high water contents implied that water was added in excess of precipitation rates. Nyhan (1989) speculated that an unlined drainage ditch routed surface water to the vicinity of the well, where the water subsequently infiltrated. Abeele et al. (1981) also alluded to the influence of surface topography as a factor in affecting infiltration rates and thus deep drainage rates.

Abeele et al. (1981) reported that the flux in the overburden above a waste disposal pit was always directed downward below a depth of about 13 ft (4 m) during a two-year period. In 1978, it was 3.5 in/yr (90 mm/yr); in 1979, it was 6 in/yr (150 mm/yr). The difference was attributed to extremely high precipitation at the end of 1978 and the beginning of 1979. At another location at LANL, Abeele et al. (1981) estimated a downward rate of 0.01 in/yr (0.3 mm/yr). It has been summarized as follows:

"Where the soil cover has not been disturbed, little if any water from precipitation infiltrates the underlying tuff (Purtymun and Kennedy 1971). Where the soil cover was disturbed, as in the waste disposal areas, the moisture content of the tuff indicates a much higher degree of infiltration than the one that might have been implied by the moisture content fluctuations found in the undisturbed tuff (Abeele et al. 1981)."

Rogers and Gallaher (Rogers 1995) reviewed the hydraulic properties of the Bandelier Tuff as well as other units. Their review included core data from several areas at the LANL facility; the data came from both mesa tops and canyon bottoms. They concluded that "[t]he canyon bottom and mesa top hydraulic head profiles suggest that downward flow of water occurs beneath the surface of the Pajarito Plateau" (Rogers 1995). They noted two exceptions where there was the suggestion of upward flow, one of which they speculated was caused by "increased external air circulation through the mesa sides."

Core data were unavailable for the DARHT and PHERMEX sites. In lieu of site-specific data, data reported by Rogers and Gallaher (Rogers 1995) for other mesa tops were used to estimate deep drainage. Assuming a hydraulic gradient close to unity, one can equate the in situ hydraulic conductivity to the drainage rate. Rogers and Gallaher lumped core data together to calculate mean in situ conductivity values. In their table 5, Rogers and Gallaher report both harmonic and arithmetic mean values of hydraulic conductivity. For Area TA-54, Rogers and Gallaher reported values ranging from 1.7×10^{-6} to 0.06 in/yr (4.3×10^{-5} to 1.5 mm/yr) for the harmonic and arithmetic means, respectively. For Area TA-16, the rates ranged from 3 to 55 in/yr (79 to 1,390 mm/yr). For Area TA-53, the rates ranged from 7 to 3,660 in/yr (180 to 93,000 mm/yr). While not from the DARHT or PHERMEX sites, these ranges indicate clearly that deep drainage can vary greatly from site to site.

The impact of early and recent LANL operations may not always be reflected in core data - and this makes interpretation difficult. For example, Allison et al. (1994) related the case of land clearing in Australia in which the recharge rate increased from 0.003 to 1.8 in/yr (0.08 to 45 mm/yr). The pressure front generated by the increase in recharge took nine years to reach the 25-ft (7.5-m) depth. Foxx and Tierney (1984) related the historical occurrence of grazing and logging as well as the impact of recent disturbances from LANL operations. Generally, such changes alter plant communities and reduce their ability to transpire water, thus increasing the potential for deep drainage. Depending on the pre-disturbance drainage rate, an increase in drainage may take decades or centuries to propagate downward through the tuff. Thus, core data collected today must be interpreted and used cautiously, especially if one does not know or account for the history of surface conditions at specific sites.

E1.4 METHOD

Deep drainage was estimated at the DARHT and PHERMEX sites using simulation modeling. Simulations were conducted using the UNSAT-H Version 2.02 computer code (Fayer and Jones 1990). The UNSAT-H computer code, developed for the Hanford site, was selected because it was developed for and has been applied to estimate deep drainage at DOE sites in the arid and semi-arid western United States. The code models one-dimensional, deep drainage, accounting for the hydrological characteristics of soil media, climate, and vegetation. The exhibit E1-1 contains a listing of an example input file for UNSAT-H. The model requires information on the domain, soil properties, initial conditions, boundary conditions, and plants.

E1.4.1 Domain

The model domain extended to 16 ft (5 m). This depth is well below the zone of evapotranspiration for most species. Some roots have been observed at greater depths within fractures (Tierney and Foxx 1987), but these were not considered in this one-dimensional modeling exercise. Also, because of the one-dimensional nature of this analysis, processes such as interflow (subsurface lateral drainage) were not addressed. The node spacing ranged from 0.1 in (0.2 cm) at the soil surface to 20 in (50 cm) at the 16-ft (5-m) depth. At the transition between different materials, the node spacing was reduced to 0.8 in (2.0 cm).

E1.4.2 Soil Properties

The soil at the center of the DARHT site is mapped as Pogna sandy loam (Nyhan et al. 1978). Some of the soil samples collected at the DARHT site for a geotechnical investigation report (Korecki 1988) indicated that there is more clay than expected for a Pogna sandy loam. Nyhan et al. (1978) indicated that the Pogna sandy loam has small inclusions of other soil types. Based on the descriptions reported by Korecki (1988), a likely candidate for some of the soil at the DARHT site is the "Typic Eutroboralf, fine," which includes layers of sandy loam, sandy clay, and clay. In the blueprints for the DARHT Facility (LANL 1993a), several drawings indicate surface modifications that include stripping the soil off and building directly on the tuff as well as covering the surface near the firing point with gravel. At some distance from the center of the DARHT site is another soil type, the Seaby loam,

Exhibit E1-1.-*Example Input File for UNSAT-H Computer Code*

```
DP1: Typic Eutroboralf, fine, with grass-shrub cover 40%, day 74 and 288

1 1 1 1 0 0 0 iplant,lower,ngrav,iswdif,etc.

0 365 365 1 1 0 0.0 nprint,dayend,ndays,nyears,etc.

1 2 0 1 0 nsurpe,nfhour,itopbc,et_opt,icloud

4 1 1 0 3 1 kopt,kest,ivapor,sh_opt,inmax,inhmax

0.0 1.00e+05 0.0 0.0 hirri,hdry,htop,dhmax

5.0e-05 1.00e+00 1.0e-08 24.0 dmaxba,delmax,delmin,stophr

0.66 288.46 0.24 1.0 tort,tsoil,vapdif,qhtop

0.0 0.0 0.0 0.0 tgrad,tsmean,tsamp,qhleak

0.5 1.6 1.0e-06 0.0e-00 wtf,rfact,rainif,dhfact
```

```
5 68 matn,npt
1 0.0 1 0.2 1 0.4 1 0.6
1 0.8 1 1.0 1 1.4 1 1.8
1 2.4 1 3.0 1 4.0 1 5.5
1 7.0 1 9.0 1 11.0 1 13.0
1 15.0 1 17.0 5 19.0 5 21.0
5 23.0 5 25.0 5 27.0 5 29.0
5 31.0 5 33.0 5 35.0 5 38.0
5 41.0 5 44.0 5 46.0 5 48.0
5 50.0 4 52.0 4 54.0 4 56.0
4 59.0 4 63.0 4 68.0 4 74.0
4 80.0 4 84.0 4 86.0 4 89.0
4 91.0 4 93.0 3 95.0 3 97.0
3 99.0 3 102.0 3 106.0 3 110.0
3 115.0 3 123.0 3 135.0 3 150.0
3 175.0 3 200.0 3 225.0 3 250.0
3 275.0 3 300.0 3 325.0 3 350.0
3 375.0 3 400.0 3 450.0 3 500.0
Sandy loam retention
0.4100 0.0650 0.0750 1.8900
Sandy loam conductivity
2 4.43 0.0750 1.8900 0.5
Gravel retention
0.419 0.0050 4.9300 2.19
```

```
Gravel conductivity

2 1260.0 4.9300 2.19 0.5

Tuff retention

0.4690 0.0450 0.0029 1.884

Tuff conductivity

2 0.1188 0.0029 1.884 0.5

Sandy clay retention

0.3800 0.1000 0.0270 1.230

Sandy clay conductivity

2 0.1200 0.0270 1.230 0.5

Clay retention

0.3800 0.0680 0.0080 1.090

Clay conductivity

2 0.2000 0.0080 1.090 0.5

*** Initial matric suction values go here
```

Exhibit E1-1.-*Example Input File for UNSAT-H Computer Code - Continued*

```
Plant information for shrubs and grasses

1 1 1 1 74 288 leaf,nfroot,nuptak,nfpet,etc

12 0.6 npoint,bare

0 0.70 91 0.70 105 1.00 121 1.33 135 1.70 ngrow,flai

213 1.70 227 1.60 244 1.50 258 1.28 274 1.08 ngrow,flai

305 0.70 366 0.70 ngrow,flai

0.000 0.0000 1.0000 aa,b1,b2

0 0 0 0 0 0 0 0 0 0 ntroot
```

```
0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0

0 0 0 0 0 0 0 0 0 0

366 366 366 366 366 366 366 366 366 366

366 366 366 366 366 366 366 366 366 366

366 366 366 366 366 366 366 366

4.0e+04 1.0e+03 30.0 hw,hd,hn

4.0e+04 1.0e+03 30.0 hw,hd,hn

4.0e+04 1.0e+03 30.0 hw,hd,hn

4.0e+04 1.0e+03 30.0 hw,hd,hn

4.0e+04 1.0e+03 30.0 hw,hd,hn

*** Meteorological data go here
```

which should be considered. Thus, five soil scenarios were envisioned for this analysis: 1) tuff, 2) gravel above tuff, 3) Pogna sandy loam, 4) Typic Eutroboralf, fine, and 5) Seaby loam. Table**Table E1-1.-*Soil Profile Descriptions for the Computer Simulations***

Soil Profile	Depth Interval (cm)	Porous Material
Tuff	0 to 500	tuff
Gravel Above Tuff	0 to 30 30 to 500	gravel tuff
Pogna Sandy Loam	0 to 30 30 to 500	sandy loam tuff

Typic Eutroboralf, fine	0 to 18 18 to 51 51 to 94 94 to 500	sandy loam clay sandy clay tuff
Seaby Loam	0 to 13 13 to 25 25 to 30 30 to 66 66 to 500	loam clay loam, 40 percent gravel clay loam, 55 percent gravel gravel tuff
Nyjack Loam	0 to 8 8 to 61 61 to 99 99 to 500	loam clay loam sandy loam, 25 percent gravel tuff
Hackroy Sandy Loam	0 to 8 8 to 25 25 to 30 30 to 500	sandy loam clay clay, 25 percent gravel tuff

E1-1 shows the soil profile description for each scenario.

The soil type at the center of the PHERMEX site is mapped as Nyjack loam (Nyhan et al. 1978). Nearby soil types include the Seaby loam (included in the DARHT scenario list) and the Hackroy sandy loam. The Nyjack loam and Hackroy sandy loam were added to the list in table E1-1 to bring the total number of soil profile scenarios to seven.

Hydraulic properties were assigned to each porous material in table E1-1. Specifically, water retention and hydraulic conductivity were described using the van Genuchten (1980) retention function and the Mualem (1976) conductivity model; table**Table E1-2.-*Parameters Used to Describe Hydraulic Properties in the Simulations***

Porous Material	**Gravel (vol %)**	**–s**	**–r**	**– (1/cm)**	**n**	**K_s (cm/h)**
Tuff	0	0.469	0.045	0.0029	1.88	0.119
Gravel	100	0.419	0.005	4.93	2.19	1260.0
Sandy loam	0	0.410	0.065	0.075	1.89	4.42
Sandy loam	25	0.308	0.049	0.075	1.89	2.83
Sandy clay	0	0.380	0.100	0.027	1.23	0.12
Loam	0	0.430	0.078	0.036	1.56	1.04
Clay loam	0	0.410	0.095	0.019	1.31	0.26
Clay loam	40	0.246	0.057	0.019	1.31	0.122
Clay loam	55	0.185	0.043	0.019	1.31	0.0846
Clay	0	0.380	0.068	0.008	1.09	0.200
Clay	25	0.285	0.051	0.008	1.09	0.130

–$_s$ Saturated moisture content.

–$_r$ Residual moisture content.

_ Fitted van Genuchten parameter, 1/cm.

n Fitted van Genuchten parameter.

K_s Saturated hydraulic conductivity, cm/h.

Note: The van Genuchten parameter m was set equal to 1-1/n. The standard value of 0.5 was used for the pore interaction term.

E1-2 shows the parameters. Hydraulic properties specific to the site soils were unavailable. Instead, the particle size description (e.g., sandy loam, clay) was used to assign parameters based on the correlations reported by Carsel and Parrish (1988). For those materials with gravel, the hydraulic parameters reported by Carsel and Parrish (1988) were modified using the method proposed by Bouwer and Rice (1983). The actual properties of the tuff unit beneath the surface of the DARHT site were unknown. For this study, the properties of the Tshirege Unit 3 were used (Rogers 1995). This unit appears to be the highest in elevation for which hydraulic properties are available. All hydraulic properties were assumed to be isothermal and non-hysteretic. Soil freezing was not addressed.

E1.4.3 Initial Conditions

There was no information on the 1980 matric suction distribution at the DARHT or PHERMEX sites. Therefore, the first year (1980) of every simulation was repeated until the water balance variables (i.e.,evaporation, transpiration, drainage, and runoff) changed by less than 0.004 in (0.1 mm) from one year to the next. The reason for the iteration was to lessen the impact of the unknown initial conditions.

E1.4.4 Boundary Conditions

The surface boundary was described with weather data, which were summarized by Bowen (1990). The daily precipitation data were obtained for the TA-59 site for 1980 to 1990 and the TA-6 site for 1991 to 1994. During each day, the precipitation was added at the rate of 0.4 in/h (1 cm/h) until the day's total was applied to the surface. Snow was treated as an equivalent rainfall. No adjustment was made for delays in snowmelt.

Daily potential evapotranspiration (PET) values were calculated using the Penman Equation in Doorenbos and Pruitt (1977) and daily weather parameters from the TA-59 and TA-6 sites. These parameters included wind speed at 75 ft (23 m), maximum and minimum air temperature and dew-point temperature at 4 ft (1.2 m), solar radiation, and cloud cover. The dew-point temperature data set was sparse. When data existed, a comparison to measured minimum air temperature showed the dew-point temperature tobe less than or equal to the minimum air temperature. Because a relatively complete record of daily minimum air temperature existed, the daily dew-point temperature was approximated as the minimum air temperature. Cloud cover data were not available. Instead, cloud cover was approximated using the measured solar radiation and calculations of the potential solar insolation for Los Alamos (Campbell 1985).

During the evaporation process, the matric suction of the surface node was not allowed to exceed a predetermined value. For most of the simulations, the value was 1,450 lb/in^2 (10 MPa). For the gravel surface scenario, however, this limit increased the difficulty of the solution. Instead, a value of 14.5 lb/in^2 (0.1 MPa) was used.

The bottom boundary was described with a unit gradient condition. Observations at other sites indicate that unit gradient conditions exist in the tuff in certain zones at certain sites, but it is not universal. For these simulations, plant roots were assumed to be no more than 3.3 ft (1 m) deep. As long as the simulations indicated that deep drainage was greater than 0.04 in/yr (1 mm/yr), the unit gradient condition at 16 ft (5 m) was assumed to be valid.

E1.4.5 Plants

Plant information consisted of the method to partition potential evapotranspiration, active season, bare fraction, root length density, and maximum root depth during the year, as well as the effectiveness of plant water withdrawal as a function of soil matric suction. According to the Environmental Restoration Program (ERP), the plant community on the PHERMEX mesa is the piñon-ponderosa-juniper association (LANL 1993b). In the vicinity of the facilities, however, this community has been eliminated and replaced by structures (e.g., roads, parking lots, buildings), bare ground, and shrubs and grasses. Data for those plants pertinent to the DARHT and PHERMEX sites were not available. Instead, literature parameters or reasonable estimates of parameters were chosen. Plant responses to precipitation and temperature variations, fire, disease, nutrient cycling, grazing, and land use changes were not addressed in the simulations.

The leaf area method was used to partition potential evapotranspiration into potential evaporation and potential transpiration. Leaf area as a function of season was described using values reported by Nyhan (1989b) for a 40 percent cover of shrubs and grasses.

The active season of the plants determined when to calculate transpiration and when roots started or stopped growing. The active season was specified with starting and ending days during the year. The shrubs and grasses were started on March 15 (day 74) and stopped on October 15 (day 288). These dates were estimates only but are reasonable given the monthly temperatures experienced at Los Alamos (Bowen 1990).

The bare fraction of soil was used to scale potential transpiration based on the amount of soil surface covered by the vegetation. If the bare fraction was zero, the cover percentage would be 100 percent and there would be no reduction in potential transpiration. For the grasses and shrubs cover, the bare fraction was assigned as 0.6. This means that the vegetation covered 40 percent of the ground surface (Nyhan 1989b); therefore, potential transpiration was appropriately reduced by 60 percent. Any reduction to potential transpiration caused by a less than 100 percent cover is added to potential evaporation. After all the manipulations, the sum of potential evaporation and potential transpiration must equal potential evapotranspiration.

Root length density data were unavailable. The roots of the grasses and shrubs were considered to be at their maximum depth throughout the growing season. The maximum depth was defined as the surface of the uppermost tuff unit. This depth ranged from 12 in (30 cm) in the Pogna sandy loam to 39 in (99 cm) in the Nyjack loam. Roots have been observed in cracks and fissures in the tuff (Tierney and Foxx 1987). For this one-dimensional analysis, however, cracks and fissures were not considered in the conceptual model.

Data on plant water uptake as a function of matric suction were also unavailable. A matric suction of 0.4 lb/in^2 (0.003 MPa) was assumed to be the limit below which plants ceased transpiration because of anaerobic conditions. From 0.4 to 14.5 lb/in^2 (0.003 to 0.1 MPa), plants were assumed to withdraw water at the potential rate. Above 14.5 lb/in^2 (0.1 MPa), but below the permanent wilting point, plants were assumed to withdraw progressively less water as the matric suction increased. Typically, the matric suction above which plants cease to transpire is 220 lb/in^2 (1.5 MPa) (i.e., the permanent wilting point). Sagebrush was reported to operate in soils with matric suctions as high as 1,000 lb/in^2 (7.0 MPa) (Fernandez and Caldwell 1975; Branson et al. 1976). For this study, as an approximation, an intermediate value of 580 lb/in^2 (4.0 MPa) was chosen.

E1.5 RESULTS

Table **Table E1-3.-*Summary of Simulation Results for 1981 to 1994***

Soil[a] Profile	Max. Root Depth (cm)	Average Annual Rates (mm/yr)				Annual Drainage Rates (mm/yr)		Average Annual Mass Error	
		Evaporation	Transpiration	Runoff	Drainage	Max	Min	mm	% of drain

Tuff	na	505.5	0.0	0.4	33.8	44.3	16.5	0.1	0.3
Gravel	na	21.5	0.0	0.0	519.5	653.6	394.1	3.0	0.6
Pogna	na	183.5	0.0	0.0	359.9	449.2	261.4	0.5	0.1
Pogna	30	209.3	166.5	0.0	164.9	211.6	88.7	1.1	0.7
Typic Eutroboralf	na	272.6	0.0	3.7	265.3	328.1	192.4	1.5	0.6
Typic Eutroboralf	94	279.1	196.7	1.9	57.1	80.8	18.0	2.3	4.1
Seaby	na	464.8	0.0	30.0	32.4	54.1	5.1	0.5	1.5
Seaby	30	337.9	164.7	13.2	9.5	23.8	1.5	0.5	4.9
Nyjack	na	395.9	0.0	22.4	124.0	168.2	67.5	0.1	0.1
Nyjack	99	310.8	200.8	11.8	4.7	11.5	0.8	0.4	7.8
Hackroy	na	200.0	0.0	25.0	318.4	397.8	248.2	1.3	0.4
Hackroy	30	189.0	190.6	15.4	142.6	197.6	91.5	7.6	5.3

[a] Tuff, Gravel, Pogna sandy loam, Typic Eutroboralf (fine), Seaby loam, Nyjack loam, Hackroy sandy loam.

E1-3 shows that the deep drainage rate is highly dependent on the soil profile and the presence of vegetation. Table E1-3 also shows that, for a given combination of soil profile and vegetation, the year-to-year rates [as estimated at the 16-ft (5.0-m depth)] can vary by more than a factor of two. Figures E1-1 to E1-6 illustrate the yearly variation more clearly.

The deep drainage rate at the center of the DARHT site was estimated to be 10 or 14 in/yr (265 or 360 mm/yr) depending on the soil type and assuming vegetation was not allowed to grow. Table E1-3 shows that the estimated rates were reduced by more than half when plants were included. If the immediate center of the site was covered with a layer of gravel (LANL 1993b), the drainage rate would nearly double to 20 in/yr (520 mm/yr), or 95 percent of the precipitation. If the tuff were left exposed at any point, the results in table E1-3 suggest that the drainage rate would be only 1.3 in/yr (34 mm/yr), which is much lower than the rates estimated for the soils. The reason is that the tuff holds infiltrating water relatively near the surface, and its soil hydraulic properties are conducive to upward unsaturated flow. Thus, higher evaporation rates occur from exposed tuff surfaces.

At some distance from the center of the DARHT site is the Seaby loam soil. The simulation results indicate the drainage rate in this soil type is much less than for either the Pogna sandy loam or Typic Eutroboralf soils.

The deep drainage rate at the center of the PHERMEX site was estimated to be 5 in/yr (124 mm/yr) (assuming vegetation was not allowed to grow). At some distance from the center of the PHERMEX site are the Seaby loam, with rates slightly higher than the Nyjack loam, and the Hackroy sandy loam, with rates three times greater than the Nyjack loam without plants, and thirty times greater than the Nyjack loam with plants.

These results are in accord with previous simulation results (Nyhan 1989a) for seepage through covers over waste disposal areas. Nyhan estimated seepage rates of 2.4 and 4.8 in/yr (60 and 120 mm/yr) for a cover with range grass and a bare cover, respectively, assuming a saturated conductivity of 0.08 in/h (0.2 cm/h) for the cover. For the years 1977 to 1987, Nyhan showed that the seepage rate varied between 0 and 6.3 in/yr (0 and 160 mm/yr) for the bare cover and for a cover with a poor range grass.

When the precipitation rate exceeds the ability of the soil to accept infiltration, water begins to accumulate on the soil surface. Once the storage capacity of the soil surface is exceeded, overland flow, or runoff, begins. The UNSAT-H model assumes zero surface storage; thus, water that does not infiltrate is considered to be runoff. Table E1-3 shows the average annual runoff for each of the simulations. Only those soil profiles that had one or more clay layers had runoff. The Nyjack loam, Seaby loam, and Hackroy sandy loams had the highest rates; the Seaby loam was highest with 1.2 in/yr (30 mm/yr). Some of these high rates were comparable to the drainage rate. For the Nyjack loam, the runoff rate was actually twice the drainage rate [which, in this case, was quite low at 0.02 in/yr (4.7 mm/yr)]. The impact of frozen soil, snow, and rapid snowmelt on runoff and deep drainage was not evaluated.

At LANL, Wilcox (1994) reported that runoff accounted for 10 to 18 percent of the precipitation received during a two-year study of the intercanopy zone of a piñon-juniper woodland. The soil was from the Hackroy series and the slope was about 4.4 to 5.3 percent. While not directly applicable to the DARHT and PHERMEX sites, the results from Wilcox (1994) demonstrate that runoff can be a significant component of the water balance at LANL and thus impacts the estimation of deep drainage rates at these two sites. The Wilcox study did consider snow and snowmelt processes. If actual runoff is higher than predicted (table E1-3) at the two sites, the predicted drainage rates are higher than they should be.

E1.6 SENSITIVITIES

Several issues that arose during this study included hourly versus daily precipitation, the use of the 14-yr record versus the longer term precipitation record, the calculation of the daily average dew-point temperature, the calculation of internodal conductances, the effect of initial conditions, and mass balance. Most of these issues were evaluated by conducting additional simulations and comparing to the originals summarized in table E1-3.

E1.6.1 Hourly Precipitation

As configured, the UNSAT-H computer code applies daily precipitation at the rate of 0.4 in/h (10 mm/h) starting at 0000 h until the day's amount has been applied to the soil surface. The concern is that the daily rates will underestimate runoff because they fail to represent the high intensities that sometimes occur. Four years (1991 to 1994) of 15-min precipitation data were used to provide hourly precipitation input for the UNSAT-H code. The Pogna sandy loam and Seaby loam profiles without plants were simulated. The Pogna sandy loam had no runoff using either daily or hourly precipitation data. In fact, the hourly precipitation resulted in a slight reduction in evaporation, mainly because hourly precipitation that occurred during the day reduced evaporation. Overall, estimated drainage increased by about 0.04 in/yr (1 mm/yr). For the Seaby loam, the hourly precipitation data resulted in a 13 percent reduction in runoff. The seemingly contradictory result is understandable. For the daily precipitation, all the rates were 0.4 in/h (10 mm/h). For the hourly precipitation, most of the rates were far less than

0.4 in/h (10 mm/h) while some rates were more. The net result of using hourly precipitation was a 0.05 in/yr (1.3 mm/yr) reduction in annual runoff.

E1.6.2 Precipitation Record

The drainage rate varies from year to year as a function of the precipitation distribution and amounts and the weather. The question that remains unanswered is whether the 14-yr record used for this study adequately represents the longer term weather that has been observed or can be reasonably expected to occur. Bowen (1990) reported precipitation extremes for LANL for the period from 1911 to 1988. The record shows that the largest annual precipitation amount was 30.3 in (770.6 mm), which occurred in 1941. That amount is about 17 percent greater than the highest value used in this study. Bowen (1990) also reported that the highest seasonal snowfall occurred in 1986-1987. That period is within the period used for this study. Both the highest annual precipitation and seasonal snowfall records are very near the estimated 100-yr values reported by Bowen (1990). If this analysis of deep drainage were to extend much beyond 100 years, consideration would have to be given to analyzing for greater precipitation amounts and intensities than used for this study.

E1.6.3 Dew-point Temperature

A clean and continuous record of daily average dew-point temperature was not available for the period 1980 to 1994. In lieu of actual data, daily dew-point temperatures were approximated as equivalent to the minimum daily air temperatures. Daily dew-point temperature from 1982 showed that the minimum air temperature may be roughly 9_F (5_C) higher than the dew-point temperature. The Pogna sandy loam scenario with and without plants was simulated using dew-point temperatures that were 9_F (5_C) lower than the minimum daily air temperature. In both cases, estimated evapotranspiration increased and drainage decreased (2 percent reduction without plants; 16 percent with plants). Similar results are expected for the other soil profiles.

E1.6.4 Internodal Conductance

For all of the simulations without plants, the geometric mean was used to approximate internodal conductances. The Pogna sandy loam simulation without plants was repeated with arithmetic averaging. The result was a much higher evaporation rate and a 24 percent reduction in the drainage rate. All of the simulations with plants were conducted using the arithmetic mean. The Pogna sandy loam simulation with plants was repeated with geometric averaging. The result was significantly reduced evaporation and a 25 percent increase in the drainage rate. One way to view the results overall, in the context of the averaging scheme, is that the simulations with plants and arithmetic averaging represent the lower estimate of deep drainage, and the simulations without plants but with geometric averaging represent the upper estimate.

E1.6.5 Initial Conditions

To overcome the lack of initial conditions, the simulation of 1980 was repeated until there was less than a 0.004-in (0.1-mm) annual change in the water balance components and in the drainage flux through the tuff. This requirement was relaxed for some of the simulations with plants because the rates under the 1980 weather conditions were either very low or the flux was actually upward. Using these initial conditions, the simulation results for some soil profiles showed drainage rates that increased slowly during part or all of the 14-yr period, indicating some sensitivity to the initial conditions. To ascertain the degree of sensitivity to initial conditions, the Pogna sandy loam and Seaby loam profiles without plants were simulated with a uniform initial matric suction profile of 39 in (100 cm), which is very wet. Figure E1-7 shows that, after two years, the annual drainage rates from the initially wet (open triangles) Pogna sandy loam were nearly identical to what was predicted using the drier initial conditions (filled triangles). The 14-yr average rate was also nearly identical to the average rate predicted using drier initial conditions. In contrast, figure E1-7 shows that the annual drainage rates from the initially wet Seaby loam took the entire 14 years to come within

3 percent of the original simulation reported in table E1-3. Also, the 14-yr average rate was double the average rate predicted using drier initial conditions. When drainage rates are high, the initial conditions appear to become unimportant after only 1 to 2 years. When the rates are low, the initial conditions appear to influence the simulation results for at least as long as 14 years. The technique of conducting two simulations, one initially dry and one initially wet, can be used to illustrate the impact and provide bounding drainage predictions. Based on testing, the limited results suggest that the initial conditions used in the study caused an underestimate of deep drainage of no more than 12 to 16 in/yr (30 to 40 mm/yr).

E1.6.6 Mass Balance

The allowable mass balance error of a given simulation is controlled by the user. As more control is exerted, the simulation time requirement increases. Generally, the mass balance error was kept to less than 1 percent of the drainage rate. For the very low rates, this requirement was relaxed to 10 percent. In two cases, the Seaby loam and Nyjack loam, even this requirement was initially not met. These soil profiles with vegetation were simulated again with tighter convergence criteria. The estimated water balance components changed by less than 0.04 in/yr (1 mm/yr), but the mass balance errors were reduced to less than 10 percent relative to the drainage estimates. Further reductions in the mass balance errors could be obtained but the results and conclusions would not likely be affected.

E1.7 SUMMARY

The results of this study showed clearly that deep drainage at the DARHT and PHERMEX sites is possible. Estimated rates ranged from 0.2 to 14 in/yr (4.7 to 360 mm/yr) and could be as high as 20 in/yr (520 mm/yr) if the surface was graveled and unvegetated. These estimates are reasonably similar to other estimates (e.g, Abeele et al. 1981; Rogers 1995).

APPENDIX E2: SOLUBILITY

AND SORPTION OF METALS

Mobilization of contaminants from the firing sites to and within Potrillo and Water canyons, and the associated subsurface environment is significantly affected by the contaminants' solubility in water and sorption onto soil and sediments. Thus, estimated solubility limits and distribution coefficients were determined for depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver at the LANL sites. The metals studied represent two classes: 1) those metals assigned annual expenditure rates (e.g. depleted uranium, beryllium, lead, and copper) (see chapter 3, table 3-4) and 2) those metals identified as included in the "other metals" category of the materials expended (see appendix B, table B-4) that werealso listed in the primary and secondary drinking water standards (i.e., 40 CFR 141 and 143) (e.g. aluminum, iron, nickel, and silver). Note, aluminum and stainless steel (hence iron) make up the majority of the "other metals" category of materials expended during tests.

Because the numerical values for solubilities, distribution coefficients (K_d), and constants in the equations defining K_d are interrelated, these numerical values are given only in the metric units used by geochemists.

E2.1 METHODOLOGIES FOR ESTIMATION

OF SOLUBILITY AND DISTRIBUTION COEFFICIENTS

Since no solubility experiments specific to the DARHT and PHERMEX sites were conducted previously, these values, except for depleted uranium, were obtained by running the geochemical model, MINTEQ (Felmy et al. 1984) with water quality data measured at Beta Hole in the Water Canyon and in Well PM-4 of the Pajarito Field (LANL

1988; LANL 1989; LANL 1990; LANL 1993c; Purtymun et al. 1994). The MINTEQ computer code was selected because it is a state-of-the-art geochemical code capable of calculating complex geochemical equilibria for reactions involving gases, aqueous solutions, adsorbed species, and minerals within a wide range of geochemical conditions and constraints. The code has associated with it a thermochemical database containing aqueous speciation and solubility data. The code was developed in the mid-1980s for the EPA as part of a system to model the migration and fate of pollutant metals; the code was subsequently modified for the Nuclear Regulatory Commission and DOE. For depleted uranium, field data measured at the E-F site (Hanson and Miera 1977), Aberdeen Proving Ground in Maryland (Erickson et al. 1993), and Yuma Proving Ground in Arizona (Erickson et al. 1993) were used to estimate solubility. Water quality data for the surface and subsurface water used for the MINTEQ modeling are shown in table **Table E2-1.-*Water Quality at the Beta Hole in Water Canyon***

and Well PM-4 in the Pajarito Field

Location	**Calcium (mg/L)**	**Magnesium (mg/L)**	**Potassium (mg/L)**	**Sodium (mg/L)**	**Carbonate plus Bicarbonate (mg/L)**	**Chloride (mg/L)**	**Sulfate (mg/L)**	**pH**
Beta Hole	12	4	3.3	17	51	11	7.5	7.8
PM-4	14	4	3	15	60	2	2.5	7.85

E2-1. Distribution coefficients for depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver were estimated by using laboratory experimental results from other sites (e.g., Yucca Mountain in Nevada and the Hanford Site in Washington).

E2.2 DEPLETED URANIUM

Depleted uranium is the isotopic form present in the studies cited here. The physical chemistry of various isotopic forms of uranium is essentially identical, so the general term "uranium" is used in this section.

E2.2.1 Solubility of Uranium

Many studies have obtained data on uranium distributions at LANL and physical/chemical characteristics (Hanson 1974; Hanson and Miera 1976; Hanson and Miera 1978; Elder et al. 1977; and Becker 1993). Common oxidation states of uranium are designated as uranium(III), uranium(IV), uranium(V), uranium(VI), but in the LANL geologic environment uranium(IV) and uranium(VI) are the most important (Onishi et al. 1981). Uranium(VI) species control the total uranium concentration in oxidizing environments. The uranyl ion (UO_2^{+2}) is a dominant species under oxidizing conditions. This cation can form many soluble and stable complexes with common ground water anions such as carbonate and sulfate (Onishi et al. 1981). In reducing conditions, uranium (IV) dominates and generally precipitates as uranium dioxide. Uranium content in solution, and thus also a distribution coefficient K_d, are a function of oxidation-reduction potential (Eh), pH, solution carbonate content, sediment characteristics (particle size, carbonate, phosphorous, and hydrous oxide contents), and organic matter content (organic carbon and humic substances) (Onishi et al. 1981). Data reviewed by Onishi et al. (1981) indicate that the uranium K_d for sediments from the Great Miami River (Ohio) ranged between 1,000 and 1,600 mL/g, while K_d values for sediments in 40 Japanese rivers varied between 1,000 and 6,000 mL/g.

Erickson et al. (1993) performed a series of experiments and geochemical modeling to determine corrosion rate, solubility, and adsorption potential for uranium at Aberdeen Proving Ground in Maryland and the Yuma Proving Ground in Arizona. Uranium pieces corrode with a corrosion rate of 0.02 to 0.04 in/yr (0.05 to 0.10 cm/y) to form uranium (VI) hydrated oxides, mostly the yellowish mineral schoepite ($UO_3 \cdot H_2O$). The corrosion rate is fast enough that uranium is available for transport through dissolution of schoepite and subsequent surface and subsurface migration. The LANL E-F site exhibits a yellow corrosion product of uranium on the soil surface, a sign of schoepite. Soils (two types) at Aberdeen Proving Ground are predominantly silt with moderate cation exchange capacity (CEC), low calcium carbonate content, and low paste pH values (pH of 4 to 6). Soils (one set) at Yuma Proving Ground are predominantly gravel and sand with higher CEC, high carbonate minerals, and slightly basic (pH of 8 to 8.5) saturation paste. Erickson et al. (1993) reported that the solubility of uranium at Aberdeen Proving Ground and Yuma Proving Ground is 10 to 280 mg/L, and 20 to 130 mg/L, respectively. They attributed the higher corrosion rate and uranium mobility measured at Yuma Proving Ground as primarily controlled by the higher dissolved carbonate, derived from the dissolution of carbonate minerals in this soil. Soil characteristics (especially carbonate content) at the LANL site fall between one of the Aberdeen Proving Ground soils and the Yuma Proving Ground soil types (LANL 1995).

Furthermore, uranium concentrations in standing water at the detonation center of the E-F site were 86 and 235 mg/L in 1975 and 1976, respectively, with nearly all of the uranium being in solution as opposed to suspended as fine solids (Hanson and Miera 1977). The uranium concentration in standing water at 66 ft (20 m) to the southwest away from the detonation center was only 63 µg/L in 1975, i.e., three orders-of-magnitude less than the concentration measured in standing water at the detonation center. A uranium concentration in runoff water measured in 1975 at 330 ft (100 m) to the southwest (still on mesa top) away from the detonation center was 52 µg/L. These concentration differences between the detonation center and the short distances away imply that not enough uranium was transported from the firing point to maintain the uranium concentration in solution at the solubility limit of uranium even 65 ft (20 m) away.

Based on these studies, we selected uranium solubility limit to be 300 mg/L for the current study. We also assumed that corrosion of uranium is fast enough for uranium to be available for subsequent surface/subsurface migration.

E2.2.2 Sorption of Uranium

Erickson et al. (1993) also conducted adsorption experiments and geochemical modeling with the chemical code, MINTEQ (Felmy et al. 1984). Experimental values for uranium distribution coefficients on the two soil types at Aberdeen Proving Ground were reported to be 4,360 and 328 mL/g. The Yuma Proving Ground site has the lowest K_d value (54 mL/g) due to the high carbonate solution concentrations despite the Yuma Proving Ground environment having the highest pH and CEC, two attributes that normally portend high adsorption. Since soil characteristics (especially carbonate concentrations) at the LANL site (Longmire 1995) fall between one of the Aberdeen Proving Ground soil types and the Yuma Proving Ground soil type, an expected K_d value with soil at the LANL site is estimated to be between 54 and 328 mL/g. We selected distribution coefficient values for the LANL soil to be 50 mL/g, and 100 mL/g as conservative and more realistic estimates. Since suspended sediment in LANL canyon streams have finer particle size, and since it is generally believed that finer sediments exhibit greater K_d values (Onishi et al. 1981; Becker 1993), we selected K_d values of 100 and 200 mL/g to be conservative and more realistic estimates for the in-stream suspended sediment.

E2.3 LEAD

E2.3.1 Solubility of Lead

The release rate of lead from the metal compounds into water depends largely on the oxidation rate of metallic lead, the dissolution of secondary minerals (e.g., lead carbonates), and the amount of water available to react with lead (Rhoads et al. 1992). However, we are not aware of any solubility and adsorption data for lead in contact with LANL waters or tuff. Thus, we performed geochemical modeling with MINTEQ to obtain lead solubility estimates for the LANL sites. The water quality data shown in table E2-1 was used to represent the LANL surface water and ground water conditions. The mineral cerrusite ($PbCO_3$) was imposed as the solubility limiting solid in this case.

MINTEQ predicted lead solubility in canyon streams and ground water to be 48.2 and 45.7 µg/L, respectively. Hence, we selected the lead solubility to be 50 µg/L for both surface and subsurface waters at the LANL sites.

Rhoads et al. (1992) conducted experiments and chemical modeling to determine the lead solubility in Hanford ground water. Assuming lead was in equilibrium with cerrusite, they used the geochemical code MINTEQ (Felmy et al. 1984) to predict the lead solubility to be 287 µg/L, which is close to solubility limits of 236 to 482 µg/L which they obtained in laboratory experiments. This result confirms the general validity of the MINTEQ simulation with cerrusite limiting lead solubility.

E2.3.2 Sorption of Lead

Adsorption of dissolved lead depends on water and soil chemistry, and properties of the lead species in solution (Rhoads et al. 1992). However, a main factor affecting lead adsorption is the amount of iron oxides in the soil.

According to Rhoads et al. (1992), batch experiments with Hanford ground water and relatively fine sediment (sand, silt, and clay mixture) yielded distribution coefficients varying from 1,190 mL/g at dissolved lead concentration of 200 µg/L to 56,000 mL/g at dissolved lead concentration of 0.005 µg/L, showing the following functional relationship:

$$K_d = 9550\ C^{-0.335}$$

where C is a dissolved lead concentration in µg/L. This relationship yields K_d values of 2,580 mL/g at the dissolved lead concentration of 50 µg/L, 1,410 mL/g at the dissolved lead concentration of 300 µg/L, and 1,150 mL/g at the dissolved lead concentration of 550 µg/L.

Based on this Hanford study, conservative and realistic distribution coefficient values of 1,000 and 10,000 mL/g, respectively, for lead transport in the subsurface of the LANL site were selected. Because of the finer suspended sediment in canyon streams, their conservative and realistic distribution coefficient values were selected to be twice the values of ground water, e.g., 2,000 and 20,000 mL/g, respectively.

E2.4 BERYLLIUM

E2.4.1 Solubility of Beryllium

Beryllium solubility was calculated using the geochemical code MINTEQ (Felmy et al. 1984) by imposing beryllium hydroxide ($Be(OH)_2$) as the solubility limiting solid. Thermodynamic data used for this study on beryllium hydride were not a part of the original MINTEQ code but are incorporated in MINTEQA2 (Version 3.0) and are reported in Serne et al. (1993). Beryllium solubility was calculated for water from Water Canyon at the Beta Hole, and ground water from water supply Well PM-4 in the Pajarito Field (see table E2-1).

Beryllium solubility for Water Canyon at the Beta Hole and Well PM-4 predicted by the MINTEQ geochemical code are 3.95 and 3.62 µg/L, respectively. The MINTEQ simulation shows the strong dependency of beryllium solubility to pH. By using MINTEQA2 (i.e., with the same thermodynamic data base as those used under the current study), Serne et al. (1993) calculated beryllium solubility for Hanford ground water (pH of 8.1) to be 2.3 µg/L, which is comparable to the 3.62 to 3.95 µg/L range we estimated for the LANL waters.

Based on these model results, the beryllium solubility selected was 4 µg/L for both the canyon streams and subsurface flow.

E2.4.2 Sorption of Beryllium

Very few data are available for beryllium adsorption on soil (Serne et al. 1993), and we are not aware of any beryllium adsorption data for LANL soils and sediments. Beryllium adsorption data for 11 soils reviewed by Rai et al. (1984) show that beryllium adsorption is greater than adsorption of other divalent metals such as zinc, cadmium, nickel, and the monovalent metal mercury.

Adsorption of divalent beryllium is expected to be somewhat similar to that of divalent strontium. Thus, we used a strontium distribution coefficient obtained from experiments on tuff deposits for beryllium adsorption values. Strontium adsorption is significantly influenced by calcium and magnesium ions. There are many strontium adsorption studies performed with Yucca Mountain tuff. These include strontium distribution coefficients of:

- 50 to 84 mL/g obtained in batch tests and 30 to 52 mL/g obtained by column tests (Erdal et al. 1980)

- 50 to 300 mL/g with batch tests and 30 to 106 mL/g with column tests (Vine et al. 1981a)

- 51 to 283 mL/g with batch tests and 19 to 395 mL/g with column tests (Vine et al. 1981b)

Based on data from five samples of devitrified tuff, the range in strontium K_d values for the LANL soil was reported to be 53 to 190 mL/g with an average value of 116 mL/g (Wolfsburg 1980).

Based on these values, we selected conservative and realistic strontium distribution coefficient values to be 50 and 100 mL/g, respectively, for subsurface water. Because beryllium adsorption by soil is expected to be similar to that of strontium, these values were also used for the beryllium distribution coefficient for subsurface flow modeling.

Because the suspended sediments in canyon streams are expected to be finer than soils in the subsurface (Becker 1993), and the finer the sediment the greater the K_d values (Onishi et al. 1981), we selected conservative and realistic beryllium K_d values for canyon stream modeling to be 100 and 200 mL/g, respectively.

E2.5 NICKEL

E2.5.1 Solubility of Nickel

The solubility of nickel was estimated by using the MINTEQ code with its existing data base, and the LANL water quality data shown in table E2-1. Geochemical simulation indicates that the most stable solid phase of nickel in both surface and ground water is nickel hydroxide ($Ni(OH)_2$) as was found for a Hanford ground water case (Serne et al. 1993). The calculated nickel solubilities for canyon streams and ground water were 1.16 and 0.904 mg/L, respectively, assuming equilibrium with nickel hydroxide. Thus, we selected the nickel solubility to be 1.0 mg/L for both surface and subsurface waters at the LANL sites.

E2.5.2 Sorption of Nickel

No nickel adsorption experiments have been conducted with LANL soils and water. Thus, we used Hanford Site nickel adsorption data to obtain an appropriate nickel distribution coefficient for this study. By using Hanford ground water with Trench-8 soil, Serne et al. (1993) obtained K_d values of 440 mL/g and 2,350 mL/g after 5 and 44 days. With Trench-94 soil, they obtained K_d values of 48 and 337 mL/g at a dissolved nickel concentration of 2 and 1,000 µg/L, respectively. Serne et al. (1993) then derived the following empirical K_d expression:

$$K_d = 240\ C^{-0.155}$$

where C is the dissolved nickel concentration in µg/L, and the K_d is the distribution coefficient in mL/g. The above equation yields K_d values of 118, 167, and 240 mL/g at the dissolved nickel concentrations of 100, 10, and 1 µg/L, respectively. Note that a dissolved nickel concentration at the LANL sites is expected to be less than 100 µg/L.

In addition, Brookins (1984) and Serne (1994) reported the conservative nickel distribution coefficients to be 50 mL/g for devitrified tuff and 20 mL/g for sandy soil, respectively.

From these data, we selected conservative and realistic nickel distribution coefficients to be 20 and 200 mL/g, respectively, for the LANL ground water. For the LANL canyon streams suspended sediments, we selected conservative and realistic values of 40 and 400 mL/g, respectively.

E2.6 COPPER

E2.6.1 Solubility of Copper

The mineral malachite ($Cu_2CO_3(OH)_2$) was specified as the copper solubility controlling solid for MINTEQ calculations of copper solubility in the canyon stream and ground water described in table E2-1. MINTEQ predicted the copper solubility to be 10.5 µg/L for both the LANL site surface and ground water. Thus, the copper solubility for this study was selected to be 10 µg/L for both canyon stream and subsurface modeling.

E2.6.2 Sorption of Copper

There are no copper adsorption data available for the LANL waters and soils or sediments. Since copper and nickel are both divalent and are expected to have similar sorption behavior, we elected to use the same K_d values for copper as for nickel. Serne (1994) reported the conservative copper K_d value for Hanford sandy soil to be 20 mg/L, the same as our conservative K_d value for nickel.

Thus we assigned the conservative and realistic K_d values for the LANL ground water to be 20 and 200 mL/g, respectively. The conservative and realistic K_d values for the canyon stream water were assigned 40 and 400 mL/g, respectively.

E2.7 ALUMINUM

E2.7.1 Solubility of Aluminum

Aluminum solubility was also calculated using the geochemical code MINTEQ (Felmy et al. 1984) by assigning the solubility limiting solid to be the mineral gibbsite ($Al(OH)_3$). With the water quality data shown in table E2-1 for Water Canyon and Well PM-4, MINTEQ predicted the aluminum solubility at equilibrium with gibbsite to be 1.22 and 1.36 µg/L for the canyon streams and ground water in the study area. Thus, we selected aluminum solubility to be 1 µg/L for both surface and subsurface flow modeling.

E2.7.2 Sorption of Aluminum

Since aluminum is a major constituent of soil, and the bulk of aluminum in the soil is not undergoing adsorption/desorption reactions with water, no meaningful adsorption experimental data for aluminum exist. Nonetheless, we selected the conservative aluminum K_d value to be 300 mL/g for the LANL ground water, as indicated by Serne (1994) for the Hanford sandy soil's conservative value. We selected a more realistic K_d value for aluminum to be 5,000 mL/g for the ground water. Because suspended sediment is finer than the bulk surface soil, we selected K_d values for the canyon streams to be twice the corresponding K_d values of the subsurface. Thus, the conservative and more realistic K_d values for canyon streams were assigned to be 600 and 10,000 mL/g, respectively.

E2.8 IRON

E2.8.1 Solubility of Iron

The solubility of iron was estimated using the MINTEQ code with its existing data base and water quality data shown in table E2-1. Because there were no redox data available for Water Canyon stream water and Well PM-4 ground water, we assumed that the water is oxidized. With this assumption, the geochemical simulation indicates that the most probable controlling solid phase of iron in both surface and ground water is amorphous iron hydroxide ($Fe(OH)_3$). The predicted iron solubility for both the canyon stream and ground water was 0.0022 µg/L. This value is very similar to the 0.002 µg/L value Morel (1983) reported for the ferric iron solubility at equilibrium with iron hydroxide at a pH of 7.8. Thus, we selected the iron solubility to be 0.002 µg/L for both surface and subsurface waters in the study area. Note that if the ground water of Well PM-4 is in a reduced condition, the iron solubility would be much higher than 0.002 µg/L due to the higher solubility of ferrous iron.

E2.8.2 Sorption of Iron

Similar to the aluminum case discussed above, iron is also a major constituent of soil and the bulk of the iron in the soil is not undergoing adsorption/desorption reactions with water. Thus, there is no meaningful adsorption experimental data for iron. However, Serne (1994) found a conservative K_d value for iron in sandy soil to be 15 mL/g, and we selected this value for subsurface flow modeling at the LANL sites. We assigned a realistic iron K_d value of 1,000 mL/g for the subsurface model. Conservative and realistic K_d values for iron in canyon streams were assigned to be 30 and 2,000 mL/g, respectively.

E2.9 SILVER

E2.9.1 Solubility of Silver

Silver chloride (AgCl) was specified as the silver solubility controlling solid for MINTEQ calculations of silver solubility in the canyon streams and ground water whose chemical quality is shown in table E2-1. MINTEQ predicted silver solubility to be 76.4 and 286 µg/L for the LANL sites' surface and ground water, respectively. Thus, the silver solubility for this study was selected to be 80 and 300 µg/L for canyon stream and subsurface models, respectively.

E2.9.2 Sorption of Silver

Serne (1994) stated that 1 mL/g may be taken as a conservative K_d value for silver in a sandy soil. Consequently, we selected the conservative K_d for the LANL subsurface water to be 1 mL/g. For canyon streams water, we assigned a conservative silver K_d value of 2 mL/g. Since silver is monovalent, we assumed a realistic K_d value for silver to be half of the divalent nickel K_d value. Thus, we selected realistic K_d values for silver in the subsurface environment and canyon streams at the LANL study area to be 100 and 200 mL/g, respectively.

E2.10 SUMMARY OF SOLUBILITY AND SORPTION OF METALS

IN LANL SURFACE AND GROUND WATERS

Mobilization of contaminants released to surrounding surface and subsurface water environments from the firing sites is significantly affected by their solubility and affinity to sorb onto soils and sediments. Thus, the solubility and distribution coefficients of depleted uranium, beryllium, lead, nickel, copper, aluminum, iron, and silver were estimated here for LANL site surface and ground waters.

Except for depleted uranium, the solubility of the metals of interest were obtained by running the geochemical model, MINTEQ (Felmy et al. 1984). Water quality data from samples taken at the Beta Hole on Water Canyon and at Well PM-4 of the Pajarito Field (LANL 1988; LANL 1989; LANL 1990; LANL 1993c; Purtymun et al. 1994) were assumed to be representative of surface and ground water quality for the study area (see table E2-1). For depleted uranium, solubility was estimated using field data measured at the E-F site at LANL (Hanson and Miera 1977), Aberdeen Proving Ground in Maryland (Erickson et al. 1993), and Yuma Proving Ground in Arizona (Erickson et al. 1993).

Table**Table E2-2.-*Estimated Solubilities and Distribution Coefficients for Metals***

in LANL Surface and Ground Water

Metals	Solubility, µg/L unless otherwise noted	Distribution Coefficients, K_d, (mL/g)			
		Subsurface Sediments and Ground Water		Suspended Sediment and Surface Water	
		Conservative	Realistic	Conservative	Realistic
Depleted Uranium	300 mg/L	50	100	100	200
Lead	50	1,000	10,000	2,000	20,000
Beryllium	4	50	100	100	200

Nickel	1000	20	200	40	400
Copper	10	20	200	40	400
Aluminum	1	300	5,000	600	10,000
Iron	0.002	15	1,000	30	2,000
Silver	300 and 80 for surface and ground water	1	100	2	200

E2-2 shows a summary of both the solubility and sorption values estimated for the metals of interest in LANL surface and ground waters. Note that except for silver, solubility for each metal is the same for surface and ground waters of the LANL study area. Both conservative and realistic estimates of distribution coefficients, K_d, are shown in the table for depleted uranium, lead, beryllium, nickel, copper, aluminum, iron, and silver.

APPENDIX E3: SURFACE WATER MODELING

Contaminant movement in runoff, stream flow, and sediment transport from both PHERMEX and DARHT has been identified as a key set of processes leading to exposure and health effects. Pathways of interest include stream flow and sediment discharge through the Water and Potrillo Canyon watersheds leading to the Rio Grande and stream flow transmission losses to the underlying ground water. This section of the appendix describes the modeling procedures used to estimate the transport and fate of depleted uranium, beryllium, and lead in the Water and Potrillo Canyon watersheds.

E3.1 MODEL DESCRIPTION

The transport and fate of depleted uranium, beryllium, and lead in the Water and Potrillo Canyon watersheds were estimated using one-dimensional event-based procedures (Lane et al. 1985) originally developed to simulate the movement of plutonium in the Los Alamos Canyon watershed. The procedures developed by Lane et al. (1995), hereafter referred to as the Lane model, were selected because they were specifically formulated to represent the hydrologic, hydraulic, sediment, and contaminant transport processes occurring in the Los Alamos region. The Lane model accounts only for the transport of contaminants sorbed to sediments and does not consider contaminant transport in the dissolved phase. Since this EIS is concerned with the transport of depleted uranium, beryllium, and lead which are soluble in LANL waters, the Lane model procedures were extended to include dissolved phase transport and sorption/desorption with sediments using partition coefficients as described by Mills (Mills et al. 1985). The model was also extended to include the transport of dissolved contaminants from the firing sites into the neighboring canyon channels. The extended model transports contaminants sorbed to sediments or dissolved in the water column. The model also estimates dissolved contaminants that infiltrate to the subsurface from mesa top firing sites and through channel transmission losses. It is important to note that the long-term observations of precipitation, stream flow, and sediment yield necessary to calibrate and validate the model were not available for the Water and Potrillo Canyon watersheds. A very conservative approach has been taken in this model to account for the substantial uncertainty that exists in the performance of the water resource system. The simulated concentrations leaving the LANL site are well below drinking water standards.

E3.2 MODEL APPLICATION

The extended Lane model was developed and applied to the Water Canyon and Potrillo Canyon watersheds. These watersheds were divided into a series of representative channel reaches. Figure E3-1 shows a schematic of the channel network and the individual reach identification numbers.

Total daily precipitation values used to drive the model for the 32-year historical period of PHERMEX operations were obtained from gage data collected at LANL (Bowen 1990). Snowmelt runoff was not explicitly included because there was not adequate information to characterize these events. Precipitation occurring as snow was simply applied as rainfall on the day of occurrence. Following Lane et al. (1985), the daily average precipitation was converted to a 1-hour rainfall and used as the input to the hydrology model.

Because stream flow in Water and Potrillo Canyons is ephemeral, a very long time may be required for contaminants to be transported downstream from the release point and attain a maximum concentration. Since the model is driven entirely by rainfall events, a hypothetical future precipitation record was required. A 5,000-year daily average precipitation record was created using the methods described by Sharpley and Williams (Sharpley and Williams 1990) and statistics computed from the measured daily rainfall record from 1947 through 1994.

Watershed subbasin areas, composite runoff curve numbers, channel widths, lengths, and slopes were obtained from McLin (1992) and are listed in table **Table E3-1.-*Channel Characteristics***

Canyon	Reach No	Drainage Area (mi^2)	Curve Number	Length (mi)	Average Width (ft)
Water	10	4.07	54	3.41	3.0
	11	2.63	62	3.36	3.0
	12	0.52	72	1.33	3.0
	13	0.90	72	2.27	3.0
	14	1.97	72	2.60	3.0
	15	0.32	77	0.95	3.0
Cañon de Valle	7	2.33	53	4.26	3.0
	8	0.78	63	1.42	3.0
	9	1.17	64	2.37	3.0

Potrillo	1	0.68	70	1.33	3.0
	2	0.68	70	1.33	3.0
	3	0.49	70	0.95	40.0
	4	0.93	70	1.80	3.0
	6	0.96	75	1.85	3.0
Fence	5	1.03	71	3.41	3.0

Canyon	Hydraulic Conductivity (in/hr)	Slope	Manning n	Median Grain Size (mm)	Silt-Clay Percentage
Water	1.5	0.13	0.040	1.3	2.5
	1.5	0.04	0.040	1.3	2.5
	1.5	0.02	0.040	0.8	0.5
	1.5	0.02	0.040	0.8	0.5
	1.5	0.04	0.040	0.8	2.5
	1.5	0.08	0.040	0.8	1.5
Cañon de Valle	1.5	0.12	0.040	1.6	3.5
	1.5	0.05	0.040	1.6	3.5
	1.5	0.04	0.040	1.6	3.5
Potrillo	1.5	0.03	0.040	1.2	2.0
	1.5	0.02	0.040	1.2	2.0
	1.5	0.02	0.040	1.2	2.0
	1.5	0.02	0.040	0.9	2.5
	1.5	0.02	0.040	0.9	2.5

Fence	1.5	0.02	0.040	1.1	0.5

E3-1. Note that overbank areas (floodplains) were not included and the active channels were assumed to have a rectangular cross section. These assumptions are conservative in that they lead to increased rates of sediment and contaminant transport and thus an accelerated movement of contaminants toward the Rio Grande. Channel widths of 3 ft (0.91 m) have been used except for the section of Potrillo Canyon (reach 3) termed the "discharge sink" by Becker (Becker 1993). The discharge sink has been noted to be a wide area without a distinct channel with a high vertical infiltration rate (Becker 1993).

Additional channel characteristics used in the model (hydraulic conductivity, Manning's n, median grain size, and silt-clay fraction) were estimated using the values chosen by Lane (Lane et al. 1985) for Los Alamos Canyon as guidance. Only two sediment size classes were considered in the model; bedload was represented as material with a median grain size diameter (d_{50}), and suspended load was represented bythe silt-clay size fraction. As recommended by Lane (Lane et al. 1985), a constant value of 5 was used for the suspended sediment transport coefficient in the model. To improve confidence in model results, future studies should be undertaken to characterize the channel sediments in Water and Potrillo Canyons. The values selected for each channel reach are listed in table E3-1. The depth of channel bed sediments available for contaminant storage was assumed to be 11.81 in (30 cm) for all reaches, which is consistent with the value selected by Lane (Lane et al. 1985).

For each reported simulation, the entire yearly contaminant mass release is assumed to be distributed uniformly over a 100-ft (30-m) radius circle centered at the firing site (PHERMEX or DARHT) at the start of each year. For days during which rainfall occurs, the contaminants are mobilized by assuming that they go into solution at the solubility limit. The volume of rainfall and associated contaminant mass is split between infiltration to the vadose zone and runoff to the canyons using the curve number method (Lane et al. 1985). Use of the runoff curve method neglects evapotranspiration; all precipitation is used for transporting contaminant as infiltration and runoff. Note, the runoff curve number used for the firing site area is the same as that used for the watershed subbasin containing the firing site listed in table E3-1. This assumes that the firing site area will be restored to natural soil and vegetation conditions after the facility is closed. Contaminants travel from the firing site to the canyon channel only through runoff; soil erosion and contaminant movement associated with the eroded soil was not considered. This assumption was made in order to avoid the additional complexities and uncertainties associated with the simulation of soil erosion and overland contaminant transport from the firing sites to the channel system. The dissolved contaminants associated with rainfall runoff are input to Potrillo Canyon in reach number 1 and to Water Canyon in reach number 12 (see figure E3-1).

Application of the curve number for the natural soils and vegetation to partition between runoff and infiltration at the DARHT Facility implies one of two situations: 1) the grounds of the DARHT Facility are seeded after construction and maintained during operation such that only a small portion of the facility grounds contaminated with depleted uranium, beryllium, and lead (e.g., the firing point) exhibit altered storm water runoff characteristics, and/or 2) the release is so long term (e.g., hundreds to tens of thousandsof years) that the different storm water runoff characteristics of the 30-year operational period are not significant to the overall release. The facility and its surrounding grounds, including access roads and parking, will certainly increase impervious surface area, and, therefore, increase peak rates of runoff from the facility. However, runoff from these surfaces will be routed into rip-rap lined ditches and culverts. The increased runoff caused by the structure and asphalt surfaces will, by design, be routed away from the firing point and surrounding contaminated soils. The storm water pollution prevention plan being implemented under the construction program calls for the placement of rip-rap at site drainage areas toprotect against erosion, and the revegetation of all areas disturbed and not covered by pavement, structures, or rip-rap. Thus, storm water runoff that would impact the contaminated soils of the firing point and adjacent grounds may not be significantly greater than that experienced in a natural setting. Concerning the second situation, the release is believed to be very long term. Becker (1993) estimated that the majority of the uranium inventory used in experiments during the last 50 years remains on the firing sites. Furthermore, the results of the present analysis demonstrated that beryllium and lead releases will require tens of thousands of years to leave the firing site. Thus, it is believed that conditions are met for the application of the curve number representative of long-term site conditions.

A source of additional runoff associated with operation of the facility is the cooling water blowdown discharge. When the facility is in operation, an estimated average of 2,000 gal/d (267 ft^3/d; 7.6 m^3/d) of cooling water will be discharged underground to a rip-rap lined trench that is drained by a culvert to a discharge point to the southeast of the east accelerator hall of the DARHT Facility. (Note, discharge of this cooling tower blowdown water has been approved and it is included in the National Pollutant Discharge Elimination System (NPDES) Permit issued to LANL by the EPA.) The discharge point is approximately 370 ft (113 m) from the firing point and is shielded from the firing point by the east accelerator hall. At this distance and being shielded, it is not anticipated that the discharge point will exhibit depleted uranium concentrations in soils that are significantly above background. Furthermore, because the culvert discharges to a rip-rap drainage area, it is anticipated that this cooling water will infiltrate into the subsurface and not discharge to Water Canyon except when cooling water discharge coincides with storm water discharge. Because this discharge is not expected to contact firing site soils and is expected to seep into the mesa rather than discharge to Water Canyon, the cooling water discharge has been neglected in this analysis.

Inclusion of runoff from storm water and cooling water discharges during the 30-year operation of the DARHT Facility could lead to minor increases in discharge to Water Canyon from the facility grounds (e.g., the 7 ac (3 ha) of the facility including structures and paved surfaces) but would not result in significantly greater flows within the canyon. Water Canyon and Cañon de Valle provide drainage to approximately 7,000 ac (11 mi^2) of upstream watershed. The relatively small increase in discharge from operation of this 7-acre facility will not significantly impact the total discharge of the canyon.

In all cases, the partition coefficients (K_d) and solubility limits for the depleted uranium, beryllium, and lead used were the conservative estimates for suspended sediments as given in appendix E2.

E3.3 NO ACTION ALTERNATIVE SIMULATIONS

In this alternative, the transport by surface runoff during the past 32 years for releases of depleted uranium, beryllium, and lead and for releases during the next 30 years from the PHERMEX site were assumed to be evenly split between Water and Potrillo Canyons with 50 percent of the release going to each canyon. The amount of depleted uranium released is assumed to be 30 percent of total mass indicated in section 2 of appendix E. For the next 30 years in the No Action Alternative, the annual releases of depleted uranium, beryllium, and lead would be 460, 22 and 33 lb/yr (210, 10, and 15 kg/yr), respectively. Table 5-3 shows the simulated peak concentration of contaminants in the infiltrated water at the discharge sink in Potrillo Canyon (reach 3) and at Water Canyon channels below the source (Reaches 12, 13, 14, and 15).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau at the end of the 5,000-year simulation, but still remain well below drinking water standards. Using the average simulated transport rates, the inventories of beryllium and lead at the firing site will be exhausted in approximately 300,000 and 40,000 years, respectively. Although beryllium and lead have relatively low solubilities, depleted uranium has a relatively higher solubility in LANL surface and ground waters. Consequently, the source of depleted uranium on the soil surface would be completely removed from the firing site in less than 1,000 years.

Table 5-3 also lists the peak concentration of dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the proposed water quality standard for uranium and several orders-of-magnitude below the drinking water standard MCLs for beryllium and lead.

The long-term average annual water volume (over the 5,000-year simulation) infiltrating at the Potrillo Canyon discharge sink was computed to be 37,400 ft^3/yr (1,000 m^3/yr). This is lower, but in the range of the 183,600 ft^3 (5,200 m^3) volume that was reported for 1990 from the short-term measurements by Becker (Becker 1993). The average annual simulated water discharge and sediment discharges entering the Rio Grande from the Water-Potrillo Canyon watersheds were 237,000 ft^3/yr (6,700 m^3/yr) and 165 tons/yr (150,000 kg/yr), respectively. No direct measurements of stream flow volume and sediment discharge to the Rio Grande were available for Water Canyon.

E3.4 DARHT BASELINE ALTERNATIVE SIMULATIONS

The annual expenditures from the DARHT site of depleted uranium, beryllium, and lead were 460, 22, and 33 lb/yr (210, 10, and 15 kg/yr), respectively. The amount of depleted uranium released is assumed to be 30 percent of total mass indicated in section 2 of appendix E. These annual expenditures from DARHT were released onto the firing site for the first 30 years of the simulation. All surface runoff from the firing site was directed to Water Canyon. Table 5-8 shows the peak concentration of contaminants and years to peak in the infiltrated water along Water Canyon (Reaches 12, 13, 14, and 15).

Because of their low solubility, the concentrations of beryllium and lead reach a plateau at the end of the 5,000-year simulation, but still remain well below drinking water standards. Using the average simulated transport rates, the inventories of beryllium and lead at the firing site will be exhausted in approximately 74,000 and 9,000 years, respectively. Although beryllium and lead have relatively low solubilities, depleted uranium has a relatively high solubility in LANL surface and ground waters. Consequently, the source of depleted uranium on the soil surface would be completely removed from the firing site in less than 1,000 years.

Table 5-8 also lists the peak and time to peak for the dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the proposed water quality standard for uranium and several orders-of-magnitude below the drinking water standard MCLs for beryllium and lead.

E3.5 ENHANCED CONTAINMENT ALTERNATIVE SIMULATIONS

Under this alternative three options were analyzed: the Vessel Containment Option, the Building Containment Option, and the Phased Containment Option (preferred alternative). The annual expenditures of depleted uranium, beryllium, and lead for each of these options are listed in table **Table E3-2.-*Annual Expenditures of Depleted Uranium, Beryllium, and Lead***

for the Enhanced Containment Alternative

Containment Option	**Depleted Uranium** **lb (kg)**	**Beryllium** **lb (kg)**	**Lead** **lb (kg)**

Vessel (30 yr)	185 (84)	6.5 (3)	10 (4.4)
Building (30 yr)	92 (42)	1.3 (0.6)	2 (0.9)
Phased	444 (200)	21 (9.5)	31 (14)
(0 to 5 yr)	315 (143)	14 (6.2)	21 (9.4)
(6 to 10 yr)	185 (84)	6.5 (3)	10 (4.4)
(11 to 30 yr)			

E3-2.

These annual expenditures from DARHT were released onto the firing site for the first 30 years of the simulation. All surface runoff from the firing site was directed to Water Canyon. Table 5-11 shows the peak concentration of contaminants and years to peak in the infiltrated water along Water Canyon (Reaches 12, 13, 14, and 15) for the three options.

Because of their low solubility, the releases of beryllium and lead are long term. Beryllium concentrations plateau before the end of the 5,000-year simulation and remain well below drinking water standards. Based on release projections, we estimate beryllium release will require 4,420, 22,000, and 34,000 years for the Vessel Containment, Building Containment, and Phased Containment options, respectively. Similarly, lead concentrations plateau within the 5,000-year simulation and remain well below drinking water standards. Because its solubility is greater than that of beryllium, lead release times are shorter. We estimate lead release to the environment will require 530, 2,590, and 4,062 years for the three options, respectively. Depleted uranium has a relatively high solubility in LANL surface and ground waters. Based on this high solubility concentration, the source of depleted uranium at the soil surface would be completely removed from the firing site in 30 years for the various containment options. Such a release is conservative or aggressive because it routes the depleted uranium into the environment more quickly than field observations (Becker 1993) indicate is occurring. The model indicates that the reach of Water Canyon (reach 12) receiving runoff from the facility could discharge water to the streambed or to the downstream reach (depending on canyon flow conditions) containing concentrations of depleted uranium at or slightly above the drinking water standard for uranium (i.e., 20 µg/L).

Table 5-11 also lists the peak and time to peak for the dissolved and sediment-sorbed contaminant concentrations entering the Rio Grande. The Rio Grande is the nearest off-LANL access point for surface water carrying contamination from the firing point. The quality of surface water entering the Rio Grande is forecast to be more than an order-of-magnitude below the proposed drinking water standard for uranium and several orders-of-magnitude below the drinking water standards for beryllium and lead.

APPENDIX E4: VADOSE ZONE AND

GROUND WATER MODEL

E4.1 INTRODUCTION

Ground water constitutes one potential environmental pathway by which contaminants originating at the DARHT and PHERMEX firing sites may, after centuries to millennia, become accessible to members of the public. Some canyons in the Los Alamos area (notably Los Alamos and Mortandad Canyons to the north of TA-15) have shallow alluvial and intermediate-depth perched aquifer systems that provide a relatively fast path for contaminants leached through canyon bottoms to appear in ground water. However, the canyons of concern in this study, Water Canyon and Potrillo Canyon, do not appear to havesuch shallow aquifer systems. Potrillo Canyon is cut directly on the Bandelier Tuff, and there is little to no alluvial fill in the upper reaches of the watershed. Therefore, it is unlikely that a permanent alluvial aquifer exists in this canyon (LANL 1993b). Water Canyon is a large canyon that heads on the flanks of the Sierra de Los Valles. A short distance downstream from the confluence of Water Canyon and Cañon de Valle, near the DARHT and PHERMEX sites, is Beta Hole, a dry well extending 187 ft (57 m) into the Bandelier Tuff (LANL 1993b; Purtymun 1995). The lack of water in Beta Hole and two other shallow wells completed in the alluvium confirm that Water Canyon in the vicinity of TA-15 contains no permanent perched or alluvial aquifers, though there is a possibility of perched zones at intermediate depth (LANL 1993b).

In the absence of a perched aquifer, water infiltrating through the vadose (unsaturated) zone may transport contaminants in liquid phase from the surface to the regional or main aquifer. However, this would occur over a long period of time, and has not been observed at LANL. Once in the main aquifer, contaminants may be transported down gradient through the saturated zone down gradient to the Rio Grande, where these contaminants may be discharged in springs or directly to the Rio Grande and become accessible in that surface water body to members of the public. Alternatively, once in the main aquifer, contaminated water might be pumped from wells for municipal and industrial use, again becoming accessible. Although no water supply wells currently exist in TA-15, which includes the DARHT and PHERMEX sites, Purtymun (Purtymun 1984) identified an area that included TA-15 as most suitable for additional water supply wells for Los Alamos County based on the desired attributes of high yield and low drawdown wells. It is surmised that these desirable attributes for well placement will make the area subject to future water well development. However, regulations would require testing before public use, and during subsequent use. The average yield from the five wells in the Pajarito Field [the PM wells are located in the zone identified by Purtymun (Purtymun 1995)] was 1,215 gpm (2.7 ft^3/s, 0.08 m^3/s) (Purtymun 1984). Therefore, well extraction of dissolved contaminant mass from the regional aquifer, if transported to the aquifer, is a possible consideration.

In spite of the above considerations with regard to the main aquifer, it may be unnecessary to model the flow and transport of contaminants in the main aquifer depending on the results of vadose zone modeling. To reach the main aquifer, contaminant mass must 1) be available at the surface for leaching into the soil profile and 2) be transported vertically downward from the surface to the water table. The travel time for recharge water through unsaturated volcanic tuffs in a semi-arid climate can be centuries to millennia. Sorption further extends the time required for contaminants to migrate to the main aquifer, and dispersion acts to reduce peak concentrations.

Ground water modeling and analysis for this study necessarily follows the assumptions made for the runoff-sediment-contaminant transport model (see appendix E3, Surface Water Modeling). Water infiltration into the bottom sediments of Water Canyon and the contaminant mass loading associated with that water as predicted by the runoff-sediment-contaminant transport model constitute the inputs to the vadose zone model for Water Canyon.

The discharge sink in Potrillo Canyon identified by Becker (1993) is taken to be the controlling feature in that canyon. Evidence in Becker (1993) demonstrated that all surface water from the Potrillo Canyon watershed above this feature drains to the subsurface very rapidly via the discharge sink (except for flood events with a recurrence frequency greater than a 1-in-10-year event). The mechanism that enables such large water intake rates to the subsurface is not well characterized. Becker (1993) concluded that the discharge sink is an area of increased sedimentation, that it contains significant amounts of uranium adsorbed onto the surface soils with depth, and that leaching and deep infiltration transport uranium (dissolved phase) to ground water. Becker (1993) could only hypothesize as to the feature that creates the discharge sink, an underlying fault with a 29-ft (9-m) offset. Because no defensible mechanism can be proposed to account for the discharge sink's hydrologic behavior at this time, no attempt was made to model the discharge sink. Instead, the approach to stream flow losses in Potrillo Canyon was to compute the concentrations of contaminants in water arriving at the sink (as all water in the upper reach of Potrillo Canyon usually collects at the discharge sink), and if those concentrations are low enough to meet regulatory criteria, no further analysis is required. If not, we would make the conservative assumption that contaminated water from the discharge sink is transferred instantly to the main aquifer (i.e., taking no credit for time delay and dispersion in the vadose zone), and examine the consequences of water supply well uptake or surface water discharge of contaminated water at the Rio Grande.

Water Canyon does not appear to exhibit any feature analogous to the discharge sink Becker discovered in Potrillo Canyon (Becker 1993). Nor does Water Canyon appear to have a perched aquifer system, based on the dry Beta Hole located in Water Canyon adjacent TA-15 (LANL 1993b; Purtymun 1995). Therefore, it was decided that modeling the vadose zone below Water Canyon might enable evaluation of the downward flow of water and transport of contaminants from stream losses to the stream bed as predicted by the surface water and sediment transport analysis model.

Finally, the vadose zone from the firing sites atop Threemile Mesa to the main aquifer was modeled. The mesa top in the vicinity of DARHT and PHERMEX is over 300 ft (91 m) above the bottom of Water Canyon. Thus, a model of vadose zone flow and transport from the bottom of Water Canyon to the main aquifer simulates a significantly shorter pathway. However, the contaminant loading at the firing sites into the soil is large enough (e.g., infiltration carrying contaminants at their solubility limit) to require vadose zone flow and transport modeling also.

E4.2 VADOSE ZONE STRATIGRAPHY

There are no deep wells in TA-15 that would provide certain knowledge of the geologic stratigraphy at the DARHT, PHERMEX, or nearby Water Canyon and Potrillo Canyon locations (LANL 1993b; Purtymun 1995). The closest wells that penetrate to the regional aquifer are the test wells DT-5A, DT-9, and DT-10 to the south of TA-15, and the municipal and industrial supply wells PM-2 and PM-4 located to the northeast of TA-15. Figure E4-1 depicts the locations of these wells and the DARHT and PHERMEX firing sites. A cross-section from test well DT-5A to supply well PM-4, based on well log data reported in Purtymun (Purtymun 1995), is shown in figure E4-2. The Tshirege, Otowi, and Guaje members are all sequences within the Bandelier Tuff. Figure E4-2 illustrates the transition in geologic units expected over the area in the vicinity of DARHT and PHERMEX. Based on this cross-section, the location of the DARHT site, and the anticipated stratigraphy (LANL 1993b), the expected geologic stratigraphy for this EIS was developed, and is shown in figure E4-3. The elevation axis at the left of figure E4-3 shows how the expected stratigraphy corresponds to elevation above mean sea level, and includes arrows to show the elevations at the DARHT and PHERMEX sites, Water Canyon (near Beta Hole), and the Potrillo Canyon discharge sink location. The water table elevation at 6,000 ft (1,830 m) (Purtymun 1984; Volzella 1994; LANL 1993b; Purtymun 1995) is shown on the stratigraphic column at 800 ft (244 m) below the well head surface. The depth of the alluvium is designated as 8 ft (2 m) based on the geologic log of the Beta Hole (Purtymun 1995). The fingered layers of Basalt Unit 2 shown in figure E4-2 are assumed not to be present based on the stratigraphy presented in the *RFI Work Plan* (LANL 1993b) and the trend of basalt layers fingered into the Fanglomerate Member of the Puye Formation to decrease from east to west as a result of the geologic processes in which they were laid down.

E4.3 VADOSE ZONE HYDROLOGIC PROPERTIES

The expected stratigraphy for Water Canyon depicted in figure E4-3 shows five hydrogeologic units in the vadose zone for which hydrologic properties are required for modeling purposes: alluvium, three members of the Bandelier Tuff (Tshirege, Otowi, and Guaje), and the Puye Formation. The properties required for water flow modeling are saturated hydraulic conductivity, porosity or saturated moisture content, residual moisture content, and the empirical curve-fitting van Genuchten (van Genuchten 1980) water retention parameters _ and n for use in the water retention and liquid relative permeability models chosen for this analysis.

Values for the vadose zone flow model parameters for each unit are reported in table**Table E4-1.-*Hydrologic Properties for Vadose Zone Flow Modeling***

Stratigraphic Layer	**Water Content Parameters**		**van Genuchten Model Parameters**		**Saturated Hydraulic Conductivity**
	–r Residual	**–s Saturated**	**_ (1/m)**	**n**	**K_s (m/s)**
Alluvium	0.038	0.433	3.85	1.558	4.40 x 10^{-6}
Tshirege	0.021	0.498	1.20	1.759	6.00 x 10^{-7}
Otowi	0.026	0.469	0.66	1.711	1.30 x 10^{-6}
Guaje	0.022	0.492	1.13	1.716	7.00 x 10^{-7}
Puye§	0.0283	0.4982	1.76	1.338	2.42 x 10^{-8}

–$_r$ Residual water content.

–$_s$ Saturated water content.

_ Fitted van Genuchten parameter, 1/m.

n Fitted van Genuchten parameter.

K_s Saturated hydraulic conductivity, m/s.

§ Ringold Unit (Rockhold et al. 1993) properties used as analogue for Puye Formation.

E4-1. All values for the alluvium and Bandelier Tuff members are based on mean values reported in Rogers and Gallaher (Rogers and Gallaher 1995). No values were reported in that document directly for the Guaje Member, so the average of all Bandelier Tuff measurements was used to provide the hydrologic properties given in table E4-1 for the Guaje Member. Figure E4-4 provides the graphical interpretation of the water retention and relative permeability parameters by showing the retention and conductivity curves resulting from the use of the parameter values given in table E4-1.

No published hydrologic data, other than field coefficients of conductivity (Purtymun 1984), were found in the literature pertaining to the Puye Formation. The Puye Formation is derived from the Tschicoma volcanic centers located in the northeastern range of the Jemez Mountains. It consists of stream flowdeposits, debris flow and block flow deposits, and ash fall and pumice fall deposits (LANL 1993b). The hydrologic properties of a similar undifferentiated unit, the Ringold Unit found at the Hanford Site in Washington State, were chosen. The Ringold Unit is taken to be an analogue to the Puye Formation, andtherefore properties used are largely approximate. Further precision will require a characterization and data collection program aimed at the Puye Formation and would only be necessary if the results of this analysis indicated that the unit imposed a significant control over the flow and transport results, which it did not. Properties for the Ringold Unit, reported in table E4-1, were taken from those reported in Rockhold et al. (1993).

E4.4 VADOSE ZONE MODELING APPROACH

We modeled the vadose zone below Water Canyon and Threemile Mesa as one-dimensional vertical stratigraphic columns extending from the regional aquifer piezometric surface (water table) at the lower boundary to the surface of Water Canyon or Threemile Mesa at the upper boundary. The upper boundary was treated as a Neumann boundary with a constant water flux rate based on the average water infiltration predicted by the runoff-sediment-contaminant transport model. Temporal variation in water infiltration was neglected because such variation is greatly damped within a few meters of the surface. The lower boundary was treated as a Dirichlet boundary and assigned a constant atmospheric pressure to representthe presence of the water table. Fracture flow was neglected because published information on this flow mechanism is incomplete (Loeven and Springer 1992); fractures are sparse features where documented (Purtymun et al. 1978), and in the low-saturation regimes such as that modeled here, fractures constitute barriers to moisture flow rather than preferential pathways (Klavetter and Peters 1986).

A computer code was used to perform the flow and transport simulations. The code we chose was the Multiphase Subsurface Transport Simulator, or MSTS (White and Nichols 1993; Nichols and White 1993). The MSTS computer code was chosen based on the following considerations:

· MSTS solves the nonlinear water mass conservation equation for variably saturated media necessary to model the vadose zone

· MSTS was developed for the Yucca Mountain Site Characterization Project, a program concerned with deep vadose zone flow and transport in arid site volcanic tuff environments, characteristics similar to the site under consideration in this study

· MSTS simulates dilute species mass transport using a convection-dispersion model with linear sorption coupled with the water mass conservation simulation, providing an integrated capability for flow and transport modeling that is much simpler than using separate flow and transport models

· Radioactive decay in the transport equation (dilute species mass conservation equation) is accounted for by the MSTS code

· The code is well documented, has been favorably reviewed (Reeves et al. 1994), and has a proven track record for flow and transport simulation in the numerically difficult volcanic tuff environment (Eslinger et al. 1991).

Numerical stability criteria were examined to construct a grid of computational cells and enable stable simulation of water flow and contaminant transport for this vadose zone model. Calculations indicated that a grid discretization of 0.5 ft (0.15 m) or less would be required, yielding 1,600 grid elements over the 800 ft (244 m) high stratigraphic column. Other calculations indicated that time steps for the transport simulations should not exceed 20 years to avoid numerical dispersion effects. Because the transport model was restricted to 1-yr time steps to match the temporal rate of contaminant mass loading resulting from the runoff-sediment-contaminant transport model, and 20-yr time steps after mass loading ended, this criterion presented no additional limitation.

E4.5 VADOSE ZONE FLOW MODEL RESULTS

Hydrologic conditions (e.g., water flow) in the unsaturated zone will depend on similar occurrences under any of the alternatives. For example, the presence of the DARHT and PHERMEX facilities does not affect the hydrology of Water Canyon appreciably, and infiltration would move water through Threemile Mesa at either location of the firing point. Therefore, the results of the vadose zone flow simulations were performed and the results reported here for all alternatives and options. Contaminant mass transport simulations that are based on the water pressure fields calculated here are reported with respect to individual alternatives and options in section 5.

A steady-state pressure field was simulated for Reach 12 of Water Canyon. Reach 12 in the surface water model is immediately downstream of the confluence of Cañon de Valle and Water Canyon (seeappendix E3). Another was simulated for a location representative of the DARHT and PHERMEX facilities on Threemile Mesa. The surface elevation difference between the two sites was neglected; the firing sites differ in elevation by approximately 36 ft (11 m) (Fresquez 1994; Korecki 1988). The conditions vary in the different reaches of the Water Canyon model depending upon the water infiltration predicted in each reach by the runoff-sediment-contaminant transport model. The liquid-phase pressure and saturations predicted from the steady-state simulation with the MSTS code for Reach 12 are plotted in figure E4-5. The abrupt changes in pressure and saturation shown in figure E4-5 reflect the variations in hydrologic properties corresponding to the stratigraphic units identified. Liquid-phase mean travel time, that is, the mean time for water to travel from the base of Water Canyon to the regional aquifer, was predicted with the MSTS code. Travel times for Reaches 12 and 13, and for the mesa-top-to-aquifer vadose zone model, are reported in table E4-2. Water travel times provide an upper bound on the arrival time of the mean concentration of a nonretarded, nondecayed contaminant. Retarded (sorbed) species, such as those under consideration in this study, will have even longer arrival times.

Table E4-2.-*Liquid Phase Vadose Zone Water Travel Times for Threemile Mesa*

and Water Canyon Reaches 12 and 13 Predicted by MSTS

Vadose Zone	Water Travel Time (yr)
Threemile Mesa	298
Water Canyon Reach 12	179
Water Canyon Reach 13	174

E4.6 CONTAMINANT TRANSPORT SIMULATIONS

Review of the similarities between alternatives for the concentration of infiltration waters predicted by the runoff-sediment-contaminant transport model reduced the number of vadose zone contaminant transport cases that were necessary to simulate for this EIS. The ground water impacts of the Plutonium Exclusion and Single Axis alternatives were the same as the DARHT Baseline Alternative; and the Upgrade PHERMEX Alternative was the same as the No Action Alternative. This review implied that simulations were necessary only under the No Action, DARHT Baseline, and Enhanced Containment alternatives. For these three alternatives, the peak concentrations of depleted uranium, beryllium, and lead in water infiltrating into the vadose zone in the four reaches of Water Canyon downstream from the firing sites, and on Threemile Mesa at the firing sites, were compared to the drinking water standards for these metals. Because transport and dispersion in the vadose zone will only further decrease the concentrations of these metals in solution, it was necessary to simulate only those cases in which the concentration of contaminants in infiltrating water at the surface exceeded the drinking water standard. Finally, comparison of concentrations of contaminants in infiltrating water in the four reaches of Water Canyon showed that the uppermost reach (Reach 12) was always subject to the highest infiltration contaminant concentration levels of the four reaches. Because no simulation of Reach 12 resulted in contaminant concentrations at the regional water table exceeding the drinking water standard for any contaminant, no simulation was necessary for the less-impacted reaches downstream. Thus, a total of 10 simulation cases were required for depleted uranium: transport through Threemile Mesa for the No Action, DARHT Baseline, and Enhanced Containment alternatives (including the three options) and transport through the sediments beneath the uppermost reach of Water Canyon (Reach 12) for the same five alternatives and options. We also simulated beryllium and lead transport from the mesa and the uppermost reach of Water Canyon to the main aquifer to examine the transport of these dissolved contaminants in the vadose zone.

Initial conditions for all simulations specified the liquid pressure field obtained for the respective reach or mesa top simulation (section E4.5, above) and zero contaminant concentration throughout the profile. Mass transport was simulated using the one-year constant time steps of the surface water model (matching the temporal rate for which the contaminant mass input values were provided by the runoff-sediment-contaminant transport model) and then using 20-year constant time steps for periods after mass input rates specified by the surface water model ceased (20-year steps being the maximum permissible under the Courant Number stability criteria). Parameters related to dilute contaminant species mass transport includevalues of the sorption coefficient (K$_d$), longitudinal hydraulic dispersivity coefficient (_$_L$), and molecular dispersion coefficient (D$_{d,l}$). Sorption coefficient values were estimated in appendix E2 ("Solubility and Distribution Coefficients") where both conservative and best-estimate values were provided. We chose to use conservative (i.e., less sorption) values in all vadose zone modeling of contaminant transport. For moderate travel distances (on the order of kilometers), longitudinal dispersivity roughly varies between 0.01 and 0.1 of the mean travel distance of the solute. Choosing the more often used and higher value, with the travel distance through the vadose zone of 800 ft (240 m), we obtained the 80 ft (24 m) value. The molecular diffusion coefficient was that of water, 1.076 x 10^{-8} ft^2/s (1.0 x 10^{-5} cm^2/s).

Contaminant mass input rates were obtained from the results of the runoff-sediment-contaminant transport model. The infiltrated volume for each year reported by the runoff-sediment-contaminant transport model was multiplied by the corresponding water concentration of the infiltrated water, and divided by the channel reach area or the area for mass distribution around the firing point to obtain a value for annual mass flux per unit area. This value was converted to appropriate units for the vadose zone flow and transport code and treated as a mass source rate in the uppermost node of the model. For each simulated case, contaminant transport was modeled for 100,000 years. For depleted uranium, 1,000 years of mass input was provided, after which the surface supply of depleted uranium on the mesa surface and in the channel reaches was exhausted (the remainder of the simulation was carried out with no contaminant source term). For beryllium and lead, 5,000 years of mass input was provided. For the simulation beyond 5,000 years, estimates (based on surface modeling) of the time to "plateau" for releases for beryllium and lead and average input concentrations thereafter were used to specify an average contaminant mass source rate and duration for the balance of the 100,000-year simulations. Table E4-3**Table E4-3.-*Vadose Zone Numerical Transport Simulation Predictions of Peak***

Concentrations and Associated Times for Water Arriving at the Regional Main

Aquifer from the Vadose Zone for All Simulated Cases

Alternative, Location	**Contaminant**		
	DU **(µg/L)**	**Be** **(µ**g/L)	**Pb** **(µ**g/L)
Drinking Water Standard	20 [56 FR 33050]	4 [40 CFR 141.62]	15 [40 CFR 141.80]
No Action, Threemile Mesa (PHERMEX)	**145** (42,850 yr)	3.4 (>100,000 yr)	**26** (55,740 yr)
No Action, Water Canyon Reach 12	0.017 (18,450 yr)	0.00069 (>100,000 yr)	2.6×10^{-6} (>100,000 yr)
DARHT Baseline, Threemile Mesa (DARHT)	**81** (42,950 yr)	3.1 (84,680 yr)	6.3 (33,800 yr)
DARHT Baseline, Water Canyon Reach 12	0.018 (18,430 yr)	0.0014 (>100,000 yr)	5.2×10^{-6} (>100,000 yr)
Vessel Containment Option Threemile Mesa (DARHT)	**32** (42,880 yr)	1.2 (41,880 yr)	0.0012 (>100,000 yr)
Vessel Containment Option Water Canyon Reach 12	0.054 (18,390 yr)	0.0027 (>100,000 yr)	1.0×10^{-5} (>100,000 yr)
Phased Containment Option Threemile Mesa (DARHT)	**43** (42,060 yr)	1.8 (50,640 yr)	0.0018 (>100,000 yr)

Phased Containment Option Water Canyon Reach 12	0.055 (18,430 yr)	0.0027 (>100,000 yr)	1.0×10^{-5} (>100,000 yr)
Building Containment Option Threemile Mesa (DARHT)	16.1 (41,980 yr)	0.233 (45,099 yr)	1.5×1.0^{-7} (>100,000 yr)
Building Containment Option Water Canyon Reach 12	0.0365 (18,468 yr)	3.4×10^{-4} (>20,870 yr)	4.5×10^{-7} (>100,000 yr)

presents the peak concentration of water arriving at the regional main aquifer for each simulated case and time of the peak occurrence, and the related drinking water standard. The significance of the arrival concentrations listed in table E4-3 is provided in the discussions of individual alternatives in sections 5.1.4.2, 5.2.4.2, and 5.4.4.2.

E4.7 GROUND WATER ISSUES AT LANL

Two issues exist with respect to ground water resources in the vicinity of LANL. The first involves the recent discovery of tritium in the main aquifer at four points in the northern portion of the LANL site. The second involves the general observation that private ground water wells located north of Pojoaque can exhibit levels of alpha contamination in excess of drinking water standards.

E4.7.1 Tritium in the Main Aquifer

Since 1991, advanced techniques, not commonly applied to ground water samples, have been used to detect tritium at ultra-low levels and to determine that recent water (no more than a few decades old) has recharged the main aquifer from the land surface in several locations at LANL (Gallaher 1995). Many samples of well and spring water taken at LANL have shown only the natural background levels of tritium and no apparent recent recharge. However, four locations have indicated tritium migration to the main aquifer from overlying contaminated perched aquifers. The levels of tritium measured range from approximately 1 percent to less than a hundredth of a percent of current drinking water standards. Thus, measured levels of tritium are significantly below drinking water standards and below levels measurable using standard measurement techniques. All four confirmed main aquifer tritium measurements indicatingyoung water are in Los Alamos, Pueblo, and Mortandad Canyons, all in the northern part of the Los Alamos site. No main aquifer samples from the southern portion of the site have shown tritium concentrations above natural background. LANL scientists are studying whether the communication between intermediate perched and deep aquifer formations is a result of poor well construction (leaks in well bore seals with casing) or recharge of the main aquifer through either fractures or faults. If the ongoing studies determine the old construction methods are resulting in communication, efforts may be undertaken to abandon and plug the older test wells (Gustafson 1995).

E4.7.2 Alpha Concentrations in Regional Ground Water

High alpha concentrations have been observed in ground water drawn from private wells in the vicinity of Nambe and Pojoaque, New Mexico (Nickeson 1994). These wells are located on the opposite side ofthe Rio Grande from LANL and to the north of Pojoaque. The relationship between LANL activities and the observed alpha concentrations was questioned at the DARHT public hearings. Nickeson noted there was no one to blame for the high alpha concentrations found in her well water. The levels found are related to the abundance of naturally occurring uranium deposits in the highly volcanic region of northern New Mexico. The Santa Fe Reporter (Bird 1995) presented a broader portrait of the high alpha contamination problem in the region, and its relation to natural uranium levels in the region. Bird indicated that the Ground Water Division of the Environment Department (State of New Mexico) was being asked to consider a study of the area's private wells. Such a study may relate the levels of natural uranium in the aquifer formation to levels observed in ground water, determine the origin of ground water in the Pojoaque area (i.e., origin to the east or west of the Rio Grande), or determine isotopic ratios of uranium species (i.e., identifying natural versus depleted uranium sources, man-made isotopes, or other alpha emitters). Because it is a regional water quality issue and is acknowledged by State of New Mexico officials as being related to natural uranium levels, resolution of this issue is clearly beyond the scope of the DARHT EIS.

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APPENDIX F

BIOTIC RESOURCES

This appendix presents the plant and animal species found in the Los Alamos National Laboratory (LANL) area by biological surveys as reported by Dunham (1995), Risberg (1995), and Keller and Risberg (1995). The lists (tables F-1, F-2, and F-3) may not be complete; some species in the LANL area may not have been found or identified during these surveys or, if listed, may not presently be found in the area.

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Table F-1.-*Checklist of Plants at TA-15*

Family	Scientific Name	Common Name
Aceraceae	Acer glabrum Acer negundo	New Mexico maple Boxelder maple

Amaranthaceae	Amaranthus retroflexus[a]	Pigweed
Anacardiaceae	Rhus trilobata	Skunk bush
Asclepiadaceae	Asclepias asperula	Immortal
Berberidaceae	Berberis fendleri	Colorado barberry
Boraginaceae	Cryptantha fendleri C. jamesii Hackelia hirsuta Lappula sp.[b] Lithospermum incisum L. multiflorum	Fendler cryptantha James hiddenflower Beggarlice Stickseed Fringed puccoon Puccoon
Cactaceae	Echinocereus viridiflorus Opuntia polyacantha O. sp.[a]	Strawberry cactus Starvation cactus Prickly pear cactus
Chenopodiaceae	Atriplex canescens Chenopodium album C. graveolans Kochia scoparia Salsola kali	Fourwing saltbush Lamb's quarters Goosefoot Summer cypress Russian thistle

Compositae	Achillea lanulosa	Western yarrow
	Ambrosia artemisiifolia	Common ragweed
	A. confertiflora	Ragweed
	A. coronopifolia	Ragweed
	Antennaria parvifolia	Pussytoes
	Artemisia carruthii	Wormwood
	A. dracunculus	False tarragon
	A. frigida[a]	Estafiata
	A. ludoviciana	Wormwood
	A. tridentata[a]	Big sagebrush
	Aster bigelovii	Bigelow aster
	A. novae-angliae	Aster
	Bahia dissecta	Wild chrysanthemum
	Berlandiera lyrata	Lyre leaf
	Brickellia californica	California brickellia
	B. sp.	Bricklebush
	Cichorium intybus	Chickory
	Chyrsopsis foliosa	Golden aster
	C. villosa	Golden aster
	Chrysothamnus nauseosus	Chamisa, Rabbitbrush
	Conyza canadensis	Horseweed

	Erigeron divergens	Fleabane daisy
	Grindelia aphanactis	Gumweed
	Gutierrezia sarothrae	Snakeweed
	Haplopappus spinulosus	Spiny goldenweed
	Helianthus petiolaris	Sunflower
	Hymenopappus filifolius	White ragweed
	Hymenoxys argentea	Perky Sue
	H. richardsonii	Bitterweed

Table F-1.-*Checklist of Plants at TA-15 - Continued*

Family	Scientific Name	Common Name
Compositae (Continued)	Kuhnia chlorolepis	Kuhnia
	Lactuca sp.	Prickly lettuce
	Machaeranthera bigelovii	Bigelow aster
	Pericome caudata	Taperleaf
	Psilostrophe tagetina	Paperflower
	Senecio eremophilus	Groundsel
	S. longilobus	Thread-leaf groundsel
	S. multicapitatus	Groundsel
	Stephanomeria tenuifolia	Skeleton weed
	Taraxacum officinale	Dandelion
	Thelesperma megapotamicum	Indian tea

	T. trifidum[a] Townsendia exscapa Tragopogon dubius T. pratensis Viguiera multiflora	Greenthread Easter daisy Salisfy, Goatsbeard Salsify Showy goldeneye
Cruciferae	Capsella bursa-pastoris Descurania richardsonii Erysimum capitatum Lepidium medium Thlaspi alpestre	Shepherd's purse Tansy mustard Western wallflower Peppergrass Mountain candytuft
Cupressaceae	Juniperus monosperma[a] J. scopulorum	One-seed juniper Rocky Mountain juniper
Cyperaceae	Carex sp.	Sedge
Euphorbiaceae	Croton texensis Euphorbia serpyllifolia E. sp.	Doveweed Thymeleaf spurge Spurge
Fagaceae	Quercus gambelii Q. undulata Q. sp.	Gambel oak Wavyleaf oak Hybrid oak

Fumariaceae	Corydalis aurea	Golden smoke
Geraniaceae	Erodium cicutarium Geranium caespitosum	Cranesbill James geranium
Gramineae	Agropyron smithii Andropogon gerardii A. scoparius Aristida sp. Blepharoneuron tricholepis Bouteloua curtipendula[a] B. eriopoda B. gracilis Bromus anomalus B. tectorum Elymus canadensis Festuca sp. Koeleria cristata Lycurus phleoides Muhlenbergia montana Oryzopsis hymenoides Poa fendleriana	Western wheatgrass Big bluestem Little bluestem Three-awn Pine dropseed Side-oats grama Black grama Blue grama Nodding brome Downy Chess Canada wildrye Fescue Junegrass Wolftail Mountain muhly Indian rice grass Bluegrass

Table F-1.-*Checklist of Plants at TA-15 - Continued*

Family	Scientific Name	Common Name
Gramineae (Continued)	Poa sp. Sitanion hystrix Sporobolus contractus S. cryptandrus S. sp. Stipa comata	Blue grass Bottlebrush squirreltail Spike dropseed Sand dropseed Dropseed Needle and thread grass
Hydrophyllaceae	Phacelia corrugata	Scorpionweed
Labiatae	Monarda menthaefolia[a] M. pectinata Prunella vulgaris	Beebalm Ponymint Selfheal
Leguminosae	Astragalus sp. Lotus wrightii Lupinus caudatus Melilotus albus M. officinalis Petalostemum candidum[a] Robinia neomexicana[a] Trifolium sp.	Milkvetch Deervetch Lupine Yellow sweet clover Yellow wild clover White prairie clover New Mexico locust Clover

	Vicia americana	American vetch
Liliaceae	Allium cernuum Yucca angustissima Y. baccata[a]	Nodding onion Narrowleaf yucca Datil yucca
Linaceae	Linum lewisii L. neomexicanum	Blue flax New Mexico yellow flax
Loasaceae	Mentzelia pumila	Stickleaf
Malvaceae	Sphaeralcea coccinea S. sp	Red globe mallow Scarlet globe mallow
Nyctaginaceae	Mirabilis multiflora Oxybaphus linearis	Showy four-o'clock Desert four-o'clock
Oleaceae	Forestiera neomexicana	New Mexico olive
Onagraceae	Oenothera albicaulis O. coronopifolia O. hookeri	Evening-primrose Cutleaf evening-primrose Hooker's evening-primrose
Orobanchaceae	Orobanche fasciculata	Broomrape

Pinaceae	Abies concolor[a] Pinus edulis[a] P. ponderosa Pseudotsuga menzesii[a]	White fir Piñon pine Ponderosa pine Douglas fir
Plantaginaceae	Plantago purshii	Wooly Indian wheat
Polemoniaceae	Ipomopsis aggregata	Scarlet trumpet
Polygonaceae	Eriogonum cernuum E. jamesii Rumex sp.	Skelton weed Antelope sage Dock
Portulacaceae	Portulaca oleracea[a]	Common purslane
Primulaceae	Androsace septentrionalis	Western rock-jasmine

Table F-1.-*Checklist of Plants at TA-15 - Continued*

Family	Scientific Name	Common Name
Ranunculaceae	Clematis pseudoalpina Thalictrum fendleri	Rocky Mountain clematis Meadowrue

Rosaceae	Cercocarpus montanus[a] Fallugia paradoxa[a] Prunus virginiana var. melanocarpa Rosa woodsii	Mountain mahogany Apache plume Western black chokecherry Fendler's rose
Rutaceae	Ptelea trifoliata	Narrowleaf hoptree
Salicaceae	Populus angustifolia Salix sp.[a]	Narrowleaf cottonwood Willow
Saxifragaceae	Heuchera parvifolia Philadelphus microphyllus Ribes cererum R. inerme	Alumroot Mockorange Wax Current Gooseberry
Scrophulariaceae	Castilleja integra Penstemon barbatus P. virgatus Verbascum thapsus	Indian paintbrush Scarlet bugler Beard tongue Mullein
Solanaceae	Physalis foetens var. neomexicana[a]	Ground cherry
Valerianaceae	Valeriana acutiloba	Valerian
Violaceae	Viola adunca	Western dog violet
Vitaceae	Parthenocissus inserta	Virginia creeper

[a] These plants have been known to be used historically by the Tewa Indians of New Mexico in the early part of the 20th century (Larson 1995).

[b] Sp. indicates that the exact species has not been identified in the field.

Source: Risberg 1995.

Table F-2.-*Fauna Found at TA-15*

Family	Scientific Name	Common Name
AMPHIBIANS		
Hylidae	Hyla arenicolor	Canyon treefrog
REPTILES		
Iguanidae	Crotaphytus collaris Phrynosoma douglasii Sceloporus undulatus	Collared lizard Short-horned lizard Eastern fence lizard
Scincidae	Eumeces obsoletus	Great Plains skink
Teiidae	Cnemidophorus exsanguis	Chihuahuan spotted whiptail
Viperidae	Crotalus atrox	Western diamondback rattlesnake
BIRDS		

Accipitridae	Accipiter cooperii Buteo albonotatus B. jamaicensis	Cooper's hawk Zone-tailed hawk Red-tailed hawk
Aegithalidae	Psaltriparus minimus	Bushtit
Apodidae	Aeronautes saxatalis	White-throated swift
Caprimulgidae	Chordeiles minor Phalaenoptilus nuttallii	Common nighthawk Common poorwill
Carthartidae	Cathartes aura	Turkey vulture
Columbidae	Zenaida macroura	Mourning dove
Corvidae	Aphelocoma coerulescens Corvus corax Cyanocitta stelleri Gymnorhinus cyanocephalus Nucifraga columbiana	Scrub jay Common raven Steller's jay Piñon jay Clark's nutcracker
Emberizidae	Aimophila ruficeps Coccothraustes vespertinus Dendroica graciae D. nigrescens Guiraca caerulea Junco hyemalis	Rufous-crowned sparrow Evening grosbeak Grace's warbler Black-throated gray warbler Blue grosbeak Dark-eyed junco

	Molothrus ater	Brown-headed cowbird
	Oporornis tolmiei	MacGillivray's warbler
	Pheucticus melanocephalus	Black-headed grosbeak
	Pipilo chlorurus	Green-tailed towhee
	P. erythrophthalmus	Rufous-sided towhee
	P. fuscus	Canyon towhee
	Piranga ludoviciana	Western tanager
	Spizella passerina	Chipping sparrow
	Vermivora celata	Orange-crowned warbler
	V. virginiae	Virginia's warbler
Falconidae	Falco sparverius	American kestrel
Fringillidae	Cardeulis pinus	Pine siskin
	Carpodacus mexicanus	House finch

Table F-2.-*Fauna Found at TA-15 - Continued*

Family	Scientific Name	Common Name
Fringillidae	C. psaltria	Lesser goldfinch
(Continued)	Loxia curvirostra	Red crossbill
Hirundinidae	Tachycineta thalassina	Violet-green swallow
	Hirundo pyrrhonota	Cliff swallow

Miscicapidae	Catharus guttatus Myadestes townsendi Polioptila caerulea Regulus calendula Sialia mexicana Turdus migratorius	Hermit thrush Townsend's solitaire Blue-grey gnatcatcher Ruby-crowned kinglet Western bluebird American robin
Paridae	Parus gambeli P. inornatus	Mountain chickadee Plain titmouse
Phasianidae	Callipepla gambelii	Gambel's quail
Picidae	Colaptes auratus Melanerpes formicivorus Picoides pubescens P. villosus	Northern flicker Acorn woodpecker Downy woodpecker Hairy woodpecker
Sittidae	Sitta pygmaea	Pygmy nuthatch
Strigidae	Bubo virginianus Otus flammeolus Strix occidentalis lucinda	Great horned owl Flammulated owl Mexican spotted owl
Trochilidae	Archilocus alexandri Selasphorus platycercus	Black-chinned hummingbird Broad-tailed hummingbird

Troglodytidae	Catherpes mexicanus Salpinctes obsoletus Thryomanes bewickii	Canyon wren Rock wren Bewick's wren
Tyarannidae	Contopus borealis C. sordidulus Empidonax hammondii E. oberholseri E. occidentalis E. wrightii Myiarchus cinerascens Sayornis nigricans S. saya Tyrannus vociferans	Olive-sided flycatcher Western wood-pewee Hammond's flycatcher Dusky flycatcher Cordilleran flycatcher Gray flycatcher Ash-throated flycatcher Black phoebe Say's phoebe Cassin's kingbird
Vireonidae	Vireo gilvus V. solitarius	Warbling vireo Solitary vireo
MAMMALS		
Canidae	Canis latrans Vulpus vulpus	Coyote Red fox

Cervidae	Cervus elaphus Odocoileus hemionus	Elk Mule deer
Muridae	Neotoma mexicana Peromyscus boylei P. maniculatus	Mexican woodrat Brush mouse Deer mouse

Table F-2.-*Fauna Found at TA-15 - Continued*

Family	Scientific Name	Common Name
Muridae (Continued)	P. truei Reithrodontomys megalotis	Piñon mouse Western harvest mouse
Molossidae	Tadarida brasiliensis	Brazilian free-tailed bat
Vespertilionidae	Antrozous pallidus Eptesicus fuscus Lasionycteris noctivagans Lasiurus cinereus Myotis californicus M. evotis M. leibi M. thysanodes M. volans M. yumanensis	Pallid bat Big brown bat Silver-haired bat Hoary bat California myotis Long-eared myotis Small-footed myotis Fringed myotis Long-legged myotis Yuma myotis

	Pipistrellus hesperus Plecotus townsendi	Western pipistrelle Townsend's big-eared bat

For bird habitats see Travis, J. R., *Atlas of the Breeding Birds of Los Alamos County*, New Mexico Pajarito Ornithological Survey.

Source: Dunham 1995

Table F-3.-*Wintering Birds of Potrillo Canyon,*

February and March 1986

Family	Scientific Name	Common Name
Accipitridae	Buteo jamaicensis	Red-tailed hawk
Columbidae	Zenaida macroura	Mourning dove
Corvidae	Aphelocoma coerulescens Corvus corax	Scrub jay Common raven
Fringillidae	Carpodacus mexicanus Junco hyemalis Pipilo erythrophthalmus P. fuscus	House finch Dark-eyed junco Rufous-sided towhee Brown towhee
Meleagrididae	Meleagris gallopavo	Wild turkey
Paridae	Parus gambeli P. inornatus	Mountain chickadee Plain titmouse

Picidae	Colaptes auratus Picoides pubescens P. villosus Sphyrapicus thyroideus	Yellow-shafted flicker Downy woodpecker Hairy woodpecker Williamson's sapsucker
Sittidae	Sitta carolinensis S. pygmaea	White-breasted nuthatch Pygmy nuthatch
Troglodytidae	Catherpes mexicanus Troglodytes aedon	Canyon wren House wren
Turdidae	Myadestes townsendi Sialia currucoides S. mexicana Turdus migratorious	Townsend's solitaire Mountain bluebird Western bluebird American robin

For Bird habitats see Travis, J. R., *Atlas of the Breeding Birds of Los Alamos County*, New Mexico, Pajarito Ornithological Survey.

Source: Dunham 1995

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APPENDIX G

SOCIOECONOMICS

G.1 REGIONAL ECONOMIC MODELING

The IMPLAN (Impact analysis for Planning) regional economic modeling system was used to construct a baseline economic model for the region-of-interest, and to measure the possible impacts of EIS alternatives on regional employment, labor income, and output of goods and services (MIG, Inc. 1993). The stock regional IMPLAN model uses Standard Industrial Classification (SIC) information provided by the Bureau of Economic Analysis (BEA) on employment, income, and production activities within the region-of-interest, which in this case is Los Alamos, Santa Fe, and Rio Arriba counties of north-central New Mexico.

IMPLAN employs a static, non-survey, input-output model which uses a 528-sector adaptation of the 538-sector BEA national input-output transactions table otherwise known as the "national table." This table was derived by BEA based on information from its national income and product accounts (NIPA accounts) covering the production and sales of all commodities. The most recent national table was released by BEA in 1994 and represents the industrial technologies in place in 1987. These values have been price-updated to 1994 constant dollars. IMPLAN provides the flexibility to update the 1987-level technology of any industry, as represented in the national table, to an improved representation of the technology currently being employed. IMPLAN also performs adjustments to the national table to permit regional tables to be constructed for application to any region of the country.

Among the more important considerations in applying the stock IMPLAN model are that: 1) the model is static in the sense of reflecting economic conditions and production technologies in place at a given point in time, with no allowance for technological changes; 2) the model uses exogenous estimates of "regional repurchasing coefficients," (RPCs) critical parameters reflecting the locally produced portion of goods or services used by industry in the region-of-interest; 3) the model characterizes all industrial production processes as requiring fixed proportional use of factors of production, making no allowances for input substitutions due to relative-price changes.

This stock IMPLAN model was modified to reflect 1993 levels of economic activity specific to the tri-county area based on two additional data files: 1) ES-202 employment data obtained from New Mexico Department of Labor, which covers 1993 annualized employment levels at the two-digit SIC level; and 2) published information on regional consumption expenditures made by LANL during FY 1992, as described in a DOE-funded study (Lansford et al. 1993). The modified IMPLAN model of the region-of-interest reflects these additional county-level data files and, correspondingly, the recent experience underlying employment and expenditures within the tri-county region.

The stock IMPLAN model was also adjusted to better approximate the local economic impacts of incremental construction and operations expenditures under each EIS alternative. These adjustments bear on the accuracy of IMPLAN's RPCs for heavy construction (SIC 16) and facility operations (SIC 28). Based on DARHT's local construction expenditures during FY 1993, IMPLAN's RPC for heavy construction was adjusted downward to 0.15 to reflect the fact that most of the value of Heavy Construction services is being procured from outside the region of influence, and in fact, from outside thestate. This parameter adjustment provides a more realistic estimate of the RPC for heavy construction in the region-of-interest. On the contrary, IMPLAN's RPC for industrial facility operations was adjusted upward to 0.80. This upward adjustment reflects the understanding that most of PHERMEX's local expenditures are on specialized equipment made onsite at other LANL defense production facilities.

Given the above adjustments, the modified IMPLAN model was run with alternative expenditure scenarios in order to estimate the consequential impacts of the various EIS alternatives on regional employment, labor income, and output of goods and services. These alternative data sets reflect the following expenditures information provided by LANL: 1) annual capital and operating expenditures for the DARHT and PHERMEX facilities under each EIS alternative (tables G-1

Table G-1.-*Capital-funded Construction Costs by Alternative (in millions of 1995 dollars)*

Alternative	1995	1996	1997	1998	1999	2000	2001	2002	Total
No Action	6.6	5.8	1.0	0	0	0	0	0	13.4
DARHT Baseline	6.6	29.5	17.9	26.8	24.0	0.6	0	0	105.3
PHERMEX Upgrade	6.6	36.6	33.7	21.7	14.8	10.2	3.1	0	126.7
Enhanced Containment Vessel Option	6.6	29.6	32.4	41.1	24.9	0.6	0	0	135.2
Enhanced Containment Building Option (150 lb)	6.6	28.3	26.9	29.9	15.5	13.9	0.8	0	121.9
Enhanced Containment Building Option (500 lb)	6.6	29.1	40.5	33.2	15.5	13.9	0.8	0	139.5
Enhanced Containment Phased Option	6.6	30.6	21.9	34.4	30.1	6.7	5.8	5.8	142.0
Plutonium Exclusion	6.6	29.5	17.9	26.8	24.0	0.6	0	0	105.3
Single Axis	6.6	29.5	17.9	5.7	0	0	0	0	59.6

Notes: The underlying capital funded cost data were provided by the DARHT field office (Burns 1995a; Burns 1995b). The costs do not include any expenses associated with site cleanup, decontamination, or decommissioning of either the DARHT or PHERMEX facilities.

Table G-2.-*Operations and Maintenance Costs by Alternative (in millions of 1995 dollars)*

Alternative	1995	1996	1997	1998	1999	2000	2001	2002	Total
No Action	4.2	4.1	4.1	4.0	4.0	4.0	3.9	3.9	32.2
DARHT Baseline	4.2	4.1	4.1	4.0	5.9	5.8	5.8	5.7	39.6
PHERMEX Upgrade	4.2	4.1	4.1	4.0	4.0	4.0	3.9	6.0	34.3
Enhanced Containment Vessel Option	4.2	4.1	4.1	4.0	9.7	9.6	9.5	9.4	54.7
Enhanced Containment Building Option (150 lb)	4.2	4.1	4.1	4.0	4.0	4.0	3.9	9.4	37.7
Enhanced Containment Building Option (500 lb)	4.2	4.1	4.1	4.0	4.0	4.0	3.9	9.4	37.7
Enhanced Containment Phased Option	4.2	4.1	4.1	4.0	6.3	6.1	5.8	5.6	40.3
Plutonium Exclusion	4.2	4.1	4.1	4.0	7.9	7.8	7.8	7.6	47.4
Single Axis	4.2	4.1	4.1	4.0	5.3	5.2	5.2	5.1	37.2

Notes: The underlying O&M cost data were provided by the DARHT field office (Burns 1995a; Burns 1995b). This primary data was adjusted using an escalation price change index for DOE defense-related construction projects (Pearman 1994). The resulting O&M cost estimates presented in the table recognize varying periods of operation of PHERMEX prior to operations at the DARHT Facility based on the DARHT implementation schedule (Burns 1995a; Burns 1995b).

and G-2) and 2) estimated duration of construction and timing of operations for the DARHT and PHERMEX facilities under each EIS alternative. Upon applying a DOE price escalation index for general construction and defense programs to these alternative expenditure projections, IMPLAN was run to estimate the consequential impacts of each DARHT alternative on employment, labor income, and output of goods and services in the region-of-interest for each year in the 1995 to 2002 period. These impacts are reported by year for that period (see table G-3**Table G-3.-*Summary of Economic Impacts by Alternative (FY 1996 to FY 2002)***

Alternative	**Employment (FTE-Equivalent)**	**Labor Income (in millions)**	**Output (in millions)**
DARHT Baseline	total 191 direct 80 indirect 111	total $4.1 direct $1.7 indirect $2.4	total $6.8 direct $3.4 indirect $3.4
PHERMEX Upgrade	total 199 direct 82 indirect 117	total $4.3 direct $1.8 indirect $2.5	total $6.9 direct $3.3 indirect $3.7
Enhanced Containment Vessel Option	total 321 direct 137 indirect 185	total $6.8 direct $2.9 indirect $3.9	total $12.0 direct $6.2 indirect $5.8
Enhanced Containment Building Option (150 lb)	total 209 direct 87 indirect 122	total $4.5 direct $1.9 indirect $2.6	total $7.6 direct $3.6 indirect $4.0
Enhanced Containment Building Option (500 lb)	total 238 direct 99 indirect 139	total $5.1 direct $2.1 indirect $3.0	total $8.4 direct $4.0 indirect $4.4

Enhanced Containment Phased Option	total 253 direct 106 indirect 147	total $5.4 direct $2.3 indirect $3.1	total $9.0 direct $4.4 indirect $4.6
Plutonium Exclusion	total 233 direct 99 indirect 134	total $4.9 direct $2.1 indirect $2.9	total $8.6 direct $4.5 indirect $4.1
Single Axis	total 104 direct 44 indirect 60	total $2.2 direct $0.9 indirect $1.3	total $3.8 direct $1.9 indirect $1.9
Notes: All monetary amounts are reported in 1995 dollar values.			

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Sums and products of numbers in this appendix may not appear consistent due to rounding.

G.2 ENVIRONMENTAL JUSTICE ANALYSIS

The geographic region underlying the analysis of environmental justice encompasses various Census tracts spanning four county boundaries, i.e., Los Alamos, Santa Fe, Rio Arriba, and Sandoval counties. Census tract boundaries within these counties are derived from a coverage of census block group boundaries provided by Geographic Data Technology, Lebanon, New Hampshire. This coverage was derived from the TIGER/Line Files of 1990 census geography provided by the U.S. Bureau of Census. In addition, the geographic region underlying the analysis of environmental justice encompasses the Native American reservations of the Cochiti, Santa Clara, Jemez, and San Ildefonso DOE/LANL accord tribes. The geographic boundaries of these reservations were derived from digital data provided by the Bureau of Indian Affairs.

Note that the scope of coverage used in the analysis excludes boundaries or locations of several categories of lands that are generally associated with tribal lands: 1) ceded lands (lands ceded to the U.S. Government to which some tribes retain treaty-protected rights); 2) possessory and usage areas that were established, in some cases, in the course of U.S. Land Claims Commission hearings; and 3) in-holdings within the tribal reservation boundaries. Such in-holdings are lands not held in trust for tribes. These may include fee lands owned by non-Indians, or public domain lands withdrawn from their former trust status (e.g., for National Park Service management or interstate highway rights-of-way).

Given the geographic coverage described above, the following demographic data were used to measure minority and low-income populations: total persons (100 percent count), total households, persons by race, persons by Race and Hispanic Origin, and household counts by income class. The data were extracted from Summary Tape File 3A of the 1990 decennial census, provided by the U.S. Bureau of Census for census block groups. Each block group is identified by its unique block group identifier and the FederalInformation Procedures System (FIPS) identifier for American Indian and Alaska Native Area (AIANAFP). The block group data were then aggregated by tracts generally, and by tracts for the Cochiti, Jemez, San Ildefonso, and Santa Clara Reservation populations only.

Minority population distributions were derived using census tract data on race and Hispanic origin. The size of the minority population within a specific scope of coverage [10, 30, or 50 mi (16, 48, or 80 km)] was measured as the difference between the general population and the white Non-Hispanic subgroup of the general population. The ratio between the derived minority subgroup and the general population constitutes the percentage of "minority population" residing within the various scopes of coverage. This percentage is greater than one half in both the 30- (48-) and 50-mi (80-km) radius, reflecting the large number of Hispanic and Native American persons residing in the region-of-interest.

Similarly, the low-income population distribution was derived using census tract data on household income. Household income data reflects wages and salaries earned by persons of 15 years of age and beyond who reside in the same household. For the region-of-interest the income class of $15,000 or lesswas chosen as the poverty threshold measure for the low-income population. This income level is the reported 1990 poverty threshold for the average-sized household in the region-of-interest. The ratio between these households and the total number of households in a specific scope of coverage [10, 30 or 50 mi (16, 48, or 80 km)] constitutes the percentage of the "low-income" households in the region-of-interest.

Finally, the presentation of both the minority and low-income distributions of the population can take a variety of forms. In the present analysis, maps and tables were constructed taking into consideration that census tracts (or block) areas tend to sprawl across the varying scopes of coverage, e.g. certain census tracts tend to lie on both sides of the 10-, 30-, and 50-mi radius (16-, 48-, and 80-km). In these instances, a detailed atlas was used to apportion persons and households situated in these census tracts to one or the other side of the boundary.

G.3 REFERENCES CITED IN APPENDIX G

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APPENDIX H

HUMAN HEALTH

This appendix presents the methods and results of calculations to estimate human health effects that could result from the airborne releases of test assembly detonations at the DARHT or PHERMEX sites under the six alternatives. The detonations would result in the aerosolization and atmospheric dispersal of a portion of the materials contained in each assembly. The hazardous components may include depleted uranium, tritium, beryllium, lead, and lithium hydride. Depleted uranium and tritium were evaluated for their radiological hazard, and uranium, beryllium, lead, and lithium hydride were evaluated for their chemical hazard. Unless otherwise stated, dose is the effective dose equivalent. Sums and products of numbers in this section may not appear consistent due to rounding.

This appendix addresses only the potential human health impacts from chronic exposures under routine operations. Appendix I (Facility Accidents) covers the health impacts from acute exposures that could result from accident events.

H.1 COMPUTER CODES

The potential health impacts of the atmospheric releases were evaluated with two computer codes. GENII (Napier et al. 1988a; Napier et al. 1988b; and Napier et al. 1988c) was used to calculate radiation dose from uranium and tritium. The Multimedia Environmental Pollutant Assessment System (MEPAS) (Droppo et al. 1989; Droppo et al. 1991; Whelan et al. 1987; Strenge et al. 1989; Buck et al. 1995) was used to calculate toxicological impacts of all constituents, except tritium, and carcinogenic risk from beryllium. The HOTSPOT code (Homann 1994) was used in a limited manner to compare explosive atmospheric dispersion to the point-source atmospheric dispersion estimates of GENII and MEPAS.

H.1.1 GENII

The GENII code was used to calculate radiation doses from depleted uranium and tritium releases. GENII models the environmental transport, accumulation, and radiation dose to an individual or population. It may be used for acute (less than 24 h) or chronic exposure scenarios. Atmospheric dispersion is modeled using a straight-line Gaussian-plume model, and the release point may be either ground level or elevated. Although it accounts for the material deposition to determine exposure to ground surface deposition, the GENII code generates conservative plume concentration estimates in part because, the code does not mathematically remove the deposition from the plume. Therefore, the material deposited is double counted and health impacts are overestimated, especially for those located at greater downwind distance.

Depleted uranium is modeled as a particulate, but GENII includes a special algorithm for modeling tritium vapor. The tritium model of GENII assumes that the tritium released is in the form of tritiated water (HTO), whereas tritium released from either the DARHT or PHERMEX facilities is in the form of tritium gas (T_2). Tritium gas is about 14,000 times less a radiological hazard than tritiated water because it is

taken up by the body to a far lesser extent. GENII calculations were made assuming the tritium to be in the form of HTO for atmospheric dispersion and environmental accumulation. Radiation dose output was **Table H-1.-*Reference Doses (Rfd) for Beryllium, Lead, Lithium Hydroxide,***

and Uranium and Their Bases

Element	Rfd (mg/kg/d)	Basis
Beryllium	Ingestion Rfd = 0.005 Inhalation Rfd = undefined	Low confidence in Rfd which is based on soluble beryllium salts. The deleterious effect of the Rfd is based on weight changes.
Lead	Ingestion Rfd = 0.0014 Inhalation Rfd = 0.00043	High level of confidence in Rfd. Health effect bases are changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development.
Lithium Hydroxide[a]	Ingestion Rfd = 0.007 Inhalation Rfd = 0.007	Low confidence in Rfd. Symptoms of lithium toxicity resemble those of sodium deficiency and include drowsiness, anorexia, nausea, tremors, blurred vision, coma, and death. Rfd is based on sodium hydroxide threshold limit values (TLV). The TLV, however, is most likely based on the caustic nature of sodium hydroxide.
Uranium	Ingestion Rfd = 0.003 Inhalation Rfd = 0.0014	Medium confidence in Rfd. Uranium is a classic nephrotoxin.

[a] Lithium hydroxide used as surrogate for lithium hydride in test assemblies.

Source: EPA 1994b and ACGIH 1991

then corrected by replacing HTO dose factors with those for T_2.

H.1.2 MEPAS

The MEPAS code was used to model the release, atmospheric transport, and receptor exposure of test assembly constituents that could cause toxicological effects (uranium, beryllium, lead, and lithium hydride) or cancer risks (beryllium). Uranium, as a heavy metal, may cause toxicological effects as well as be a source of radiation dose. MEPAS has the capability to model only chronic releases. Like GENII, MEPAS uses a straight-line Gaussian-plume model for atmospheric dispersion modeling, from either ground-level or elevated release points.

The MEPAS code output for toxicological effects from uranium, beryllium, lead, and lithium hydride is in terms of hazard index (HI). Hazard index is used to estimate the potential occurrence of noncarcinogenic effects that may result from chronic exposure to a metal or chemical. Toxicological effects are nonprobabilistic and have an occurrence threshold. They are specific to a given substance because the toxicological endpoints differ for different substances. The HI is equal to the individual's estimated exposure divided by the U.S. Environmental Protection Agency (EPA) constituent-specific reference dose (EPA 1994b). This EPA reference dose is based on a contamination level where a deleterious effect is noted following chronic exposure. No toxicological effects would be expected where the HI was less than unity (1). The reference doses and their bases are provided in table H-1.

MEPAS output for carcinogens is presented as risk of cancer incidence. Beryllium is a potential carcinogen as well as a toxicological hazard. EPA (EPA 1994a) has published a beryllium slope factor, based on chronic exposure, that is used to estimate the probability that an individual will contract cancer in his or her lifetime. The carcinogenic effect results from the inhalation of beryllium. The inhalation slope factor is $8.4\ [\text{mg}_{\text{Be}}/(\text{kg}_{\text{body wt}}\cdot\text{d})]^{-1}$; slope factors for other exposure pathways are undefined.

H.1.3 HOTSPOT

HOTSPOT is a code developed for the initial assessment of accidents involving atmospheric releases of radioactive material. The code module used for these analyses was the "uranium explosion." HOTSPOT was used in one limited application to compare its explosive atmospheric dispersion estimates to the single-point atmospheric dispersion estimates of GENII and MEPAS. The initial plume of the postdetonation release modeled in HOTSPOT is more disperse and spacious than the point release modeled by GENII and MEPAS. The dispersion estimate comparison, while rather extensive in examining dispersion estimates at several different locations, for different quantities of high explosives, and under various meteorological conditions, was limited due to the relatively unsophisticated meteorological input used by HOTSPOT. HOTSPOT was not used for any consequence (dose, toxicological effect, or cancer risk) analysis.

H.2 METEOROLOGICAL DATA AND ATMOSPHERIC DISPERSION

This section presents an overview of the meteorological data used for the human health analyses, as well as a description of the atmospheric dispersion analyses and assumptions made in modeling human health impacts.

H.2.1 Meteorological Data

A comparison was made of available LANL site-specific meteorological data to determine which was most appropriate for use in atmospheric dispersion and transport calculations for releases from the DARHT and PHERMEX sites (Area III) in TA-15. TA-15 has no meteorological tower. Data were available for two nearby areas, TA-6 and TA-49, which are north-northwest and south, respectively, of TA-15. These two sets of meteorological data were selected for comparison because they were from towers closest to TA-15, approximately equidistant from TA-15, and from towers with topography similar to TA-15.

To make a determination on which data set to use, GENII code analyses were carried out using three alternative meteorological data sets: TA-6, TA-49, and the average of TA-6 and TA-49. Doses to three different receptor locations (Los Alamos, Bandelier, and White Rock) were modeled using three different exposure scenarios (i.e., acute, chronic annual, and 30-yr cumulative exposure), as well as the 50-mi (80-km) population. Unit releases of depleted uranium and tritium were used as the source term and held constant among the different comparison cases.

The hourly meteorological data from TA-6 was selected as the input data set for modeling the atmospheric dispersion from the DARHT and PHERMEX sites in TA-15 because it consistently resulted in the highestdose estimates; therefore, potential impacts would less likely be underestimated. In the 3 of 13 cases where the TA-6 data did not result in the highest dose, the difference between the maximum and the TA-6 dose estimate was less than a factor of two.

Both GENII and MEPAS use the site-specific, hourly meteorological data in the form of joint frequency data. Joint frequency data are shown in appendix C, exhibit C1-1. Ninety-fifth-percentile, __/Q´ atmospheric dispersion values were calculated by GENII and MEPAS and used for chronic release calculations. GENII calculates 95th-percentile E/Q values for acute releases. Where hand calculations were necessary for acute release calculations (appendix I), these 95th-percentile E/Q values were used as the atmospheric dispersion input.

H.2.2 Atmospheric Dispersion

The GENII and MEPAS codes are routinely used for point (e.g., a building vent) or area (e.g., buried waste near the soil surface) source releases. However, material from the DARHT and PHERMEX sites would be released via explosive detonations. Initial post-detonation source term plumes for open-air detonations (as described below for the five uncontained alternatives) are roughly a vertical cylinder or stem-and-cap shape. Several analyses were performed to compare the impacts of using the GENII and MEPAS point sources release models to simulate the explosive detonation releases.

The initial analysis evaluated the model release geometry. The HOTSPOT code (Homann 1994) was used to compare post-detonation dispersion to point-source dispersion estimates used in GENII and MEPAS. HOTSPOT models five plumes stacked vertically for its model of nonnuclear detonations of uranium. The dispersion estimates for HOTSPOT and GENII/MEPAS were compared at several different receptor locations, for different quantities of high explosives, and under various meteorological conditions. The comparison was limited due to the relatively unsophisticated, generic meteorological input used by HOTSPOT. This analysis determined that the GENII and MEPAS point-source estimates could significantly *under estimate* atmospheric dispersion of explosive dispersal and therefore *over estimate* the human health impacts.

HOTSPOT has only limited air dispersion and dose modeling capabilities and was not used for any consequence analysis. However, HOTSPOT proved useful by providing an equation for effective release height that would allow GENII and MEPAS to more realistically simulate atmospheric dispersion from uncontained detonations. The effective release height is defined by the following empirical equation (Church 1969, as cited by Homann 1994):

$$\mathrm{eff}_{ht} = 0.6(76w^{0.25})$$

where eff_{ht} = effective release height (m) and

w = amount of high explosives (lb).

This equation defines the mid-point of the explosively dispersed plume, with approximately 50 percent of the aerosolized source term above and 50 percent below the effective release height. The height of release is dependent on the amount of high explosives used; larger amounts of high explosives result in greater initial dispersion and a higher effective release height. The amounts of high explosives used in hydrodynamic tests may range from approximately 10 to 500 lb (5 to 225 kg), with correspondingeffective release heights of 270 to 700 ft (80 to 215 m). The release height used for all uncontained detonations of chronic exposure scenarios is 400 ft (120 m) corresponding to the use of 50 lb (22 kg) of high explosives.

Table H-2.-*Atmospheric Dispersion Values Used to Compare Different*

Explosive Dispersion Models

Location	**__/Q´**		
	GENII/MEPAS	**HOTSPOT[a]**	**Stem & Cap**

10 lb (4.5 kg) of high explosives Los Alamos Bandelier White Rock	4.0×10^{-8} 3.5×10^{-8} 4.3×10^{-8}	4.6×10^{-10} 3.6×10^{-10} 2.6×10^{-10}	4.5×10^{-8} 5.5×10^{-8} 7.3×10^{-8}
500 lb (230 kg) of high explosives Los Alamos Bandelier White Rock	1.6×10^{-8} 2.9×10^{-9} 4.2×10^{-9}	1.1×10^{-10} 7.1×10^{-11} 1.1×10^{-10}	2.3×10^{-8} 1.1×10^{-8} 1.4×10^{-8}
[a] Most conservative (nighttime) __/Q´ values from HOTSPOT.			

A second evaluation compared the single-point release and dispersion model to the stem-and-cap (mushroom-shaped) atmospheric dispersion model. This comparison was made to ensure that the single-point release model was adequate to represent the explosive atmospheric dispersion that may be more appropriately represented by the stem-and-cap model.

Stem-and-cap releases are most accurately represented by double plume releases, with cap and stem sections modeled at different release elevations (Shinn et al. 1989). The stem-and-cap evaluation was performed for a variety of high explosive amounts with unit releases of depleted uranium. Using effective release height information gained from the initial comparison, dose consequences were calculated for a dose receptor in Los Alamos, [2.7 mi (4.4 km) NNW of TA-15]. For large amounts of explosives, the estimated dose from the stem-and-cap, double-plume release could be a maximum of 40 percent higher than that modeled for an elevated, single-point release. The dose from a representative test, using 20 lb (9 kg) of high explosives, could be up to 10 percent higher. Considering the ordinarily assumed factor of 10 uncertainty in atmospheric dispersion model results, a 10 to 40 percent difference (i.e., factor of 1.1 to 1.4) in dose estimates did not warrant the additional effort of stem-and-cap modeling. Table H-2 presents atmospheric dispersion data typical of that used in the stem-and-cap release geometry evaluations.

The Enhanced Containment Alternative release scenarios differ from those of the uncontained alternatives. The Vessel Containment and Phased Containment options assume some detonations are contained within a vessel and some are uncontained; all Building Containment Option detonations are contained. The contained releases were modeled as ground-level releases. The results of the point-release versus explosively dispersed plume and the stem-and-cap evaluations, above, are not applicable to these contained ground-level releases.

Materials from 6 percent of the contained detonations of the Enhanced Containment Alternative were assumed to be released to the environment, based on previous operational experience at LANL. The bounding assumption of 6 percent containment release is used to account for potential leakage or failure of the vessel or building containment in a nonaccident scenario. Accidents are examined separately in appendix I.

H.2.3 Summary

Site-specific hourly meteorological data was evaluated and data from TA-6 was selected for use in atmospheric dispersion estimates. Several different atmospheric dispersion models were evaluated and it was determined that estimates made using the single-point release model in GENII and MEPAS were acceptable to conservatively represent the explosive dispersal of material from detonations. The single-point release model may overestimate potential impacts by up to a factor of 100. This potential over estimation would not apply to ground-level releases from contained detonations.

H.3 SOURCE TERM

The constituents of test assemblies that may be released to the atmosphere and have the potential to adversely impact humans include uranium, tritium, beryllium, lead, and lithium hydride. At detonation, test assembly material is dispersed in various size fractions ranging from large pieces or chunks to very small, micron or sub-micron size particles. Of particular interest is the aerosolized fraction of the material with particles sizes that are considered respirable, 10 µm or less aerodynamic diameter (see appendix C).

H.3.1 Usages and Environmental Releases

The estimated releases of materials to the environment from detonation activities are indicated in table H-3.

Table H-3.- ***Maximum Anticipated Annual Environmental Releases***

of Materials from Test Assemblies

Constituent	Uncontained Alternatives[a]	Vessel Containment Option	Building Containment Option
Deleted uranium (lb)	1540	385 uncontained 70 contained	92 contained
Tritium (Ci)	3	3	3
Beryllium (lb)	22	5.5 uncontained 1.1 contained	1.3 contained
Lead (lb)	33	9 uncontained 2 contained	2 contained
Lithium Hydride (lb)	220	55 uncontained 11 contained	13 contained

[a] No Action, DARHT Baseline, Upgrade PHERMEX, Single Axis, and Plutonium Exclusion alternatives.

The annual usages of materials in uncontained detonations under the No Action, DARHT Baseline, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis alternatives are identical. The impacts of each of these alternatives are identical as well. The impacts of the Enhanced Containment Alternative were evaluated separately. The values listed are the largest foreseeable annual releases. The releases listed for the Vessel Containment Option represent 25 percent of the annual inventory used during uncontained detonations and the use of a containment vessel for the remaining 75 percent of the inventory. It was conservatively assumed, based on operating experience, that 6 percent of the inventory detonated in a vessel annually would be released to the atmosphere. The Building Containment Option similarly assumed 6 percent of the total annual inventory is released from the building. The Phased Containment Option assumed 5 percent vessel containment during the first 5 years of the project 30-year operational period, 40 percent vessel containment during the second 5 years, and 75 percent vessel containment for the final 20 years.

The radionuclide source term used in the health effects evaluation is based on the radionuclides present in 10-year-old Rocky Flats depleted uranium, containing, by mass, 99.8 percent uranium-238, 0.22 percent uranium-235, and 0.00057 percent uranium-234. Depleted uranium is a usable residual product left after extracting some portion of uranium-235 from uranium ore. Naturally occurring uranium has typical uranium isotope mass fractions of 99.3 percent uranium-238, 0.7 percent uranium-235, and minutequantities of uranium-234 and uranium-236. The mass percentage and activity of the constituents 10-year-old Rocky Flats depleted uranium constituents are presented in table H-4. Radionuclides other than uranium in this table are the radioactive progeny produced by decay of the parent uranium radionuclides.

Table H-4.-*Radionuclide Constituents of Depleted Uranium by Mass Activity*

Radionuclide	Mass Percent	Activity of Depleted Uranium Constituents (Ci/g)[a]
Uranium-234	0.00057	3.7×10^{-8}
Uranium-235	0.22	4.9×10^{-9}
Uranium-238	99.8	3.4×10^{-7}
Protactinium-234	(negligible)	3.4×10^{-7}
Thorium-231	(negligible)	4.9×10^{-9}
Thorium-234	(negligible)	3.4×10^{-7}
[a] Activity of constituents is based on 10-year-old Rocky Flats Plant depleted uranium.		

Lithium hydroxide (LiOH) was used in MEPAS as a surrogate for lithium hydride (LiH), which was not part of the MEPAS database. Lithium hydride readily converts to LiOH upon contact with water. A stoichiometric correction was made in the modeled release of the LiH because the LiOH surrogate has three times the mass of LiH because of the addition of the oxygen atom. Therefore, the release source terms of the surrogate LiOH used in the risk calculations are three times those listed in table H-3.

H.3.2 Aerosolization

Upon detonation of the test assembly, the depleted uranium is ejected in the form of large fragments, small fragments (from 0.08 to 1.1 in^2 [0.5 to 7 cm^2]), and aerosols, as discussed in appendix B (McClure 1995). The amount of depleted uranium aerosolized and available for atmospheric dispersion beyond the firing site could range from 0.2 to 10 percent of the test assembly inventory (Mishima et al. 1985; Dahl and Johnson 1977; McClure 1995). All analyses performed for the EIS assume 10 percent aerosolization of depleted uranium.

There is uncertainty about the magnitude of the aerosolization fraction of the detonated hazardous constituents. Much of the uncertainty results from the difficulty in sampling close to high explosive detonations (Baskett and Cederwall 1991). Dahl and Johnson estimated that 2 percent of the beryllium is aerosolized, whereas Shinn et al. estimate 8 percent based on their re-analysis of the Dahl and Johnson results (Dahl and Johnson 1977; Shinn et al. 1989). Little information was available on the aerosolization of the lead and lithium hydride. Due to the lack of a strong basis for constituent-specific aerosolization fractions, an aerosolization fraction of 10 percent was used for all constituents, the same as for depleted uranium.

Respirable-size particles (less than 10 µm AMAD) may comprise 20 to 90 percent of the aerosolized fraction (2 to 9 percent of the total source term); however, for the purposes of these analyses, the aerosolized fraction of the depleted uranium and other constituents was assumed to be 100 percent respirable (10 percent of the total source term).

H.4 EXPOSURE SCENARIOS

Human health impacts resulting from routine, chronic exposure of the public and workers were evaluated by making exposure assumptions about the individuals and population. Annual chronic exposure scenarios consider impacts from routine releases over a one-year period. Cumulative exposure scenarios, an extension of the annual chronic exposure scenario, sum the annual exposures during the 30-yr operational life of the facility and exposure to any soil accumulation that had occurred as a consequence of the 30-yr operational period. The annual and cumulative radiological dose and risk, and the carcinogenic risk from beryllium exposure to the population residing within 50 mi (80 km) of TA-15 were also estimated. The potential impact to the 50-mi (80-km) population from toxicological effects due to chemical exposure (indicated by Hazard Index) were not calculated. These effects are nonprobabilistic and have an occurrence threshold, so low results for the maximally exposed individual were an adequate indication that population calculations were not needed.

Three residential locations around LANL (Los Alamos, White Rock, and Bandelier) were chosen at which to evaluate the maximally exposed individual (MEI) for radiation dose and chemical exposure. Residents were assumed to be at their homes continuously and to consume home-grown crops. Assessing impacts at multiple locations provided a better indication of possible impacts, and also provided allowance for slight differences in the atmospheric dispersion and deposition algorithms used in the two consequence assessment codes (GENII and MEPAS) to ensure that individuals with the highest potential impacts were identified.

H.4.1 Receptor Type and Location

The general categories of individual receptors evaluated included the annual-chronic MEI, cumulative (over 30 years of operations) MEI, and noninvolved worker (see table H-5). Both public MEI categories considered offsite residents nearest to TA-15 (i.e., Los Alamos, White Rock, and Bandelier). The noninvolved worker was assumed to be located on the road leading to DARHT or PHERMEX about 2,500 ft (750 m) away. This distance is based on a series of administrative hazard radii that LANL has established for protection of personnel from fragment injury and would be a typical exclusion for test assembly detonations. The hazard radius determinations are included in LANL operating procedures, based on principles presented in the DOE Explosives Safety Manual (DOE 1994). The above individual receptor locations are presented in the table H-5. Table H-6

Table H-5.-*Locations of Individuals Evaluated for Impacts from Chronic and Cumulative Exposures*

Category	**Location Name**	**Location**
Maximally Exposed Individual (MEI)	Bandelier	3 mi (5 km) SSE
Chronic (Annual) and Cumulative	White Rock	3.8 mi (6 km) ESE
(30 Years of Operation)	Los Alamos	2.7 mi (4.4 km) NNW
Noninvolved worker		2,500 ft (750 m) NW

Table H-6.-*The 1993 Population Distribution within the 50-mi (80-km)*

Polar Grid Centered on TA-15

Direction (Sector)	**Distance (mi)**										
	0-1	**1-2**	**2-3**	**3-4**	**4-5**	**5-10**	**10-20**	**20-30**	**30-40**	**40-50**	**Sector Total**
S	0	0	0	0	1	0	1,295	3,511	697	6,195	11,699
SSW	0	0	1	0	1	0	216	38	4,310	114,102	118,668
SW	0	0	1	0	1	0	0	37	1,048	45	1,132
WSW	0	0	1	3	1	0	17	516	2,198	6	2,742
W	0	0	0	2	1	11	268	489	29	146	946
WNW	0	0	0	0	1	10	53	41	149	1,970	2,224
NW	0	0	0	0	0	0	17	24	357	632	1,030
NNW	0	0	5	3,961	148	0	10	42	231	206	4,603

N	0	0	39	4,459	65	0	56	232	1,038	655	6,544
NNE	0	0	39	1,827	472	1	262	1,450	821	360	5,232
NE	0	0	12	241	37	1	12,500	5,898	2,594	2,167	23,450
ENE	0	0	0	6	2	865	5,591	5,057	1,332	1,147	14,000
E	0	0	0	220	3,631	1	1,179	1,175	74	186	6,466
ESE[a]	0	0	0	498	1,518	1	481	41,322	1,955	2,782	48,557
SE	0	0	0	5	43	0	797	33,390	5,735	293	40,263
SSE	0	0	0	49	0	3	9	1,161	2,291	202	3,715
Population Total	0	0	98	11,271	5,922	893	22,751	94,383	24,859	131,094	291,271
Distance Midpoint (km)	0.8	2.4	4.0	5.6	7.2	12	24	40	56	72	

[a] The ESE sector was determined to be the maximally exposed population sector for accident analysis (appendix I).

presents the 1993 population distribution data for the 50-mi (80-km) area surrounding TA-15, used in population impact calculations.

Due to the close proximity of DARHT and PHERMEX sites [0.4 mi (0.6 km) apart], the MEI distances used for each site were assumed to be equivalent. The PHERMEX facility was modeled in the No Action Alternative as operational for an additional 30 years.

H.4.2 Exposure Pathways

Table H-7**Table H-7.-*Exposure Pathways Evaluated for Impacts from Routine Releases***

Pathway	**Chronic MEI[a]**	**Cumulative MEI[a]**	**Noninvolved Worker**	**Population**

External exposure from:	x	x	x	x
plume	x	x	x	x
ground surface	x	x	x	x
Dermal absorption[b]				
Inhalation of plume and resuspended soil/dust	x	x	x	x
Ingestion of:	x	x	x	x
incidental soil	x	x	NA	x
crops [c]	NA	x	NA	x
animal products[d]				

[a] MEI = maximum exposed individual.

[b] Nonradioactive constituents only.

[c] Leafy vegetables, "other" vegetables, fruit, grains.

[d] Meat and milk.

lists the exposure pathways included in evaluating impacts of routine exposures. The annual chronic MEI's pathways included external exposure and dermal absorption, inhalation of airborne constituents and resuspended soil, ingestion of food crops, and the inadvertent ingestion of soil. The cumulative MEI and population included these same pathways as well as additional pathways of meat and milk ingestion. The noninvolved worker pathways were more limited. The noninvolved worker would be present onsite, and only for a fraction of the year, during working hours. Exposure pathways included were external exposure, dermal absorption and inhalation of the airborne plume, and inhalation of resuspended soil. Table H-8**Table H-8.-*Code Input Parameters and Values Used in Evaluating***

Human Health Effects of Routine Releases

Pathway/Parameter	Chronic MEI	Cumulative MEI[a]	Noninvolved Worker (Chronic)	Population

External exposure from:	8,766	8,766	2,000	8,766
plume (h)	8,766	8,766	2,000	8,766
ground surface (h)	8,766	8,766	2,000	8,766
dermal absorption (h)				
Inhalation (h)	8,766	8,766	2,000	8,766
Ingestion of:	100	100	100	100
incidental soil (mg/d)	16.5	16.5	0	16.5
crops (kg)[b]	34.9	34.9	0	34.9
leafy vegetables	55.7	55.7	0	55.7
other vegetables	73.9	73.9	0	73.9
fruit	0	95	0	95
grain	0	110	0	110
meat (kg)[c]				
milk (kg)[c]				

[a] For Hazard Index (HI) and post-operation calculations, 30 years of previous facility operation have been assumed. MEI = maximum exposed individual.

[b] All crops 1 day holdup.

[c] Beef 20 day holdup, 75 percent fresh forage consumption.

Milk 2 day holdup, 75 percent fresh forage consumption.

Note: Annual exposure times are shown unless otherwise indicated.

Miscellaneous parameters:

absolute humidity - 3×10^{-4} lb/ft^3 (0.0048 kg/m^3)

soil density - 100 lb/ft^3 (1.6×10^3 kg/m^3)

roots - 60 percent upper soil, 40 percent deep soil manual redistribution factor - 0.15

surface soil density - 15 lb/ft^2 (240 kg/m^2)

mass loading - 4.5 x 10^{-9} lb/ft^3 (7.2 x 10^{-5} g/m^3)

presents the code input parameters of most interest that were used to evaluate the human health impacts.

H.5 RESULTS

Results are presented for potential radiological, toxicological, and carcinogenic impacts of releases of uranium, tritium, lead, beryllium, and lithium hydride. Radiation dose estimates are presented in terms of effective dose equivalent (EDE). The radiation dose estimates were translated into a measure of latent cancer fatalities (LCFs) using recommendations of the International Commission on Radiological Protection in its Publication 60 (ICRP 1991). The ICRP estimated the risk of cancer from data based on populations exposed to relatively high doses and dose rates. A dose reduction factor of 2 was used when doses were below 20 rad, as is the case with all doses estimated in these analyses. The dose-to-risk conversion factors used for estimating cancer deaths from exposure to low dose rates of ionizing radiation were 500 cancer deaths (latent cancer fatalities) per million person-rem effective dose equivalent (5 x 10^{-4} deaths per person-rem) for the general population and 400 cancer deaths per million person-rem (4 x 10^{-4} deaths per person-rem) for workers. The difference is attributable to more diverse age groups in the general population. These values include the dose reduction factor. For purposes of explaining potentialimpacts to individual members of the public or individual workers, these dose-to-risk conversion factors have also been used to estimate the "probability" of contracting a latent cancer for the representative member of the public or worker.

The HI is used to estimate potential occurrence of toxicological effects resulting from chronic exposure to a chemical. The basis is the EPA's constituent-specific reference dose (EPA 1994a) which is based onchronic exposure at a contamination level where a deleterious effect is noted. The HI for a specific contaminant is equal to the individual's estimated exposure divided by the EPA reference dose, and thus is a unitless measure. The critical value - 1.0 - indicates that the individual is exposed at a level equivalent to the reference dose and, therefore, would be expected to experience the health effect

upon which the reference dose is based. No deleterious effects would be expected when the hazard index is less than 1.0.

The risk of cancer incidence (as compared to the risk of cancer fatalities, as is estimated from radiation dose) from exposure to beryllium was also calculated, using the EPA slope factor for beryllium (EPA 1994a).

Estimated impacts of expected normal releases under the uncontained detonation alternatives (No Action, DARHT Baseline, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis) are described in section H.5.1. Analysis and results of these impacts apply to all uncontained alternatives. The estimated impacts of the Enhanced Containment Alternative are shown in section H.5.2. Results are presented for individuals and population, for annual and cumulative exposures. Results of accident analyses are presented in appendix I.

For all alternatives, the radiation dose from tritium, in the form of T_2, was determined to be approximately 1 x 10^{-7} (1/10,000,000) that of depleted uranium. An analysis was performed, using GENII along with hand calculations to correct for the tritium chemical form difference, to compare dose consequences of the projected chronic annual releases of depleted uranium and tritium. Because it was determined to be an insignificant contributor to the radiation dose, tritium impacts were not explicitly calculated.

H.5.1 Uncontained Alternatives

Analysis of the uncontained alternatives - No Action, DARHT Baseline, Upgrade PHERMEX, Plutonium Exclusion, and Single Axis - involved only uncontained detonation and atmospheric releases of test assembly material, including depleted uranium, tritium, beryllium, lead, and lithium hydride.

H.5.1.1 Public

Health impacts would not be expected in the maximally exposed members of the public, located at Los Alamos, Bandelier, and White Rock, from routine annual releases under the uncontained alternatives (seetables H-9 and H-10**Table H-9.-*Estimated Annual Doses and Carcinogenic Risks for Members of the Public***

and the Noninvolved Worker for Routine Release from All Uncontained Alternatives

Maximally Exposed Individual Location	Annual Dose (rem)	Annual Probability of Radiation-Induced LCF[a]	Annual Probability of Beryllium-Induced Cancer
Los Alamos	2×10^{-5}	1×10^{-8}	3×10^{-11}
Bandelier	1×10^{-5}	7×10^{-9}	6×10^{-12}
White Rock	2×10^{-5}	8×10^{-9}	4×10^{-11}
Noninvolved Worker	2×10^{-5}	9×10^{-9}	3×10^{-11}
[a] LCF = latent cancer fatality.			

Table H-10.-*Estimated Toxicological Effects to Members of the Public and the*

Noninvolved Worker for Annual Routine Releases from All Uncontained Alternatives

Individual Location	Hazard Index (HI)[a]			
	Uranium	Beryllium	Lead	Lithium Hydride
Los Alamos	1×10^{-7}	5×10^{-10}	8×10^{-9}	1×10^{-8}
Bandelier	3×10^{-8}	1×10^{-10}	2×10^{-9}	2×10^{-9}
White Rock	1×10^{-7}	1×10^{-9}	5×10^{-9}	8×10^{-9}

Noninvolved Worker	2×10^{-7}	0	1×10^{-8}	1×10^{-8}

[a] Toxicological effects would not be expected for a hazard index value less than 1.

Table H-11.-***Estimated Cumulative Dose and Probability of Cancer from Radiation and Beryllium Exposure from 30 Years of Operation for all Uncontained Alternatives***

Individual Location	Cumulative Dose (rem)	Cumulative Probability of Radiation-Induced LCF[a]	Soil Buildup Dose[b] (rem)	Cumulative Probability of Beryllium-Induced Cancer	Soil Buildup Probability of Beryllium-Induced Cancer[b]
Los Alamos	7×10^{-4}	4×10^{-7}	2×10^{-8}	9×10^{-10}	1×10^{-11}
Bandelier	4×10^{-4}	2×10^{-7}	1×10^{-8}	2×10^{-10}	2×10^{-12}
White Rock	5×10^{-4}	3×10^{-7}	1×10^{-8}	1×10^{-9}	9×10^{-12}
Noninvolved Worker	7×10^{-4}	3×10^{-7}	-	9×10^{-10}	-

[a] LCF = latent cancer fatality.

[b] Reflects the potential impact from buildup of released material in soil; evaluated during the first year following 30 years of operations.

). Neither would health impacts be expected in maximally exposed members of the public at these locations from exposure over the projected 30 years of facility operations (tables H-11 and H-12). This table includes values calculated from releases of uranium, tritium, and beryllium, as well as the dose and risk projected in the first year immediately following 30 years of operations from the deposition and accumulation of depleted uranium and beryllium in the soil. Table H-12**Table H-12.**-***Estimated Toxicological Effects to Members of the Public after 30 Years of Facility Operation for All Uncontained Alternatives***[a]

Maximally Exposed Individual Location	Hazard Index[b] (HI)			
	Uranium	Beryllium	Lead	Lithium Hydride

Los Alamos	1×10^{-7}	4×10^{-10}	8×10^{-9}	1×10^{-8}
Bandelier	3×10^{-8}	9×10^{-11}	2×10^{-9}	2×10^{-9}
White Rock	9×10^{-8}	7×10^{-10}	4×10^{-9}	6×10^{-9}

[a] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.

[b] Toxicological effects would not be expected for a hazard index value less than 1.

presents an estimate of the potential toxicological effects that would occur as a result of deposition and accumulation of uranium, beryllium, lead, and lithium hydride in the soil. The results are presented for the first year immediately following 30 years of operations, when buildup of the materials in the soil would be at a maximum. All values are well below 1.0; therefore, toxicological effects would not be expected. These results indicate that any environmental accumulation of released materials in the soil would create a negligible residual health risk to members of the public living around LANL after termination of DARHT or PHERMEX operations.

The projected annual dose to the population of 290,000 individuals living in the 50-mi (80-km) radius of TA-15 would be 0.91 person-rem. Latent cancer fatalities would not be expected among the population from this population dose (5×10^{-4} LCFs). Beryllium-induced cancer would not be expected in this population (4×10^{-7} cancers). Cumulative dose to the population over 30 years would be 27 person-rem; latent fatal cancers would not be expected (1×10^{-2} LCFs). Cancer from cumulative exposure to beryllium would not be expected (1×10^{-5} total cancers).

H.5.1.2 Noninvolved Worker

Health impacts would not be expected in noninvolved workers as a result of releases to the atmosphere under the uncontained alternatives (see tables H-9 and H-10). Neither would any health impacts be expected from cumulative exposures over the 30-yr anticipated life of the project (table H-11).

H.5.1.3 Workers

The average annual dose to workers at the facility was estimated to be no more than 0.01 rem. The maximum probability of such a worker contracting a latent fatal cancer would be 4×10^{-6}. Over the 30-yr operating life of the facility, an involved worker's maximum probability of contracting a latent fatal cancer would be 1×10^{-4}. An annual collective worker dose similar to that observed for PHERMEX in the past was assumed to be representative for future operation, or about 0.3 person-rem/year. Latent cancer fatalities would not be expected among the worker population (1×10^{-4} LCFs). Collective worker dose over the anticipated 30 years of operations would be about 9 person-rem. Latent cancer fatalities would not be expected among the worker population (4×10^{-3} LCFs). The collective dose estimate was based on a maximum of 100 workers at the facility, each receiving an average of 0.003 rem per year. No operating information was available on exposure to chemicals or metals. The risks of exposure to these materials would be expected to be similarly low to those for radiation exposure.

H.5.2 Enhanced Containment Alternative

Under the Enhanced Containment Alternative, three operations were evaluated: the Vessel Containment Option, the

Building Containment Option, and the Phased Containment Option. The Vessel ContainmentOption assumed 25 percent of annual usages were uncontained detonations, and 6 percent of the contained inventory of the detonations was released routinely via ground-level leakage. The Building Containment Option assumed that all detonations were contained and that 6 percent of the inventory was released routinely via ground-level leakage. The Phased Containment Option assumed 5 percent vessel containment during the first 5 years of the project 30-year operational period, 40 percent vessel containment during the second 5 years, and 75 percent vessel containment for the final 20 years. The Vessel Containment Option would have slightly higher potential impacts than the Building Containment Option in all cases. The Phased Containment Option impacts would be essentially the same for impacts to individuals, but somewhat higher than the other two options for population impacts; about 30 percent higher than the Vessel Containment Option and twice the Building Containment Option over the 30-year operating lifetime of DARHT. Over the last 20 years of the operating period potential impacts would be identical to those of the Vessel Containment Option.

H.5.2.1 Public

Health impacts would not be expected in maximally exposed members of the public, located at Los Alamos, Bandelier, and White Rock, from routine annual releases under the Enhanced Containment Alternative (see tables H-13**Table H-13.-*Estimated Annual Doses and Carcinogenic Risk for Members of the Public***

for the Enhanced Containment Alternative

Enhanced Containment Option	Maximally Exposed Individual Location	Annual Total Dose (rem)	Annual Probability of Radiation-Induced LCF[a]	Annual Probability of Beryllium-Induced Cancer
Vessel and Phased	Los Alamos	1×10^{-5}	5×10^{-9}	1×10^{-11}
	Bandelier	1×10^{-5}	6×10^{-9}	2×10^{-12}
	White Rock	2×10^{-5}	8×10^{-9}	1×10^{-11}
Building	Los Alamos	5×10^{-6}	2×10^{-9}	4×10^{-12}
	Bandelier	1×10^{-5}	5×10^{-9}	8×10^{-13}
	White Rock	2×10^{-5}	8×10^{-9}	4×10^{-12}

[a] LCF = latent cancer fatality.

Table H-14.-*Estimated Toxicological Effects to Members of the Public for Annual Routine Releases for the Enhanced Containment Alternative*

Enhanced Containment Option	Maximally Exposed Individual Location	Hazard Index (HI)[a]

		Uranium	Beryllium	Lead	Lithium Hydride
Vessel and Phased	Los Alamos	5×10^{-8}	2×10^{-10}	4×10^{-9}	6×10^{-9}
	Bandelier	1×10^{-8}	4×10^{-11}	7×10^{-10}	1×10^{-9}
	White Rock	5×10^{-8}	4×10^{-10}	2×10^{-9}	4×10^{-9}
Building	Los Alamos	2×10^{-8}	7×10^{-11}	1×10^{-9}	2×10^{-9}
	Bandelier	4×10^{-9}	2×10^{-11}	2×10^{-10}	4×10^{-10}
	White Rock	2×10^{-8}	1×10^{-10}	9×10^{-10}	2×10^{-9}

[a] Toxicological effects would not be expected for a hazard index value less than 1.

and H-14). Neither would health impacts be expected in maximally exposed members of the public at these locations over the projected 30 years of facility operations (see table H-15).

Table H-15.-*Estimated Cumulative Dose and Probability of Cancer from Radiation and Beryllium Exposure from 30 Years of Operation for the Enhanced Containment Alternative*

Enhanced Containment Option	Maximally Exposed Individual Location	Cumulative Dose (rem)	Probability of Radiation-Induced LCF[a]	Soil Buildup Dose[b] (rem)	Probability of Beryllium-Induced Cancer	Soil Buildup Probability of Beryllium-Induced Cancer[b]
Vessel and Phased	Los Alamos	3×10^{-4}	1×10^{-7}	8×10^{-8}	3×10^{-10}	3×10^{-12}
	Bandelier	3×10^{-4}	2×10^{-7}	8×10^{-8}	7×10^{-11}	6×10^{-13}
	White Rock	(5×10^{-4})[c] (6×10^{-4})[d]	(2×10^{-7})[c] (3×10^{-7})[d]	1×10^{-7}	3×10^{-10}	2×10^{-12}
Building	Los Alamos	1×10^{-4}	5×10^{-8}	4×10^{-8}	1×10^{-10}	3×10^{-13}
	Bandelier	3×10^{-4}	7×10^{-8}	8×10^{-8}	2×10^{-11}	7×10^{-14}
	White Rock	5×10^{-4}	2×10^{-7}	1×10^{-7}	1×10^{-10}	3×10^{-13}

[a] LCF = latent cancer fatality.

[b] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.

[c] Vessel Containment Option.

[d] Phased Containment Option.

Table H-16.-*Estimated Toxicological Effects to Members of the Public after 30 Years of Facility Operation for the Enhanced Containment Alternative*[a]

Enhanced Containment Option	Maximally Exposed Individual Location	Hazard Index[b] (HI)			
		Uranium	Beryllium	Lead	Lithium Hydride
Vessel and Phased	Los Alamos	4×10^{-8}	1×10^{-10}	3×10^{-9}	4×10^{-9}
	Bandelier	7×10^{-9}	2×10^{-11}	5×10^{-10}	8×10^{-10}
	White Rock	3×10^{-8}	2×10^{-10}	1×10^{-9}	2×10^{-9}
Building	Los Alamos	6×10^{-9}	1×10^{-11}	4×10^{-10}	6×10^{-10}
	Bandelier	1×10^{-9}	3×10^{-12}	7×10^{-11}	1×10^{-10}
	White Rock	4×10^{-9}	1×10^{-11}	2×10^{-10}	4×10^{-10}

[a] Reflects the potential impact from buildup of released material in soil; evaluated during the first year immediately following 30 years of operations.

[b] Toxicological effect would not be expected for a hazard index value less than 1.

This table includes the projected cumulative impact from releases of uranium, tritium, and beryllium, as well as the dose projected in the first year immediately following 30 years of operations from the deposition and accumulation of depleted uranium and beryllium in the soil. Table H-16 presents an estimate of the potential toxicological effects that would occur as a result of deposition and accumulation of uranium, beryllium, lead, and lithium hydride in the soil. The results are presented for the first year immediately following 30 years of operations, when buildup of the materials in the soil would be at a maximum. All values are well below 1.0; therefore, toxicological effects would not be expected. These results indicate that any environmental accumulation of released materials in the soil would create a negligible residual health risk to members of the public living around LANL after termination of the enhanced containment operations.

The projected annual dose to the population of 290,000 individuals living in the 50-mi (80-km) radius of TA-15 from the Vessel Containment, Phased Containment, and Building Containment options would be about 0.44, 0.57, and 0.27 person-rem, respectively. No LCFs would be expected among the population from these population doses (2×10^{-4}, 2×10^{-4}, and 1×10^{-4} LCFs, respectively). Beryllium-induced cancer would not be expected in this population (1×10^{-7}, 1×10^{-7}, and 5×10^{-8} cancers, respectively).

Cumulative impacts over the anticipated 30-year life of the project for the Vessel Containment, Phased Containment, and Building Containment options would be about 13, 17, and 8 person-rem, respectively. Latent cancer fatalities would not be expected (6×10^{-3}, 8×10^{-3}, and 4×10^{-3} LCFs, respectively). Cancers from cumulative exposure to beryllium would not be expected (1×10^{-4}, 1×10^{-4}, and 6×10^{-5}, respectively).

H.5.2.2 Noninvolved Worker

The annual radiation dose from chronic exposure of a noninvolved worker under the Vessel Containment and Phased Containment Options would be about 2×10^{-5} rem. The maximum probability of this worker contracting a latent fatal cancer from this dose would be about 6×10^{-9}. The cumulative dose over the 30-year operating life of the facility to the same worker would be about 5×10^{-4} rem. The worker'scumulative maximum probability of contracting a latent fatal cancer from this dose would be about 2×10^{-7}. The maximum annual probability of a beryllium-induced cancer in a noninvolved worker would be about 2×10^{-11}. This worker's cumulative probability of contracting a beryllium-induced cancer over the 30-year operating life of the facility would be about 5×10^{-10}.

The annual radiation dose from chronic exposure of a noninvolved worker under the Building Containment Option would be about 1×10^{-5} rem. The maximum probability of this worker contracting a latent fatal cancer would be about 5×10^{-9}. The cumulative dose over the 30-yr operating life of the facility to the same worker would be about 4×10^{-4} rem. The worker's maximum probability of contracting a latent fatal cancer from this dose would be about 2×10^{-7}. The maximum annual probability of a beryllium-associated cancer in a noninvolved worker would be about 1×10^{-11}. This worker's cumulative probability of contracting a beryllium-associated cancer over the 30-year operating life of the facility would be about 3×10^{-10}.

Potential toxicological impacts to noninvolved workers under the Vessel Containment, Phased Containment, and Building Containment options are presented in table H-17**Table H-17.*-Estimated Toxicological Effect to Noninvolved Workers for Annual***

Routine Releases for the Enhanced Containment Alternative

Enhanced Containment Alternative	Hazard Index (HI)[a]			
	Uranium	Beryllium	Lead	Lithium Hydride
Vessel and Phased	9×10^{-8}	0	8×10^{-9}	8×10^{-9}
Building	6×10^{-8}	0	4×10^{-9}	4×10^{-9}

[a] Toxicological effects would not be expected for a hazard index value less than 1.

. Toxicological effects would not be expected, as Hazard Index values are all well below 1.0.

H.5.2.3 Workers

Impacts to workers under the Enhanced Containment Alternative could be somewhat higher than those previously observed under PHERMEX operating conditions or projected for the uncontained alternatives because cleanup of contained space (vessels or buildings) could involve exposure to greater quantities and concentrations of materials. Worker exposures were projected to be higher than that previously observed at PHERMEX or those for other alternatives. The average annual worker dose would probably not exceed 0.020 rem. The maximum probability of a latent cancer fatality from this dose would be 8 x 10^{-6}. The annual collective worker dose, assuming a maximum of 100 workers, would probably not exceed 2 person-rem. No latent cancer fatalities would be expected from this dose (8 x 10^{-4} LCFs). The collective worker dose over the assumed 30-yr lifetime of the facility would probably not exceed 60 person-rem. No latent cancer fatalities would be expected from this dose (2 x 10^{-2} LCFs).

Involved worker exposures to radiation and radioactive materials under normal operations would be controlled under established procedures that require doses to be kept as low as reasonably achievable (ALARA). Any potential hazards would be evaluated as part of the radiation worker and occupational safety programs at LANL, and no impacts outside the scope of normal work activities would be anticipated.

H.5.3 Routine Operations Involving Plutonium

This section summarizes evaluations of the potential impacts to the public and workers from routine operations that could involve plutonium. Details about these impact evaluations are included in a classified supplement that is not available to the general public. Any use of plutonium would be the same under each alternative, so distinctions between alternatives are not made. Potential health consequences of exposure to plutonium are well understood and have been greatly exaggerated by the popular press (Sutcliffe et al. 1995).

Routine operations for plutonium experiments were assumed to be conducted in a double-walled containment vessel with high-efficiency particulate air (HEPA) filters having particulate retention efficiencies of 99 percent to 99.9 percent (gases would not be impeded) and an effluent monitor with a detection limit of 6 x 10^{-10} Ci. Under routine operating conditions, a doubly contained plutonium experiment would not be expected to release any gases or particulates to the atmosphere. However, to conservatively estimate the consequences from potential releases associated with routine operations during plutonium experiments, the release for each experiment was assumed to equal the detection limit of the monitoring instrument. Thus, a maximum of 6 x 10^{-10} Ci of plutonium was assumed to be released to the atmosphere during each experiment. Other methods and assumptions used were as described earlier in this appendix.

H.5.3.1 Public

The dose to the MEI among the general public over the 30-year life of the project would be about 2 x 10^{-10} rem. This would be the same whether the tests were conducted at the PHERMEX site or the DARHT site. The maximum probability of contracting a latent fatal cancer from this dose would be about 8 x 10^{-14}. The population dose over the life of the project would be about 3 x 10^{-7} person-rem. No LCFs would be expected (1 x 10^{-10} LCFs).

H.5.3.2 Noninvolved Workers

The dose to a noninvolved worker 2,500 ft (750 m) away over the 30-year life of the project would be about 6 x 10^{-10}

rem. This would be the same whether the tests were conducted at the PHERMEX site or the DARHT site. The maximum probability of contracting a latent fatal cancer from this dose would be about 2 x 10^{-13}. Assuming a noninvolved work force of 15 workers at this point, the collective dose over 30 years would be 9 x 10^{-9} person-rem. No latent cancer fatalities (3 x 10^{-12} LCFs) would be expected.

H.5.3.3 Workers

No exposure to plutonium would be expected for DARHT or PHERMEX workers during any normal operations. This is based on past operating experience with dynamic experiments involving plutonium. Any radiological impacts on workers would come from the handling of depleted uranium and would be the same as reported under each of the alternatives. There would be no incremental increase in impacts due to routine operations involving plutonium.

H.6 REFERENCES CITED IN APPENDIX H

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APPENDIX I

FACILITY ACCIDENTS

This appendix presents the approach used to determine and analyze impacts of accidents that might occur at the PHERMEX or DARHT facilities under all of the alternatives examined in this EIS. Section I.1 describes the Preliminary Hazards Analysis that identifies potentially hazardous conditions and potential accidents that might result. Section I.2 describes the identification of representative or bounding accidents selected for detailed evaluation. Section I.3 provides information on the consequence evaluation of these accidents, if they were to occur. Much of the technical basis for evaluating the human health impact of accidental releases is included in appendix H, Human Health. These analyses do not include the impacts from accidents involving transportation of materials, which are included in appendix J, Transportation. Unless otherwise stated, dose is the effective dose equivalent. Sums and products of numbers in this section may not appear consistent due to rounding.

I.1 PRELIMINARY HAZARDS ANALYSIS

The first step in the accident analysis process was to prepare a preliminary hazards analysis (PHA). The objective of a PHA is to identify the potentially hazardous conditions in a system and to determine the significance of the potential accidents. The PHA defines a set of abnormal operations and potential accidents that could occur at the PHERMEX or DARHT facilities. The PHA examined causes of potential accidents and qualitatively evaluated the possible consequences. A tabular summary of the PHA is shown in table I-1.

Table I-1.-*Preliminary Hazards Analysis for DARHT and PHERMEX*

Facility Operations (All Alternatives)

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures
Firing Site	Explosives	Inadvertent detonation	U - Procedures and training; lockout on firing set (detonators)	Fatal to all persons on the firing site (up to 15); **evaluate public impact**	Building design and location; firing site isolation; blast shadow of buildings; access control
Firing Site	Explosives/ radiation	Worker enters firing site during detonation sequence	E - Interlocks on facility doors; cameras at firing site; access control; warning lights and sirens; procedures and training	Fatal to worker	Building design and location; firing site isolation; access control

General Facility	Explosives	Inadvertent detonation	E - HE & radioactive material prohibited from facility; no storage or staging locations; procedures and training	Fatalities among facility personnel	Building design and location; firing site isolation; procedures and training
Exclusion Zone	Explosives, hazardous materials	Noninvolved worker inside the exclusion zone during detonation	U - Access control; procedures & training; warning signs and sirens; physical lockouts	Inhalation of radioactive & other detonated material; possible injury from fragments; **evaluate impact**	Access control; procedures & training; warning signs and sirens
Firing Site	Radiation	Exposure to accelerator beam on firing site	E - Physical lockout of accelerator operation; limited accelerator keys; beam stop in place during testing; pro-cedures & training	Possible large, localized radiation dose to a worker	Physical lockout of accelerator operation; limited accelerator keys; beam stop in place during testing; procedures & training
Accelerator Bay	Hazardous materials	Spill of insulator liquids or transformer oil	U - Procedures and training; low frequency of change-out	Minimal impact to workers unless ingested; no offsite impacts	System design; berms around tanks and accelerators; dedicated drains and tanks for material spills
Entire Facility	Flammable	Facility is set afire internally: rags/paper ignite spontaneously; cable fire	U - Sprinklers; cable integrity and inspection; manual fire extinguishing; fire department response	Normal fire hazard for workers; no offsite impact	Alarms; emergency procedures and training

Table I-1.-*Preliminary Hazards Analysis for DARHT and PHERMEX*

Facility Operations (All Alternatives) - Continued

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/Control Measures

Entire Facility	Natural initiator - lightning - brush fire	Facility is set afire by a lightning strike or brush fire	A - High lightning area; explosive detonation often sets brush afire	Normal fire hazard for workers; no offsite impacts	Brush control; lightning control; canyons as natural fire breaks; fire department response capability; non-flammable facility construction (concrete); control of combustible loading
Entire Facility	Natural initiator - earthquake - tornado - high wind - heavy snowfall	Major structural damage to facility	U - Infrequent occurrence of events; building structural integrity; little material at risk in facility	Significant for workers in facility; no offsite impacts	Building structural integrity; no HE or radioactive material in facility
Entire Facility	Natural initiator - flood	Major structural damage to facility	I - Facility not sited in floodplain	Incredible event not requiring additional evaluation	Building siting
Entire Facility	Aircraft	Aircraft strikes facility causing detonation of assembly on firing site	I - Distance from airport; direct overflights are limited; amount of aircraft traffic;	Incredible event not requiring additional evaluation	Amount of time assemblies at facility or on firing site
General Facility	Explosives/ radiation	Electrical power fails at facility	A - Normal electrical failures; no back-up power for facility except data back-up	No impact	Detonation system de-energized when power fails; accelerator de-energized; recovery plans; procedures and training

Containment Structure or Vessel	Explosive	Catastrophic loss of containment	E - Design specifications of vessel or building; administrative controls on HE quantities; procedures and training	**Evaluate impact**	Building design and location; firing site isolation; access control
Confinement Vessel for Pu Experiments	Explosives/ plutonium	Catastrophic loss of double confinement	I-Based on related DOE safety studies	**Evaluate impacts regardless of frequency categorization**	Design and location; testing; double & triple contingency factors; access control; procedures and training
General Facility	Explosives/ plutonium	Inadvertent detonation of plutonium-containing assembly	E,U-Based on related DOE safety studies	**Evaluate impacts**	Building design and location; firing site isolation; access control; procedures and training

[a] A is anticipated; U is unlikely; E is extremely unlikely, I is incredible.

Potential hazards were identified using a modified energy barrier approach, in which abnormal events or potential accidents were selected by considering energy sources potentially capable of being released from control or containment barriers. Barriers between the source and the receptor may be present to prevent or restrict the release of energy. For example, major portions of the DARHT facilities are located below grade, using the earth as a barrier between the firing point and occupied areas. In this example, the high explosives on the firing point represent the energy source potentially capable of being released. Other examples of energy sources include radioactive materials and radiation, kinetic energy (e.g., moving vehicles, hoisting equipment), potential energy (hoisted loads), hazardous chemical materials, electrical energy, and flammable materials.

In the process described above, components associated with the PHERMEX and DARHT facilities under each alternative were analyzed using engineering judgment based on previous operating experience with PHERMEX and similar types of firing-site operations in Technical Area (TA) 15. Each of the major work locations or processes in the facilities was evaluated for potential hazards to the general public, onsite personnel, and the operating staff.

Safety features provided to prevent or mitigate hazards were also identified. Review of the hazards led to generating a list of potentially hazardous events and associated safety features.

The PHA is intended to identify hazards from which accidents are selected that may be bounding, and considers only accident pathways that for a given frequency category may have significant effects. Theinitial estimate of safety significance is based on historical experience with similar hazards and engineering judgment. Not all of the events described in the PHA were analyzed in detail to assign frequency categories or to determine expected consequences. Instead, conservative estimates were made to select a limited number of accident scenarios for detailed review (evaluation or analysis) as potentially bounding accidents.

Frequency categories are based on the entire set of events included in the accident scenario, not just the initiating event frequency. The entire event includes the initiating event and any subsequent equipment failures or human errors. As a result, it is possible for accidents with similar (or identical) initiating events to have greatly different frequency assignments. This is due to the assumptions regarding subsequent events and system failures.

The form of the PHA does not allow a detailed listing of all of the specific event assumptions. The PHA summary table succinctly describes the overall event or scenario and initiating event. Where lack of historical data or prior experience forces frequencies to be estimated based on engineering judgment, conservative assumptions were made.

The frequency categorization column of the table lists those items considered in assigning a frequency category and consequence to the event. The last column, mitigation/control measures, lists measures present principally for limiting the consequences of the event. An event in the anticipated frequency category may be constrained by physical systems (e.g., shielding walls) and administrative controls (e.g., procedures and training). Another event may be in the unlikely or extremely unlikely frequency category based on the same considerations, but may also consider the failure of one or more of the mitigation/control measures. The event frequency determination may consider the existing or planned administrative control to limit frequency or to limit consequences.

Frequency categories used in the PHA are the following.

· Anticipated (A) (1 to 10^{-2} per year) - accidents and natural phenomena that may occur a few times during the lifetime of the operation or facility.

· Unlikely (U) (10^{-2} to 10^{-4} per year) - accidents and natural phenomena that will probably not occur during the lifetime of the operation or facility.

· Extremely Unlikely (EU) (10^{-4} to 10^{-6} per year) - accidents and natural phenomena that are credible but very unlikely to occur during the lifetime of the operation or facility.

· Incredible (I) ($<10^{-6}$ per year) - scenarios of exceedingly small probability. By definition, scenarios determined to occur less than once every 1,000,000 years are not credible.

The PHERMEX and DARHT facilities are rather unique from a hazard analysis and accident selection perspective in that the source of potential consequences to the general public from the normal operation - that is, detonation of high explosives and dispersal of depleted uranium and other materials from the site - is also the source of bounding consequences for accidents. Consequences of most accidents impact only the involved workers. For this reason, hazards and potential accidents that impact only involved workers are included in table I-2.

Table I-2.-*Preliminary Hazards Analysis of Hazards and Potential Accidents*

that Would Affect Facility Workers (Involved Workers) Only

Facility Area	Hazardous Element	Event Description	Frequency Categorization[a]	Consequence	Mitigation/ Control Measures
Accelerator Rooms	Electrical energy	Workers contacts accelerator injector power supply	U - Procedures and training	Potentially fatal to involved workers	

Accelerator Bay & Laser Room	Electrical energy	Worker contacts with laser power supply	U - Procedures and training	Potentially fatal to involved workers	
General Facility Areas	Potential/ kinetic energy	Failure of mechanical lift	U - Periodic inspections; preventive maintenance; procedures & training	Potentially fatal to involved workers	First aid available; hospital nearby
General Facility Areas	Toxic materials	Worker spills solvents used in facility	A - Frequent but small usage	Minor inhalation or uptake	Room ventilation
Camera Room	Potential/ kinetic energy	High-speed camera flies apart, producing fragments	U - Camera construction and reliability	Worker could be injured by fragment	Camera room is an exclusion area when cameras operating
Accelerator Hall	Inert gas	Confined space entry into accelerator during maintenance	U - Procedures and training; confined space entry program	Possible asphyxiation due to SF_6 inhalation	SF_6 required to be vented from area prior to accelerator entry
Laser Room	Radiation (non-ionizing)	Exposure to laser beam during maintenance or operations	U - Procedures and training	Possible eye injury or skin burn	
Accelerator Rooms	Radiation (ionizing)	Exposure to accelerator beam scattered radiation or bremsstrahlung	U - Exclusion area; shielding	Radiation exposure within LANL administrative guidelines	Procedures and training

[a] A is anticipated; U is unlikely; E is extremely unlikely, I is incredible.

I.2 BOUNDING ACCIDENT SELECTION

As noted in section I.1, the source of potential impacts to the public from PHERMEX or DARHT accidents is identical to normal operations, namely the detonation of high explosives and dispersal ofmaterials from the firing site. Most of the differences between accidents are noted in potential impacts to involved workers, and less difference in impacts to noninvolved workers and members of the public.

The PHA provided the basis for selecting bounding accidents. Bounding accidents are those which, if they occurred, would result in the highest potential consequences (impacts) to members of the public and noninvolved or involved workers. Bounding accidents were selected from the PHA based on potential consequences, with little or no consideration of the frequency of occurrence; that is, they were considered as "what if" accidents, although the likelihood of occurrence would be small. Accidents with expected smaller consequences than the bounding accidents were eliminated from further consideration. The accident selected for more detailed analysis under all alternatives was the inadvertent uncontained detonation of a test assembly. Under the Enhanced Containment Alternative, the catastrophic failure of a containment vessel was selected for the Vessel Containment and Phased Containment options. Under the Building Containment Option, the bounding accident was the cracking and loss of integrity of the containment walls or major failure of the HEPA-filtered overpressure release system.

For involved workers at and around the firing site, inadvertent detonation is clearly the bounding case for all alternatives. The number of workers and observers on the firing site when explosives are present is limited to 15; under an inadvertent detonation scenario all of these individuals could be killed. Other accidents, mainly industrial-type accidents, could also result in worker fatalities. However, only an explosives-type accident has the capability of injuring or killing a large number of workers. In addition, for all alternatives, the direct exposure of a worker to the accelerator beam pulse was selected because it falls well outside the scope of hazards typically encountered in an industrial or laboratory setting.

Two postulated accidents involving plutonium, an inadvertent detonation and the breach of a double-walled containment vessel, identified in table I-1, were selected and evaluated on a "what if" basis. Impacts to the public maximally exposed individual (MEI), the population, noninvolved workers, and involved workers were all evaluated.

I.3 ACCIDENT ANALYSES

This section presents the methods used to analyze the human health impacts from facility accidents, and also presents the detailed results of the analyses. Some of the technical basis for evaluating the impacts of accidents is the same as for evaluating impacts from normal operations. Therefore, some of the technical basis for these analyses is contained in appendix H, Human Health.

The detonation of a test assembly results in the aerosolization and atmospheric dispersal of a portion of the materials contained in the assembly. Depleted uranium and tritium were evaluated for their radiological hazard; and uranium, beryllium, lead, and lithium hydride were evaluated for their chemical hazard. The potential for carcinogenesis from exposures to uranium, tritium, and beryllium was evaluated, as well as the potential occurrence of toxicological effects from exposure to uranium, beryllium, lead, and lithium hydride.

An inadvertent uncontained detonation was evaluated as the bounding accident for all uncontained alternatives, that is the No Action, DARHT Baseline, PHERMEX Upgrade, Plutonium Exclusion, and Single Axis alternatives, as well as the uncontained detonations under the Vessel Containment and PhasedContainment options of the Enhanced Containment Alternative. This accident considered the impact from uncontained inadvertent detonation of a test assembly with release of all assembly materials to the environment.

Two accident scenarios, applicable for the three options, were evaluated under the Enhanced Containment Alternative. The vessel accident scenario considered a catastrophic failure of a containment vessel, releasing all test assembly materials to the environment. The building accident scenario considered a building wall cracking or a HEPA filter failure during a detonation, allowing the release of a portion of the detonated inventory.

Evaluation of impacts from accidents involving plutonium are applicable for each of the alternatives in the EIS.

I.3.1 EXPOSURE MODELING

The GENII code, spreadsheet, and hand calculations were used for the health impact evaluation of accident scenarios. A description of the GENII code and model approach can be found in appendix H, Human Health. Whereas the MEPAS code was used in the evaluation of the chronic exposures in appendix H, it was not appropriate to use this code for the acute exposure scenarios of accidental releases. Therefore, hand calculations were used to estimate the intake of the nonradioactive hazardous releases.

Hazard indexes (HI) are to be used to describe the potential for toxicological effects only in situations of chronic exposures; they are inappropriate to use for acute exposure evaluations. Therefore, only the acute intake of nonradioactive constituents via the inhalation pathway over the plume passage period was evaluated. GENII acute-scenario atmospheric dispersion estimates (using 95th percentile E/Q values) were used in the spreadsheets to determine the amount of nonradioactive constituent inhaled. Inhalation intakes were then calculated and compared to equivalent intakes for the NIOSH Immediately Dangerous to Life or Health (IDLH) values (NIOSH 1995).

A test assembly inventory was established for each of the accident release cases that would be within the operating limits of the facility, represent normal assembly configuration, but would maximize possible consequences. Each inventory has the same quantity of potentially hazardous constituents as presented in table I-3.

Table I-3.-*Assumed Inventory of an Individual Test Assembly for Accident Analysis*

Accident Release Scenario	Inventory				
	DU	Tritium	Be	Pb	LiH
Uncontained Detonation	50	0.75	0.5	4	25
Enhanced Containment Vessel Containment Breach Building Containment Breach	50	0.75	0.5	4	25
Note: All inventories in kg, except for tritium, which is in Ci.					

The radionuclide composition of the depleted uranium is presented in appendix H, table H-4. The high-explosive content for the uncontained detonation case was assumed to be relatively low to decrease dispersion and therefore *increase* potential impacts; thereby conservatively estimating impacts. The high-explosive content of assemblies under the containment breach cases would be higher, to effect the loss of containment.

For the uncontained detonation accident case, the effective point of material release is based on the amount of explosives used in the detonation (see appendix H). The amount of explosives detonated in the test assembly was assumed to be 22 lb (10 kg), with an effective midpoint release height of 330 ft (100 m). As discussed in appendix H for chronic releases, the single-point release assumption used in the modeling may cause potential impacts to be overestimated by up to a factor of 100.

For both of the containment-breach accident scenarios under the Enhanced Containment Alternative, a ground-level release was modeled because the containment was assumed to diminish the upward pressure of the blast. This assumption minimizes atmospheric dispersion and, as a consequence, increases calculated potential impacts.

For the uncontained detonation and vessel breach cases, 100 percent of the test assembly inventory was assumed to be released to the environment. For the building containment breach case, only 10 percent of the test assembly inventory was assumed to be released. For all accident cases, only a portion of the released hazardous constituents would be of respirable size. An aerosolization fraction of 0.1 (10 percent) was assumed for this EIS (see appendix H), with the entire aerosolized portion assumed to be respirable. Therefore, the percentage of the test assembly inventory available for intake by human receptors would be 10 percent for uncontained detonations and the vessel containment breach, and 1 percent for the building containment breach.

Potential impacts to the MEI were evaluated at three points of public access near the PHERMEX and DARHT facilities: the nearest point of State Road 4, Pajarito Road, and Bandelier National Monument. A nearby noninvolved worker was evaluated in each case for onsite impacts. For the uncontained alternatives, impacts to noninvolved workers were evaluated at hazard radius boundary 2,500 ft (750 m), a typical hazard radius for hydrodynamic tests. For the Enhanced Containment Alternative, the noninvolved worker location, 1,300 ft (400 m), was applicable to the scenario where the noninvolved worker was located at the assumed vessel containment hazard radius boundary that was assumed to be reduced from the uncontained detonation hazard radius boundary. This scenario is also bounding for impacts to a noninvolved worker inside the hazard radius during an uncontained release. Involved workers were assumed to be near the blast and killed or seriously injured by overpressure or fragments. Table I-4 presents the locations of these individuals.

Table I-4.- ***Locations of Individuals Evaluated***

for Accidental Release Cases

Category	Location Description	Location
MEI[a]	State Road 4 (SR4)	0.9 mi (1.5 km) SW
Public Individual	Pajarito Road	1.7 mi (2.7 km) NE
Public Individual	Bandelier	3 mi (5 km) SSE
Noninvolved Worker Uncontained Detonation		2,500 ft (750 m) NW
Noninvolved Worker Containment Breach		1,300 ft (400 m) NW
[a] MEI is the maximally exposed individual.		

The basis for selecting the public access locations was the frequented points of closest approach by offsite individuals. These individuals are assumed to remain at that point for a brief period of time; for example, an individual changing a tire located on State Road 4 or Pajarito Road or a hiker in the Bandelier National Monument at the time of the acute release.

The noninvolved worker was located on the roadway just outside the hazard radius, approximately 2,500 ft (750 m) away for uncontained detonations. The hazard radius was assumed to be smaller for the contained detonations under the Enhanced Containment Alternative, with the noninvolved worker 1,300 ft

(400 m) away. These distances are based on administrative hazard radii that LANL has established for protection of personnel from fragment injury and would be a typical exclusion for test assembly detonations. The hazard radius determinations are included in LANL operating procedures, based on principles presented in the DOE Explosives Safety Manual (DOE 1994).

The exposure pathways and parameters values for those of greatest importance and interest are presented in table I-5.

Table I-5.-*Code Input Parameters Used to Evaluate Accident Release Consequences*

Pathway	**Dose Receptor/Applicable Accident Scenario**[a]		
	Public Individual **All Accident Scenarios**	**Noninvolved Worker** **Uncontained Detonation**	**Noninvolved Worker** **Containment Breach**
External exposure external plume ground surface (hours)	Plume passage 1	Plume passage 0.25	Plume passage 0.25
Inhalation	Plume passage	Plume passage	Plume passage

[a] Individuals are located in the plume centerline during the entire time of its passage.

Miscellaneous parameters:

soil density, 100 lb/ft^3 (1.6 x 10^3 kg/m^3)

surface soil density, 15 lb/ft^3 (240 kg/m^2)

mass loading, 4.5 x 10^{-9} lb/ft^3 (7.2 x 10^{-5} g/m^3)

For radioactive material, the exposure pathways considered under the acute accidental release scenarios included inhalation and external exposure from the material in the plume and deposited on the ground surface. This was principally depleted uranium because for all six alternatives, the radiation dose from tritium, in the form of T_2, was determined to be about 1 x 10^{-8} (about 1 in 100 million) that of depleted uranium. An analysis was performed, using GENII, to compare dose consequences of the acute releases of depleted uranium and tritium. Because it was determined to be an insignificant contributor to the radiation dose, tritium impacts were not explicitly calculated. To evaluate the potential toxicological effects of uranium, beryllium, lead, and lithium hydride, and the carcinogenic risk from beryllium, only the inhalation exposure pathway was considered.

In the past, DOE has conducted dynamic experiments with plutonium at LANL. Future experiments with plutonium would always be conducted in double-walled containment vessels; these experiments could not reasonably be expected to result in any release of plutonium to the environment. DOE has evaluated the potential impacts of two types of accidents that could involve plutonium: inadvertent detonation and containment breach. It is important to note that any accidents involving plutonium would not be nuclear detonations, but rather detonations of the high explosive that could disperse particles of plutonium. This analysis is documented in a classified supplement to the EIS. Results and unclassified calculation assumptions and modeling methods are included in this appendix and in applicable sections of Chapter 5.

Radionuclide-independent exposure modeling assumptions and methods for accidents involving plutonium were the same as those presented for depleted uranium with the following exceptions for population dose calculations:

· Plume depletion due to natural settling and deposition processes was taken into account.

· Diffusion of released material across an entire exposed sector was taken into account, rather than assuming that all exposure took place on the plume centerline.

· Estimates of population dose were made using both the 50th and 95th percentile atmospheric dispersion factors, rather than just the 95th percentile value.

Accounting for plume depletion and diffusion of released material resulted in lowering values for the atmospheric dispersion factors, with consequently lower estimated atmospheric concentrations for a given unit of release. This resulted in estimates of plutonium air concentrations approximately 38 and 10 times lower for ground-level (containment breach) and elevated (inadvertent detonation) releases, respectively, than would have been estimated had these factors not been taken into account. Use of the 50th and 95th percentile atmospheric dispersion factors provide a range of estimates using realistic (50th) and a reasonable upper bound (95th) of atmospheric dispersion conditions.

In addition to calculating the potential dose to the population in the hypothetical maximally exposed sector, at the request of the State of New Mexico Environment Department and various American Indian pueblos, the potential dose to the populations of a number of individual communities in the vicinity of LANL were calculated. The communities included in this evaluation and community-specific input parameters are presented in table I-6**Table I-6.-*Additional Communities Evaluated for Impacts from***

Postulated Accidents Involving Plutonium

Communities	Population	Distance [mi (km)]	Direction from TA-15	E/Q (s/m^3)	
				50th	95th
Cochiti Pueblo[a]	936	13 (21)	SSW	3.6 x 10^{-7}	8.6 x 10^{-7}

Santa Clara Pueblo[a]	1742	10 (16)	NNE	3.7 x 10^{-7}	1.1 x 10^{-6}
San Ildefonso Pueblo[a]	634	8 (12)	NE	6.8 x 10^{-7}	1.4 x 10^{-6}
Jemez Pueblo[a]	2642	13 (21)	SW	1.2 x 10^{-7}	8.3 x 10^{-7}
Española[b]	9026	12 (20)	NNE	3.3 x 10^{-7}	8.8 x 10^{-7}
Pojoaque Pueblo[a]	162	15 (24)	E	3.0 x 10^{-7}	6.4 x 10^{-7}
Los Alamos[b]	3965	3.5 (6)	NNW	4.2 x 10^{-7}	3.2 x 10^{-6}
White Rock[b]	498	4 (6)	ESE	5.3 x 10^{-7}	2.4 x 10^{-6}
Santa Fe[b]	41300	25 (40)	ESE	1.8 x 10^{-7}	4.4 x 10^{-7}

[a] Population data from the Pueblo Cultural Center.

[b] Population data from the 1990 U.S. Census.

. As was done for other accidental release calculations, it was assumed that the plume released from the accident passed directly over the community. This explains why results are presented for communities in opposite directions; for example, Cochiti Pueblo that is south-southwest, and Santa Clara Pueblo that is north-northeast. These calculations included plume depletion but did not account for the diffusion of material in the plume; that is, the communities were assumed to be on the centerline of the plume of released material. Calculations were done using both the 50th and 95th percentile atmospheric dispersion factors.

I.3.2 ACCIDENT ANALYSIS RESULTS

The estimated radiation dose and carcinogenic risk impacts to members of the public and noninvolved workers from exposure to radioactive material and beryllium released during an accident are presented in table I-7**Table I-7.-** ***Estimated Doses and Carcinogenic Risk from Bounding Case Accidents***

Accidental Release Case	Total dose (rem EDE)	Probability of Radiation-Induced LCF[c]	Probability of Beryllium-Induced Cancer

Uncontained Detonation Public MEI[b], State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker Population (ESE)[a] (number of LCFs)	6 x 10^{-4} 3 x 10^{-4} 3 x 10^{-4} 7 x 10^{-4} 1.9 person-rem	3 x 10^{-7} 2 x 10^{-7} 1 x 10^{-7} 3 x 10^{-7} none (9 x 10^{-4} LCFs)	4 x 10^{-10} 2 x 10^{-10} 2 x 10^{-10} 5 x 10^{-10} none (1 x 10^{-6} total cancers)
Vessel Containment Breach Public MEI, State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker Population (ESE) (number of LCFs) **Building Containment Breach** Public, MEI, State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker Population (ESE)[a] (number of LCFs)	1 x 10^{-2} 8 x 10^{-3} 3 x 10^{-3} 5 x 10^{-2} 17 person-rem 1 x 10^{-3} 8 x 10^{-4} 4 x 10^{-4} 5 x 10^{-3} 1.7 person-rem	6 x 10^{-6} 4 x 10^{-6} 2 x 10^{-6} 2 x 10^{-5} none (9 x 10^{-3} LCFs) 6 x 10^{-7} 4 x 10^{-7} 2 x 10^{-7} 2 x 10^{-6} none (9 x 10^{-4} LCFs)	8 x 10^{-9} 5 x 10^{-9} 3 x 10^{-9} 3 x 10^{-8} none (1 x 10^{-5} total cancers) 8 x 10^{-10} 5 x 10^{-10} 3 x 10^{-9} 3 x 10^{-9} none (1 x 10^{-6} total cancers)

[a] The east-southeast (ESE) sector.

[b] MEI is the maximally exposed individual.

[c] LCF is latent cancer fatality.

Note: Population impacts are shown as expected number of LCFs and cancers rather than an individual probability of occurrence.

. The maximum radiation dose to a member of the public was estimated to be 0.011 rem to the MEI, located at State Road 4, in the event of a catastrophic failure of a containment vessel during a detonation. The maximum probability of a latent cancer fatality (LCF) from this accident scenario would be 6 x 10^{-6}. Dose to members of the public at Pajarito Road, Bandelier, and other locations would be lower than those at the State Road 4 location. The estimated maximum dose to the surrounding population within 50 mi (80 km), also from a containment vessel failure, would be about 17 person-rem. No LCFs would be expected among the population from this dose (9 x 10^{-3} LCFs).

The maximum probability of a beryllium-induced cancer, again to the MEI at the State Road 4 location from a containment vessel failure, would be 8 x 10^{-9}. Inhalation intakes of material released during the accidents are presented in table I-8**Table I-8.-*Inhalation Intakes of Materials Released***

in the Accident Release Cases

Accidental Release Case	**E/Q[a] (s/m^3)**	**Plume Exposure Time(s)**	**U (µg)**	**Be (µg)**	**Pb (µg)**	**LiH (µg)**
Uncontained Detonation	7.5 x 10^{-6}	180	9	0.09	0.7	4
Public MEI, State Road 4	4.4 x 10^{-6}	182	5	0.05	0.4	4
Public, Pajarito Road	3.5 x 10^{-6}	309	4	0.04	0.3	2
Public, Bandelier	8.9 x 10^{-6}	140	10	0.4	0.8	5
Noninvolved worker						

Vessel Containment Breach	1.4×10^{-4}	160	200	2	10	80
Public MEI, State Road 4	9.6×10^{-5}	218	100	1	9	60
Public, Pajarito Road	4.7×10^{-5}	500	50	0.5	4	30
Public, Bandelier	6.2×10^{-4}	51	700	7	60	400
Noninvolved worker						
Building Containment Breach	1.4×10^{-4}	160	20	0.2	1	8
Public MEI, State Road 4	9.6×10^{-5}	218	10	0.1	0.9	6
Public, Pajarito Road	4.7×10^{-5}	500	5	0.05	0.4	3
Public, Bandelier	6.2×10^{-4}	51	70	0.7	6	40
Noninvolved worker						
IDLH[b] Value (mg/m^3)			10,000	4,000	100,000	500
Equivalent intake (µg)			100,000	40,000	1,000,000	5,000

[a] The E/Q (E over Q) is a measure of atmospheric dispersion for short-term (acute) atmospheric releases using gaussian dispersion plume modeling, with units of s/m^3. For a given point or location at some distance from the source, it represents the time-integrated air concentration (e.g., Ci-s/m^3) divided by the total release from the source (e.g., Ci). Integrated air concentrations used are usually plume centerline values. E/Qs are typically used for releases lasting no longer than 8 to 24 hours.

[b] IDLH (Immediately dangerous to life or health) values from NIOSH 1995.

, and calculated air concentrations and their comparison to the IDLH values are presented in table I-9. The transitory air concentrations that would be experienced by the MEI at the State Road 4 location would be, at the greatest, less than 1 percent of the IDLH values.

A noninvolved worker would receive the highest dose from the vessel containment failure, receiving a dose of about 0.05 rem (table I-7). The maximum probability of a LCF from this accident scenario would be 2×10^{-5}. The maximum probability of a beryllium-induced cancer would be about 3×10^{-8}. Inhalation intakes of material released during the accidents are presented in table I-8. The amount of material inhaled was estimated from the E/Q information. However, the IDLH health impact guidelines for acute exposures to hazardous materials are based on air concentrations (NIOSH 1995). The IDLH values are the best available for determining health impact, but are not ideal, given the original intendeduse of the IDLHs for emergency response purposes. IDLH values are based on 30-minute exposure times. The exposure times of the modeled individuals are much shorter than 30 minutes (see table I-8).

The IDLHs are based on breathing 353 ft^3 (10 m^3) of air over the 30-minute exposure time. Since it would be difficult to draw health impact conclusions from air concentrations that are based on 30-minute exposure levels for the MEI 1 to 8 min exposure levels, the IDLH-equivalent intake was calculated for comparison to the MEI intakes. The IDLH-equivalent intake values are the product of the constituent-specific IDLH (µg/m^3) (NIOSH 1995) and the volume of air intake [353 ft^3 (10 m^3)] and are listed in table I-8 for the constituents of interest. All MEI intakes of the hazardous constituents are less than their respective IDLH-equivalent intake values. Table I-9**Table I-9.-*Percent of the IDLH Intake Basis Inhaled by the Individual***

Accidental Release Case	**U**	**Be**	**Pb**	**LiH**
Uncontained Detonation Public MEI, State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker 2,500 ft (760 m)	9×10^{-3} 5×10^{-3} 4×10^{-3} 1×10^{-2}	2×10^{-4} 1×10^{-4} 1×10^{-4} 1×10^{-3}	7×10^{-5} 4×10^{-5} 3×10^{-5} 8×10^{-5}	8×10^{-2} 8×10^{-2} 4×10^{-2} 1×10^{-1}
Vessel Containment Breach Public MEI, State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker 1,300 ft (400 m)	2×10^{-1} 1×10^{-1} 5×10^{-2} 7×10^{-1}	5×10^{-3} 3×10^{-3} 1×10^{-3} 2×10^{-2}	1×10^{-3} 9×10^{-4} 4×10^{-4} 6×10^{-3}	2 1 6×10^{-1} 8
Building Containment Breach Public MEI, State Road 4 Public, Pajarito Road Public, Bandelier Noninvolved worker 1,300 ft (400 m)	2×10^{-2} 1×10^{-2} 5×10^{-3} 7×10^{-2}	5×10^{-4} 3×10^{-4} 1×10^{-4} 2×10^{-3}	1×10^{-4} 9×10^{-5} 4×10^{-5} 6×10^{-4}	2×10^{-1} 1×10^{-1} 6×10^{-2} 8×10^{-1}
IDLH[a] equivalent intake (mg)	100	40	1,000	5

[a] IDLH (Immediately Dangerous to Life or Health).

indicates each individual's exposure as a percent ofthe IDLH. Most intakes are less than 1 percent of the IDLH; the highest is for the noninvolved worker exposed to a level of 8 percent of the LiH IDLH during a vessel containment failure.

Containment breach releases have greater potential impacts than uncontained releases (tables I-7 to I-9) mainly because there is less atmospheric dispersion of ground-level containment releases than for the explosive elevated uncontained releases. This can result in a greater atmospheric concentration at the nearby point of exposure. Other important considerations are the quantity of material released and the population distribution (for population dose calculations). Appendix C (section C.1.3.3) provides some additional discussion on comparative impacts of releases from containment and uncontained detonations.

Potential impacts from postulated accidents involving plutonium are shown in tables I-10 **Table I-10.-*Hypothetical Impacts to Workers and the Public from***

Postulated Accidents Involving Plutonium

Affected Category	**Inadvertent Detonation**		**Containment Breach**	
	Dose (rem)	**Maximum Probability of LCFs**	**Dose (rem)**	**Maximum Probability of LCFs**
Workers	-[a]	NA	no impact	no impact
Noninvolved Workers 750 m 400 m	90 160	0.04 0.06	20 60	0.009 0.02
Public MEI	76	0.04	14	0.007

[a] No radiological impact estimated; up to 15 fatalities could result from explosion blast effects.

[b] NA = not applicable

Table I-11.-*Hypothetical Impacts to the Maximally Exposed Sector*

of the Population from Postulated Accidents Involving Plutonium

Atmospheric Dispersion Assumption	Inadvertent Detonation		Containment Breach	
	Population Dose (person-rem)	Number of LCFs	Population Dose (person-rem)	Number of LCFs
50th[a]	9,000	5	210	0 (0.1)
95th[b]	24,000	12	560	0 (0.3)

[a] 50th percentile of atmospheric dispersion conditions.

[b] 95th percentile of atmospheric dispersion conditions.

Note: The communities of Santa Fe and White Rock are included within the population of this sector.

and I-11. Potential health consequences of exposure to plutonium are well understood and have been greatly exaggerated by the popular press (Sutcliffe et al. 1995). These results include hypothetical impacts to thepublic MEI, population in the maximally exposed sector, noninvolved workers, and involved workers. The MEI, located at State Road 4, could receive up to 76 rem in the event of an accident. The maximum probability of a LCF occurring in this hypothetical individual would be 0.04. The dose to the potentially maximally exposed sector of the population, east-southeast of the DARHT and PHERMEX sites that includes the communities of White Rock and Santa Fe, could be between 9,000 and 24,000 person-rem, taking into consideration the 50th and 95th percentile meteorology, respectively. Between 5 and 12 LCFs would be projected from radiation doses such as these to the population.

Impacts to noninvolved workers could be as high as 160 rem, for a worker 1,300 ft (400 m) away from an uncontained detonation. The maximum probability of an LCF occurring in a worker from this radiation dose would be 0.06. More likely, a noninvolved worker would be no closer than 2,500 ft (750 m). The dose to a worker at this distance would be about 90 rem, with a corresponding maximum probability of about 0.04 of an LCF occurring.

Table I-12 **Table I-12.-*Hypothetical Impacts to Nearby Communities from***

a Postulated Inadvertent Detonation Accident Involving Plutonium

Community	50th Percentile Meteorology[a]		95th Percentile Meteorology[b]	
	Population Dose (person-rem)	Number of LCFs	Population Dose (person-rem)	Number of LCFs

Cochiti Pueblo	300	0	800	0
Santa Clara Pueblo	1000	0	2900	1
San Ildefonso Pueblo	400	0	900	0
Jemez Pueblo	600	0	4400	2
Española	4400	2	12100	6
Pojoaque Pueblo	50	0	100	0
Los Alamos	5900	3	45100	22
White Rock	500	0	2400	1
Santa Fe	7500	3	18700	9

[a] 50th percentile of atmospheric dispersion conditions.

[b] 95th percentile of atmospheric dispersion conditions.

Note: Values for communities in different compass directions are not additive (see table I-6).

Table I-13.-*Plutonium Isotope Unit Dose Factors for Evaluation of Potential Human Health Impacts from Acute, Ground-Level Releases*[a]

Accident Release Case **Dose Receptor**	**Pu-236**	**Pu-238**	**Pu-239**	**Pu-240**	**Pu-241**	**Pu-242**	**Pu-244**
Public (rem/µCi released) [b] MEI, State Road 4 Pajarito Road Bandelier	6.2×10^{-6} 4.3×10^{-6} 2.0×10^{-6}	1.3×10^{-5} 9.2×10^{-6} 4.3×10^{-6}	1.4×10^{-5} 9.7×10^{-6} 4.6×10^{-6}	1.4×10^{-5} 9.7×10^{-6} 4.6×10^{-6}	2.3×10^{-7} 1.6×10^{-7} 7.4×10^{-8}	1.3×10^{-5} 9.3×10^{-6} 4.4×10^{-6}	1.3×10^{-5} 9.2×10^{-6} 4.3×10^{-6}

Population (person-rem per µCi released) East-southeast	9.6 x 10^{-3}	2.0 x 10^{-2}	2.2 x 10^{-2}	2.2 x 10^{-2}	3.6 x 10^{-4}	2.1 x 10^{-2}	2.1 x 10^{-2}
Noninvolved Worker (rem/µCi released) 1,300 ft (400 m) 2,500 ft (760 m)	2.7 x 10^{-5} 9.8 x 10^{-6}	5.7 x 10^{-5} 2.1 x 10^{-5}	6.1 x 10^{-5} 2.2 x 10^{-5}	6.1 x 10^{-5} 2.2 x 10^{-5}	9.8 x 10^{-7} 3.6 x 10^{-7}	5.8 x 10^{-5} 2.1 x 10^{-5}	5.8 x 10^{-5} 2.1 x 10^{-5}
Specific Activity (µCi/g)	5.3 x 10^{8}	1.7 x 10^{7}	6.2 x 10^{4}	2.3 x 10^{5}	1.0 x 10^{8}	3.9 x 10^{3}	1.8 x 10^{1}

[a] Includes all applicable exposure pathways described in table I-5.

[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

shows hypothetical impacts to nearby communities in the event of an inadvertent uncontained detonation involving plutonium. These values are likely to be overestimated because of the assumption that all of the community population is located on or near the plume centerline. In particular, the value for Los Alamos is likely to be overestimated because the airborne plume would be relatively narrow at this distance and would expose only a small fraction of the population shown in table I-6, leaving most of the population unexposed. Because of its closeness to LANL, however, Los Alamos could be one of the most affected communities if the plume passed that way. Some of the other small communities could receivehigh enough population doses in the event of an accident under the specific exposure conditions assumed in the analysis that some LCFs could occur. Up to one LCF could occur at White Rock and Santa Clara Pueblo, up to two at Jemez Pueblo, between two and six at Española, and between three and nine in Santa Fe. No LCFs would be projected for the other communities evaluated. Values for communities in different compass directions are not additive (see table I-6). Only values for Santa Clara and Española, and White Rock and Santa Fe, may be added since these two sets of communities lie in the same direction from TA-15.

Some individuals may wish to explore potential human health consequences of hypothetical accidental releases of plutonium from proposed PHERMEX or DARHT activities. Estimates of the potential dose impact from unit releases of plutonium isotopes are provided in tables I-13, I-14**Table I-14.-*Plutonium Isotope Unit Dose Factors for Evaluation of Potential***

Human Health Impacts from Acute, 330-ft (100-m) Releases[a]

Accident Release Case **Dose Receptor**	**Pu-236**	**Pu-238**	**Pu-239**	**Pu-240**	**Pu-241**	**Pu-242**	**Pu-244**

Public (rem/µCi released) [b] MEI, State Road 4 Pajarito Road Bandelier	3.4 x 10^{-7} 2.0 x 10^{-7} 1.6 x 10^{-7}	7.2 x 10^{-7} 4.3 x 10^{-7} 3.4 x 10^{-7}	7.6 x 10^{-7} 4.6 x 10^{-7} 3.6 x 10^{-7}	7.6 x 10^{-7} 4.6 x 10^{-7} 3.6 x 10^{-7}	1.2 x 10^{-8} 7.4 x 10^{-9} 5.9 x 10^{-9}	7.3 x 10^{-7} 4.4 x 10^{-7} 3.5 x 10^{-7}	7.2 x 10^{-7} 4.3 x 10^{-7} 3.5 x 10^{-7}
Population (person-rem per µCi released) East-southeast	1.1 x 10^{-3}	2.3 x 10^{-3}	2.4 x 10^{-3}	2.4 x 10^{-3}	4.1 x 10^{-5}	2.3 x 10^{-3}	2.3 x 10^{-3}
Noninvolved Worker (rem/µCi released) 1,300 ft (400 m) 2,500 ft (760 m)	7.0 x 10^{-7} 3.9 x 10^{-7}	1.5 x 10^{-6} 8.3 x 10^{-7}	1.6 x 10^{-6} 8.8 x 10^{-7}	1.6 x 10^{-6} 8.8 x 10^{-7}	2.6 x 10^{-8} 1.4 x 10^{-8}	1.5 x 10^{-6} 8.5 x 10^{-7}	1.5 x 10^{-6} 8.4 x 10^{-7}
Specific Activity (µCi/g)	5.3 x 10^{8}	1.7 x 10^{7}	6.2 x 10^{4}	2.3 x 10^{5}	1.0 x 10^{8}	3.9 x 10^{3}	1.8 x 10^{1}

[a] Includes all applicable exposure pathways described in table I-5.

[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

Table I-15.-*Plutonium Isotope Unit Dose Factors for Evaluation of Potential Human Health Impacts from Acute, 400-ft (120-m) Releases*[a]

Accident Release Case **Dose Receptor**	**Pu-236**	**Pu-238**	**Pu-239**	**Pu-240**	**Pu-241**	**Pu-242**	**Pu-244**

Public (rem/µCi released) **[b]** MEI, State Road 4 Pajarito Road Bandelier	2.4 x 10^{-7} 1.1 x 10^{-7} 1.1 x 10^{-7}	5.2 x 10^{-7} 2.4 x 10^{-7} 2.3 x 10^{-7}	5.5 x 10^{-7} 2.6 x 10^{-7} 2.4 x 10^{-7}	5.5 x 10^{-7} 2.6 x 10^{-7} 2.4 x 10^{-7}	8.9 x 10^{-9} 4.2 x 10^{-9} 3.9 x 10^{-9}	5.2 x 10^{-7} 2.5 x 10^{-7} 2.3 x 10^{-7}	5.2 x 10^{-7} 2.5 x 10^{-7} 2.3 x 10^{-7}
Population (person-rem per µCi released) East-southeast	7.3 x 10^{-4}	1.6 x 10^{-3}	1.6 x 10^{-3}	1.6 x 10^{-3}	2.7 x 10^{-5}	1.6 x 10^{-3}	1.6 x 10^{-3}
Noninvolved Worker (rem/µCi released) 1,300 ft (400 m) 2,500 ft (760 m)	4.7 x 10^{-7} 3.1 x 10^{-7}	1.0 x 10^{-6} 6.6 x 10^{-7}	1.1 x 10^{-6} 7.0 x 10^{-7}	1.1 x 10^{-6} 7.0 x 10^{-7}	1.7 x 10^{-8} 1.1 x 10^{-8}	1.0 x 10^{-6} 6.7 x 10^{-7}	1.0 x 10^{-6} 6.6 x 10^{-7}
Specific Activity (µCi/g)	5.3 x 10^{8}	1.7 x 10^{7}	6.2 x 10^{4}	2.3 x 10^{5}	1.0 x 10^{8}	3.9 x 10^{3}	1.8 x 10^{1}

[a] Includes all applicable exposure pathways described in table I-5.

[b] Release can be estimated as follows: inventory x fraction released x respirable fraction.

, and I-15 for ground-level, 330-ft (100-m), and 400-ft (120-m) releases, respectively.

I.4 REFERENCES CITED IN APPENDIX I

DOE (U.S. Department of Energy), 1994, *DOE Explosives Safety Manual*, DOE/EV/06194, August, Washington, D. C.

NIOSH (National Institute for Occupational Safety and Health), 1995, *NIOSH Pocket Guide to Chemical Hazards*, in Tomes-Toxicological, Occupational Medicine, and Environmental Series (CD-ROM), Database used: NIOSH Pocket Guide.

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APPENDIX J

TRANSPORTATION

This appendix discusses the methods, data, and results used to analyze the impacts of transporting test assemblies from the assembly facility to the firing site. With respect to transportation impacts, there are only two different transportation scenarios and analyses. The No Action and Upgrade PHERMEX alternatives, in which activities at the DARHT site would be terminated, are slightly different from the other alternatives, which would take place at the DARHT site. The No Action and Upgrade alternatives are discussed as the No Action Alternative while the other alternatives are discussed collectively as the DARHT Baseline Alternative.

J.1 SHIPPING SCENARIOS

The options for shipping test assemblies from the assembly facility to firing sites are discussed in this section. All scenarios assume that the test assembly is assembled by the WX division, and that the fully assembled test assembly would be transported via truck to the magazine for interim storage, and following interim storage would be transported via truck to the firing site. It was further assumed that only one test assembly would be transported at a time and all testing apparatus would be installed at the firing site. There may be up to six supporting equipment shipments associated with each test assembly detonation. These would not involve hazardous materials and would occur within the facility boundary; therefore, these supporting shipments have not been included in this analysis.

The test assembly would consist of a steel frame work, high explosive, and depleted uranium. Although the quantity of high explosives may vary per test assembly, it is assumed that the quantity of depleted uranium will remain constant. The test assemblies were assumed to be transported on a flat bed truck. Once the device is assembled, all testing equipment, consisting of x-ray triggering devices and the high explosives detonators, would be installed at the firing site. In accordance with U. S. Department of Transportation (DOT) regulations, the detonators would not be transported on the same vehicle as the high explosives.

The following subsections discuss the shipping scenarios, transportation and packaging systems, and the affected facilities.

J.1.1 Facilities

For both transportation scenarios, the test assembly would be assembled at the WX facility (TA-16-410) and transported to a magazine (Building R-242), which is used for interim storage. From the magazine, the test assemblies would be transported to the PHERMEX (No Action Alternative) or to the DARHT Facility (DARHT Baseline Alternative). These facilities were identified to estimate the consequences to LANL facility workers during normal or incident-free shipping and during shipping accidents.

J.1.2 Transport Scenario

The test assembly would be fully assembled, without detonators, by the WX division in TA-16-410 and transported to the PHERMEX or the DARHT Facility via truck on roads internal to TA-16 and TA-15. The fully assembled device would be loaded and secured at TA-16-410 on a flat bed truck and transported to a magazine (Building R-242). If required, the device could be staged at the magazine on the transport vehicle for a few hours with attending personnel before being shipped from the magazine to the receiving facility where it would be unloaded.

J.2 SHIPPING SYSTEM DESCRIPTION

This section describes the shipping container and the truck used to transport the test assembly. The information presented in this discussion focuses primarily on the parameters that would affect the analysis results, that is, the shipping container, the radionuclide inventory, the hazardous chemical inventory, and the quantity and characteristics of the high explosives.

The test assembly would be secured to a flat bed truck and would not be transported in a shipping container. The estimated radionuclide and hazardous chemical inventories for depleted uranium, beryllium, lead, copper, tritium, and lithium hydride are presented in section 3.11, table 3-4. It is anticipated that there would be 20 shipments per year, with a maximum of 110 lb (50 kg) depleted uranium per test assembly and a maximum annual usage of 1,540 lb (700 kg). The high explosives used in test assemblies may be sensitive to heat and impact. Three bounding test assemblies have been identified: Test Assembly 1 containing 22 lb (10 kg) high explosive, Test Assembly 2 containing 500 lb (230 kg) explosive, and Test Assembly 3 containing 1,010 lb (460 kg) high explosives. These larger high explosives tests were assumed not to contain any additional depleted uranium.

J.3 TRANSPORTATION ROUTE INFORMATION

The assembled test assemblies would be transported from TA-16-410 to the PHERMEX or the DARHT Facility using roads internal to TA-16 and TA-15. The truck would be loaded at TA-16-410 and transported nonstop approximately 5 mi (8 km) to the magazine (Building R-242). From the magazine, the test assembly would be transported nonstop approximately 1.2 mi (2 km) to the PHERMEX gate or 1 mi (1.5 km) to the DARHT gates. At each of the facilities, the test assembly would be transported approximately 1,600 ft (490 m) from the facility gate to the firing site. It was assumed that 10 people would be exposed to the shipment at each of the stops (i.e., magazine, and facility gates), and that approximately 60 percent of the route is through LANL open space (~5 workers/km^2) and 40 percent of the route is past occupied buildings (~360 workers/km^2). These assumptions were based on an examination of a LANL site map.

J.4 DESCRIPTION OF METHODS USED TO ESTIMATE CONSEQUENCES

This section describes the methods used to estimate the impacts to individuals at the LANL site due to transporting test assemblies for both incident-free and accident conditions. Any impacts would be due to exposures to radiological and hazardous materials and physical traumas from explosion of the highexplosives. The RADTRAN 4 (Neuhauser and Kanipe 1992) and GENII (Napier et al. 1988) computer codes were used to estimate radiological consequences. The hazardous material consequences were calculated by hand using the same site meteorological characteristics data used in the GENII analyses. The consequences associated with explosions of the high explosives were calculated using explosion modeling data presented in Rhoads et al. (1986).

J.4.1 RADTRAN 4 Computer Code

The RADTRAN 4 computer code (Neuhauser and Kanipe 1992) was used to perform the analyses of the radiological impacts of routine transport, and the integrated population risks of accidents during transport of the test assembly. RADTRAN was developed by Sandia National Laboratories (SNL) to calculate the risks associated with the transportation of radioactive materials. The original code was written by SNL in 1977 in association with the preparation of NUREG-0170, *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). The code has since been refined and expanded and is currently maintained by SNL under contract with DOE. RADTRAN 4 is an update of the RADTRAN 3 (Madsen et al. 1986) and RADTRAN 2 (Taylor and Daniel 1982; Madsen et al. 1983) computer codes.

The RADTRAN 4 computer code is organized into the following seven models (Neuhauser and Kanipe 1992):

- Material model

- Transportation model

- Population distribution model

- Health effects model

- Accident severity and package release model

- Meteorological dispersion model

- Economic model

The code uses the first three models to calculate the potential population dose from normal, incident-free transportation and the first six models to calculate the risk to the population from user-defined accident scenarios. The economic model is not used in this study.

J.4.1.1 Material Model

The material model defines the source as either a point source or as a line source. For exposure distances less than twice the package dimension, the source is conservatively assumed to be a line source. For all other cases, the source is modeled as a point source that emits radiation equally in all directions. The material model also contains a library of 59 isotopes, each of which has 11 defining parameters that are used in the calculation of dose. The user can add isotopes not in the RADTRAN library by creating a data table in the input file consisting of 11 parameters.

J.4.1.2 Transportation Model

The transportation model allows the user to input descriptions of the transportation route. A transportation route may be divided into links or segments of the journey with information for each link on population density, mode of travel (e.g., trailer truck or ship), accident rate, vehicle speed, road type, vehicle density, and link length. Alternatively, the transportation route also can be described by aggregate route data for rural, urban, and suburban areas. For this analysis, the aggregate route method was used for each potential origin-destination combination.

J.4.1.3 Health Effects Model

The health effects model in RADTRAN 4 is outdated and is replaced by hand calculations. The health effects are determined by multiplying the population dose (person-rem) supplied by RADTRAN 4 by a conversion factor (ICRP 1991).

J.4.1.4 Accident Severity and Package Release Model

Accident analysis in RADTRAN 4 is performed using the accident severity and package release model. The user can define up to 20 severity categories for three population densities (such as urban, suburban, and rural), each increasing in magnitude. Eight severity categories for Spent Nuclear Fuel containers that are related to fire, puncture, crush, and immersion environments are defined in NUREG-0170 (NRC 1977). Various other studies also have been performed for small packages (Clarke et al. 1976) and large packages (Dennis et al. 1978) that also can be used to generate severity categories. The accident scenarios are further defined by allowing the user to input release fractions and aerosol and respirable fractions for each severity category. These fractions are also a function of the physical-chemical properties of the materials being transported. The source term for RADTRAN 4 is adjusted to account for the presumed explosion in an accident scenario.

J.4.1.5 Meteorological Dispersion Model

RADTRAN 4 allows the user to choose two different methods for modeling the atmospheric transport of radionuclides after a potential accident. The user can either input Pasquill atmospheric-stability category data or averaged time-integrated concentrations. In this analysis, the dispersion of radionuclides after a potential accident is modeled by the use of time-integrated concentration values in downwind areas compiled from meteorological data acquired in TA-6.

J.4.1.6 Routine Transport

The models described above are used by RADTRAN 4 to determine dose from routine transportation or risk from potential accidents. The public and worker doses calculated by RADTRAN 4 for routine transportation are dependent on the type of material being transported and the transportation index (TI) of the package or packages. The TI is defined in 49 CFR 173.403(bb) as the highest package dose rate in millirem per hour at a distance of 3.3 ft (1 m) from the external surface of the package. Doseconsequences are also dependent on the size of the package, which, as indicated in the material model description, will determine whether the package is modeled as a point source or line source for close-proximity exposures.

J.4.1.7 Analysis of Potential Accidents

The accident analysis performed in RADTRAN 4 calculates population doses for each accident severity category using six exposure pathway models. They include inhalation, resuspension, groundshine, cloudshine, ingestion, and direct exposure. This RADTRAN 4 analysis assumes that any contaminated area is either mitigated or public access controlled so the dose via the ingestion pathway equals zero. The consequences calculated for each severity category are multiplied by the appropriate frequencies for accidents in each category and summed to give a total point estimate of risk for a radiological accident.

J.4.2 GENII

GENII (Napier et al. 1988), which is also referred to as the Hanford Environmental Dosimetry Software System, was developed and written by the Pacific Northwest Laboratory to analyze radiological releases to the environment. GENII is composed of seven linked computer programs and their associated data libraries. This includes user interface programs, internal and external dose factor generators, and the environmental dosimetry programs. GENII is capable of calculating:

- Doses resulting from acute or chronic releases, including options for annual dose, committed dose, and accumulated dose

- Doses from various exposure pathways evaluated including those through direct exposure via water, soil, and air as well as inhalation and ingestion pathways

- Acute and chronic elevated and ground level releases to air

- Acute and chronic releases to water

- Initial contamination of soil or surfaces

· Radionuclide decay

The pathways considered in this analysis include inhalation, submersion (in explosive cloud), and external exposures due to ground contamination.

J.4.3 Explosives Model

The explosive effects model was taken from Rhoads et al. (1986), which evaluated the effects produced by TNT explosions. The physical effects of explosions are related to the blast pressure, which will decrease with distance from the point of explosion. The assessment contained in Rhoads et al. assumed that a 27 lb/in^2 (186 kPa) peak overpressure was 100 percent fatal. Assuming that the blast wave expands equally from the center point, the distance to the peak overpressure for an unconfined explosion can be calculated using the following formula:

$$D = ZW^{1/3}$$

where D is the distance from the blast, Z ($ft/lb^{1/3}$) ($m/kg^{1/3}$) is the scaled range and W is the TNT equivalent of the explosion. For this assessment, Z was assumed to be equal to 5.5 $ft/lb^{1/3}$ (3.7 $m/kg^{1/3}$), which corresponds to a peak overpressure of 27 lb/in^2 (186 kPa).

J.4.4 Microshield

Microshield (Grove Engineering 1988) was used to analyze the shielding of gamma radiation in such areas as shielding design, container design, temporary shielding selection, source strength inference from radiation measurements, ALARA planning, and teaching. This program is a microcomputer adaptation of the main frame code ISOSHLD, a public domain "point kernel" code first written in the early 1960s. Microshield was used in this analysis to calculate the TI or estimated dose rate (mrem/h) at 3 ft (1 m) from the test assembly. This estimated dose rate is required in RADTRAN to calculate doses to truck crews and onsite and offsite individuals during routine transportation. The depleted uranium was modeled as a solid spherical source, approximately 8 in (20 cm) in diameter, shielded by plastic (high explosives). Table J-1**Table J-1.-*Microshield Input Data***

Input Parameter	**Value**
Sphere radius (cm)	25 (10)
Shielding material[a] - Plastic (cm)	2.5 (1)
Distance to receptor (cm)	250 (100)

Radionuclides (Ci)[b]:	
Th-231 Th-234 Pa-234 Pa-234m U-234 U-235 U-238	$2.5 X 10^{-4}$ $1.7 X 10^{-2}$ $1.7 X 10^{-2}$ $1.7 X 10^{-2}$ $1.9 X 10^{-3}$ $2.5 X 10^{-4}$ $1.7 X 10^{-2}$

[a] Modeled as water.

[b] Appendix H.

Table J-2.-*Input Parameters for RADTRAN and Explosives Model*

Parameter	Value
Fraction of travel time, rural population zone[a]	60
Fraction of travel time, suburban population zone[b]	40
Fraction of travel time, urban population zone	0
Dose rate at 3.3 ft from package (mrem/h)[c]	$5.9 x 10^{-1}$
Length of package (ft)	13

Velocity (mi/h)	35
Number of crewmen	2
Distance from source to crew	10
Stop time per mi, h/mL (1hr/stop 2 stops/trip)	0.27
Persons exposed while stopped	10
Average exposure distance while stopped (ft)	66
Shipments per year	20

[a] Data taken from Romero and Jolly (1989).

[b] Estimated percentages based on a review of site layout drawings. For the purposes of this analysis the suburban population zone is used to characterize onsite activities.

[c] The dose rate from the package at 1 m calculated using microshield (Grove Engineering 1988).

presents the input data used to determine the dose rate at one meter.

J.4.5 Analysis Input Parameters

Table J-2 presents the input parameters used to perform the incident-free and accident analysis using the RADTRAN computer code.

J.5 ANALYSIS OF INCIDENT-FREE (ROUTINE TRANSPORTATION) IMPACTS

The following section discusses the radiological and nonradiological impacts to the truck crew and the public during incident-free or routine transportation of the test assembly. The impacts due to interim storage of the test assembly at the magazine, if necessary, are not addressed in this analysis. The results of the analyses are presented in section 5.7.

J.5.1 Radiological Impacts due to Routine Transportation Activities

The radiological doses to the truck crew, onsite worker, and the public due to transportation activities were calculated using RADTRAN 4 (see section J.4.1). As discussed in section J.4.1, RADTRAN 4 uses a combination of meteorological, demographic, health physics, transportation, packaging, and material factors to analyze the risk due to incident-free transport activities. Input data used to perform the analysis are shown in section 5.7 and tables J-1 and J-2.

The calculated annual dose is based on 20 shipments per year. The dose to the truck crew for the No Action Alternative would be 6 x 10^{-6} person-rem for each shipment or 1 x 10^{-4} person-rem annually. The calculated dose to the public would be less than 1 x 10^{-10} person-rem and for this analysis is considered zero. The total dose to the onsite worker population for the No Action Alternative would be 2 x 10^{-4} person-rem for each shipment or 3 x 10^{-3} person-rem annually.

The potential health effects or latent cancer fatalities (LCFs) were calculated using the methodology described in ICRP 60 (1991), i.e., 4.0 x 10^{-4} LCFs/person-rem to the onsite worker and truck crew respectively. The annual health effects for truck crews, were estimated to be 4 x 10^{-8} (No Action Alternative) and 4 x 10^{-8} (DARHT Baseline Alternative). The annual health effects for the onsite worker, were estimated to be 1 x 10^{-6} and 1 x 10^{-6} for the No Action and DARHT Baseline alternatives, respectively.

J.5.2 Nonradiological Impacts due to Routine Transportation Activities

Impacts to the public from nonradiological causes were also evaluated. This included fatalities resulting from pollutants emitted from the vehicles during normal transportation. Based on the information contained in Rao et al. (1982), the types of pollutants that are present and can impact the public are sulfur oxides (SO_x), particulates, nitrogen oxides (NO_x), carbon monoxide (CO), hydrocarbons (HC), and photochemical oxidants (O_x). Of these pollutants, Rao et al. (1982) determined that the majority of the health effects are due to SO_x and the particulates. Unit risk factors (fatalities per kilometer) for truck shipments were developed by Rao et al. (1982) for travel in urban population densities (1.0 x 10^{-7}/km for truck). Although, this unit risk factor is for urban population densities, it was combined with the total shipping distance past occupied buildings [40 percent of the total distance of 2.5 and 2.4 mi (4 and 3.8 km) for the No Action and DARHT Baseline alternatives, respectively] to calculate the nonradiological routine impacts to the public. Based on travel distances per shipment or per year, the estimated number of fatalities due to routine nonradiological impacts, as presented in section 5.7, table 5-17, are very low (roughly 4.0 x 10^{-7} per shipment or 8 x 10^{-6} annually).

J.6 ANALYSIS OF TRANSPORTATION ACCIDENTS

The following section discusses the potential radiological and nonradiological impacts due to transportation accidents. Radiological accident impacts to the collective population (public) were calculated using the RADTRAN 4 computer code (Neuhauser and Kanipe 1992). The radiological impacts to a nearby individual and the maximally exposed individual (MEI), both onsite and offsite, were performed using GENII (Napier 1988). For analysis purposes, the nearby individual was assumed to be located 330 ft (100 m) from the point of release, the onsite MEI was assumed to be located at the nearest occupied facility, and the offsite MEI was assumed to be located at the site boundary. This scenario assumes that the high explosives detonate and the depleted uranium is released to the environment.

J.6.1 Radiological Impacts to the Public from Transportation Accidents

This section describes the analyses performed to assess radiological impacts to the public from transportation accidents.

J.6.1.1 Radiological Impacts to the Public

For these analyses the impacts were expressed as MEI doses or as integrated population risks. The integrated population risk was determined by multiplying the expected consequences by the accidentfrequency integrated over the entire shipping campaign or estimated number of shipments annually. The potential consequences to the population from transportation accidents were expressed in terms of radiological dose and LCFs. Typically these impacts can result from breaches in the shipping cask or damage to the cask shielding; however, in this analysis these impacts would be due to detonation and release of the radiological materials.

Once the material is released to the environment it would be dispersed and diluted by weather action and a small amount would be deposited on the ground due to plume depletion. Access to the area adjacent to the transportation accident would be controlled by emergency response personnel until the area could be remediated and the radiation monitoring personnel have declared the area safe.

The input data used to calculate the radiological dose to the public (i.e., population densities, travel times and distances) were the same as the inputs used to calculate the incident-free dose to the population and are discussed in section J.4.1. The accident frequency used in the analysis was based on a review of local or state specific accident data. It was assumed, because of the characteristics of the high explosives, that all transportation accidents were severe enough to detonate the high explosives and result in a release to the environment. This was a conservative assumption that would tend to overstate the expected consequences. The initial accident data [or rates expressed as accidents/mi (accidents/km)] used in this analysis were taken from Saricks and Kvitek (1994) for the state of New Mexico. The accident rate used, 3.78×10^{-7} accidents/mi (2.35×10^{-7} accidents/km), was a combination of accident rates for rural and urban federally aided highway systems.

It was assumed that 10 percent of the material in a test assembly was aerosolized and respirable (appendix H).

Radiological doses were calculated using RADTRAN for the two population densities of interest (i.e., LANL open space and occupied buildings). The calculated dose, on a per shipment basis, to the two populations was estimated to be 2.4 x 10^{-1} person-rem and 1.7 x 10^{1} person-rem, respectively. The integrated risk to the public (i.e., consequences times accident frequency integrated over the entire shipping distance) was estimated to be 9.8 x 10^{-5} person-rem and 9.3 x 10^{-5} person-rem for the No Action Alternative and DARHT Baseline Alternative, respectively.

J.6.1.2 Radiological Impacts to Individuals

In addition to the radiological dose to the collective population, the LANL site was reviewed to identify an onsite MEI, i.e., an individual located at the nearest occupied facility, and offsite MEI, i.e., an individual located at the site boundary. For this analysis, based on the location of the site boundary and the nearest public roadway and the meteorological data, the offsite MEI was assumed to be located approximately 1 mi (1.5 km) to the northwest and north-northwest. The location is dependent on the median effective release height (see appendix H.1). Meteorological data for TA-6 at LANL is used in the dose consequence analyses.

The location of the maximally exposed onsite worker, was determined by reviewing the LANL site drawings with respect to the location of the PHERMEX and DARHT facilities. It was assumed that the onsite MEI is located 0.50 mi (0.75 km) to the northwest and north-northwest.

Radiological accident impacts to the offsite and onsite MEIs and the MEI were calculated using GENII (Napier 1988). The source term for GENII is adjusted to account for the presumed explosion in an accident scenario; the adjustment takes the form of specifying a median effective release height. To calculate the impacts to the receptor, a median effective release height of 327 ft (99 m), 713 ft (216 m), and 848 ft (257 m) was used for Test Assembly 1, Test Assembly 2, and Test Assembly 3, respectively. This was calculated using the methodology described in appendix H. The results of the radiological analyses to the MEIs are presented in section 5.7, table 5-19.

In the past, DOE has conducted dynamic experiments at LANL with plutonium. Any future experiments with plutonium would always be conducted in double-walled containment vessels; these experiments would not reasonably be expected to result in any release of plutonium to the environment. DOE has evaluated the potential impacts of two types of accidents that could involve plutonium - inadvertent detonation and containment breach. This analysis is documented in a classified supplement to this EIS; and results, unclassified calculations, and assumption and modeling methods are included in appendix I, section I.3.2, and in applicable sections of chapter 5.

The bounding accident for accidents during transportation of materials was assumed to be a hypothetical detonation of a plutonium experiment while outside of its double containment vessel. The impacts were calculated as if the event took place at the PHERMEX or DARHT site (rather than at some other location within LANL where the experimental device might be handled) because these sites are closest to the LANL boundary. The impacts would be the same regardless of whether this accident took place at the PHERMEX site or the DARHT site. Such an accident has never happened nor has any mechanism been identified that would initiate such an event, hence it was examined only as a "what if?" accident. Related DOE safety studies indicate that the probability of an accidental uncontained detonation of the type analyzed would be less than 10^{-6} per year, which is considered to be an incredible event.

Because, under this scenario, detonation of the explosive would be uncontained, the release was modeled as a 330-ft (100-m) elevated release (see Appendix I). The MEI, located at State Road 4, could receive up to 76 rem in the event of an accident. The maximum probability of a LCF occurring in this hypothetical individual would be 0.04. The dose to the potentially maximally exposed sector of the population, east-southeast of the DARHT and PHERMEX sites that includes the communities of White Rock and Santa Fe, could be between 9,000 and 24,000 person-rem, taking into consideration the 50th and 95th percentile meteorology, respectively. Between 5 and 12 LCFs would be projected from radiation doses such as these to the population.

J.6.2 Nonradiological Impacts to the Public from Transportation Accidents

This section describes the analyses performed to assess nonradiological impacts to the public and the MEIs.

J.6.2.1 Nonradiological Impacts

The vehicle travel speed is limited to 35 mi/h (56 km/h); therefore, vehicle impacts are not considered severe enough to cause fatalities to the truck occupants or occupants of other vehicles involved in theaccident. For the purposes of this analysis it was assumed that the transport vehicle impacted a stationary object with sufficient force to detonate the high explosive.

The lethal limits due to the blast wave were estimated using the formula and assumptions discussed in section J.4.3 and the high explosive inventories discussed in section 5.7. The impacts due to explosions were modelled for each of the test assemblies. Assuming that a peak overpressure of 27 lb/in^2 (186 kPa) is fatal, all individuals within an approximate radius of 15 ft (5 m), 43 ft (13 m), and 53 ft (16 m) for test assemblies 1, 2, and 3, respectively, would be subjected to potentially fatal overpressures. This would include the truck crews which are assumed to be located within 33 ft (10 m) of the test assembly. In addition to impacting the truck crew, depending on the quantity of high explosive involved, 50 percent of the individuals at distances up to 80 ft (24 m) could be killed due to the blast wave. Individuals located further away may not be impacted by overpressure but could be seriously injured or killed by fragments ejected by the detonation.

In addition to evaluating the impacts from a detonation of the high explosives, an assessment of the consequences of a release of the hazardous materials identified in section 5.7, was performed. The release fraction and percentage respirable was the same release fraction used for the depleted uranium; 10 percent of the total material in the device was assumed respirable. The results, based on the meteorological data for the LANL site, are shown in section 5.7, table 5-18. For comparison, although plume passage times are very short in duration, the immediately dangerous to life and health (IDLH) exposure limits are also provided in table 5-18.

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APPENDIX K

THREATENED AND ENDANGERED SPECIES

CONSULTATIONS

This appendix describes the consultation process between the Department of Energy (DOE) and the U. S. Fish and Wildlife Service (USFWS) associated with the DARHT EIS. It also summarizes the biological assessment prepared by the Los Alamos National Laboratory (LANL) in July 1995 (Keller and Risberg 1995). The following sections discuss the threatened, endangered, or sensitive species that could potentially inhabit the proposed area, and mitigation measures to minimize potential impacts to those species.

K.1 INTRODUCTION

Under the Endangered Species Act (ESA) of 1973 [16 USC 1531-1544], Federal agencies are required to consult with the USFWS to ensure that a proposed action is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of critical habitat of such species.

The Section 7 consultation process involves the identification of the possible presence of a listed or proposed species or their critical habitat that could be affected by the proposed action. If present, a biological assessment is prepared to determine whether the proposed action is likely to adversely affect listed or proposed species or designated or proposed critical habitat and to consider modifications to the action that would avoid adverse impacts. Concurrence is requested from the USFWS if the action is not likely to adversely affect listed species or designated critical habitat. An "is likely to adversely affect" determination requires formal Section 7 consultation and a resulting biological opinion.

A biological assessment was prepared by LANL in May of 1995 (Keller and Risberg 1995) for completion of the DARHT Facility. This was forwarded to the USFWS for review. Following this initial submission, the Mexican spotted owl, a federally threatened species, was sighted within two miles of the proposed DARHT Facility area. The biological assessment was revised to include the new information on the owl and submitted to USFWS in July, 1995. The letter enclosed with the revised biological assessment requested that the USFWS (exhibit 1) concur with the DOE's determination that the proposed DARHT site will not likely adversely affect any endangered or threatened species, or modify their critical habitat as provided under 50 CFR 402.14b. After reviewing the biological assessment, concurrence was provided by the USFWS (exhibit 2).

The potential for occurrence of each threatened, endangered, and candidate species potentially inhabiting the area surrounding the DARHT site was systematically analyzed. It was determined that suitable habitats (e.g. water courses, riparian vegetation, and open grassland) are not found in the proposed project area for all potential species. This eliminated some species from consideration as shown in table 1 of the biological assessment. This assessment lists those species that have no potential for occurrence in the project area because of lack of a suitable habitat. Due to variations in findings by different researchers atvarious times, these species are included as potential Threatened and Endangered Species by other researchers (Dunham 1995, Risberg 1995) and are indicated in table 4-12.

K.2 AFFECTED ENVIRONMENT

The proposed DARHT project is located at LANL's TA-15, Area 3, in the central portion of LANL (see figure 4-1). Habitat in the proposed area is potentially suitable for 11 federal or state protected species.

K.2.1 Threatened, Endangered, and Sensitive Animal Species

Several threatened, endangered, or sensitive species inhabit, or potentially inhabit, the proposed DARHT area. Federal candidate species previously found (Dunham 1995), and thus having a high potential for inhabiting the area, include four species of bats; the long-eared myotis, fringed myotis, long-legged myotis, and Yuma myotis (see table 4-12). The state endangered, federal candidate wildlife that have a low potential for inhabiting the area are the spotted bat, New Mexican jumping mouse, and the Jemez Mountains salamander. The federal candidate species that has a moderate potential for inhabiting the area is the northern goshawk. The peregrine falcon is a federal and state endangered species that has a low potential for occurrence.

As stated, the federally threatened Mexican spotted owl has been observed within 2 mi (3.2 km) of the proposed DARHT site. A nesting site has been confirmed to be greater than 0.25 mi (0.4 km) from the construction site. Additional suitable nesting habitat lies within 0.25 mi (0.4 km) of the proposed area, and all of the area within 0.5 mi (0.8 km) of DARHT is suitable foraging habitat.

K.2.2 Other Protected Animal Species

There are confirmed nesting sites and hunting areas for two raptors: the red-tailed hawk, and Cooper's hawk in the general TA-15 area. Other species, such as the American kestrel, the flammulated owl, and the great-horned owl are known to use the area. All these birds are protected by the Migratory Bird Treaty Act and New Mexico Statutes Annotated, Chapter 17-2-14.

K.2.3 Threatened, Endangered, and Sensitive Plant Species

No rare, threatened, or endangered plant species have been found; however, it was determined that the checker lily and wood lily, both state endangered, could occur in the area because the habitat is suitable.

K.3 POTENTIAL IMPACTS

The following sections describe potential construction and operation impacts on the threatened and endangered species in the DARHT area.

K.3.1 Potential Construction Impacts

The biological assessment describes construction and operation impacts or protected species in the DARHT area.

Construction of the DARHT Facility has led to the loss of 7 ac (2.8 ha) of ponderosa pine/piñon-juniper habitat. This vegetation removal has resulted in minimal loss of foraging habitat and without mitigation could result in erosion on the mesa top and possibly into the adjacent canyon bottoms. Erosion control measures are in place to prevent slope disturbance during construction activities. Permanent erosion control measures will be implemented. Under the Enhanced Containment Alternative, an additional 1 ac (0.4 ha) of habitat would be altered due to construction of the vessel cleanout facility.

Construction noise and lighting could also disturb potential nesting and foraging habitats for a variety of species from several trophic levels. Noise from vehicular traffic and construction equipment could lead to both temporary and possibly permanent avoidance of the area by some wildlife species. Lighting would be used during some phases of construction, which could possibly increase predation on certain wildlife species during the breeding season or act as an artificial attractant to others.

The species that could potentially be most affected by construction activities would be the Mexican spotted owl. Foraging habitat has been diminished by DARHT construction, but this habitat loss is insignificant when compared to the existing overall foraging range. Excessive noise, above expected values, during the breeding and nesting season (March 1 to August 31) could disturb any nesting owls nearby, possibly causing nest failure, and could discourage future colonization of the area by the owls. Maximum noise levels from construction at the site would translate into a noise level of 41 dBA in the Mexican spotted owl habitat. These noise levels are well within the normal background levels in this canyon system. Therefore, the noise associated with construction of the facility would not likely adversely affect the Mexican spotted owl. The northern goshawk, if present, could also be disturbed by excessive noise during the mating and nesting season, which could lead to nest abandonment and nest failure.

Although no spotted bats, Jemez Mountains Salamanders, or New Mexican jumping mice have been identified in the DARHT project area, suitable canyon habitat exists for these species nearby. It is unlikely that completion of the project would adversely affect these habitats. Soil erosion could affect nearby streams or water sources, thus affecting potential foraging areas and habitat.

No suitable nesting habitat for the peregrine falcon exists within the range of the proposed DARHT Facility. Previous removal of 7 ac (2.8 ha) of foraging habitat has occurred, but this is very small compared to the total foraging area available to the peregrine falcon. Future DARHT construction activities would have little adverse effect on the peregrine falcon habitat.

Because most of the groundbreaking activities and tree removal have already occurred, future construction at the DARHT site would not be expected to cause any significant impacts to plants, unless vehicles are driven off established roads and large staging areas are situated in undisturbed habitat.

The many construction activities at LANL have caused significant changes in the land use of many wildlife species. If completed, a fence around the DARHT perimeter may segregate an area on the mesa top, possibly cutting off daily and/or seasonal travel corridors to wintering areas, breeding habitat, foraginghabitat, bedding areas, and other necessary travel corridors. Construction may also disturb other nesting bird species in the DARHT project area.

K.3.2 Potential Operational Impacts

The DARHT project could have an increased cumulative impact when added to the disturbance from existing projects in the surrounding area. Operation would consist mainly of small amounts of time with a great deal of activity and then long periods of time with little activity. The activities at the facility would include vehicles used to set up an experiment (e.g. delivery trucks and cranes for larger experiments) and office building activity (e.g. normal vehicle traffic).

The only threatened, endangered, or sensitive species potentially affected by DARHT operations would be the Mexican spotted owl. Noise from nighttime activity could cause a greater impact at the proposed DARHT Facility than the same noise level generated during the day. Noise from an experiment would be comparable to the sound of thunder, approximately 80 dbA at 0.25 mi (0.4 km). All the secondary activity associated with an experiment would make less noise than that generated by construction. Additionally, the current experiments in the area seem to have little effect on the current success of the Mexican spotted owl habitat.

Two other impacts are possible as a result of DARHT operations. First, an increase in light pollution from outdoor lighting at the facility could decrease nighttime Mexican spotted owl prey activity and availability. The second impact is the possibility of an owl being hit by flying debris or fragments from a test event. The probability of a hit is approximately 1/8,500 shots at 600 ft (183 m) from the firing point, 1/600,000 at 800 ft (245 m), and 1/10 million at 1,200 ft (365 m).

Operation of the proposed DARHT Facility would not be expected to affect vegetation, but could possibly change any established migration corridors and foraging areas of deer, elk, mountain lion, black bear, bobcat, and various bird species.

Contaminants that could result from operation of the DARHT Facility might potentially affect both threatened and nonthreatened wildlife species through a number of pathways. Radionuclides adsorb to soils and sediments; aerial redistribution could transport radionuclides, or erosional processes might move the radionuclide-contaminated soils from slopes to stream channels by surface water runoff. Fragments could affect wildlife, both directly (by being hit by an exploded fragment) and indirectly (by being exposed to any radiological contamination from the fragments).

K.4 MITIGATION

This section describes the mitigation measures that have been implemented or would be implemented if the proposed DARHT Facility were to be completed and operated. Mitigation measures include a Storm Water Pollution Prevention Plan (SWPPP) for the facility which was implemented before construction activities commenced. The plan includes measures for erosion control (temporary and permanent), sedimentation control, surface restoration and revegetation, storm water attenuation in paved and unpaved areas, and a Best Management Plan. The Best Management Plan includes good housekeeping practices,minimization of fuel and oil spills, and control of stored materials and soil stockpiles. All storm water pollution prevention mitigations will be maintained until the site is fully recovered.

K.4.1 Threatened, Endangered, and Sensitive Species

The DOE, through LANL's Environmental Safety and Health Division (ESH) would develop a LANL-wide Habitat Management Plan for all threatened and endangered species occurring on LANL property. This plan would be used to determine the combined effects of the many projects that occur at LANL and provide long-range planning information for all future projects. Any proposed action at LANL that may affect a threatened, endangered, or sensitive species or its habitat would be coordinated with the USFWS. In the event of an emergency (e.g. a fire, flood, or storm), LANL would not need to formally consult with USFWS before responding to the incident. Instead, action may be taken immediately to control or contain the emergency and then LANL would contact USFWS as soon as reasonably possible [50 CFR 402.05].

The mitigation measures described in the following sections will be used to protect the habitat of threatened, endangered, or sensitive species and other wildlife and may become part of the Mitigation Action Plan supporting the NEPA Record of Decision for the DARHT Facility.

K.4.1.1 Mexican Spotted Owl

Part of the LANL-wide Habitat Management Plan would provide for long-term monitoring by the ecological studies team of Mexican spotted owl habitat in Potrillo, Valle, and Fish-ladder canyons, and would include sample collection (e.g., sound levels, soils, plants, small mammals, and owl pellets) for monitoring possible contaminant loading of the ecosystem. The plan would also provide long-term monitoring of Mexican spotted owl reproduction.

Minimal impact to the Mexican spotted owl is expected from construction or operation activities at the proposed DARHT Facility, even if a nest is located within 0.25 mi (0.4 km) of the facility. The following mitigation measures would be necessary to ensure no adverse impacts result from construction activities.

· The LANL ecological studies team must be contacted prior to any new removal of mature trees (live or snag) to determine the potential impact to nesting Mexican spotted owls. If no impact is determined, the tree removal will be allowed. If impacts are thought likely to occur, the proposed tree removal must be postponed until the following breeding season (March 1 to August 31).

· No additional habitat will be disturbed within 0.25 mi (0.4 km) of known Mexican spotted owl nesting habitat.

· Construction light sources will be arranged so that light is not directed toward the canyons, or is shielded, during the breeding season (March 1 to August 31).

· Construction noise associated with the facility will be restricted as much as possible at night.

· Noise from construction equipment will be kept as quiet as possible so as not to disturb normal Mexican spotted owl activities and will be directed away from the canyons as much as possible.

· Equipment associated with construction will remain at least 25 ft (8 m) from the surrounding canyon edges during the breeding season (March 1 to August 31).

· Construction personnel will not be allowed beyond the canyon edges.

· Flowchecks will be constructed to slow the rate of any water (e.g. storm water or construction water) released in the canyons originating from the facility; and native vegetation will be planted, as appropriate, to prevent erosion associated with this water release.

· Native trees will be planted, as appropriate, along roads, disturbed canyon edges, and the edges of parking lots.

· A warning siren will be placed on the mesa side of the facility.

· Construction equipment will be well maintained and kept as quiet as reasonably possible.

Each year the LANL ecological studies team would conduct a Mexican spotted owl survey to determine any owl nesting activity in the area. Once a known nest location is determined, this information would be used to evaluate any proposed nighttime shot activity at DARHT.

The following mitigation measures are necessary to ensure no adverse impacts result from operational activities.

· Lights used during shot setup will be directed away or shielded from the canyons.

· Operational and setup noise (e.g., air conditioning cooling fans and electrical generators) will be kept at a minimal level at night, so as not to disturb normal Mexican spotted owl activities, and will be directed away or shielded from the canyons as much as possible.

· Night shots will be conducted during the breeding season (March 1 to August 31), only if the nest is located more than 0.25 (0.4 km) from the proposed facility; a limited number of night shots (no more than one per month) would then be permitted during the breeding season.

· Equipment associated with the facility operations will remain at least 25 ft (8 m) from the surrounding canyon edge.

· Operations personnel will be restricted to the mesa top and will not be allowed beyond the canyon edges, except as allowed by the LANL ecological studies team for specific fragment removal operations.

· Flowchecks will be maintained to slow the rate of the released water in the canyons originating from the facility.

· Water flow from the facility will be monitored to ensure compliance with permitted outfalls.

· Glass plates or other shielding material will be used during large uncontained shots to break up fragments, buffer noise, and limit contaminant release to the Mexican spotted owl habitat.

· Operational equipment will be well maintained and kept as quiet as reasonably possible.

· The LANL ecological studies team must be notified in order to conduct an owl survey, prior to conducting any activities, such as fragment removal in or on the slopes of canyons used by the Mexican spotted owl. If no nesting Mexican spotted owls are found, the activity will be allowed; if a nest is found, the activity will not be allowed until after the breeding season (March 1 to August 31).

K.4.1.2 Northern Goshawk

To preserve goshawk habitat, the following mitigation measures are necessary.

· The LANL ecological studies team must be contacted prior to any new removal of trees (live or snag) to determine impact to the nesting and foraging habitat of the northern goshawk. The vegetation, such as shrubs and grasses, in the canyons and on the mesa top surrounding the facility will be preserved.

· The LANL ecological studies team will provide long-term monitoring of potential goshawk habitat in Potrillo and Valle canyons.

K.4.1.3 Spotted Bat

To protect suitable bat habitat, the following mitigation measure is necessary.

· The ecological studies team must be notified to conduct a survey, prior to any activities that would disturb the slopes of Potrillo, Valle, or Water canyons. If no spotted bats are found, the activity will be allowed; if a spotted bat is found, the activity will not be allowed until after the breeding season.

K.4.1.4. New Mexican Jumping Mouse

To protect the habitat of the New Mexican jumping mouse, the following mitigation measure is necessary.

· The LANL ecological studies team must be notified to conduct a habitat evaluation, prior to any activities that would disturb the canyon bottoms of Potrillo, Valle, or Water canyons. If no meadow jumping mice are found, the activity will be allowed; if a New Mexican jumping mouse is found, the activity will not be allowed until after the time of their highest activity (June to July).

K.4.1.5 Jemez Mountains Salamander

To protect the habitat of the Jemez Mountains salamander, the following mitigation measures are necessary.

· The LANL ecological studies team must be notified to conduct a survey, prior to any activities that would disturb the slopes of Potrillo, Valle, or Water canyons. If no Jemez Mountains salamanders are found, the activity will be allowed; if a Jemez Mountains salamander is found, the activity will not be allowed during the time of their highest activity (June to September).

· The LANL ecological studies team must be contacted prior to any removal of trees (live, snag, or downed log) at the DARHT site to determine the impact to Jemez Mountains salamander habitat. If no Jemez Mountains salamander habitat is found, the activity will be allowed; if a Jemez Mountains salamander is found, the activity will not be allowed during the time of their highest activity (June to September).

K.4.1.6 Peregrine Falcon

To protect the habitat of the peregrine falcon, the following mitigation measures are necessary.

· The LANL ecological studies team must be contacted prior to any removal of trees (live or snag) at the DARHT site to determine impact to peregrine falcon foraging habitat. If no peregrine falcons are found, the activity will be allowed; if a peregrine falcon is found, the activity will not be allowed until after the breeding season (March to September).

· The ecological studies team must be notified to conduct a survey, prior to any activities that would disturb the slopes of Potrillo, Valle, or Water canyons. If no peregrine falcons are found nesting, the activity will be allowed; if a peregrine falcon nest is found, the activity will not be allowed until after the breeding season (March to September).

K.4.2 Nonprotected Species

The following sections describe mitigation measures that would be used to minimize adverse impacts to nonprotected plants and wildlife.

K.4.2.1 Plants

Because most groundbreaking and tree removal at the DARHT site is already complete, additional damage to plants would be minimal. Measures have been taken and will continue to be implemented to minimize future erosion. In general, workers must avoid off-road activity and stay within approved right-of-ways except during cleanup procedures. Any proposed activities requiring the disturbance of mature trees and shrubs or new groundbreaking must first be approved by the LANL ecological studies team. The ecological studies team will review all new sites, evaluate any proposed impacts associated with the action, and provide mitigation measures to minimize potential impacts. Revegetation, as addressed in the SWPPP, would be required so that the loss of vegetation would not initiate or increase erosion.

In addition to the mitigation measures, the size of a vegetation buffer zone between the facilities and the edges of the mesa tops will be determined by the LANL ecological studies team based on topographic aspects and vegetation composition; this is to prevent runoff from eroding adjacent canyons.

K.4.2.2 Wildlife

Temporary fencing is currently in place surrounding the DARHT Facility. Any future installation of impenetrable security fencing could possibly affect wildlife movements; project managers must consult with the LANL ecological studies team to minimize effects on large mammal and predator species movements. The ecological studies team will provide site-specific measures regarding the construction of fences and other barriers to facilitate the movement of wildlife, as appropriate.

In addition to the committed SWPPP mitigation measures, personnel would avoid cutting any standing tree (live or snag) unless the LANL ecological studies team has given approval.

K.4.3 Contaminants

To monitor for expected contaminant releases, the LANL ecological studies team will perform the following activities.

· During the construction phase of the facility, baseline data will be collected on any contaminants present at the facility and in the surrounding areas from soils, plants, mammals, birds, and roadkill, as well as at a control site away from the DARHT Facility.

· Once the facility is operational, the ecological studies team will monitor contaminants by sampling soils, plants, mammals, birds, and roadkill at the above mentioned locations once per year, or as appropriate.

K.5 REFERENCE CITED IN APPENDIX K

Keller, D.C., and D. Risberg, 1995, Draft Biological and Floodplain/Wetland Assessment for the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility, July, LAUR-95-647, Los Alamos National Laboratory, Los Alamos, New Mexico.

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