Draft Final Report of the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) Project

Prepared for the Centers for Disease Control and Prevention (CDC)
National Center for Environmental Health
Division of Environmental Hazards and Health Effects
Radiation Studies Branch

June 2009
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Prepared as a team effort by individuals from:
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June 2009
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## LIST OF ACRONYMS, INITIALISMS, AND ABBREVIATIONS

**25** Early code name for uranium-235;
(from the isotope’s atomic number (92) and atomic weight (235))

**28** Early code name for uranium-238;
(from the isotope’s atomic number (92) and atomic weight (238))

**37** Early code name for neptunium-237
(from the isotope’s atomic number (93) and atomic weight (237))

**49** Early code name for plutonium-239
(from the isotope’s atomic number (94) and atomic weight (239))

**410** Early code name for plutonium-240
(from the isotope’s atomic number (94) and atomic weight (240);
i.e., one higher than 239, hence the 10)

**ACIS** Automated Chemical Inventory System

**ADWEM** Associate Laboratory Directorate for Nuclear Weapons Engineering and Manufacturing- formerly ALDNW

**AEC** U.S. Atomic Energy Commission (DOE predecessor agency)

**AIRNET** A LANL network of ambient air sampling stations

**AKA** “also known as”

**ALDNW** Former Office of Associate Laboratory Directorate for Nuclear Weapons

**ANP** Aircraft Nuclear Propulsion

**ARF** Atmospheric Release Fraction

**ATSDR** Agency for Toxic Substances and Disease Registry

**BR Site** Bruns Railhead Site (in Santa Fe, NM)

**BZ** Breathing Zone

**CAS** Chemical Abstracts Service, a registry for chemicals

**Case** Early code word for curie, especially when referring to polonium shipments
("200 cases of Postum” meant 200 curies of polonium).

**CBD** Chronic Beryllium Disease

**cc** Cubic Centimeters

**CCNS** Concerned Citizens for Nuclear Safety

**Cd** Cadmium

**CDC** Centers for Disease Control and Prevention

**CEARP** Comprehensive Environmental Assessment and Response Program

**CEDE** Committed Effective Dose Equivalent, a unit of radiation dose

**CFM** Cubic Feet per Minute

**CFR** Code of Federal Regulations

**Ci** Curie, a unit of radioactivity; 1 Ci = 3.7 x 10¹⁰ disintegrations per second.

**CIC** Former Computing, Information and Communications (CIC) Division, now the Computing, Communications, and Networking Division (CCN).

**CM** Chemistry and Metallurgy

**CMB** Former Chemistry/Metallurgy/Baker Division, which later became MST Division

**CMR** Chemistry and Metallurgical Research

**CMR-12** The radiochemistry group at early LASL

**CO₂** Carbon dioxide

**DARHT** Dual-Axis Radiographic Hydrodynamics Test

**D-Building** Earliest plutonium processing facilities at Los Alamos

**DE** Dose Equivalent, a unit of radiation dose
There are several theories about the origin of the "DP Site" name for TA-21. It may stand for D-Prime, since it replaced D Building, "D Plant," "Displaced Persons," "D-Plutonium," or "D-Production" (Martin 1998).
HSPT  Human Studies Project Team
HYPO  Water Boiler Reactor in its high-power configuration
IAEA  International Atomic Energy Agency
ICRP  International Commission on Radiological Protection
ICRU  International Commission on Radiation Units and Measurements
IH  Industrial Hygiene
IM-5  The Records Management Group within the LANL Information Management Division
INEEL  Idaho National Engineering and Environmental Laboratory
IP  Internet Protocol
IPM  Images per minute
JHSPH  Johns Hopkins School of Public Health

kW  kilowatt, one thousand watts of power

LA-  A prefix in many Los Alamos technical report designators
LAHDRA  Los Alamos Historical Document Retrieval and Assessment project
LALP  A type of LANL publication, from Los Alamos Laboratory publication
LAMS  A type of Los Alamos technical report, from Los Alamos Manuscript
LAMPF  Los Alamos Meson Physics Facility
LAMPRE  Los Alamos Molten Plutonium Reactor Experiment
LANL  Los Alamos National Laboratory (January 1981 to present)
LANSCE  Los Alamos Neutron Science Center- formerly LAMPF
LA-PR  A type of Los Alamos technical report, from Los Alamos Progress Report
LAPRE  Los Alamos Power Reactor Experiment
LAPRE I  First Los Alamos Power Reactor Experiment
LAPRE II  Second Los Alamos Power Reactor Experiment
LASL  Los Alamos Scientific Laboratory (January 1947 to December 1980; name changed to Los Alamos National Laboratory in January 1981)
LA- UR  A type of Los Alamos technical report, from Los Alamos Unlimited Release
LCLS  LANL’s Legal Counsel Litigation Support Database
LMFBR  Liquid Metal Fast Breeder Reactor
LOAEI  Lowest Observed Adverse Effect Level
LOPO  Water Boiler Reactor in its low-power configuration
LSSS  Limiting Safety System Setting

mA-hr  Millampere-hours, a measure of work load for accelerators like at LANSCE
MAP  Mixed Activation Products
MDL  Minimum Detection Level
MED  Manhattan Engineer District
MeV  Million Electron Volts
MFP  Mixed Fission Products
mL  milliliter, one thousandth of a liter
mm  millimeter, one thousandth of a meter
MDA  Minimum Detectable Activity
MOU  Memorandum of Understanding
MPC  Maximum Permissible Concentration
MST  Materials Science and Technology Division
MTR  Materials Test Reactor
MW  Megawatt, one million watts of power
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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NBS</td>
<td>National Bureau of Standards (predecessor to NIST)</td>
</tr>
<tr>
<td>NCEH</td>
<td>National Center for Environmental Health, part of CDC</td>
</tr>
<tr>
<td>NCRP</td>
<td>National Council on Radiation Protection and Measurements</td>
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<tr>
<td>NEPA</td>
<td>Nuclear Energy for the Propulsion of Aircraft (a USAF project)</td>
</tr>
<tr>
<td>NERVA</td>
<td>Nuclear Engine for Rocket Vehicle Application</td>
</tr>
<tr>
<td>NESHAPS</td>
<td>National Emissions Standards for Hazardous Air Pollutants</td>
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<tr>
<td>NIOSH</td>
<td>National Institute for Occupational Safety and Health</td>
</tr>
<tr>
<td>NMT</td>
<td>Nuclear Materials Technology</td>
</tr>
<tr>
<td>NOAEL</td>
<td>No Observed Adverse Effect level</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>Oxides of nitrogen</td>
</tr>
<tr>
<td>NRC</td>
<td>U.S. Nuclear Regulatory Commission</td>
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<tr>
<td>NRDS</td>
<td>Nuclear Rocket Development Station (at NTS)</td>
</tr>
<tr>
<td>NSA</td>
<td>Nuclear Science Abstracts</td>
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<tr>
<td>NTK</td>
<td>Need-to-know</td>
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<td>NTS</td>
<td>Nevada Test Site</td>
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<tr>
<td>OCR</td>
<td>Optical Character Recognition</td>
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<td>ORNL</td>
<td>Oak Ridge National Laboratory</td>
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<td>ORF</td>
<td>Overall Release Fraction</td>
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<td>ORR</td>
<td>Oak Ridge Reservation</td>
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<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
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<td>Off-Site Releases Database</td>
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<td>OSTI</td>
<td>Office of Scientific and Technical Information</td>
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<td>OUO</td>
<td>Official Use Only</td>
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<td>OWR</td>
<td>Omega West Reactor</td>
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<td>OWREX</td>
<td>Omega West Reactor Experiment</td>
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<td>PARKA</td>
<td>A Phoebus 1 reactor set up as a critical assembly</td>
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<tr>
<td>PBX</td>
<td>Plastic Bonded Explosive</td>
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<td>PCB</td>
<td>Polychlorinated Biphenyls</td>
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<tr>
<td>PDF</td>
<td>Portable Document Format</td>
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<tr>
<td>PEL</td>
<td>Permissible Exposure Limit</td>
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<tr>
<td>PETN</td>
<td>pentaerythritol tetranitrate, an explosive</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>Pulsed High-Energy Radiation Machine Emitting X-rays</td>
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<tr>
<td>PI</td>
<td>Priority Index</td>
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<tr>
<td>Postum</td>
<td>Early code word for polonium, a material used at Los Alamos.</td>
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<tr>
<td>PPM</td>
<td>Pages Per Minute</td>
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**PROJECTS**

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<tr>
<th>Project</th>
<th>Facility</th>
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<tbody>
<tr>
<td>Project Apple</td>
<td>Rocky Flats Plant</td>
</tr>
<tr>
<td>Project Camel</td>
<td>The first full-scale test firing of the &quot;Fat Man&quot; type bomb (minus the plutonium) at the China Lake Naval Ordnance Sta. in CA.</td>
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<tr>
<td>Project Orange</td>
<td>Pantex Plant</td>
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<tr>
<td>Project Royal</td>
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<tr>
<td>Project Sugar</td>
<td>Burlington Army Ordnance Plant in Iowa</td>
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<tr>
<td>Project Tee</td>
<td>unknown</td>
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<table>
<thead>
<tr>
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<th>Description</th>
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<td>PRG</td>
<td>Preliminary Remediation Goals</td>
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<tr>
<td>PRS</td>
<td>Potential Release Sites</td>
</tr>
<tr>
<td>PSR</td>
<td>Proton Storage Ring</td>
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<tr>
<td>P/VAP</td>
<td>Particulate Various Activation Products</td>
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</table>

Q The top level of security clearance granted by DOE
R  Roentgen, a unit of radiation exposure
RAEHP  Rio Arriba Environmental Health Partnership
RaLa  Radioactive Lanthanum
RCRA  Resource Conservation and Recovery Act
RDX  Rapid detonating explosive
rem  A unit of radiation dose equivalent, from Roentgen Equivalent Man
RF  Respirable Fraction
RfC  Reference Concentration
RFETS  Rocky Flats Environmental Technology Site
RFI  RCRA Facility Investigation
RMAD  Reactor Maintenance, Assembly, and Disassembly building at NRDS.
RMC  Records Management Center
RPF  Records Processing Facility
RRES  Risk Reduction and Environmental Stewardship
RSAC  Radiological Safety Analysis Computer program
RSB  CDC’s Radiation Studies Branch

S Site  TA-16; S is from Sawmill Site, after a former sawmill in the area.
S-7  LANL’s Classification Office
SAP  Special Access Program
SCI  Sensitive Compartmented Information
SED  Special Engineering Detachment, in the Manhattan District era
SL-1  A 3-MW experimental reactor in Idaho, Stationary Low-Power Plant No. 1, that was destroyed in 1961 when a control rod was removed manually.
SM  South Mesa
SNM  Special Nuclear Material
SNPO  Space Nuclear Propulsion Office, a joint office between the AEC and NASA.
Soda Pulp  Early code name for bismuth, which was irradiated to make polonium.
SRA  Shonka Research Associates, Inc.
SRS  Savannah River Site
SUPO  Water Boiler Reactor in its highest (Super) power configuration
SWMU  Solid Waste Management Unit

TA  Technical Area; a section of land at Los Alamos, with TA number from 0 to 74, that has been the site of identified operations or activities
TATB  1,3,5-triamino-2,4,6-trinitrobenzene, an explosive
TD Site  Trap Door Site
TFF  Target Fabrication Facility
TLD  ThermoLuminescent Dosimeter
TNT  Trinitrotoluene, an explosive
TR  Transfer Record
TR  Trinity Project
TRU  Transuranic, that is elements having atomic numbers greater than 92
TSTA  Tritium Systems Test Assembly
TU  Tuballoy, an early code name for depleted uranium (from the British Tube Alloys project, a code name for their atomic bomb program)

UC  University of California, operator of the Los Alamos facility since its founding
UCNI  Unclassified Controlled Nuclear Information
UHTREX  Ultra High-Temperature Reactor Experiment
UK  United Kingdom
UNM  University of New Mexico
USAEC  United States Atomic Energy Commission
USEPA  United States Environmental Protection Agency
USGS  United States Geological Survey
VHS  Video Home System, a video cassette format patented by JVC
Vitamin B  Early code name for the isotope boron-10, a material used at Los Alamos.
VJ Day  The day of Allied victory over Japan in WW II
VRS  Virtual ReScan technology
VTR  Vault Type Room

W  Site W, the Hanford Plant near Richland, Washington
W-47  Code designation for Wendover Air Base in Utah that was the training site of the 509th Composite Group, which dropped the atomic bombs over Japan.
WB  whole body
WEM  Weapons Engineering and Manufacturing
WETF  Weapons Engineering Tritium Facility (at TA-16)
WFO  Work for Others
WIPP  Waste Isolation Pilot Plant
WNR  Weapons Neutron Research Facility
WP  Weapons Physics
WX  Weapons Group WX

X-10  The X-10 Site in Oak Ridge, Tennessee; now Oak Ridge National Laboratory

Y  Site Y, the code name for Los Alamos Laboratory under the MED from April 1943 to December 1946.

Z  Z Division (named for Jerrold R. Zacharias, a physicist from MIT's Radiation Laboratory), an ordnance design, testing, and assembly group formed at LASL in July of 1945. Moved to the old Oxnard Air Field, east of Kirtland Air Base, just outside of Albuquerque between fall of 1945 and January of 1947 and became informally known as Sandia Base.

Reference:

Metric (SI) Prefixes

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<th>Factor</th>
<th>Prefix</th>
<th>Symbol</th>
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<th>Prefix</th>
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<tr>
<td>$10^{18}$</td>
<td>exa</td>
<td>E</td>
<td>$10^{-1}$</td>
<td>Deci</td>
<td>d</td>
</tr>
<tr>
<td>$10^{15}$</td>
<td>peta</td>
<td>P</td>
<td>$10^{-2}$</td>
<td>Centi</td>
<td>c</td>
</tr>
<tr>
<td>$10^{12}$</td>
<td>tera</td>
<td>T</td>
<td>$10^{-3}$</td>
<td>Milli</td>
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<td>$10^9$</td>
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<td>h</td>
<td>$10^{-15}$</td>
<td>Femto</td>
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<tr>
<td>$10^1$</td>
<td>deka</td>
<td>da</td>
<td>$10^{-18}$</td>
<td>Atto</td>
<td>a</td>
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Summary of New and Old Radiological Units

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<th>Quantity</th>
<th>Name</th>
<th>Symbol</th>
<th>In other units</th>
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<tr>
<td>radioactivity</td>
<td>becquerel</td>
<td>Bq</td>
<td>1 disintegrations per second (dps)</td>
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<tr>
<td>(old)</td>
<td>curie</td>
<td>Ci</td>
<td>$3.7 \times 10^{10}$ Bq</td>
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<tr>
<td>absorbed dose</td>
<td>gray</td>
<td>Gy</td>
<td>joule/kilogram (J/kg)</td>
</tr>
<tr>
<td>(old)</td>
<td>rad</td>
<td>rad</td>
<td>$10^{-2}$ Gy</td>
</tr>
<tr>
<td>dose equivalent</td>
<td>sievert</td>
<td>Sv</td>
<td>J/kg</td>
</tr>
<tr>
<td>(old)</td>
<td>rem</td>
<td>rem</td>
<td>$10^{-2}$ Sv</td>
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<tr>
<td>exposure</td>
<td>coulomb per kilogram</td>
<td>C/kg</td>
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<tr>
<td>(old)</td>
<td>roentgen</td>
<td>R</td>
<td>$2.58 \times 10^{-4}$ C/kg</td>
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</table>

Chemical Concentrations

1.0 mg/L = 0.001 g/L = 1,000 µg/L = 1,000,000 ng/L
1.0 µg/L = 0.001 mg/L = 1,000 ng/L
1.0 ng/L = 0.001 µg/L = 0.000001 mg/L

1.0 percent = 1.0 g/100g = $10^0/100$ (parts per thousand) = 10 g/kg = 10,000 mg/kg
1.0 g/kg = 0.10 percent = 1,000 mg/kg
1.0 mg/kg = 0.0010 g/kg = 0.00010 percent = 1,000 µg/kg
1.0 µg/kg = 0.001 mg/kg = 1,000 ng/kg
<table>
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<th>Z #</th>
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<td>Am</td>
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<td>Antimony</td>
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<td>Radon</td>
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<td>Manganese</td>
<td>Mn</td>
<td>40</td>
<td>Zirconium</td>
<td>Zr</td>
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*The Z Number, or Atomic Number, of an element is the number of protons in its atomic nucleus.
Executive Summary

The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999. It was conducted by the Centers for Disease Control and Prevention (CDC), with much of the work performed by contractors to CDC, namely ChemRisk Inc. and subcontractors Shonka Research Associates Inc., ENSR Corporation, Advanced Technologies and Laboratories International, Inc., and several individual consultants. The purpose of the LAHDRA project was to identify the information that is available concerning past releases of radionuclides and chemicals from the government complex at Los Alamos, New Mexico. “Project Y” was born as part of the Manhattan Project to create the first atomic weapons. LANL’s activities expanded after the war to include thermonuclear weapon design, high explosives development and testing, weapons safety, nuclear reactor research, waste disposal and incineration, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.

This report presents a summary of information that has been obtained by the LAHDRA team regarding:

- historical operations at Los Alamos,
- the materials that were used,
- the materials that were likely released off site,
- development of residential areas in Los Alamos, and
- the relative importance of identified releases in terms of potential health risks.

The information in this report was obtained from millions of records reviewed at Los Alamos by the project team, some books and reports that are publicly available, and interviews with past and current Los Alamos workers and members of the public.

Products of the LAHDRA Project

The products of the LAHDRA project include:

- this report, which summarizes historical operation and prioritizes associated releases;
- a project information database that contains bibliographic information and summaries of the content of relevant documents that were located by the project team;
- sets of copies of the documents that were selected as relevant documents, made available in a reading room in Albuquerque;
- a collection of electronic document images, as Portable Document Format (PDF) files, of all documents for which paper copies or electronic files were obtained; and
- a chronology of incidents and off-normal events identified in review of reports prepared by Los Alamos’ Health Division.

A Document Summary Form (DSF) was completed for each selected document (or set of related documents) to capture bibliographic data, project-specific information, and analyst comments. A Microsoft® Access database was created to describe and catalogue the information reviewed and collected.
during this project. There are currently 8,372 records in the LAHDRA database. A user-friendly front-end was developed for analysts to enter, review, and search the assembled information. As the number of paper copies grew and scanning technology matured, it was decided that a better way to preserve and present the reference material being collected by the LAHDRA team would be as scanned images. All documents were scanned, optical character recognition (OCR) processed, and saved as searchable PDF files of optimal quality. The collection of image files was indexed to support searching. In 2006, a new user interface and search engine based on X1 technology was put into place. This controlled-access, Internet based application called DocSleuth allows filtered, full text searching of bibliographic data for included documents and the text of associated image files. The included image files currently represent over 264,000 pages of historical documents.

**Systematic Document Reviews Conducted**

LAHDRA document analysts had unprecedented access for an independent study team reviewing historical records at LANL. A core group of approximately 15 analysts, most of whom held Q-level security clearances, worked on the project on a part-time basis. As originally specified, the LAHDRA project was divided into six phases that were planned to be completed sequentially. Each phase was meant to target a specific group of records, as outlined below:

- **Phase 1:** The LANL Records Management Center
- **Phase 2:** The LANL Archives
- **Phase 3:** The Technical Report Library
- **Phase 4:** Records at the Technical Areas
- **Phase 5:** Records pertaining to “Work for Others”
- **Phase 6:** Documents located at other sites

Because of restrictions that were placed on the number of analysts that could work in a given repository at any time, the sequential approach was abandoned and work progressed in multiple repositories concurrently. The systematic document searches that were performed by the LAHDRA team are described in Chapter 3. The main elements of the information gathering process are summarized in Table ES-1 along with approximations of the quantities of documents reviewed at each repository.

The initial and principal focus of the LAHDRA document review effort was the LANL Central Records Management Center. The LANL Records Center was a 15,000 square foot building located at 180 6th Street in Los Alamos. The function of the Records Center is to receive and catalogue records from the various LANL groups and divisions, to place and maintain these records in retrievable storage, and disposition them in accordance with DOE retention and disposition guidelines and other associated requirements (such as the moratorium on destruction of records deemed pertinent to epidemiological studies). Late in the project, the Records Center was relocated to the new National Security Sciences
Table ES-1. Summary of LAHDRA systematic document review efforts at Los Alamos

<table>
<thead>
<tr>
<th>Location</th>
<th>Approximate Quantities Reviewed</th>
<th>Documents (or Groups of Documents) Selected and Summarized</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANL Records Center</td>
<td>16,896 boxes of documents; 18,000 rolls of microfilm; 31,420 notebooks</td>
<td>2,902</td>
</tr>
<tr>
<td>LANL Reports Collection</td>
<td>3,085 classified reports by LANL and 32,000 by others. 12,000 unclassified LANL reports in vault and 25,000 online. 90,000 unclassified reports by other plus 600,000 on microfiche</td>
<td>1,529</td>
</tr>
<tr>
<td>ES&amp;H Records Center and satellites</td>
<td>1,197 boxes of documents plus dosimetry and air quality records</td>
<td>333</td>
</tr>
<tr>
<td>LANL Archives</td>
<td>1,532 archived collections, with 125,000 folders</td>
<td>992</td>
</tr>
<tr>
<td>Litigation Support Database</td>
<td>75,724 documents by title; 3,813 full documents</td>
<td>347</td>
</tr>
<tr>
<td>LANSCE Division</td>
<td>10,000 documents by title and 2,500 full documents in Admin. Building; 3,375 documents in Radiological Air Monitoring Archive</td>
<td>43</td>
</tr>
<tr>
<td>WEM / WP Divisions</td>
<td>18,876 documents and 1,126 photos in vault; 36 safes containing 7,056 documents</td>
<td>2</td>
</tr>
<tr>
<td>Engineering Drawings Center</td>
<td>2,550 drawings on aperture cards plus ~1,000 reels of microfilm</td>
<td>188 and ~1,000 drawings</td>
</tr>
<tr>
<td>Environmental Stewardship Division</td>
<td>250,000 documents from the ERSS database, 137 boxes of NEPA/EA records, 12 drawers of EIS documents, ~100 Cultural Resources reports</td>
<td>1,056</td>
</tr>
<tr>
<td>Industrial Hygiene &amp; Safety Records</td>
<td>8 lateral file drawers of historical records</td>
<td>17</td>
</tr>
<tr>
<td>Former J Division (Field Testing)</td>
<td>699 boxes with approximately 11,000 folders</td>
<td>0</td>
</tr>
</tbody>
</table>


Building (NSSB) at TA-3. Systematic review of the contents of the LANL Records Center that were accessioned prior to December 31, 1999 was completed in early June 2005, with all of the selected material received from LANL by the end of that month. During late 2008 into 2009, the project team reviewed records accessioned by the Records Center since 1999.
During the first calendar quarter of 2005, LAHDRA analysts began reviewing printouts of LANL Archives collections and the folders that exist within each collection, identifying (based on review of folder titles) folders to be reviewed by the project team. The project team began the review of records at the LANL Archives in early June of 2005, and this review was completed in early May of 2006. During late 2008 into 2009, the project team reviewed collections added to the LANL Archives since 2005.

From 1942 to 1992, the LANL Reports Collection was a filing point for reports issued by LANL and by other Department of Energy sites. There are three types of records in the Report Collection vault, which is located below the LANL Research Library in the Oppenheimer Study Center building at TA-3: classified reports in paper format, unclassified reports in paper format, and reports on microfiche. Approximately 3,000 classified report titles issued by LANL as LA- or LAMS- reports are located in the Report Collection. In the second half of the project, the project team was denied access to the following categories of classified information in document repositories at LANL:

- Nuclear weapons design information,
- Information falling under Sigma levels 14 and 15,
- Sensitive Compartmented Information (SCI),
- Special Access Programs (SAPs),
- Foreign Government Information (FGI), and
- Unclassified Sensitive Vendor Proprietary Information.

Access to classified reports issued by any of the following entities with publication dates after 1962 was denied beginning March 2001: LANL, Lawrence Livermore National Laboratory, Sandia National Laboratory, the Defense Nuclear Agency and its predecessor and successor agencies, and DOE Albuquerque Area Office. During 2005, C.M. Wood of CDC reviewed the titles of Los Alamos technical reports that fell within this restriction and selected 18 for review. These classified technical reports were reviewed by a LAHDRA document analyst, and several were selected as relevant, summarized, and added to the project information database.

Approximately 55-60% of the classified LANL-issued technical reports had been reviewed prior to March 2001. Approximately 1,144 classified LANL reports issued after 1962 were not initially reviewed by the project team because of the March 2001 decision by LANL to withhold them. LAHDRA document analysts were allowed to review the titles of these withheld reports, but that approach proved to be ineffective and problematic due to the vagueness of many titles. All of the classified “LA-“ and “LAMS”-series reports issued before 1963 that were present at the Report Collection were reviewed by the LAHDRA team. Access to classified reports issued by entities other than LANL has been denied to LAHDRA analysts since November 2001. The project team had reviewed approximately 35-40% of the classified reports issued by entities other than LANL (up to letter “L” in the alphabetically-shelved
documents) prior to the withdrawal of access. The remaining reports in this group were reviewed during 2005 by a LAHDRA analyst working in tandem with a LANL person trained to recognize deniable category information.

Approximately 10,000 unclassified report titles issued by LANL as LA- or LAMS- reports are located in the Report Collection vault. Images of approximately 25,000 unclassified LA-, LA-MS-, LA-UR, and LA-PR reports are available as PDF files in the LANL electronic library catalog. Prior to the heightening of security measures that followed the terrorist attacks of September 11, 2001, the unclassified “LA” reports were publicly available on the LANL Web site. The project team reviewed 100% of the unclassified “LA” reports that were formerly available without restriction on the Internet.

There are also approximately 90,000 unclassified reports in the Report Collection vault that were issued by DOE sites other than LANL, academic institutions, private corporations that conducted research on behalf of DOE, and other defense-related agencies. The project team reviewed 70 to 75% of the non-LANL unclassified reports shelved in the Report Collection vault (up to letter “P” in the alphabetically shelved documents) before work was halted in 2004, and the remainder were completed early in 2007.

There are also approximately 1.5 million documents on microfiche at the LANL Reports Collection. A search of two relevant databases indicated that LANL is the authoring institution for approximately 11,000 NSA reports and 53,000 DOE Energy reports, or about 10% of each database’s contents. The project team completed review of the reports on microfiche in November 2006.

The ES&H Records Center has been in operation since 1998. Its purpose is to receive records from the various ES&H Groups, catalogue and consolidate those records, and to eventually forward them on to the LANL Central Records Center. Many of the records stored at the ES&H Records Center are recent, i.e., from the 1990s. A total of 1,187 boxes were reviewed in the ES&H Records Center. Of these, 227 were deemed to contain material relevant to the project and thus had DSFs completed for them. In early 2009, LAHDRA analysts reviewed records that had been added to the ES&H collection since their previous review of those holdings.

Reviews completed during this project also included holdings of the Weapons Engineering and Manufacturing (WEM) and Weapons Physics (WP) divisions. These LANL divisions are organized under the Directorate’s Office of the Associate Laboratory Directorate for Nuclear Weapons Engineering and Manufacturing (ADWEM), formerly known as Office of Associate Laboratory Directorate for Nuclear Weapons (ALDNW). The WEM/WP vault-type room (VTR) contained approximately 18,876 classified documents and 1126 classified photographs. Thirty-six classified safes within the ADWEM main offices were also reviewed for potentially relevant information. The safes contained 7,056 documents marked “RESTRICTED DATA”. No titles were identified as potentially relevant to the
LAHDRA project. Based on a review of a list of classified vaults and repositories at LANL, it is estimated that 21 vaults, 107 VTRs, 5 alarmed rooms, and 1,600 repositories (file cabinets, 2-5 drawers each, with combination locks) are present. Not all of the vaults or VTRs contain only records– some contain weapon parts and/or special nuclear material.

Review of documents located at the Los Alamos Neutron Science Center (LANSCE Division, formerly LAMPF) focused on office files within the Main Administration Building 1 located at TA-53 and the Radiological Air Monitoring (RAM) Records Archive. Of these documents, 2,500 were considered potentially relevant and underwent detailed review. Copies of 36 documents were requested and summarized for the LAHDRA project database. Highlights of these records are the Shift Supervisor Logbooks that contain daily beam current and beam-hour information dating back to 1971. Forty-five boxes of documents (3,375 documents) located at the RAM Records Archive (Building 3R) were reviewed. Copies of 97 documents were requested and summarized. This archive would be a source of relevant information for any future studies of off-site releases from TA-53.

During the LAHDRA project, team members made several attempts to gain access to the contents of the Legal Counsel Litigation Support Database (LCLS), sometimes called the Legal Database. While the database itself was not made available, in late 2003/early 2004 the LAHDRA team received and reviewed a hardcopy listing of the documents contained in that database. The list includes document number, title, author, addressee and copy recipient, date, status, and page count. The LCLS database consists of the following document categories: H-Division, Human Studies Project Team, Central Records Management, “Other” documents, and Records Processing Facility documents. During 2005, LAHDRA analysts reviewed the hardcopy indices of the LCLS database and selected documents for review. Images of these documents were made available to LAHDRA analysts by Legal Counsel staff, and they were reviewed between May and September of 2005. Documents selected as relevant were printed and released to the project team.

In February of 2006, the project team began reviewing documents held by the LANL Engineering Drawings Facility at TA-63. This facility housed engineering drawings and associated documents (memos, letters, specifications, etc.) dating back to the 1940s. The initial searching was for drawings pertinent to Original Technical Area buildings (especially D Building), Omega Site facilities and associated stacks, DP Site facilities and ventilation systems, and the Los Alamos town site. Approximately 1,000 historical drawings were selected as relevant to the LAHDRA project, obtained from LANL, and scanned to make them available via DocSleuth. The project team also completed systematic review of the TA-63 microfilm records, which contain correspondence and documents pertaining to many modifications of Lab facilities.
LAHDRA analysts reviewed the holdings of a small library of environmental restoration related documents at TA-21 and at the Environmental Restoration group’s Records Processing Facility (RPF). The TA-21 library was a collection of material housed in a portable building at DP West Site. Its purpose was to act as a resource for individuals involved in decommissioning activities there. The facility included binders of memoranda, remediation investigation reports, and drawings. Much of this material had already been collected by the project team from its review activities in the Records Center and elsewhere. The RPF managed records of what was formerly the Environmental Restoration (ER) group at LANL. Most of the holdings of the LANL Records Processing Facility, located at the Pueblo School Complex, had been scanned to PDF files and were available through an electronic document management utility called Domino. Review of this material is discussed below. In addition to these electronic records, the project team also reviewed some hardcopy records that existed at the RPF earlier in the project, and records that had recently been acquired and not yet scanned.

As the project team completed its systematic review activities for LANL’s centralized records collections it migrated its focus to records held within division or group offices. The initial focus of the review of division and group records was the Environmental Stewardship (ENV) Division. The ENV Division consisted of a large number of groups, many of which held records of interest to the project team. Review of these records was therefore a substantial part of the team’s activities once reviews at the centralized collections were winding down. Project team members also met with representatives of the following other LANL divisions and groups to inquire about their activities and any records they held:

- Associate Directorate for Security and Safeguards
- Chemistry
- Dynamic and Energetic Materials
- Earth and Environmental Science
- Environmental Protection
- Hydrodynamic Experiments
- Industrial Hygiene and Safety
- Materials Science and Technology
- Plutonium Manufacturing and Technology
- Radiation Protection
- Weapons Component Manufacturing
- Weapons Engineering Technology

In May of 2006, the LAHDRA team obtained a summary of records and databases generated by the groups and programs within the LANL ENV Division. There were approximately 50 groups and programs listed, along with a number of electronic databases. Of the document collections and other information sources identified within the ENV Division, the largest by far was the RPF’s Domino
database. The Domino database was an electronic storehouse for historical and current RPF records, that is, environmental restoration files. These included environmental project case files, remediation management records, regulatory compliance records, and decontamination and decommissioning records. The records were stored as PDF files and managed using the IBM Lotus Domino application. Records in the Domino application were indexed using a unique identifier known as an ERID number. The system contained approximately 100,000 ERIDs, amounting to approximately 250,000 documents. Systematic review of the Domino records was performed by going through them sequentially by ERID number and reviewing the image files for those with titles that were either of potential interest or were too ambiguous to support a judgment. Documents deemed relevant to the LAHDRA project were printed and a DSF was completed.

The project team also reviewed the RPF’s Potential Release Sites (PRS) database, which is far more limited in content compared to the Domino database, using the same approach as for Domino. Other ENV Division records collections that were reviewed include records pertinent to compliance with the National Environmental Policy Act (NEPA), associated environmental impact assessments, Meteorology and Air Quality (MAQ) group records, meteorological data, and Cultural Resources Group reports that include historical information about operations at LANL facilities.

**Challenges and Accomplishments in Information Gathering at Los Alamos**

Access to classified documents at Los Alamos has been more difficult than CDC personnel or LAHDRA team members have experienced at any of the other DOE sites that have been subjects of dose reconstruction investigations. The main challenges that were faced in accessing, reviewing, and arranging for public release of relevant documents were associated with the following issues:

- The Cerro Grande fire,
- security stand-downs and the fallout of security incidents involving LANL staff,
- frequent requirements to re-establish need-to-know,
- establishment of security plans for accessing and reviewing documents,
- increased escorting requirements and limitations on numbers of analysts that could work concurrently,
- calls by LANL staff for review of documents by titles alone,
- establishment of seven categories of information to be withheld from the LAHDRA analysts,
- pre-screening by document “owners” and/or classification office contractors to identify deniable-category information,
- difficulties in gaining access to reports issued by entities that no longer exist,
- establishment of an appeal process for use when potentially relevant information was withheld,
- arranging for access to documents at LANL generated by a foreign government (the UK),
- a significant backlog of selected documents awaiting classification review and public release,
limited resources (staffing) at repositories impacting ability of LAHDRA analysts to be present, a LANL shutdown in response to a security incident, and initiation of pre-screening of documents by LANL Legal staff for privileged information.

**Prioritization of Airborne Releases**

During the period of LANL’s existence, many operations involving radionuclides have been performed at LANL, and effluents of various kinds have resulted. As the initial step towards prioritization of historical airborne releases from LANL, Priority Index (PI) values were calculated by computing the air volume required to dilute the annual activity released to be equal to the maximum effluent concentration per federal regulations. This priority index is intended to be a guideline to determine if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other nuclides. For example: a PI of $10^4$ indicates that $10^4$ L of air would be required to dilute the released material to a concentration equal to the MPC. A Microsoft Access® Off-Site Releases (OSR) Database was created to tabulate effluent information and to link it to existing LANL documents that have been assembled by the LAHDRA project team. The processes used to prioritize releases of radionuclides from LANL operations are described in Chapter 17.

Prioritization of releases requires estimates of quantities that were released. There has been no comprehensive compilation or accounting of historical airborne radionuclide releases prepared by LANL. The most complete compilation of airborne radionuclide effluent data available from LANL was assembled in the 1970s to support preparation of a Final Environmental Impact Statement (FEIS). Airborne plutonium releases were prioritized based on values compiled for the 1979 FEIS and also documented in a 1975 publication. Values for 1948–1955 were adjusted upward by the LAHDRA team (by roughly a factor of 20) based on a study conducted by the LANL industrial hygiene group in 1955 and 1956. In that study, stack releases were measured with improved, isokinetic stack sampling systems that were operated alongside the original systems. Correction factors were determined and applied to releases previously reported for 1948-1955. All values from 1948 through 1975 were adjusted further using a sample line loss correction factor (equal to 5 for 1945-1958 and 2 for 1959-1975) and a filter burial correction factor of 2.33 based on assessments performed by LANL staff. No effluent data were located for the wartime processing of plutonium in D Building, and LANL’s release estimates include no contribution from D Building during any period of its operations or from the DP West Site plutonium processing that occurred 1945–1947.

Uranium usage and release data were located for 1949–1996. Available documents provide estimates of the quantities of uranium used in explosive testing and some results of stack sampling and analysis. Sample line loss and filter burial correction factors were applied to uranium stack sampling results for
periods prior to 1976 as was discussed for plutonium. For explosive test inventory data, Atmospheric Release Fractions and Respirable Fractions were applied to yield a range of Overall Release Fractions (ORF). The geometric mean of the ORF values, 0.001, was applied to the inventory of uranium used in explosive tests.

Airborne tritium release estimates were located for 1967–1996, and no correction factors were applied. Prioritization of radioactive lanthanum (RaLa) releases from 254 explosive tests conducted in Bayo Canyon 1944–1961 was based on a source term evaluation performed by LANL personnel. The ORF used for uranium (geometric mean of 0.001) was also applied to reported source quantities for the RaLa tests. A class of airborne effluents was reported by LANL as mixed fission products (MFP) from 1961 through 1996, with the main sources being the Omega Site (TA-2) reactors. Radioactivity included in the MFP “nuclide group” for prioritization included releases reported as MFP or as fission product nuclides such as $^{60}$Co and $^{137}$Cs. Another class of airborne effluents called mixed activation products (MAP) was reported by LANL for 1976–1996, with the most significant source being accelerator operations. Radioactivity included in the MAP “nuclide group” for prioritization included releases reported as MAP, Gaseous Mixed Activation Products (G/MAP), Particulate Various Activation Products (P/VAP) and the air activation products $^{11}$C, $^{13}$N, $^{15}$O, and $^{41}$Ar.

Annual values of Priority Index (dilution volume required, L) were calculated by dividing the estimated annual release of each category of radionuclide by the effluent concentration limit from 10 CFR 20 for a radionuclide representative of the radionuclide or nuclide group. The value for $^{239}$Pu was used for plutonium; $^{235}$U for all uranium; $^{140}$La for radioactive lanthanum, radioactive barium, and $^{140}$La; a value of $1 \times 10^{-7}$ µCi mL$^{-1}$ from Footnote 2 to the radionuclide tables in 10 CFR 20 Appendix B was used for all MFP radionuclides; and a value of $2 \times 10^{-7}$ µCi mL$^{-1}$ published by the International Atomic Energy Agency was used for all MAP radionuclides.

Priority Indices could be generated for the earliest years for the RaLa tests that were active 1944–1962. As shown in Table ES-2, Priority Index values for plutonium were the highest of all calculated Priority Indices overall and were higher than all other airborne radionuclide classes for 1948 through 1966 and again from 1970 through 1974. While uranium yielded the highest Priority Indices for 1967 though 1969, 1975, and 1991, tritium had the highest values for 1976 and 1977 and again for 1990. Mixed activation product releases yielded the highest values for 1978 to 1989 and again for 1992 to 1996.

A review and calculation was completed in October 2006 that addresses reported releases from DP West for 1957, using the actual daily stack reports. The results show that 40% of all operating hours were not monitored, mostly weekends and holidays. Therefore, a method for estimating effluent concentrations for the hours during which the stacks were not monitored was needed. The method used by LASL is likely
conservative, in that it scales from operating hours to estimate releases during hours in which no stack measurement was made. The calculation also showed that some simple assumptions made in the early 1970s, such as stack or sampler flow rates, were inappropriately used for all periods.

<table>
<thead>
<tr>
<th>Years</th>
<th>Radionuclide Class with Highest Priority Indices</th>
<th>Range of Annual Priority Indices (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944-1947</td>
<td>Radioactive Lanthanum</td>
<td>$6 \times 10^{11}$ to $1 \times 10^{13}$</td>
</tr>
<tr>
<td>1948-1966</td>
<td>Plutonium</td>
<td>$7 \times 10^{14}$ to $1 \times 10^{18}$</td>
</tr>
<tr>
<td>1967-1969</td>
<td>Uranium</td>
<td>$1 \times 10^{17}$ to $1 \times 10^{17}$</td>
</tr>
<tr>
<td>1970-1974</td>
<td>Plutonium</td>
<td>$2 \times 10^{14}$ to $3 \times 10^{15}$</td>
</tr>
<tr>
<td>1975</td>
<td>Uranium</td>
<td>$7 \times 10^{13}$ to $7 \times 10^{13}$</td>
</tr>
<tr>
<td>1976-1977</td>
<td>Tritium</td>
<td>$3 \times 10^{13}$ to $4 \times 10^{14}$</td>
</tr>
<tr>
<td>1978-1989</td>
<td>Mixed Activation Products</td>
<td>$6 \times 10^{14}$ to $4 \times 10^{15}$</td>
</tr>
<tr>
<td>1990</td>
<td>Tritium</td>
<td>$1 \times 10^{14}$ to $1 \times 10^{14}$</td>
</tr>
<tr>
<td>1991</td>
<td>Uranium</td>
<td>$1 \times 10^{15}$ to $1 \times 10^{15}$</td>
</tr>
<tr>
<td>1992-1996</td>
<td>Mixed Activation Products</td>
<td>$6 \times 10^{13}$ to $7 \times 10^{14}$</td>
</tr>
</tbody>
</table>

The prioritization of airborne radionuclide releases indicates that plutonium was most important from 1948 through the mid-1960s. It appears that the crudeness of LANL’s early plutonium processing facilities and delayed adoption of single-bank and ultimately multiple-stage HEPA filtration relative to other plants that were more clearly recognized as production facilities were factors in LANL becoming a more significant source of airborne plutonium emissions than it would otherwise have been. While documents discovered in this study indicate that airborne plutonium releases from LANL before the 1970s were significantly higher than has been officially reported, the relative importance of airborne plutonium releases could increase with further investigation if other identified sources were characterized. These sources include D Building, DP West Building 12 stacks before 1948, other release points at DP West, early Chemistry and Metallurgical Research (CMR) Building operations beginning in 1953, non-point sources, accidents, and waste disposal operations. These sources were not monitored by LANL or reflected in estimates of plutonium historically released from the site.

If airborne plutonium releases from DP West Building 12 stacks between 1948 and 1955 were as high as the 1956 reports by the Lab’s industrial hygiene staff indicate, plutonium releases from LANL could easily exceed the independently reconstructed airborne plutonium release totals from the production plants at Hanford, Rocky Flats, and Savannah River combined, even without the other sources and other years at LANL included.
The level of interest in characterizing past releases of plutonium from Los Alamos operations is heightened by the fact that residential areas were built closer to production areas at LANL than at any other major Manhattan Project, AEC, or DOE site. The nearest residences, Sundt apartments, were located approximately 200 m from D Building in the Original Technical Area (TA-1) and as little as 50 m from other key buildings in TA-1. Another housing area, a trailer park on the rim of Los Alamos Canyon just west of DP West site, was in use from 1948 to 1963. That housing was 1 km west of the DP West Building 12 stacks and was separated from Material Disposal Area B, a radioactive waste burial ground that experienced a major fire in 1948, by only a fence. The trailer park was also situated directly above Omega Site (TA-2), where five versions of nuclear reactors were operated on the canyon floor because of perceived dangers of associated operations. When a flexible tubing line was run up the wall of Los Alamos Canyon and tied to a tree atop South Mesa to serve as the release point for gases released from the reactors, airborne radioactivity was released at roughly the same elevation as trailer park residents.

Airborne releases of Mixed Activation Products from accelerator operations appear to have been most significant in a majority of years after the 1970s, by which time controls and monitoring of other airborne effluents such as plutonium had significantly advanced. Uranium releases yielded relatively high Priority Indices for the late 1960s, 1975, and 1991, but in general associated values were lower than those for plutonium. The uranium releases reported by LANL for 1967-1969 appear to be anomalously high, and some quantities documented as released might actually have been amounts of uranium used in explosive testing, with no accounting for the fraction aerosolized in the tests.

Airborne tritium releases yielded the highest Priority Indices of all radionuclides in the mid-1970s and in 1990, but the true importance of the radionuclide cannot yet be definitively evaluated because of the scattered and incomplete nature of effluent measurements or estimates prior to 1967. Incident reports indicate that sizable episodic releases of tritium occurred between the mid-1940s and 1967, the earliest year for which reports of tritium releases were compiled by LANL.

**Prioritization of Waterborne Radionuclide Releases**

Priority Indices for waterborne radionuclides were calculated for total plutonium, $^{238}$Pu, $^{239}$Pu, $^{89}$Sr, $^{90}$Sr, tritium, gross alpha, and gross beta radioactivity. That assessment is described as part of Chapter 17. Estimates of historical releases were obtained from the compilation of data for the 1979 FEIS, from excerpts and compilations of AEC effluent records, and from annual environmental surveillance reports that were issued by LANL beginning in 1971. No summary waterborne effluent data were found for the years 1974-1976. Priority Indices were calculated by computing the volume of liquid required to dilute the annual activity released to be equal to the maximum effluent concentration per 10 CFR 20. The maximum effluent concentration for $^{239}$Pu was used to calculate the Priority Indices for gross alpha
The waterborne radionuclide classes that yielded the highest Priority Indices for each period from 1945 through 1996 are identified in Table ES-3.

<table>
<thead>
<tr>
<th>Years</th>
<th>Radionuclide Class</th>
<th>Range of Annual Priority Indices (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945-1952</td>
<td>Plutonium</td>
<td>$5 \times 10^{10}$ to $1 \times 10^{11}$</td>
</tr>
<tr>
<td>1953-1954</td>
<td>Strontium-90</td>
<td>$3 \times 10^{8}$ to $3 \times 10^{8}$</td>
</tr>
<tr>
<td>1955-1957</td>
<td>Gross alpha radioactivity</td>
<td>$8 \times 10^{8}$ to $5 \times 10^{9}$</td>
</tr>
<tr>
<td>1958</td>
<td>Plutonium</td>
<td>$5 \times 10^{9}$ to $5 \times 10^{9}$</td>
</tr>
<tr>
<td>1959</td>
<td>Gross beta radioactivity</td>
<td>$6 \times 10^{8}$ to $6 \times 10^{8}$</td>
</tr>
<tr>
<td>1960-1963</td>
<td>Gross alpha radioactivity</td>
<td>$6 \times 10^{8}$ to $4 \times 10^{10}$</td>
</tr>
<tr>
<td>1964</td>
<td>Gross beta radioactivity</td>
<td>$3 \times 10^{8}$ to $3 \times 10^{8}$</td>
</tr>
<tr>
<td>1965-1968</td>
<td>Gross alpha radioactivity</td>
<td>$2 \times 10^{8}$ to $8 \times 10^{8}$</td>
</tr>
<tr>
<td>1969</td>
<td>Plutonium</td>
<td>$4 \times 10^{8}$ to $4 \times 10^{8}$</td>
</tr>
<tr>
<td>1970-1973</td>
<td>Gross alpha radioactivity</td>
<td>$4 \times 10^{8}$ to $8 \times 10^{8}$</td>
</tr>
<tr>
<td>1977-1980</td>
<td>Plutonium-238</td>
<td>$9 \times 10^{7}$ to $4 \times 10^{8}$</td>
</tr>
<tr>
<td>1981-1989</td>
<td>Plutonium-239</td>
<td>$1 \times 10^{8}$ to $3 \times 10^{9}$</td>
</tr>
<tr>
<td>1990-1992</td>
<td>Strontium-90</td>
<td>$3 \times 10^{7}$ to $5 \times 10^{8}$</td>
</tr>
<tr>
<td>1993</td>
<td>Plutonium-239</td>
<td>$5 \times 10^{7}$ to $5 \times 10^{7}$</td>
</tr>
<tr>
<td>1994-1996</td>
<td>Plutonium-238</td>
<td>$1 \times 10^{8}$ to $2 \times 10^{8}$</td>
</tr>
</tbody>
</table>

Preliminary prioritization analyses for waterborne radionuclides indicated that plutonium releases were most important for just over half of the years of LANL operations between 1945 and 1996 for which effluent data are available (27 y out of 49). Liquid radioactive waste was discharged to Acid-Pueblo Canyon without treatment or monitoring from 1945 through 1950, prior to a treatment plant becoming operational in 1951 and an improved plant in 1963. $^{90}$Sr appears to have been most important for several years in the mid-1950s and early 1990s, while gross alpha-emitting radioactivity was most important for most years between 1955 and 1973 and gross beta-emitting radioactivity yielded highest Priority Indices for 1959 and 1964. Unlike airborne tritium releases, which were not quantified by LANL prior to 1967, waterborne releases of tritium were quantified beginning with 1945 but appear to have been less important than the other radionuclides reported to have been present in liquid effluents.

**Measurements of Plutonium in Soil as Indicators of Historical Releases**

Because releases of airborne plutonium from LANL were either not measured at all or were poorly quantified and reported until around 1978, the LAHDRA team recognized a need to estimate potential releases from LANL operations using methods beyond those based on reported stack monitoring results.
One method identified was to use amounts of plutonium measures in soil samples collected around Los Alamos to estimate the amount of airborne plutonium that was released. That assessment is described as part of Chapter 17. Scientists at LASL attempted to measure the amount of plutonium in the soils around LANL in the 1957-1958 timeframe. Their effort was documented in a 1958 publication “Evaluation of the Air Pollution Problem Resulting from Discharge of a Radioactive Effluent” by Harry Jordan and Ralph Black. Based on analyses of soil samples collected along circles of increasing distance from the main stacks at DP West Site (up to a radius of 1 mi), the authors asserted that they were able to compare release estimates that they generated with the releases calculated by LANL staff based on stack sampling at DP West. Jordan and Black selected results from only six of about 40 sample locations because they “show rather remarkable agreement” with the LANL stack effluent records that were said to show that 13.1 g or 0.82 Ci of plutonium had been released. Results that were substantially higher were not used because they were thought to be higher because of failure of “attempts to avoid extraneous contamination.”

Although Jordan and Black asserted agreement with release estimates based on stack sampling, they were apparently unaware of or ignored major changes in the stack sampling system in 1955 that were the subject of a study by Edwin Hyatt that resulted in significant modification of release estimates for 1948 to 1955. LANL has been unable to produce, and LAHDRA analysts have been unable to find, any supporting records or logbooks about the referenced work. Jordan and Black excluded any high samples for reasons that do not appear to be well justified. It now appears that the associated measurements of radioactivity in soil used too large of a volume of soil, resulting in low and variable recovery of plutonium from soil in the acid leaching process. And perhaps most importantly, the radiochemist responsible for the analyses has stated that his results were only intended to be qualitative (whether plutonium was present or not) rather than quantitative (how much plutonium is present).

As a result of the lack of effluent measurements for early airborne releases of plutonium, the LAHDRA team has considered several nontraditional methods to gain information about the potential magnitude of historical plutonium releases. Measurements of plutonium in soil around LANL make up an “environmental record” that is a potentially useful indicator of past releases. Members of the project team have performed several iterations of analysis to estimate the total airborne plutonium release that would be consistent with the environmental record of plutonium found in soil samples in the Los Alamos area.

The initial iteration of the assessment by LAHDRA team members to estimate airborne plutonium releases was based on 37 measurements of plutonium in soil samples collected near Los Alamos from 1975 to 1977. These measured concentrations of $^{239}\text{Pu}$ in soil included global fallout from atmospheric testing of nuclear devices. The average concentration of $^{239}\text{Pu}$ of distant sample sites (approximately 50
mi from LANL) was subtracted from the 37 values used in the analysis. The “corrected” soil concentrations reflected 0.003 to 0.045 pCi g\(^{-1}\) net positive contributions of \(^{239}\)Pu from LANL operations.

The Radiological Safety Analysis Computer (RSAC) program was run with LANL meteorological data to calculate \(^{239}\)Pu deposition at various distances in each direction from a unit release (1 Ci) of \(^{239}\)Pu over 50 y. The calculated deposition at each distance was converted to a soil concentration based on the annular area involved and the soil density and sampling depth reported by LANL. The ratio of each measured soil concentration to the concentration calculated for that same area from the RSAC modeling of a unit release yielded a factor that corrects the unit source in RSAC to give agreement between the soil data and the RSAC results. For example, a ratio of 15 would indicate that 15 Ci of plutonium had been released rather than the 1 Ci assumed. The ratios over the 37 sampling locations were log-normally distributed. Based on the distances involved with releases from D Building, the geometric mean (GM) was 620 Ci, with a factor of uncertainty (geometric standard deviation of the mean, GSD) of 1.2. For the distances associated with releases from the DP West Site the GM was 670 Ci, with a factor of uncertainty of 1.3. While these results have a high degree of uncertainty, they indicated that airborne plutonium releases from LANL operations could have been hundreds of times higher than the 1.2 Ci officially reported.

Following the initial analyses, additional soil sampling data was obtained, and a new analysis was performed using this expanded dataset of 679 soil samples from 34 locations. Of these, 106 samples at 24 sample points were judged impacted by LASL operations based on analysis of the plot of plutonium-to-cesium ratios. In the second approach, a total uncertainty for each soil sample was calculated, and only those measurements with uncertainty in the plutonium to cesium ratio less than 25% were analyzed. For these 37 samples, the net plutonium and the range and bearing from the D Building and DP West Site were calculated. RSAC was used to calculate the soil concentration as a function of wind direction and distance for a unit release. When divided into the net sample data, an estimate of the integrated LANL source term was obtained for each of the 37 samples. If the release was attributed to the DP West Site, an average of 60 Ci and a median of 12 Ci were obtained with a GSD (factor of uncertainty) of 9. If the site releases were attributed solely to D Building, an average of 101 Ci and a median of 46 Ci were obtained with a corresponding GSD (factor of uncertainty) of 5.

**Analysis of Measurements of Plutonium in Body Tissues of Los Alamos Residents**

The LANL Human Tissue Analysis Program was a 35-y effort by LANL to study the levels of plutonium in workers and in the general population of the United States. The collection and analysis of tissues was intended to answer questions about the behavior of plutonium in the human body. In later years, the program was expanded to other areas of the country in order to estimate the amount of nuclear fallout people were subjected to from the atmospheric testing of nuclear weapons. The non-worker tissue
program ended in 1980. Nearly 1,000 decedents had tissues removed during their autopsies and sent to LANL by coroners.

The LAHDRA staff attempted an independent analysis of the autopsy program results. This effort, described as part of Chapter 17, demonstrated that excess plutonium is present in non-worker residents of Los Alamos over what would be expected from global fallout from nuclear weapons testing. It also established and tests a method for uncovering the history of residence locations for autopsy cases. This history establishes the range and bearing from LANL release points along with the years of occupancy at each residence. This method could be used to reduce the uncertainty in retrospective dose reconstructions and possibly permit use of the autopsy data for bounding LANL releases.

The autopsy data reported by McInroy et al. in 1979 shows that the cumulative frequency distributions (CFDs) of liver concentrations (dpm kg⁻¹ liver) are nearly identical between Los Alamos and Denver. However, the vertebrae autopsy samples from Los Alamos are higher than Denver, and their different slope indicates the plutonium has been in the body longer. If Los Alamos indeed had one half (or less) of the fallout as Denver, as documented by Purtymun and Krey, the liver results should show this. However, this is not the case. The liver data would seem to indicate the plutonium present at Los Alamos is roughly equal that of Denver. If one accepts the earlier fallout data from Purtymun and Krey, then this implies that the “extra” or “added” plutonium (that which makes the plutonium liver concentrations equal) is due to LANL emissions. The liver results show that autopsy samples from residents of Los Alamos appear to have “added” plutonium. If there were two distinct populations among those exposed around Los Alamos, one might expect to see a bend in the CFD curve indicating added plutonium in the fraction of the population living nearest the release points. However, no bend is seen. It is likely that releases from the site were not sufficient to cause this “bend” in the CFD plot or that the inherent variability of various factors dominates the distribution and masks the presence of two populations.

The vertebrae results show differences between Los Alamos and Denver, with the differences occurring in the population with higher bone concentrations. This result also appears to be consistent with a hypothesis that releases at Los Alamos impacted the population. The data also show significant divergence in the ratio of concentrations in the skeleton to that of the liver. Cumulative frequency distribution graphs for the ratio of vertebrae results to those of liver were analyzed for all autopsy cases that had data for both organs. An exponential function provides a good fit to the data, which implies that the data are log-normally distributed. The median value, read from the chart at zero for the “X-Axis”, shows a value of 1.73 for Denver, corresponding to less-aged exposures. Los Alamos shows a median value for the vertebrae-to-liver ratio of nearly 2.72. The geometric standard deviation is 2.3 times larger for Los Alamos compared to Denver. If the air concentration had been constant over time, this would be
a ratio indicative of exposure that began about 10 y prior to autopsy. Given the large values of the ratio for Los Alamos, these data indicate that exposures in the early years were higher than the later years.

To reduce the uncertainties of the analyses of human tissue samples, death certificates and a case index key for participants in the autopsy program that were found in the LANL Archives during 2006 were used to develop residence histories for each autopsy case. Starting with the information on the death certificates, the LAHDRA team used telephone directories, obituaries, marriage licenses, and other public records to recreate the residential history of each decedent to the extent possible. In total, there were 236 autopsy cases for the Los Alamos area for which tissue activity data were available, with 60 of those participants having been LANL employees. Associated with these participants were 809 residential locations, of which 677 were identified as addresses and 542 could be geocoded using an Internet-based service so that distance to D Building and DP West could be calculated. For some addresses, a global positioning satellite (GPS) unit was used to determine coordinates. In some cases, the historical address is no longer a residence. To support spatial analysis, coordinates were obtained for the addresses of the participants using TeleAtlas®. For each address, range from D Building and DP West were calculated.

Solutions of the original samples taken under the LANL human tissue analysis program, as well as logbooks associated with the program, have been maintained by the United States Transuranium and Uranium Registries (USTUR) for many of the autopsy cases. Because of that, it may be possible to determine how much of any autopsied individual’s exposure was due to fallout or releases from LANL. A new method of measurement called Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can distinguish between weapons-grade plutonium that has not been used in a nuclear weapon and plutonium from fallout that resulted from a nuclear detonation. USTUR has performed an initial study of the method with promising results. This method and new analysis of the samples might permit more accurate estimation of how much of the plutonium found in the tissues of any former Los Alamos resident was due to global fallout and how much was due to releases of plutonium from LANL.

**Prioritization of Chemical Releases**

Operations at LANL have involved many non-radioactive materials, including metals, inorganic chemicals, and organic chemicals including solvents. To prioritize chemical releases, chemical use and release data were extracted from chemical inventories and various LANL documents. Details regarding these data sources can be found in Chapter 19. Prioritization of chemicals took into account estimates of annual usage and U.S. Environmental Protection Agency (USEPA) toxicity values such as cancer potency slope factors and reference doses (RfDs). Chemicals that were considered carcinogenic were ranked based on estimated annual usage multiplied by the applicable cancer slope factor. Oral slope factors were used in all but one case because they provided a more conservative (higher) estimate of toxicity for
prioritization than the inhalation slope factors. All chemicals with published RfDs were ranked by dividing the annual usage by the applicable RfD. For agents that have both ingestion and inhalation RfDs, the more conservative (lower) value was used. Table ES-4 presents a ranking of each chemical that was documented as used at LANL, for which some usage quantity information was obtained, and for which a cancer potency slope factor and/or reference dose has been published.

The prioritization of chemical releases based on their potential to cause cancer indicated that four of the top five ranked chemicals were organic solvents, which were commonly used in chemical processing and for cleaning of metals and other materials. Trichloroethylene ranked highest, indicating highest relative potential for health effects, for both cancer and non-cancer effects. For chemicals with cancer potency slope factors and some usage data available, 2,4,6-trinitrotoluene (TNT) yielded the highest ranking for a material that was not a solvent, while uranium as a heavy metal toxin ranked highest for non-cancer effects among materials that are not solvents, followed by TNT.

**Development of Residential Areas in Los Alamos**

Evaluation of off-site exposures from activities at Los Alamos technical areas would require documentation of the development of nearby residential areas over time. While it was initially thought that the 31 houses commandeered from the Los Alamos Ranch School and Anchor Ranch would provide sufficient housing for the projected staff of 30 scientists and their families, it soon became clear that the scope of the challenge to provide housing for Los Alamos residents had been severely underestimated. Pressure to provide housing and the limited availability of suitable land in the region of finger-like mesas and canyons led to the development of housing that in some cases was much closer to operational areas than has become customary for government facilities that undertake processing of nuclear materials and high explosives and/or operation of devices such as reactors or high-energy particle accelerators.

Based on reviews of historical documents that were performed, nine locations were identified as being among the sites where historical operations took place that appear to warrant evaluation in terms of potential off-site releases or health effects. The LAHDRA project team collected maps, photographs, and historical documents that describe the history of development of each Los Alamos housing area. The assembled information is summarized in Chapter 15. For each of the nine locations of interest, the following parameters were evaluated to support evaluation of the potential for public health effects:

- The distance from the area to housing areas that were in place during the period(s) that associated operations were active,
- The direction from the location to each housing area, and
- The prevalence of winds from the location toward each the housing area.
Table ES-4. Ranking of LANL chemicals based on toxicity parameters and indicators of annual usage

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Slope Factor (SF) (mg kg(^{-1}) d(^{-1}))</th>
<th>Reference Dose (RfD) (mg kg(^{-1}) d(^{-1}))</th>
<th>Peak annual use (kg)</th>
<th>Ranked based on cancer effects</th>
<th>Ranked based on non-cancer effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>-</td>
<td>0.9</td>
<td>18,800</td>
<td>-</td>
<td>20,889</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.055</td>
<td>0.004</td>
<td>181</td>
<td>10</td>
<td>45,250</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>0.13</td>
<td>0.0007</td>
<td>558</td>
<td>73</td>
<td>797,143</td>
</tr>
<tr>
<td>Chlorodifluoromethane(^b)</td>
<td>-</td>
<td>14.3</td>
<td>32,200</td>
<td>-</td>
<td>2,252</td>
</tr>
<tr>
<td>Chloroform(^c)</td>
<td>0.0805</td>
<td>0.01</td>
<td>3,088</td>
<td>249</td>
<td>308,800</td>
</tr>
<tr>
<td>Dichlorodifluoromethane(^b)</td>
<td>-</td>
<td>0.0571</td>
<td>32,200</td>
<td>-</td>
<td>563,923</td>
</tr>
<tr>
<td>Dioxane</td>
<td>0.011</td>
<td>-</td>
<td>32</td>
<td>0.35</td>
<td>-</td>
</tr>
<tr>
<td>Methanol</td>
<td>-</td>
<td>0.5</td>
<td>6,600</td>
<td>-</td>
<td>13,200</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>-</td>
<td>0.6</td>
<td>22,000</td>
<td>-</td>
<td>36,667</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>0.008</td>
<td>0.06</td>
<td>2,200</td>
<td>17</td>
<td>36,667</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>-</td>
<td>0.06</td>
<td>304</td>
<td>-</td>
<td>5,067</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.54</td>
<td>0.01</td>
<td>10,540</td>
<td>5,692</td>
<td>1,054,000</td>
</tr>
<tr>
<td>TNT (2,4,6-trinitrotoluene)</td>
<td>0.03</td>
<td>0.0005</td>
<td>37,950</td>
<td>1,139</td>
<td>75,900,909</td>
</tr>
<tr>
<td>Toluene</td>
<td>-</td>
<td>0.08</td>
<td>3,300</td>
<td>-</td>
<td>41,250</td>
</tr>
<tr>
<td>Trichloroethane (methyl chloroform)</td>
<td>-</td>
<td>0.2</td>
<td>39,300</td>
<td>-</td>
<td>16,500</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.4</td>
<td>0.0003</td>
<td>27,719</td>
<td>11,088</td>
<td>92,396,667</td>
</tr>
<tr>
<td>Uranium (as a heavy metal)</td>
<td>-</td>
<td>0.0006</td>
<td>47,500</td>
<td>-</td>
<td>79,166,667</td>
</tr>
<tr>
<td>Xylene(^b,d)</td>
<td>-</td>
<td>0.0286</td>
<td>290</td>
<td>-</td>
<td>10,140</td>
</tr>
</tbody>
</table>

\(^a\) All toxicity parameter values were obtained from Oak Ridge National Laboratory, Risk Assessment Information System.
\(^b\) The inhalation RfD was used because it was more conservative than the oral RfD. In all other cases, oral RfDs were used.
\(^c\) The inhalation SF was used because it was more conservative than the oral RfD. In all other cases, oral SFs were used.
\(^d\) Combined congener values were used (combined, \(p\), \(m\), \(o\)).
Screening-Level Assessment of Airborne Plutonium Releases

Because airborne plutonium releases from DP West site were documented to have been significantly higher than officially reported, a screening assessment using the methodology of National Council on Radiation Protection and Measurements (NCRP) Report No. 123 was performed for releases from DP West Site Building 12 stacks during 1949, the apparent year of peak emissions. That assessment is described in Chapter 18. In Level I screening, the release of 86.6 g of $^{239}$Pu from the Building 12 stacks in 1949 was converted to an average stack concentration based on documented annual exhaust volume. Level I screening uses the simplest approach and incorporates a high degree of conservatism to avoid underestimating doses to people. Based on the assumption made in Level I screening that the wind blew toward the closest potentially exposed individual (a resident at the trailer park located 1 km west of the stacks) 25% of the time, concentrations at that point were estimated as one-quarter of that stack concentration. The exposure point concentration (Bq m$^{-3}$) was multiplied by the all-pathways screening factor (Sv per Bq m$^{-3}$) from Table 1.1 of NCRP Report No. 123 to yield a screening value that was compared to a limiting value. The limiting value was set at $1.67 \times 10^{-4}$ Sv y$^{-1}$ based on 1 in 100,000 added risk of fatal or non-fatal cancer using a risk factor of $6.0 \times 10^{-2}$ Sv$^{-1}$.

Level II screening as proceduralized by the NCRP accounts for dispersion in the atmosphere and combines all significant pathways into a single screening factor. The atmospheric concentration at the exposure point was estimated using a straight-line Gaussian dispersion model, and the resulting concentration was multiplied by the atmospheric screening factor from Table 1.1 of NCRP Report No. 123 to obtain the Level II screening value. In accordance with NCRP recommendations, that screening value was compared to 10% of the limiting value in recognition of uncertainties inherent within the calculations and associated assumptions.

In Level III screening, which includes more definitive pathways analysis, the exposure point air concentration from Level II screening was multiplied by a screening factor for inhalation and external sources/submersion from Table 1.1 of NCRP Report No. 123 and by a second screening factor for vegetable consumption from the same table to obtain screening values for inhalation and external exposure as well as for consumption of home grown vegetables. Historical documents and interviews with residents of Los Alamos indicate that residents were allowed to maintain vegetable gardens after World War II, including at the trailer park west of DP Site, but no evidence has been found of production of animal food products within the townsite. The two screening values were summed and compared to the screening limit (i.e., the limiting value divided by 10 as in Level II) to determine whether further evaluation of historical exposures is warranted.
The results of preliminary screening of airborne $^{239}$Pu releases from DP West site Building 12 stacks during 1949 are presented in ES-5. In Level I and Level II screening, the screening value exceeded the limiting value by at least four orders of magnitude, prompting application of the screening methodology at the next highest level. It is important to emphasize that the results of the screening calculations are strictly for comparison with an environmental standard (limiting value), to determine if compliance with that standard is assured or further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals. The results of Level III screening, which again exceeded the limiting value by over four orders of magnitude, indicate that airborne $^{239}$Pu releases from Building 12 stacks— as represented by estimated releases during 1949—warrant further evaluation by experts in environmental radiological assessment.

### Table ES-5. Summary of the preliminary screening of airborne $^{239}$Pu releases from DP West Site Building 12 stacks during 1949

<table>
<thead>
<tr>
<th>Level of Screening</th>
<th>Features of Screening Methodology</th>
<th>Screening Value (Sv y$^{-1}$)</th>
<th>Screening Limit exceeded?</th>
<th>NCRP Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Vent air, all pathways, concentration at exposure point set equal to 25% of stack concentration.</td>
<td>313</td>
<td>Yes</td>
<td>Proceed to Level II</td>
</tr>
<tr>
<td>II</td>
<td>Vent air, all pathways, Gaussian plume modeling to exposure point outside near-wake region, wind blows toward exposure point 25% of the time.</td>
<td>0.367</td>
<td>Yes</td>
<td>Proceed to Level III</td>
</tr>
<tr>
<td>III</td>
<td>Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.</td>
<td>0.367</td>
<td>Yes</td>
<td>&quot;Seek assistance from experts in environmental radiological assessment&quot;</td>
</tr>
</tbody>
</table>

### Screening-Level Assessment of Airborne Beryllium Releases

A screening assessment of beryllium concentrations in public areas was performed based on information from historical documents and the atmospheric dispersion screening methods of NCRP Report No. 123. That assessment is described in Chapter 20. Peak releases of airborne beryllium from the “new” SM-39 Shops at TA-3 for years after 1963 were estimated based on documented annual releases for 1964-1966 and 1968-1970, within which the highest value was for 1970. Peak SM-39 Shop releases representative of 1953-1963, before high efficiency particulate air (HEPA) filters of nominal 99.97% efficiency were added, were estimated based on 1970 releases multiplied times a factor of 167. That value is the ratio of
the effluent reduction factor for HEPA filters to the reduction factor for the filters (of assumed 95% efficiency) that were in place before HEPA filters were installed. Because of similarity of operations, peak release rates of airborne beryllium from V Shop at TA-1 for 1943 to 1953 were assumed to be equal to those from the SM-39 shop before HEPA filters were added.

Releases from the hot pressing of beryllium oxide (BeO) powder in Q Building at TA-1 were estimated based on a document that indicates that 6,100 lbs of BeO was obtained during 1944 for production of reactor components. Based on an assumed release fraction of 0.25%, it was estimated that 6,900 g of BeO (containing 2,500 g of beryllium) was released over 1,600 working hours in 1944. Releases from the testing of beryllium-containing atomic weapon components fired from a cannon in an annex to B Building at TA-1 were estimated based on a frequency of 1 shot per day, 7 d per week. LAHDRA team members estimated that each 20-mm diameter projectile contained 120 g of beryllium, of which 10% was aerosolized, yielding a release of 12 g per test over a 6-minute period. Peak beryllium releases from explosive testing at the Pulsed High Energy Radiographic Machine Emitting X-rays (PHERMEX) facility at TA-15 were estimated based on a report that beryllium use in explosive tests peaked at 106 kg in 1964. The calculation assumed that 100 shots occurred in 1964, of which 80% did not involve beryllium and 20% did. Of the 20 shots that used beryllium, it was assumed that 16 used 3.31 kg beryllium and four used 13.25 kg. If 10% of the beryllium in one of the larger shots was aerosolized, 1.325 kg would have been released over 15 min.

For the beryllium shops and oxide pressing operations, release or usage estimates were found only in the form of annual totals. In order to estimate how high release rates could have been over shorter periods, detailed monitoring data that are available for airborne plutonium releases from DP West site stacks for 1956 and 1957 were analyzed. The relationships between daily concentrations and weekly, monthly, and annual average concentrations were characterized, and a table of multipliers was generated that can be applied to annual data to estimate peak releases over a series of shorter durations. To support preliminary screening, airborne beryllium releases were assumed to vary over time like the measured airborne plutonium releases, and annual beryllium releases were converted to release rates over shorter durations so that airborne concentrations could be compared to occupational and ambient exposure limits.

For each beryllium emission source, the distance to the nearest residential area was estimated, and dilution factors were estimated using the method of NCRP Report No. 123’s Gaussian plume modeling of releases to the atmosphere. The estimated exposure point concentrations were compared to occupational and ambient concentration limits.

The results of screening of airborne releases from the beryllium operations are presented in Table ES-6. The release rate and concentration values for BeO powder pressing, V Shop, and SM-39 Shop releases are
presented as 6-min, 30-min, and 8-h average values that would be expected to be reached or exceeded once per year and monthly average concentrations that would be expected to be reached or exceeded 5% of the time. For the explosive tests at TA-15, the results in Table ES-6 for periods longer than a week are average values over the periods shown based on 100 shots/y, each with 0.25-h duration, that together released 10% of the total beryllium reported expended in 1964. For periods shorter than a month, the results are average values over the periods shown based on one shot, with 0.25-h duration of exposure, occurring during the period and releasing 1.25% of the total beryllium reported expended in 1964.

The screening results indicate that the 8-h time weighted average permissible exposure limit of 2 µg m⁻³ for beryllium adopted for workers by the Occupational Health and Safety Administration (OSHA) and the AEC could have been exceeded in residential areas by releases from the B-Building gun tests. The OSHA/AEC ceiling limit of 25 µg m⁻³ for workers could also have been exceeded for releases from those tests based on concentrations estimated for 0.5-h and 0.1-h averaging periods. The USEPA reference concentration of 0.02 µg m⁻³ could have been exceeded in residential areas by releases from B-Building gun testing, BeO powder pressing, V-Shop machining, and tests at PHERMEX. The National Emission Standard of 0.01 µg m⁻³ for beryllium in ambient air averaged over a 30-d period could have been exceeded in residential areas from the B-Building gun tests and BeO powder pressing.

The importance of the early beryllium releases is again heightened by the fact that residential areas were unusually close to the original Technical Area, with the nearest residences roughly 50 m from B Building, which was literally across Trinity Drive from numerous Sundt apartments. Sigma, Q, and V Buildings— which all housed beryllium operations— were all within 170 m or less of the nearest residences. While it is clear that beryllium was viewed as an occupational hazard after 1947, it appears that the potential for public exposure has not been fully evaluated.

**Screening-Level Assessment of Airborne Tritium Releases**

The benefits of incorporating tritium into nuclear weapons design was recognized early in the Manhattan Project. Information regarding tritium uses is summarized in Chapter 7. Project Y personnel requested tritium from Oak Ridge, TN in the spring of 1944. While LASL received tritium in increasing quantities over the decades for use at 10 or more TAs, no airborne tritium effluent data were included in LANL compilations of effluent data for years prior to 1967. Tritium was released to the air at TAs 3, 21, 33, 35, and 41. In addition, tritium was used in firing site (explosive testing) activities, at TA-15 for example. Between 1967 and 1995, annual airborne tritium releases reported by LANL were never lower than 10,700 Ci and peaked at 38,600 Ci in 1977. Scattered incident reports located by LAHDRA analysts describe episodic releases of tritium that total as much as 64,890 Ci in 1965 and 39,000 Ci as early as
Table ES-6. Results of a preliminary screening assessment of airborne beryllium concentrations in residential areas from identified emission sources at LANL

<table>
<thead>
<tr>
<th>Distance to exposure point (m)</th>
<th>B-Building Gun Tests(^a)</th>
<th>BeO Powder Pressing</th>
<th>V Shop 1943-48</th>
<th>V Shop 1949-53</th>
<th>SM-39 Shop 1953 to 1963</th>
<th>SM-39 Shop after 1963</th>
<th>PHERMEX Tests(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>49</td>
<td>140</td>
<td>170</td>
<td>170</td>
<td>960</td>
<td>960</td>
<td>4500</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>2.5×10(^{-4})</td>
<td>1.1×10(^{-4})</td>
<td>6.9×10(^{-6})</td>
<td>6.9×10(^{-6})</td>
<td>2.5×10(^{-6})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative concentration (s m(^{-3}))</td>
<td>1.1×10(^{-2})</td>
<td>2.5×10(^{-4})</td>
<td>1.1×10(^{-4})</td>
<td>1.1×10(^{-4})</td>
<td>6.9×10(^{-6})</td>
<td>6.9×10(^{-6})</td>
<td>2.5×10(^{-6})</td>
</tr>
<tr>
<td>Release rates (µg s(^{-1})) for relevant averaging periods;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 h:</td>
<td>33,000</td>
<td>64,000</td>
<td>12,000</td>
<td>610</td>
<td>610</td>
<td>3.7</td>
<td>1,500,000</td>
</tr>
<tr>
<td>0.5 h:</td>
<td>6,700</td>
<td>20,000</td>
<td>3,900</td>
<td>190</td>
<td>190</td>
<td>1.2</td>
<td>740,000</td>
</tr>
<tr>
<td>8 h:</td>
<td>420</td>
<td>3,600</td>
<td>680</td>
<td>34</td>
<td>34</td>
<td>0.20</td>
<td>46,000</td>
</tr>
<tr>
<td>730 h (1 month):</td>
<td>140</td>
<td>150</td>
<td>29</td>
<td>1.4</td>
<td>1.4</td>
<td>0.0086</td>
<td>670</td>
</tr>
<tr>
<td>Exposure point concentrations (µg m(^{-3})) for relevant averaging periods;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 h:</td>
<td>350(^{c,d})</td>
<td>16(^d)</td>
<td>1.4(^d)</td>
<td>0.069(^d)</td>
<td>0.0042</td>
<td>0.000025</td>
<td>3.7(^d)</td>
</tr>
<tr>
<td>0.5 h:</td>
<td>71(^d)</td>
<td>5.1(^d)</td>
<td>0.44(^d)</td>
<td>0.022(^d)</td>
<td>0.0013</td>
<td>0.0000080</td>
<td>1.8(^d)</td>
</tr>
<tr>
<td>8 h:</td>
<td>4.4(^{b,d})</td>
<td>0.90(^d)</td>
<td>0.077(^d)</td>
<td>0.0038</td>
<td>0.00023</td>
<td>0.0000014</td>
<td>0.12(^d)</td>
</tr>
<tr>
<td>730 h (1 month):</td>
<td>1.5(^{c,e})</td>
<td>0.038(^{d,e})</td>
<td>0.0033</td>
<td>0.00016</td>
<td>0.000010</td>
<td>0.000000059</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

\(^a\) Episodic releases
\(^b\) Possible exceedance of OSHA/AEC 8-h time weighted average limit = 2 µg m\(^{-3}\)
\(^c\) Possible exceedance of OSHA/AEC ceiling limit = 25 µg m\(^{-3}\)
\(^d\) Possible exceedance of USEPA Reference Concentration = 0.02 µg m\(^{-3}\)
\(^e\) Possible exceedance of National Emission Standard for ambient air averaged over a 30-d period = 0.01 µg m\(^{-3}\)
1958, each from within the 22-y period of tritium usage for which official reports of LANL releases include no data for the radionuclide. LANL did not begin monitoring tritium stack releases until 1971. In 1973, the Lab prepared estimates of atmospheric releases for 1967 through 1970 based on accountability data. There are no formal estimates of total tritium releases prior to 1967, though the LAHDRA document collection contains effluent monitoring and other tritium release data for some tritium facilities prior to 1967. How complete a picture this information might represent with regard to LANL’s total atmospheric tritium releases for the pre-1967 period is currently unknown. Mid-way through the project, the LAHDRA team made a limited effort to compile tritium effluent data from its document collection into a database. Specifically, the focus was on the Lab’s formally reported tritium releases for the period from 1967 forward. These data were entered into a database known as the Off-Site Releases (OSR) database as an internal tool used by the LAHDRA team to support prioritization of historical radionuclide releases from LANL.

One of the most important factors to consider in evaluating atmospheric releases of tritium for potential health risks is the chemical composition of the release. The difference between tritium gas and tritium oxide is enormous in terms of radiation dose to a human receiver. If inhaled, tritium gas is not incorporated into the body to any appreciable degree, and the only dose consequence is the direct exposure to lung tissue. Tritium oxide, in contrast, behaves as water and is readily incorporated into body tissues. In terms of radiation dose per unit intake, the dose from tritium oxide exceeds that from tritium gas by four orders of magnitude (ICRP 1996).

Given its application in the weapons program and accelerator operations, tritium at Los Alamos has primarily been used in the form of tritium gas. However, there are some circumstances where an assumption of the oxide form is appropriate, at least for purposes of initial screening. Examples would include the use of tritium in explosive testing and operations involving water reactions with tritium-bearing salts resulting in oxide formation.

The NCRP Report No. 123 screening method for radionuclide releases to the environment was used to evaluate atmospheric tritium releases from LANL in terms of their potential risk to local residents. That assessment is described in Chapter 7. The source term used was the maximum release reported for each of the six TAs that represented the largest contributors to LANL’s atmospheric tritium releases. To ensure a meaningful screening result, these release totals were re-stated in terms of the corresponding tritium oxide activity for each total value. The upper bound for the fraction of a tritium gas source that has converted to an oxide form was taken to be 1% based on published studies (see Chapter 7).

Screening was performed against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 6% per sievert (Sv). This corresponds to a dose equivalent of $1.67 \times 10^4$ Sv. The
exposed population selected for each screening assessment was the residential population nearest each release point. The pathways considered for each residential location were inhalation of contaminated air and consumption of contaminated soil and vegetables. Consumption of locally raised meat or milk were not considered.

A Level I screen was performed for the TA-3 release first, since it was the smallest contributor to the tritium oxide source term. The Level I screening evaluation for the TA-3 tritium releases exceeded the screening criterion by a substantial margin. Screening therefore proceeded to Level II/III.

In the Level II screening process, the estimated distances from the release points to the nearest residential locations were used to determine a plume diffusion factor from plots provided in NCRP Report No. 123. The Level II screening evaluations showed that only in the case of TA-35, for which the maximum release was treated as 100% HTO, was the adjusted screening criterion exceeded.

The screening-level evaluation suggests that airborne tritium releases from LANL after 1966 were unlikely to have been a source of health risks to local residents around Los Alamos that warrants high priority in any assessment of historical releases from LANL. The possibility cannot be ruled out entirely, however, in light of the screening result for TA-35. The situation could change if releases consisted of a greater fraction as tritium oxide than has been considered here. However, given the degree of conservatism used in application of the NCRP screening method, it appears the impacts of such effects would have to have been substantial before atmospheric tritium releases after 1966 would have posed a significant health risk. Tritium releases events before 1967 are described in numerous scattered documents found by the LAHDRA team, but release totals have not been compiled that would support an evaluation of potential off-site exposures. Airborne tritium releases before 1967 represent a notable data gap in what is known about historical releases from Los Alamos operations.

**Screening-Level Assessment of Airborne Uranium Releases**

Uranium, at various levels of $^{235}$U enrichment, has been used in a wide variety of applications at Los Alamos. Information about uranium use is summarized as part of Chapter 9. Uranium was used as a fissile material in atomic weapons and in “tampers” that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the critical mass of fissile material required to achieve an atomic explosion. Uranium was also used in liquid and solid forms as fuel in various forms of nuclear reactors developed and tested at Los Alamos. Some LASL facilities, including DP East Site, produced fuel for reactors operated elsewhere, such as those in the Rover program. DP West Site’s Building 4 housed laboratories for production of enriched uranium hydride, then was converted to a hot cell facility for examination of irradiated plutonium and enriched uranium fuel elements. Uranium was
also used in explosive testing at Los Alamos—LASL staff estimated in 1971 that between 75,000 and 95,000 kg of uranium had been expended in experimental shots at the Lab from 1949 through 1970.

In the Original Technical Area (TA-1), uranium was processed in a "normal" uranium machine shop in C Building’s southeast section, in chemistry and metallurgical experiments in D Building, in the HT (Heat Treatment) Building. Enriched uranium processing, metallurgy, and recovery were conducted in M Building, while normal and enriched uranium were cast and machined in Sigma Building; the eastern portion of the building processed normal uranium while the western portion processed enriched uranium. TU Building housed machining of normal uranium (“tuballoy”), while TU-1 Building housed recovery of enriched uranium. The original machine shop in V Building machined uranium and beryllium.

The Sigma Complex in TA-3, built in the 1950s and 1960s, has housed extensive laboratory areas for materials synthesis, and processing, characterization, and fabrication of materials such as beryllium, uranium, thallium, and aluminum alloys. These activities have included large-scale metallurgy and fabrication of normal and fully enriched uranium. As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Wing 9 contained hot cells for handling of irradiated uranium and plutonium (see Chapter 8).

To gauge what impact LANL’s atmospheric uranium releases may have had in terms of human health risk, the NCRP Report No. 123 screening model was applied to airborne uranium source term information for 1972, for which LANL reported a relatively large release of 1,200 µCi of $^{234}$U/$^{235}$U from TA-21. The 1972 uranium release was screened against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 6% per sievert (Sv). This corresponds to a dose equivalent of $1.67 \times 10^{-4}$ Sv (16.7 mrem). The exposed population selected was the residential area nearest the release point, apartments within the townsite at an estimated distance of 1,460 m. The pathways considered for the residential location were inhalation of contaminated air, plume immersion, irradiation from contaminated ground, and consumption of contaminated soil and vegetables. The calculation gave a screening value of $1.7 \times 10^{-6}$ Sv (0.17 mrem), much smaller than the screening criterion. The screening dose was also compared against screening criterion reduced by a factor of ten, as recommended by NCRP Report No. 123 for Level II screening to account for uncertainties. This gives an adjusted screening value of $1.67 \times 10^{-5}$ Sv (1.67 mrem), still much larger than the screening dose. Thus, a significant human health risk (relative to the risk criterion) is not indicated for the uranium release reported for TA-21 for 1972.

A screening evaluation was also performed for depleted uranium (DU). The effluent data for 1973 were used, with a release of 640 kg of DU from TA-3. On an activity basis, this equates to a release of $2.11 \times 10^5$ µCi, assuming the material was 100% $^{238}$U (specific activity = 0.33 µCi g$^{-1}$). The airborne DU release reported for TA-3 was assumed to have originated from the Sigma Complex. The nearest
residential area was determined to be the Western Area at a distance of about 1,040 m. The screening evaluation for the 1973 DU releases from TA-3 gave a screening value of $4.4 \times 10^{-4}$ Sv (44 mrem). This value exceeds the unadjusted screening criterion, indicating further investigation into potential health risks is warranted. As with the evaluation for TA-21, the release value was used as reported by LANL and has not been adjusted in any way or independently verified.

It seems counterintuitive that DU releases would screen so much higher than $^{235}$U, but that result reflects the large quantities of DU processed at Los Alamos over its history. DU was also expended in substantial quantities in dynamic experiments at firing sites such as TA-15 and TA-36.

To follow-up on the result of the DU screening, the maximum average air concentration values reported by LANL’s ambient environmental air monitoring network for 1973 were evaluated in terms of the screening dose they represented. Assuming the measured air concentration values reflected $^{235}$U activity (the conservative choice), applying the NCRP Report No. 123 screening factor for $^{235}$U to the maximum offsite average for 1973 (in consistent units) gave a screening dose of $5.4 \times 10^{-6}$ Sv (0.54 mrem). This is well below the screening criterion of $1.67 \times 10^{-4}$ Sv even if the order of magnitude adjustment is applied to account for uncertainties. Treating the measured concentration as $^{238}$U would yield an even lower dose.

The above evaluations do not paint a clear picture of the potential for health risks to Los Alamos residents from historical atmospheric releases of uranium. NCRP Report No. 123 screening evaluations have indicated enriched uranium releases were not significant in terms of potential risk relative to the limiting value selected, and showed releases of depleted uranium warranted further investigation. The ambient air monitoring data for 1973 did not suggest significant risk. None of these evaluations, however, consider releases from earlier in LANL’s history. Earlier releases may have been much larger than those from the 1970s forward for which atmospheric effluent data have been conveniently summarized.

**Potential Doses to Members of the Public from the Trinity Test**

During World War II, two atomic weapon concepts were carried through to production at Los Alamos. The implosion-assembled plutonium-based design was by far the more complicated. A test of that device was considered necessary because of the “enormous step” from theory and experiments to production of a combat weapon and realization that, if the device failed over enemy territory, “the surprise factor would be lost and the enemy would be presented with a large amount of active material in recoverable form.” A “Fat Man” device was successfully tested at the Trinity Site near Socorro, New Mexico on 16 July 1945 and another was dropped over Japan 24 d later. Seen by some as one of the most significant events in world history, the Trinity test fell within the scope of the LAHDRA investigation. Information about the Trinity test that was gathered by the LAHDRA team is summarized in Chapter 10 of this report.
To preserve the secrecy of the atomic bomb mission, residents of New Mexico were not warned before the 16 July 1945 Trinity blast or informed of residual health hazards afterward, and no residents were evacuated. Exposure rates on the day of the world’s first nuclear explosion measured up to 15 or 20 R h\(^{-1}\) in public areas northeast of ground zero at distances around 20 miles, near Hoot Owl Canyon. These critical measurements were made using instruments that were crude, ill suited to field use, and incapable of effectively measuring alpha contamination from about 4.8 kg of unfissioned plutonium that was dispersed. Vehicle shielding and contamination were recognized but not corrected for. The terrain and air flow patterns caused the highest levels of fallout to occur in areas in and around what became known to MED and Army personnel as “Hot Canyon.” The residential areas where highest exposure rates were measured on the day following the test were unknown to monitoring teams and were not even visited on 16 July 1945, so exposure rates there on test day could have been even higher. Ranchers reported that fallout “snowed down” on local surfaces for days after the blast. A rancher whose house was 20 mi northeast of Trinity, reported that “for four or five days after [the blast], a white substance like flour settled on everything.” Because local ground water was not palatable to humans, many local residents collected rain water off their metal roofs into cisterns and used it for drinking water. It is documented that it rained the night after the test, so fresh fallout was likely consumed in collected water. Livestock were raised in the area, with most ranches having one or more dairy cows and a ranch near Hot Canyon maintaining a herd of 200 goats.

Fallout from the world’s first nuclear test was measured in cardboard used by Kodak after they observed spotting on their film. The contamination was traced back to contaminated cardboard that had been caused by an Indiana paper mill’s use of river water that had been contaminated by the Trinity fallout. Airplanes equipped with filters followed the Trinity cloud across Kansas, Iowa, Indiana, upstate New York, New England, and out to sea. With modern monitoring methods, the contamination would likely have been detectable worldwide.

All evaluations of public exposures from the Trinity blast that have been published to date have been incomplete in that they have not reflected the internal doses that were received by residents from intakes of airborne radioactivity and contaminated water and foods. Some unique characteristics of the Trinity event amplified the significance of those omissions. Because the Fat Man device was detonated so close to the ground, members of the public lived less than 20 mi downwind and were not relocated, terrain features and wind patterns caused “hot spots” of radioactive fallout, and lifestyles of local ranchers led to intakes of radioactivity via consumption of water, milk, and homegrown vegetables, it appears that internal radiation doses could have posed significant health risks for individuals exposed after the blast.

The young health physics community had never faced the challenge of monitoring such an extensive environmental release of fission products, activation products, and unfissioned plutonium, and wartime
pressures to maintain secrecy and minimize legal claims led to decisions that would not likely have been made in later tests. Different standards of safety were applied to informed project workers than to uninformed members of the public. Project workers knew enough to evacuate areas when high exposure rates were measured, to wear respirators, to close their windows and breathe through a slice of bread, and to bury their contaminated food rather than eat it. But members of the public did not realize that changes in their behavior were prudent, and project staff did not call for evacuations or protective measures even though predetermined tolerances for exposure rate and projected total exposure had been exceeded.

Too much remains undetermined about exposures from the Trinity test to put the event in perspective as a source of public radiation exposure or to defensibly address the extent to which people were harmed. Beyond omission of internal doses, all assessments released to date are based on monitoring data that have not been subjected to the processes used in modern dose reconstruction studies that include quality checking, cross-checking against other data sources, application of appropriate adjustments or corrections, and uncertainty analysis.

Findings of the LAHDRA Project

The LAHDRA project has significantly expanded the quantity of original documentation that is publicly available relevant to past operations at Los Alamos, activities by LANL personnel within New Mexico, and the potential for public health effects from past environmental releases.

The gathered set of information is not perfect or complete. Some documents that were generated will never be found due to their loss or destruction, others are difficult to read because of their age and repeated photocopying, and most of the authors and participants from the periods of highest releases have passed away. In spite of these factors, the members of the LAHDRA study team believe that enough information exists to reconstruct public exposures from the most significant of LANL’s releases to a degree of certainty sufficient to allow health professionals to judge if significant elevations of health effects should be expected or measurable. For the latter part of the project, some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because documents in these categories included nuclear weapon design details, foreign intelligence, and other types of information that are truly not relevant to studies of off-site releases or health effects, it does not appear that any information needed for dose reconstruction was withheld. And while text was redacted from many selected documents prior to public release, LAHDRA analysts had access to original and redacted copies and could verify that the redacted text did not contain information that would be needed for dose reconstruction.

The information gathered by the LAHDRA team indicates that airborne releases to the environment from Los Alamos operations were significantly greater than has been officially reported or published to the
scientific community. The preliminary prioritization steps that have been performed within the LAHDRA project, while they have been quite simple, have provided information regarding the relative importance of past releases of airborne radionuclides, waterborne radionuclides, and chemicals. In general, it has been shown that early releases (1940s-1960s) were most important than those that followed, and that plutonium was the most important radionuclide in those early years. Airborne activation products from accelerator operations were most important after the mid-1970s, and gross alpha-emitting radioactivity was important for waterborne releases from the mid-1950s to the mid-1970s. Among chemicals, organic solvents as a class were likely most important, followed by TNT and uranium as a heavy metal.

While prioritization analyses have provided relative rankings of contaminants within categories, the preliminary analyses described herein provided no estimates of concentrations to which members of the public were exposed, resulting intakes, or doses to members of the public that could be converted to estimated health risks or compared to toxicologic benchmarks or decision criteria. Priority Indices based on dilution volumes required to be in compliance with maximum allowable effluent concentrations do not reflect how uptake factors vary between radionuclides or the decay that occurs between release point and the location of potential public exposure. And because of the paucity of details regarding uses and releases of chemicals before the 1970s, the preliminary ranking process used for toxic chemicals did not incorporate estimates of the fractions of quantities of chemicals that were on-hand or used were available for release to the environment or were likely released.

LAHDRA has been almost exclusively an information gathering effort. If estimates of historical exposures to members of the public are desired for the releases that have been identified and prioritized by the LAHDRA team, it will be necessary to delineate pathways of human exposure that were complete, to characterize environmental fate and transport, and to calculate doses and the subsequent health risks to groups who were exposed. Methods to perform these steps have been developed and applied for numerous other atomic weapons complex sites, but would have added dimensions to properly reflect the effects of the complex terrain in which LANL is set and to represent the transport of waterborne releases that often soak into dry stream beds before they travel very far, to be transported to a large part by occasional high flow events that wash contaminants toward the Rio Grande.

A number of historical operations have been identified by LAHDRA analysts as areas that might have been particularly important in terms of off-site exposures. In addition, critical information gaps have been identified in several areas.

- **Early airborne releases of plutonium.** Plutonium was processed in crude facilities in D Building during World War II, and many roof-top vents were unfiltered and unmonitored. After DP West Site took over production late in 1945, there was some filtering of releases, but poor monitoring practices
caused releases to be underestimated. DP West releases for 1948-1955 alone were over 100-times the total reported by the Lab for operations before 1973. A screening assessment of public exposures from peak releases from DP West Site in 1949 showed that airborne plutonium releases warrant further evaluation.

- **Airborne beryllium releases.** Los Alamos used significant quantities of beryllium before the health hazards of the material were fully appreciated, and it was processed very close to residential areas. Preliminary screening indicated that early beryllium processing could have resulted in concentrations in residential areas that exceeded worker exposure limits, the USEPA reference concentration, and the National Emission Standard for beryllium.

- **Public exposures from the Trinity test.** Residents of New Mexico were not warned before the 1945 Trinity blast or informed of health hazards afterward, and no residents were evacuated. Exposure rates in public areas from the world’s first nuclear explosion were measured at levels 10,000-times higher than currently allowed. Residents reported that fallout “snowed down” for days after the blast, most had dairy cows, and most collected rain water off their roofs for drinking. All assessments of doses from the Trinity test issued to date have been incomplete in that they have not addressed internal doses received after intakes of radioactivity through inhalation or consumption of contaminated water or food products.

- **Airborne uranium releases.** LANL has used uranium since its beginnings in enrichments ranging from depleted to highly enriched. It has been machined and fabricated into weapon and reactor components and large quantities have been expended in explosive testing. Preliminary screening assessments indicate that enriched uranium releases do not warrant high priority in terms of potential health risk, but show that releases of depleted uranium warrant further investigation. None of these evaluations, however, consider releases from LANL’s early operations. Early releases could have been much larger than those from the 1970s forward, for which effluent data have been summarized. Further investigation is needed before a conclusive assessment can be made of potential health risks from LANL’s airborne uranium releases.

- **Tritium releases before 1967.** Los Alamos used tritium as early as 1944, and received it in increasing quantities in the decades that followed for use at ten or more areas of the Lab. In spite of this, LANL compilations of effluent data include no tritium releases before 1967. LAHDRA team members located scattered documents that describe numerous episodic releases within the 22-y period of tritium usage for which official reports of LANL releases include no data for the radionuclide. These documents call into question the release estimates reported by LANL for 1967 forward and
indicate that releases before 1967 constitute a data gap that must be addressed if the health significance of LANL tritium releases is to be evaluated.

Based upon the findings of the LAHDRA project, CDC and other interested parties will judge if the available information indicates that past releases of any materials could have been sufficiently high that detailed investigation of past releases and public exposures is warranted, and if it appears that sufficient information exists to support detailed investigation if the requisite funding could be made available.

Potential further investigations that could be undertaken for one or more contaminants of highest priority could range from screening level assessments of potential public exposures to more rigorous exposure assessments like those that have been conducted for other MED/AEC/DOE sites and have become known as dose reconstructions. Unlike the prioritization analyses performed to date, these assessments, if they are undertaken, would likely incorporate modeling of environmental transport, exposure pathway analysis, and reflection of the uncertainties and variability associated with input data, assumptions, and models so that the ranges of exposures received by likely members of the public can be specified at a stated level of confidence. Assessments of that type are often performed in an iterative fashion, with uncertainty analyses focusing research on components of the assessment that are contributing most to the overall uncertainty of results. Further refinement can be directed to those elements, and the process repeated until the uncertainty of results is acceptable or cannot be further reduced.
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Chapter 1: Introduction to the LAHDRA Project

The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999. It is being conducted by the Centers for Disease Control and Prevention (CDC), National Center for Environmental Health. Much of the work of the project was conducted by contractors to CDC, namely ChemRisk Inc. and subcontractors Shonka Research Associates Inc., ENSR Corporation, and Advanced Technologies and Laboratories International, Inc.

Shortly after the Manhattan Engineer District (MED) was formed in 1942 to develop the world’s first atomic bombs, construction of major research and production facilities began near secret areas that are now known as Oak Ridge, Tennessee; Los Alamos, New Mexico; and Richland, Washington. After the Atomic Energy Commission (AEC) was established in 1947, a second wave of construction added facilities in Idaho, South Carolina, and Colorado. Starting with one uranium bomb and approximately four plutonium bombs produced at Los Alamos in 1945 (Wahl 1947) the nation’s nuclear warhead stockpile grew to a total explosive yield equivalent to approximately 20 billion tons of TNT by 1959 (USDOE 1997). Because facilities of the nuclear weapons complex used a wide variety of toxic materials and operated for decades behind a “cloak of secrecy,” public concern about potential health risks from their operations grew as more was learned about past activities and events.

Between 1979 and 1992, retrospective evaluations of historical releases and potential health effects were initiated for each of the major early MED/AEC sites except Los Alamos (Church et al. 1990, Ripple et al. 1994, Shipler et al. 1996, HAP/CDPHE 1999, McGavran and Case 1999, Devine et al. 2000, Meyer et al. 2002, Widner and Flack 2002, ATL International 2006). Because the first several assessments were carried out by the U.S. Department of Energy (DOE) or contractors closely associated with nuclear weapon production efforts, and many documents upon which these studies were based were classified or considered proprietary, a general distrust of the results of the studies developed (National Research Council 2006). Under a Memorandum of Understanding signed with DOE in December 1990 and updated in 1996 and 2000, the Department of Health and Human Services (HHS) accepted the responsibility for conducting analytic epidemiologic investigations of residents of communities in the vicinity of DOE facilities (National Research Council 2006). HHS delegated program responsibility to the Centers for Disease Control and Prevention (CDC). In response to requests from elected officials in New Mexico, CDC began exploratory investigations at Los Alamos National Laboratory (LANL) in 1994. These investigations indicated that off-site releases had occurred and large repositories of records existed at the facility, many of which were classified. CDC noted major uncertainties at the time regarding the number of records requiring review at LANL and the extent to which they could be
effectively reviewed by outside investigators. CDC awarded a contract that allowed work to begin on the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project early in 1999, with a focus on identifying the information that is available concerning past releases of radionuclides and chemicals from the government complex at Los Alamos.

The stated goals of the LAHDRA project were to:

1) retrieve historical documents and evaluate their usefulness for off-site dose assessment,
2) declassify (as necessary) relevant documents and release them to the public,
3) enter relevant documents into a project information database, and
4) develop a prioritized list of contaminant releases from the LANL site.

The primary purpose of the LAHDRA project is to identify the information that is available concerning past releases of radionuclides and chemicals from the government complex at Los Alamos, New Mexico. Sited in northern New Mexico and owned by the Department of Energy, the Los Alamos facilities were managed by the University of California from 1943, when “Project Y” was born as part of the Manhattan Project to create the first atomic weapons, until a new team was put in a management role within the last several years. Project Y became known as Los Alamos Laboratory, and its name changed to Los Alamos Scientific Laboratory in 1947 and then to Los Alamos National Laboratory in 1981. For sake of simplicity in this document, we will in some cases refer to LANL for all time periods. LANL’s responsibilities have expanded since the wartime years, to include thermonuclear weapon design, high explosives and ordnance development and testing, weapons safety, nuclear reactor research, waste disposal or incineration, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.

LANL operations have not proceeded without health hazards or environmental impacts. Approximately 30 people have been killed in incidents including criticality experiments and accidents with high explosives. Significant quantities of plutonium, uranium, and a wide variety of other toxic substances have been processed and released to the environment in quantities that in some cases are not well known. The project team investigated the materials used throughout LANL’s history of operations to identify and prioritize releases in terms of their apparent relative importance from the standpoint of potential off-site health effects. Based on the project’s findings, CDC will work with stakeholders to determine if more-detailed assessments of past releases are warranted. Should additional investigations be warranted, they might be in the form of screening-level evaluations, or could progress to detailed dose reconstruction for those releases of highest priority.
In more specific terms, CDC’s model of dose reconstruction involves a process that can be broken up into as many as five phases:

- Retrieval and Assessment of Data
- Initial Source Term Development and Pathway Analysis
- Screening Dose and Exposure Calculations
- Development of Methods for Assessing Environmental Doses
- Calculation of Environmental Exposures, Doses, and Risks

CDC has completed various stages of this process at INEEL, Savannah River, and Los Alamos. Various stages of the process may overlap in time, and stages may be performed iteratively. All stages may not be necessary at all sites. Each stage involves CDC staff, contractors, and the public. While CDC’s LAHDRA represented the information-gathering phase, some work advanced into prioritization of releases and simple, screening-level assessment of potential exposures for several operations that appeared to have been particularly important.

The Products of the LAHDRA Project

The products of the LAHDRA project include:

- This Draft Final Report
- A database that contains bibliographic information and summaries of the content of relevant documents that were located by the project team.
- Sets of copies of the most relevant documents, to be made available by DOE in a reading room in Albuquerque.
- A collection of electronic document images, as Portable Document Format (PDF) files, of all documents for which paper copies or electronic files were obtained.
- A chronology of incidents and off-normal events identified in review of reports prepared by Los Alamos’ Health Division.

The Project Information Database

A Microsoft® Access database was created to store the information reviewed and collected during this project. The CDC defined the basic database structure and values of many of the fields at the onset of the project. A user-friendly front-end was developed for use by the project analysts for reviewing the information collected. The database includes a form created for entering the information from the document summary forms (DSFs) filled out by document analysts in the field, and also a form to perform
searches on all the information that has been entered. In the search form, users can search on every field on the DSF.

As each DSF was entered into the project database, it was assigned a unique sequential Repository Number. This designation was used to track the information throughout the remainder of the project. Most of the reference citations in this report include repository numbers, often abbreviated “Repos. No.” Note that a repository number may represent a number of related, individual documents.

The project database has been made available to the public by placing it in three regional libraries: the Zimmerman Library at the University of New Mexico in Albuquerque, the Mesa Public Library in Los Alamos, and the Northern New Mexico Community College library in Española.

The project repository contains paper copies of documents selected as relevant by the project team and released by LANL (see Fig. 1-1). This repository currently contains over 264,000 pages of documents. These documents, or sets of documents, are arranged sequentially under 8,372 Repository Numbers. A duplicate set of the project’s document repository is maintained at the Zimmerman Library at the University of New Mexico in Albuquerque. This location was selected by the U.S. Department of Energy as the official Public Reading Room for this Project. The Zimmerman Library is located on the University of New Mexico's (UNM's) main campus. The library’s Government Information Department is a regional depository for government documents. Documents can be requested at the information desk, and photocopies can be made at a nominal cost using copy machines in the immediate area.

**Document Images**

As the number of paper copies grew and scanning technology matured, it was decided that a better way to preserve and present the reference material being collected by the LAHDRA team would be as scanned images. Ultimately, all of the information was scanned in as PDF files and an Adobe Acrobat full text search capability was developed. A controlled-access, Internet-based application called DocSleuth was developed by the LAHDRA team to make the information collected for the project available to the project team, libraries, and trusted researchers. As described in Chapter 3, DocSleuth offers capabilities for filtered, full-text searching of bibliographic information and scanned text from collected documents.
Chronology of Incidents and Off-Normal Events

As described in Chapter 13, progress reports issues by the Los Alamos Health Division (H Division) are particularly useful sources of information about operations, releases, episodic events, and accidents involving radionuclides and other toxic materials. The LAHDRA team made a concerted effort to obtain as many H-Division progress reports as possible. The project information database currently contains summary data for hundreds of Health Group and H-Division progress reports. At present, these reports cover a date range from 1943 to 1990. Most of the reports cover a one month period, though there are also annual reports and, in later years, quarterly reports. The monthly reports were discontinued around early 1965 in favor of quarterly reports.

A chronology of episodic or off-normal events described in these reports will be a valuable resource for depicting historical release pathways, particularly in describing mechanisms for fugitive emissions and other unmonitored pathways that might otherwise go unaccounted for. And for hazardous chemicals, the anecdotal information contained in many H-Division reports makes up a large part of what we know about historical usage and actual or potential releases. The latest available version of a chronology of episodic or off-normal events, based on reports that have been reviewed as of the date of release of this report, is presented in Chapter 16. Each event is described briefly, and Repository Number and page number references are provided.

The H-Division progress reports were compiled by the Division Leader and contained information submitted by the leaders of the individual groups that made up the Health Division at a given time. While the material they provide is largely of a summary nature, the reports are nonetheless detailed and provide an array of information. Collectively, the reports provide a chronology of laboratory operations with an emphasis on experience with hazardous materials. They cover the breadth of what are now known as health physics and industrial hygiene, and provide information in a number of areas of interest to the LAHDRA Project, including:

- materials (contaminants) of concern (radionuclides, chemicals, and explosives)
- instrumentation issues
- monitoring/sampling of waste streams/effluents
- monitoring of special (short-duration) programs and experiments
- unmonitored releases and fugitive emissions
- environmental monitoring
- episodic events and incidents involving spread of materials to private property or residences
• facility operations (including ventilation system issues, modifications, etc.)
• waste disposal practices and issues

Of particular note is the fact the reports provide information on various chemicals and compounds that were being utilized at various times, where the materials were being used, and what they were being used for. While this information is largely qualitative, it still provides a valuable resource for prioritization of non-radioactive hazardous materials for time periods for which such information is scarce. The reports also yield valuable information regarding sources of unmonitored releases and fugitive emissions that are always difficult to evaluate in retrospective assessments.

Beyond the specific information contained in the individual H-division progress reports, the continuity of the information they provide collectively (the monthly reports in particular) gives insight into chronic and recurring concerns that may not have been apparent at the time. Applied retrospectively, this information can be used to advance both the document search tasks and the evaluation of information obtained relative to off-site releases and potential effects.

**The Contents of this Report**

This report represents a summary of information that has been obtained by the LAHDRA project team regarding:

• historical operations at Los Alamos,
• the materials that were used,
• the materials that were likely released off site,
• development of residential areas around Los Alamos, and
• the relative importance of identified releases in terms of potential health risks.

The information in this report was obtained from records reviewed at Los Alamos by the project team, information from several off-site collections, some books and reports that are publicly available, and some interviews with past and current Los Alamos workers and members of the public. Preparation of LAHDRA project reports has been an open and iterative process. Interim reports have been issued at approximate one-year intervals so that interested parties could see the types of information the LAHDRA team was finding, be introduced to the approaches being taken to interpret the information that was found, and offer comments and criticism as to how the information gathering process and the report could be improved as work progressed.
Based on the findings of the ongoing information gathering process, which are summarized in this report and evidenced in the project information database, CDC will work with stakeholders to evaluate whether historical releases for radionuclides or other toxic materials from Los Alamos operations warrant more detailed evaluation.

References


Devine OJ, Qualters JR, Morrissey JL, Wall PA. Fernald risk assessment project Phase II screening level estimates of the lifetime risk of developing kidney cancer, female breast cancer, bone cancer, leukemia resulting from the maximum estimated exposure to radioactive materials released from the former Feed Materials Production Center (FMPC). Final report. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Environmental Health; 2000.


Chapter 2: Overview of Historical Operations at Los Alamos

When the Los Alamos facility was initiated, it had a single mission—perfection of the design and manufacture of the first atomic bombs. The initial plan for the first atomic weapon was for a “gun assembled” device that would use slow-burning propellants, as shown in concept in Fig. 2-1 (LANL 1983). Gun-assembled weapons may be designed on the principle of using a propellant to drive a mass of fissile material at a target of the same material to attain a supercritical assembly. To develop and build gun-assembled weapons, Los Alamos personnel initially experimented with use of enriched uranium ($^{235}$U) and plutonium as the fissionable material. Other materials that were needed included the explosive propellant, a detonator to set off that propellant, and precision machined housings to support assembly of the critical mass in the necessary configuration within the required time frame. Part of the housings were cases of heavy metal (such as uranium), called “tampers,” that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the “critical mass” of fissile material required to give rise to an atomic explosion (Serber et al., 1992).

![Fig. 2-1. Concepts of a gun-assembled atomic weapon](image)

Early development work centered on potential use of $^{235}$U or $^{239}$Pu in gun-assembled devices. Top priority was given to development of a plutonium-projectile gun device, with posed more problems than the uranium design due to tighter purity specifications and the need for a faster assembly velocity. In July 1944, it was found that the plutonium that was being received at Los Alamos would not work in gun-assembled weapons due to the presence of more of the $^{240}$Pu isotope than expected amidst the desired $^{239}$Pu. The spontaneous neutron emission rate from that plutonium was several hundred times greater than allowable. As a result, while research on the “certain to work” uranium gun device continued, development of a plutonium device shifted to an implosion-assembled design. A second design was
needed because the delivery rate for enriched uranium would only support production of a single uranium weapon within the imposed schedule, and it was thought that more than one weapon would be necessary. Implosion-assembled weapons may be designed on the principle of squeezing (compressing) the fissile material to super-criticality by detonation of a high-explosive implosion system. The implosion type bomb is depicted conceptually in Fig. 2-2 (LANL 1983).

![Concepts of the implosion-assembled atomic weapon](image)

**Fig. 2-2. Concepts of the implosion-assembled atomic weapon**

To develop and build implosion-assembled devices, much experimentation had to be done with getting chemical high explosives to precisely assemble something with great symmetry, in contrast to their typical uses in blowing things up. Work on high explosives centered on achieving precise timing of detonations at the surface of the explosive and use of “lenses” of a different explosive to focus the resulting shock waves on the metal sphere in the center of the device (Serber et al. 1992). In addition to fissionable material, high explosives, detonators, and tamper material, work on implosion-assembled devices included development of “initiators” that acted as strong sources of neutrons at the precise time that the supercritical masses came into position, to make sure that the fission chain reaction started when it had to. These initiators used materials including radium, beryllium, and polonium (Serber et al. 1992).

With the successful demonstration of fission devices, scientists were able to achieve the high temperatures necessary to bring about fusion of hydrogen nuclei for use in the “Super” bomb that had been studied for years as a theoretical possibility. Viewed by some as Los Alamos’ second historic mission, development of thermonuclear or “hydrogen” devices led to the first full-scale testing in the Mike shot in the Pacific in late 1952. Thermonuclear devices rely on a two-staged process, in which energy from a fission “primary” is contained and used to trigger a fusion or fusion-fission reaction in a physically-separate “secondary” portion of the device. These concepts of a staged thermonuclear weapon are shown in Fig. 2-3 (LANL, 1983).
Materials needed for thermonuclear devices included many of those needed for a gun-assembled or implosion-assembled device, plus fuel for the fusion reaction. The first thermonuclear devices used liquid fuel, such as deuterium, that required significant developments in cryogenics in order to keep the fuel below its boiling point of –250 Celsius. Later devices used lithium deuteride fuel, in solid form, which “breeds” tritium when exposed to neutrons.

![Fig. 2-3. Concepts of a staged nuclear weapon](image)

After World War II, Los Alamos scientists and engineers were involved in development and testing of numerous designs of nuclear devices that were more and more powerful, compact, reliable, dependably deployable in the field, and contained in a variety of delivery vehicles suited to various combat objectives. They were involved in many tests of nuclear devices within the continental United States, in the Pacific, and in Alaska, including some that were part of the Plowshare program that aimed to develop peaceful applications for nuclear explosives.

Los Alamos was the lead site for U.S. nuclear component fabrication until 1949, when the Hanford Plutonium Finishing Plant in Washington began making “pits,” the central cores of the primary stages of nuclear devices (USDOE 1997). In 1952, the Rocky Flats Plant near Denver began making pit components. After 1949, Los Alamos was a backup production facility and designed, developed, and fabricated nuclear components for test devices. Pit production stopped at the Hanford facility in 1965, and the Rocky Flats Plant ceased operations in 1989. From time to time, Los Alamos was called upon to perform special functions in its backup role. For example, because of an accident at the Hanford Plutonium Finishing Plant in 1984, plutonium was sent in oxide form to Los Alamos for conversion to metal (USDOE 1997). Special activity at Los Alamos might also have occurred after major fires in plutonium facilities at Rocky Flats in 1957 and 1969.
Operations, facilities, and capabilities that were needed to support development and production of the various types of nuclear devices expanded in many cases to support other missions after World War II. Programs in chemistry, metallurgy, and low temperature physics expanded into nonmilitary development and fundamental research. For example, Los Alamos developed one of the largest experimental machine shops in the country. The Health Division grew significantly and expanded into many areas of health physics, industrial hygiene, medicine, safety, and biomedical research regarding people and radiation. Early reactors that were built to confirm critical masses for fissionable materials and to study properties of fission and the behavior of resulting neutrons, were the forerunners of a variety of reactors that were designed and in some cases built and operated at Los Alamos. While some of these reactors served as sources of neutrons for various types of nuclear research or for materials testing, other designs were pursued for potential applications in power generation and propulsion of nuclear rockets into deep space. Some of the first significant steps towards controlled nuclear fusion as a power source were taken at Los Alamos, and the plasma thermocouple program explored methods for direct conversion of fission energy to electricity for potential application in propulsion of spacecraft.

Operations at Los Alamos have taken place in land divisions called Technical Areas, or TAs. Table 2-1 contains a listing of these Technical Areas, including some that have been abandoned, some that were combined with other TAs, and some that were cancelled before they ever became operational. Table 2-1 also contains listings of some of the various radioactive materials that are documented to have been used at each technical area, based on information reviewed to date. A similar tabulation of chemicals used at each technical area has not yet been compiled.

Figures 2-4 and 2-5 show the location of LANL within New Mexico and the layout of the modern-day Technical Areas, while Fig. 2-6 presents a timeline of some selected operations and activities at (or related to) Los Alamos.

References


Table 2-1. Los Alamos Technical Areas past and present

<table>
<thead>
<tr>
<th>TA</th>
<th>Name and Description</th>
<th>Materials Involveda</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA-0</td>
<td>Los Alamos Townsite: leased space in Los Alamos and White Rock for training, support, unclassified research and development, community outreach, museum</td>
<td>None</td>
</tr>
<tr>
<td>TA-1</td>
<td>Original Main Technical Area (inactive): 1943-65 active; turned over to Los Alamos County or private interest in 1966; all contamination removed by 1975</td>
<td>EU, DU, $^{238,239}$Pu, $^{241}$Am, $^{210}$Po, $^{140}$Ba, $^{140}$La</td>
</tr>
<tr>
<td>TA-2</td>
<td>a.k.a. Omega Site: Early critical assembly experiments. Water Boilers (1944-1974); Pu Fast Reactor, a.k.a. Clementine (1946–1950); and Omega West Reactor (1956-1992); reactors used for critical experiments up until 1946 when experiments were moved to TA-18. Omega Site reactors operations were then centered around neutron experiments and isotope production</td>
<td>$^{235}$U; $^{239}$Pu; $^{137}$I; $^{88}$Rb; $^{137}$Cs; $^{131}$Xe; $^{125}$I; $^{41}$Ar; $^3$H</td>
</tr>
<tr>
<td>TA-3</td>
<td>Core Area (a.k.a. South Mesa Site; active 1949 to present): detonator manufacturing, metallurgy burn pit, firing sites from 1943-49. Listed below are brief descriptions of key TA-3 operations.</td>
<td>$^{238,239}$Pu, $^{235,238}$U, DU, NU, $^{210}$Po</td>
</tr>
<tr>
<td>TA-29</td>
<td>Chemistry and Metallurgy Research: actinide chemistry and metallurgy research since 1952 to present</td>
<td>$^{235}$Pu, $^{238}$Pu, $^{235}$U, $^{238}$U, DU</td>
</tr>
<tr>
<td>TA-366</td>
<td>Sigma: materials fabrication since 1958; also –141 Rolling Mill, -35 Press Bldg, -159 thorium storage</td>
<td>$^{235}$U; DU</td>
</tr>
<tr>
<td>TA-31698</td>
<td>Materials Science Laboratory: processing, mechanical research</td>
<td>DU</td>
</tr>
<tr>
<td>TA-339,102</td>
<td>Machine shops: since 1953; Be in Bldg 39, DU in Bldg 102</td>
<td>DU</td>
</tr>
<tr>
<td>TA-4</td>
<td>Alpha Site: firing site until 1956; Material Disposal Area C</td>
<td>DU</td>
</tr>
<tr>
<td>TA-5</td>
<td>Beta Site: former firing site used extensively in 1945</td>
<td>DU</td>
</tr>
<tr>
<td>TA-6</td>
<td>Two-Mile Mesa Site: mostly undeveloped; detonator manufacturing and testing 1944-50</td>
<td>DU</td>
</tr>
<tr>
<td>TA-7</td>
<td>Gomez Ranch Site: former firing site used from 1944-47 for small explosive experiments with short-lived radioisotopes</td>
<td>DU; unknown</td>
</tr>
<tr>
<td>TA-8</td>
<td>GT Site (a.k.a. Anchor Site West): gun firing sites 1943-45; explosives processing 1945-50; nondestructive X-ray testing 1950-present</td>
<td>$^{235}$Pu; $^{238}$Pu; $^{235}$U; DU; $^{60}$Co; $^{192}$Ir; $^{137}$Cs; X-rays</td>
</tr>
<tr>
<td>TA-9</td>
<td>Anchor Site East (a.k.a. Anchor Ranch): firing areas; explosives research (active)</td>
<td>DU; $^8$H</td>
</tr>
<tr>
<td>TA-10</td>
<td>Bayo Canyon: Radioactive lanthanum test shots 1944-61; Radioactive lanthanum radiochemistry 1944-50; site removed in 1963</td>
<td>$^{90}$Sr; DU; NU; $^{137}$La</td>
</tr>
<tr>
<td>TA-11</td>
<td>K Site (active): implosion studies; later drop and vibration tests, dates unknown at this time</td>
<td>DU; $^{226}$Ra, betatron</td>
</tr>
<tr>
<td>TA-12</td>
<td>L Site: explosives testing (1945-46); abandoned in mid-1950s</td>
<td>DU</td>
</tr>
<tr>
<td>TA-13</td>
<td>P Site: X-ray studies of explosives; later incorporated with TA-16, status unknown</td>
<td>X-rays, DU, $^{239}$Po</td>
</tr>
<tr>
<td>TA-14</td>
<td>Q Site (active): explosives testing 1944-present</td>
<td>DU</td>
</tr>
<tr>
<td>TA-15</td>
<td>R Site: explosives testing; eight inactive firing sites (A-H, R44, R45); Pulsed High-Energy Radiation Machine Emitting X-Rays (PHERMX) 1962-present; Dual-Axis Radiographic Hydrodynamics Test (DARHT) Facility</td>
<td>$^{239}$Pu; DU; $^3$H; X-rays</td>
</tr>
<tr>
<td>TA-16</td>
<td>S Site (active): former explosives casting/machining operations; burning ground; Weapons Engineering Tritium Facility. Began in the 1950s</td>
<td>$^{239}$Pu; DU; $^3$H; X-rays</td>
</tr>
<tr>
<td>TA-17</td>
<td>X Site (canceled)</td>
<td>None</td>
</tr>
<tr>
<td>TA-18</td>
<td>Pajarito Laboratory: criticality testing 1946-present; Rover 1955-73; Hydro assembly 1957</td>
<td>$^{235}$U; $^{239}$Pu; $^{240}$Pu; $^{233}$U; MFP; $^{137}$I; polonium; neutron</td>
</tr>
<tr>
<td>TA-19</td>
<td>East Gate Laboratory: released to U.S. Atomic Energy Commission in 1962</td>
<td>None</td>
</tr>
<tr>
<td>TA</td>
<td>Name and Description</td>
<td>Materials Involved&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>---------</td>
<td>---------------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>TA-20</td>
<td>Sandia Canyon Site: former firing site abandoned in 1957</td>
<td>DU</td>
</tr>
<tr>
<td>TA-21</td>
<td>DP Site: former plutonium operations (DP West); uranium/polonium operations (DP East); Material Disposal Areas A,B,T,U,V; Tritium Systems Test Assembly, Tritium Science and Fabrication Facility (1945 to 1978)</td>
<td>$^{239,235}$Pu, $^{238,240}$Pu, $^{241}$Pu, $^{241}$Am, $^{235}$U, $^{238}$U, $^{210}$Po, $^{227}$Ac, $^{3}$H</td>
</tr>
<tr>
<td>TA-22</td>
<td>TD (Trap Door) Site: detonator development; shops; disposal pits</td>
<td>DU</td>
</tr>
<tr>
<td>TA-23</td>
<td>NU Site: reduced firing load at TA-9 1945-50</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-24</td>
<td>T Site: X-ray studies of explosives; later incorporated with TA-16</td>
<td>X-rays, DU</td>
</tr>
<tr>
<td>TA-25</td>
<td>V Site: explosives assembly; later incorporated with TA-16</td>
<td>DU</td>
</tr>
<tr>
<td>TA-26</td>
<td>D Site: storage vault and guard building 1946-48; removed in 1966</td>
<td>$^{3}$H, $^{235}$U, $^{239}$U</td>
</tr>
<tr>
<td>TA-27</td>
<td>Gamma Site: plutonium gun assembly 1945-47</td>
<td>$^{239}$Pu, DU, thorium</td>
</tr>
<tr>
<td>TA-28</td>
<td>Magazine Area A (active): firing site 1979; explosives storage area</td>
<td>DU</td>
</tr>
<tr>
<td>TA-29</td>
<td>Magazine Area B: explosives storage area; abandoned in 1957</td>
<td>DU</td>
</tr>
<tr>
<td>TA-30</td>
<td>Electronics Test Area: electronics testing 1945-48</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-31</td>
<td>East Receiving Yard: 1948-54 warehouses W of airport; removed 1954</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-32</td>
<td>Medical Research Laboratory: bio-research facility; 1943-54; removed in 1954; incinerator use included</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-33</td>
<td>HP (Hot Point) Site: 1948-56 shaft experiments; High Pressure Tritium Laboratory 1970s; Material Disposal Areas D, E, K</td>
<td>$^{3}$H</td>
</tr>
<tr>
<td>TA-34</td>
<td>New Laboratory Warehouse Area (canceled)</td>
<td>None</td>
</tr>
<tr>
<td>TA-35</td>
<td>Ten Site: Radioactive lanthanum 1951-63; Los Alamos Power Reactor Experiment (LAPRE) I/II 1950s; Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) I 1960s; laser fusion research 1974</td>
<td>$^{3}$H, $^{90}$Sr, $^{140}$Ba, $^{140}$La, $^{235}$U, DU, $^{237}$Np, Pu, Po, Co, VFP</td>
</tr>
<tr>
<td>TA-36</td>
<td>Kappa Site: replaced TAs-9, 23, 12 in 1950; four active firing sites; nonnuclear ordnance and armor</td>
<td>DU</td>
</tr>
<tr>
<td>TA-37</td>
<td>Magazine Area C (active): explosives storage area</td>
<td>DU</td>
</tr>
<tr>
<td>TA-38</td>
<td>Monterey Site (canceled)</td>
<td>None</td>
</tr>
<tr>
<td>TA-39</td>
<td>Ancho Canyon Site: five firing points; incinerator 1955-60; photographic study of the behavior of nonnuclear weapons</td>
<td>NU, DU; thorium</td>
</tr>
<tr>
<td>TA-40</td>
<td>DF (Detonator Firing) Site: six firing points; detonator development</td>
<td>$^{3}$H</td>
</tr>
<tr>
<td>TA-41</td>
<td>W (Weapons Group WX) Site: engineering of nuclear components; fabrication of test materials</td>
<td>$^{3}$H, plutonium, uranium, americium</td>
</tr>
<tr>
<td>TA-42</td>
<td>Incinerator Site: for low-level Pu contaminated waste; abandoned 1970</td>
<td>All</td>
</tr>
<tr>
<td>TA-43</td>
<td>Health Research Laboratory: biological research 1953-70; replaced TA-32</td>
<td>All</td>
</tr>
<tr>
<td>TA-44</td>
<td>Los Angeles Shop: experimental machine shop in Los Angeles, CA 1949-58; abandoned in 1958</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-45</td>
<td>Radioactive Liquid Waste Treatment Plant (inactive): removed majority of plutonium before discharge to Acid Canyon</td>
<td>$^{238,239}$Pu, $^{235,238}$U</td>
</tr>
<tr>
<td>TA-46</td>
<td>WA Site: Rover batteries 1950-74; U isotope separation 1976-early 1980s; photochemistry research; lasers</td>
<td>$^{235}$U, $^{238}$U thorium</td>
</tr>
<tr>
<td>TA-47</td>
<td>BR Site (Bruns Railhead): shipped materials via a railhead near Bruns Hospital in Santa Fe, 1943-58; abandoned in 1958</td>
<td>DU; unknown</td>
</tr>
<tr>
<td>TA-48</td>
<td>Radiochemistry Site: actinide chemistry and hot cell isotope production, area used for analyzing samples from weapon test shots, 1950s to present</td>
<td>U; TRU; MAP; MFP</td>
</tr>
<tr>
<td>TA-49</td>
<td>Frijoles Mesa Site: underground hydronuclear experiments 1960-61; now Hazardous Devices Team Training</td>
<td>$^{3}$H, plutonium, uranium</td>
</tr>
<tr>
<td>TA-50</td>
<td>Waste Management Site: treated liquid wastes before discharge to Mortandad Canyon; replaced TA-45, 35; controlled air incinerator 1976</td>
<td>All</td>
</tr>
<tr>
<td>TA-51</td>
<td>Environmental Research Site: animal exposure facility 1962; now studies of impact of waste and waste storage on the environment</td>
<td>$^{60}$Co, strontium</td>
</tr>
<tr>
<td>TA-52</td>
<td>Reactor Development: Ultra-High Temperature Reactor Experiment (UHTREX)</td>
<td>$^{235}$U, $^{239}$Pu, $^{3}$H, VFP, Kr, Xe</td>
</tr>
</tbody>
</table>
### Table 2-1: Los Alamos Technical Areas Past and Present (Continued)

<table>
<thead>
<tr>
<th>TA</th>
<th>Name and Description</th>
<th>Radioactive Materials Involved&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA-53</td>
<td>Los Alamos Neutron Science Center (LANSCE)</td>
<td>3H; 41Ar; 11C; 15O; U</td>
</tr>
<tr>
<td>TA-54</td>
<td>Waste Disposal Site: solid wastes; Materials Disposal Areas G, H, J, L</td>
<td>All</td>
</tr>
<tr>
<td>TA-55</td>
<td>Plutonium Facility Site (active): replaced TA-21; SNM storage, 1978 to present</td>
<td>239Pu; 3H</td>
</tr>
<tr>
<td>TA-56</td>
<td>Subterranean Basalt Site: melting basalt with electrically heated penetrator;</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>abandoned in 1976</td>
<td></td>
</tr>
<tr>
<td>TA-57</td>
<td>Fenton Hill Site: Hot Dry Rock geothermal project (inactive)</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-58</td>
<td>Two-Mile North Site: experimental sciences for TA-3 programs</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-59</td>
<td>Occupational Health Site: Office of Environment, Safety, and Health offices,</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>emergency management</td>
<td></td>
</tr>
<tr>
<td>TA-60</td>
<td>Sigma Mesa: Test Fabrication Facility and Rack Assembly; Alignment Complex</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-61</td>
<td>East Jemez Road: physical support and sanitary landfill</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-62</td>
<td>Northwest Site: reserved for experiments, research, buffer zones</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-63</td>
<td>Pajarito Service Area: environmental and waste management functions</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-64</td>
<td>Central Guard Facility, Hazardous Materials Response Team</td>
<td>None</td>
</tr>
<tr>
<td>TA-65</td>
<td>Not currently active or never assigned</td>
<td>None</td>
</tr>
<tr>
<td>TA-66</td>
<td>Central Technical Support Site: industrial partnership activities</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-67</td>
<td>Pajarito Mesa: former TA-12; dynamic testing area; archeological sites</td>
<td>DU</td>
</tr>
<tr>
<td>TA-68</td>
<td>Water Canyon Site: dynamic testing area with study areas</td>
<td>DU</td>
</tr>
<tr>
<td>TA-69</td>
<td>Anchor North Site: undeveloped; buffer for the dynamic testing area</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-70</td>
<td>Rio Grande Site: undeveloped; buffer for the high-explosives test area</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-71</td>
<td>Southeast Site: undeveloped; buffer for the high-explosives test area</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-72</td>
<td>East Entry Site: Protective Forces Training Facility</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-73</td>
<td>Los Alamos Airport: on-site disposal area; incinerator 1950s</td>
<td>All</td>
</tr>
<tr>
<td>TA-74</td>
<td>Otowi Tract: water wells, archeological sites, endangered breeding area</td>
<td>None</td>
</tr>
</tbody>
</table>

### Miscellaneous Locations of Activities that Involved Los Alamos Personnel

<table>
<thead>
<tr>
<th>Location</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific</td>
<td>Nuclear tests: Marshall Islands (1945-51)</td>
</tr>
<tr>
<td>AK</td>
<td>Nuclear tests: Amchitka (Long Shot, Milrow, Cannikin) 1965,1969,1971</td>
</tr>
<tr>
<td>NV</td>
<td>Nevada Test Site: nuclear tests, Rover nuclear rocket engine program</td>
</tr>
<tr>
<td></td>
<td>Nuclear tests, non-NTS: Fallon (Shoal); Tonopah (Faultless) 1968</td>
</tr>
<tr>
<td>CO</td>
<td>Nuclear tests: Grand Valley (Rulison) 1970; Rifle (Rio Blanco) 1973</td>
</tr>
<tr>
<td>NM</td>
<td>Nuclear tests: White Sands (Trinity) 1945; Carlsbad (Gnome) 1961; Farmington (Gasbuggy) 1967</td>
</tr>
<tr>
<td>MS</td>
<td>Nuclear tests: Hattiesburg (Salmon and Sterling)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Key for table entries:

- All = 239Pu; 240Pu; 218Po; 235U; 235U; DU; 3H; 210Po; 227Ac; 226Ra;
- DU = depleted uranium- 238U;
- MAP = mixed activation products (e.g., 41Ar; 7Be; 11C; 13N; 15O);
- MFP = mixed fission products;
- NU = natural uranium;
- VFP = volatile fission products.

Element names without number (e.g., plutonium, uranium) indicate isotope not specified.

a.k.a. = also known as.

SNM = Special Nuclear Material.
Figure 2-4: Location of Los Alamos and LANL
Figure 2-6: Timeline of Selected Los Alamos Operations and Activities

- **1943**: D Building opens for use
- **1945**: Main Pu processing performed in D Building (mg quantities at first)
- **1947**: 2500 experiments had been completed with 51 g of Pu
- **1949**: Fire in C Shop at TA-1
- **1951**: First large quantity Pu shipment arrived
- **1953**: Pu for Trinity test purified
- **1955**: Pu for Nagasaki bomb purified
- **1957**: Pu for second combat weapon purified
- **1959**: Trinity Test
- **1961**: Nagasaki bombing
- **1963**: Pu for first composite weapon core purified
- **1965**: D Building remained in use for metallurgical R & D, analytical work, etc.
- **1967**: Pu production conducted at DP Site (TA-21).
- **1969**: Pu processed at TA-55
- **1971**: CMR Building operational at TA-3, including Pu metallurgy work
- **1973**: Water Boiler operated in LOPO mode at TA-2, Omega Site
- **1975**: Anchor Site West-casting room operational
- **1977**: Firing Sites A & B operational
- **1979**: L Site operational (high explosives casting and machining, burning ground)
- **1981**: Water Boiler operated in HYPO mode at TA-35, "Ten Site"
- **1983**: Firing Sites C, D, E, F added
- **1985**: Firing Sites G & H added
- **1987**: TA-33 tritium handling facility operational
- **1989**: Rover program active
- **1991**: LANL Rover tests in Nevada
- **1993**: TA-50 liquid waste treatment plant operated
- **1995**: "WETF" tritium facility operational at TA-16
- **1997**: Area G disposal ground used
- **1999**: TSTA operational at DP East
- **2001**: Rover program active
- **2003**: TSTA operational at DP East
- **2005**: Rover program active
- **2007**: "WETF" tritium facility operational at TA-16
- **2009**: Rover program active

- **1943**: B Building open for use
- **1945**: First gram-scale quantities of Pu arrived
- **1947**: 2500 experiments had been completed with 51 g of Pu
- **1949**: Pu for Trinity test purified
- **1951**: Pu for Nagasaki bomb purified
- **1953**: Pu for second combat weapon purified
- **1955**: Trinity Test
- **1957**: Nagasaki bombing
- **1959**: Pu for first composite weapon core purified
- **1961**: D Building remained in use for metallurgical R & D, analytical work, etc.
- **1963**: Pu production conducted at DP Site (TA-21).
- **1965**: Pu processed at TA-55
- **1967**: CMR Building operational at TA-3, including Pu metallurgy work
- **1969**: Water Boiler operated in LOPO mode at TA-2, Omega Site
- **1971**: Anchor Site West-casting room operational
- **1973**: Firing Sites A & B operational
- **1975**: L Site operational (high explosives testing)
- **1977**: Water Boiler operated in HYPO mode at TA-35, "Ten Site"
- **1979**: Firing Sites C, D, E, F added
- **1981**: Firing Sites G & H added
- **1983**: TA-33 tritium handling facility operational
- **1985**: Rover program active
- **1987**: LANL Rover tests in Nevada
- **1989**: TA-50 liquid waste treatment plant operated
- **1991**: "WETF" tritium facility operational at TA-16
- **1993**: Area G disposal ground used
- **1995**: TSTA operational at DP East
- **1997**: Rover program active
- **1999**: TSTA operational at DP East
- **2001**: Rover program active
- **2003**: Rover program active
- **2005**: Rover program active
- **2007**: "WETF" tritium facility operational at TA-16
Chapter 3: Information Gathering at Los Alamos

The goal of the information gathering process at Los Alamos was to identify and retrieve information relevant to off-site releases of chemicals or radionuclides, or potential health effects, associated with LANL-sponsored activities within the State of New Mexico. Information gathering began with a focus on centralized records repositories, then progressed to records held by individual groups or divisions. The latter were selected on a prioritized basis, that is, those most likely to include information of interest.

The principal method employed for information gathering at Los Alamos was what is known as systematic document review (or searching). Systematic searching involves identifying the document collections that exist at a site or facility, both classified and unclassified, then progressing through those collections in an appropriate and orderly fashion until all potentially relevant documents have been reviewed. All reviews were conducted by analysts qualified to recognize information that a competent scientist would use to evaluate historical releases and/or the potential for off-site health hazards. This approach best supports the “leave no stone unturned” goal that best fosters public credibility in public dose reconstruction studies. Systematic document searching can be contrasted with “directed” document searching, where researchers have identified needs for specific types of information and go directly to the document locations or particular types of documents believed most likely to contain it. Systematic searching, directed searching, and combinations of the two approaches have been applied in dose reconstruction studies in the U.S. over the past 15 years.

Some quasi-directed searching activities were conducted at Los Alamos as the information gathering process progressed. These consisted of re-visiting records collections that had been searched earlier in the project to capitalize on information that had been garnered from the initial searches. These subsequent search activities were not entirely directed in nature, as they still maintained characteristics of systematic searching. However, they were not entirely systematic either, as they had a narrower focus than the initial search activities. Another practice employed by the project team was focused systematic searching, in which subsets of records within a given collection were identified based on some defined criteria. These subsets were then subjected to systematic search.

Fig. 3-1. Two LAHDRA analysts review records at Los Alamos
Throughout this section the words “record” or “document” are used to describe a number of different types of information. In this context, records or documents are not limited to physical documents, but also include materials such as electronic databases of information, microfiche records, microfilm records, photographs, video, audio recordings, and engineering drawings. In addition to physical records, other sources of information explored by the project team included interviews with past and current LANL staff members and tours of LANL facilities.

**How Documents were Categorized, Summarized and Catalogued**

When a document relevant to off-site releases or health effects was identified by a LAHDRA analyst, a Document Summary Form (DSF) was completed. The DSF provided a bibliographic summary of the document and included information on where it was located so it could be retrieved again in the future if needed. Copies were requested of documents that were clearly relevant to the estimation of offsite releases or health effects. For other documents, such as those that contained supporting information or were otherwise not directly applicable, copies were sometimes, but not always requested. A DSF was completed for all relevant documents regardless of whether a copy was requested from LANL.

Copies of documents requested by the project team, as well as all DSFs completed at Los Alamos, were required to go through a review process before they could be released. All DSFs and documents were reviewed by LANL to ensure they contained no classified information, personal information that was protected under the Privacy Act or information that was proprietary or legally privileged. If a document had been deemed Official Use Only (OUO) by its originator, the review process expanded further to include an effort to contact the originating author or organization and have the OUO designation removed. In all but a few cases this was accomplished and the documents were released to the public. One aim of the LAHDRA project was to place all of the material retrieved from Los Alamos in the public domain. However, there were a few cases where OUO restrictions could not be removed from documents desired by the project team. In these instances the documents were provided to the project team for its use, subject to appropriate controls for OUO material.

After receipt from Los Alamos, each DSF and associated document (if any) was assigned a LAHDRA Repository Number, and the information from the DSF was entered into a project information database. The database fields reflected those from the DSF. The Repository Number was simply a sequential number used for indexing the database entries. Documents were scanned to Portable Document Format (PDF) files and indexed using Optical Character Recognition (OCR) software to provide a full-text searchable electronic version. The PDF files were linked to each database record so a user could access the document associated with an entry.
The project information database, which will be described later, was provided to a limited number of public libraries in the northern New Mexico and Albuquerque. It was updated periodically as information was added. In addition, copies of documents retrieved from Los Alamos were made available to members of the public at the Zimmerman Library at the University of New Mexico in Albuquerque.

**The LAHDRA Document Summary Form**

The DSF was revised several times during the information gathering process. A copy of the latest version, Revision 7, is shown in Fig. 3-2. Most of the entries on the DSF are self-explanatory. However, two that are of particular interest are described here for completeness.

**Item Number/Other Identifier**

This field was added later in the project to be used in conjunction with creation of the Document Request Log, which will be described later. A separate log was created for each document collection being searched. For each log sheet, entries were given a sequential item number. The item number was entered on the corresponding DSF so it and any associated copies could be tracked through the review process. The item number allowed copies of documents to be readily associated with the corresponding DSF if the two became separated.

**CDC Document Category**

Analysts selected one of three categories for a document using the criteria below:

**Category 1.** Documents that a competent scientist would use in estimating off-site releases or their health effects from operations at LANL or other LANL-sponsored operations within the State of New Mexico (such as the Trinity test). Examples of Category 1 documents include effluent monitoring data, accident reports with estimates of releases, release point information, or results of environmental monitoring performed near locations where people lived or recreated.

**Category 2.** Documents that contained supporting or confirming information that could be useful in estimation of off-site releases or health effects from operations at LANL or other LANL-sponsored operations within the State of New Mexico. Examples of Category 2 documents included historical descriptions of site activities, notebooks for relevant operations, or process flow sheets.

**Category 3.** Documents that could be used to estimate or confirm off-site releases or health effects from nuclear weapons complex sites outside of New Mexico or from operations sponsored by groups other than LANL at non-LANL sites within New Mexico (such as Sandia National Laboratory).
**Fig. 3-2.** The LAHDRA Document Summary Form (DSF)
In contrast, documents about activities by LANL personnel that occurred beyond LANL’s boundaries but within New Mexico (such as the Trinity test) would fall under Category 1 or 2. Documents concerning operations at foreign nuclear weapon sites or nuclear power plants (foreign or domestic) were not Category 3 material since such activities were not within the responsibility of the U.S. Department of Energy or its predecessor agencies. In general, copies were not requested for Category 3 documents, but there were cases where copies of Category 3 material were obtained.

Table 3-1 provides a summary of how documents were categorized based on the location and sponsorship of the activity they described. A document could only be assigned one category number.

<table>
<thead>
<tr>
<th>Activity's Sponsor</th>
<th>Location of Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At LANL</td>
</tr>
<tr>
<td>LANL</td>
<td>Category 1 or 2</td>
</tr>
<tr>
<td>Others</td>
<td>Category 1 or 2</td>
</tr>
</tbody>
</table>

The Document Request Log

Toward the later stages of the project, the information gathering process was augmented to include the use of a log sheet called the document request log. Its purpose was to record information about each DSF and any associated document copies generated or requested by the project team. Individual log sheets were used for each specific LANL records facility or collection where review activities were performed.

The document request log provided a formal record of material requested by the project team. It was used to track items (DSFs and documents) from the time they were requested until they were received. The request log became necessary because of significant delays that would sometimes occur between request and receipt. In some cases material would get lost in the review process, so the request log provided a means for identifying and retrieving missing material.

A separate request log was created for each document collection or facility being searched. Each entry on a given log was assigned a unique item number. Item numbers were used as a reference when tracking the progress of material through the review process and for associating documents with DSFs in cases where they were not reviewed together. The fields on the log sheets varied somewhat depending on the records facility where they were used, but they all included fields for the document title, page count, location, accession numbers or other identifiers, and so forth. A request log entry was made for each DSF
regardless of whether the underlying document was copied so there was a complete record of everything the project team identified as relevant within a given document collection. The request log also included fields for use by the classification reviewers to indicate they had reviewed each document, and whether it had been declassified, redacted, etc.

The Project Information Database

As they were received from LANL, the bibliographic information from each DSF was entered into a Microsoft® Access database created for that purpose. The basic structure of the database was defined by the CDC at the outset of the project. As each DSF was entered into the database it was assigned a unique Repository Number. A Repository Number was simply a sequential number used for reference and indexing. Following data entry, the DSFs and associated documents were filed by Repository Number.

As the size of the document collection grew and scanning technology matured, a decision was made to scan all of the documents received from LANL to PDF files. OCR software was used to create a full-text searchable image, within the constraints of the image quality of the original. The OCR process is not 100% reliable given the poor quality of some of the documents.

Fig. 3-3 depicts the progression of a document from a handwritten DSF through entry of the DSF information into the information database and the creation of a searchable PDF image file.

The project database, including the searchable image files, was made available to the public at three regional libraries within New Mexico: the Zimmerman Library at the University of New Mexico in Albuquerque, the Mesa Public Library in Los Alamos, and the Northern New Mexico Community College library in Española. Users may search the bibliographic information from the DSFs and perform full-text searches of the document images. As mentioned above, the OCR process can miss words or text in poor quality originals, so it is recommended that users utilize both full-text searches and searches of the DSF information (i.e., fielded or filtered searches) to find information of interest.

In addition to the Access-based database, the project team developed a Web-based application that is a versatile searching tool for the database and scanned documents. The application, called DocSleuth, is hosted by ChemRisk and is available over the Internet to project team members and other selected individuals. DocSleuth employs sophisticated indexing technology to a flat-fielded version of the project database. The database was re-indexed periodically as information was added. DocSleuth allows global or fielded searches, or combinations of these, and provides a comprehensive tool for garnering information from the large collection of material retrieved from Los Alamos. An image of the DocSleuth search screen is presented in Fig. 3-4.
Fig. 3-3. Original DSF, DSF printed from DocSleuth, Original Document PDF
Documents are “filtered” to those whose bibliographic data (from DSFs) contain terms entered in these oval fields. More fields can be seen by scrolling to the right.

A full-text search of OCR-processed documents is performed for terms entered in this rectangular field.

**Fig. 3-4.** The Search Screen of the LAHDRA DocSleuth Database
Public Reading Room for Documents Obtained by the Project Team

The LAHDRA document repository contains paper copies of documents obtained from LANL by the project team. As of this writing, the repository contains an estimated 264,000 pages of documents, filed under 8,370 Repository Numbers. A duplicate set of the documents is available at the Zimmerman Library at the University of New Mexico in Albuquerque (Fig. 3-5). This location was selected as the official Public Reading Room for the LAHDRA project.

The Zimmerman Library is located on the University of New Mexico’s main campus. The library’s Government Information Department is a regional depository for government documents. Documents can be requested at the information desk, and photocopies can be made at a nominal cost using copiers located in the immediate area.

Directions to the Public Reading Room at the University of New Mexico:

Head east from the Central Avenue exit from I-25. Continuing east on Central Avenue, pass through the signal at University Avenue. UNM will be on the left. The third light after University Avenue will be Stanford Drive. Take a left on Stanford Drive to enter the UNM campus. Take another left at the "T." On the right will be Visitor Parking. After parking, head north and slightly west across campus. Zimmerman Library is just northwest of the Student Union Building. The Government Information Department is located in the basement of the library.

Contact: Dan Barkley, phone: (505) 277-7180; barkley@unm.edu

Restrictions on the Project Team’s Access to Certain Categories of Information

Accessing and reviewing documents at Los Alamos National Laboratory has been more difficult than in any similar project conducted at the other DOE sites that have been subjects of dose reconstruction investigations. The LAHDRA project was impacted by several events at LANL, unrelated to LAHDRA activities, that resulted in stand downs of Laboratory operations and the subsequent implementation of increasingly restrictive security measures. Initially, these developments severely impeded the team’s
ability to complete its review, but over time solutions were put in place that allowed the team to complete its work in concert with increased information security measures.

When the project began, project team members that held the requisite levels of security clearance were not restricted in their access to classified information in support of systematic search activities. However, a few years into the project, following some highly-publicized information security issues at LANL and a stand down of its operations, the Laboratory enacted new security practices that encumbered the project team’s access to classified documents. These new security practices included denying the project team access to specific types of information (discussed below) and requiring analysts to have permission from document owners before being allowed to review classified information. The latter constraint was a particular problem, especially in the classified reports collection, where many reports were issued by organizations other than LANL, many of which no longer existed. In an effort to accommodate this requirement, LANL requested that project team members review reports by their title alone. However, this was problematic because in many cases document titles are not a reliable means of identifying relevant content. Then, at one stage, the Lab determined it was not authorized to grant the project team “need to know” for documents issued by organizations other than LANL. This was a reversal from how LANL staff had been operating up until that time. Additional impediments were stricter limits on the number of project team members that could work in a given location at one time, and the requirement that documents be pre-screened for “deniable category information” before team members could review them. This presented two constraints. First, the requirement for pre-screening meant the project team could only work as fast the contractor LANL hired to do the screening. Second, the presence of the screeners counted against the total number of people the project team could have working in a given area.

In February of 2005; after a number of iterations between DOE, LANL, CDC, and the project team; a number of the security restrictions that had been preventing the project team from conducting systematic review activities were relaxed. This left the excluded categories of information and the associated requirement for pre-screening in place as the mechanism for addressing concerns over “need to know” issues that had been raised during internal and external reviews of LANL’s security practices.

Table 3-2 below summarizes the categories of information to which project team members were denied access. These restrictions meant classified information to be reviewed by the project team first had to be reviewed by an authorized individual to ensure that no deniable information was present. If deniable information was present, a general description of the contents was provided, to the extent practical, to allow the project team to make a judgment as to whether the material potentially contained relevant information. In general this proved to be a workable, though time-consuming, solution. In the event the
project team felt denied documents could contain relevant information, a process was available where an appropriately-cleared CDC employee could review the material. The reason for the distinction between CDC employees and its contractor (the project team) was unclear, since all of the pre-screening of classified material was performed by subcontractors hired by LANL.

Table 3-2. Categories of Information Withheld from the LAHDRA Team by LANL

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nuclear Weapons Design Information</strong></td>
<td>Documents relating to nuclear weapon design, such as weapon component blue prints, drawings, or other schematic or graphical design information.</td>
</tr>
<tr>
<td><strong>Sigma 14 Information</strong></td>
<td>Concerns the vulnerability of nuclear weapons to deliberate, unauthorized nuclear detonation.</td>
</tr>
<tr>
<td><strong>Sigma 15 Information</strong></td>
<td>Concerns the design and function of nuclear weapons use control systems, features, and their components. This includes use control information for passive and active systems.</td>
</tr>
<tr>
<td><strong>Sensitive Compartmented Information (SCI)</strong></td>
<td>Includes information that has been determined pursuant to Executive Order 12958 or any predecessor order to require protection against unauthorized disclosure and that is so designated. Includes conventional weapons, security systems, foreign relations, and information regarding intelligence sources and methods.</td>
</tr>
<tr>
<td><strong>Special Access Program (SAP) Information</strong></td>
<td>Deals with programs that are judged to require access limitation beyond that of the three-tiered classification system (Confidential, Secret, and Top Secret). These include programs within the Departments of Energy, Defense, and State. For example, the Congressional Emergency Relocation Site located under the Greenbriar Hotel in West Virginia, built to house Congress and key staff in the event of a national emergency, was designed, constructed, and maintained as a SAP for over 30 years until declassified in 1994.</td>
</tr>
<tr>
<td><strong>Foreign Government Information (FGI)</strong></td>
<td>Includes information provided to the U.S. Government by a foreign government or governments, an international organization of government, or any element thereof, with the expectation that the information, the source of the information, or both, are to be held in confidence.</td>
</tr>
<tr>
<td><strong>Unclassified Sensitive Vendor Proprietary Information</strong></td>
<td>Includes information that is deemed sensitive unclassified and touches on areas such as trade secrets and privileged or confidential commercial or financial information.</td>
</tr>
</tbody>
</table>

Summary of Information Gathering Activities for Specific Document Collections

Document review activities began with an emphasis on the large, centralized records repositories at LANL. It then progressed to include records held within specific divisions or groups. Systematic searching was the predominant method used for all information gathering activities at LANL. For the larger, centralized repositories, systematic search activities generally occurred over multiple stages. After an initial systematic review, follow-up review activities were performed as needed to evaluate information accessioned since the initial review was completed.
Centralized Repositories

The LANL Records Center

A principal focus of the information gathering task at Los Alamos was the LANL Records Center. Initially this facility was housed in Building 1001 in Technical Area 21 (TA-21-1001). Later in the project the Records Center was relocated to the National Security Sciences Building (NSSB). The project team performed records review activities in both locations. In addition to the Records Center, the LANL Archives was also housed in Building TA-21-1001 until the time it too was relocated to the NSSB. The Archives collection was stored, maintained, and managed separately from the Records Center’s holdings, and review of that facility was conducted separately from that for the Records Center. The systematic review of the Archives is discussed later in this chapter.

The original LANL Records Center was a 15,000 square foot building located at 180 6th Street in Los Alamos. The function of the Records Center is to receive and catalog records from the various LANL groups and divisions, place and maintain them in retrievable storage, and disposition them in accordance with DOE retention and disposition guidelines and other associated requirements (such as the moratorium on destruction of records deemed pertinent to epidemiological studies).

Building TA-21-1001 (the original Records Center) was sub-divided into six “bays” denoted A through F. It also included a seventh bay, denoted G-Bay, located in a separate building (TA-21-1002) behind the primary facility. The primary facility, Building TA-21-1001, was a designated Vault-Type Room, and included classified holdings. The records stored in G-Bay were considered unclassified for access control purposes. The Records Center holdings were stored in bays B, C, E, F, and G. Each bay contained a number of rows consisting of either tall (10-drawer) filing cabinets or shelving. Shelving and file drawers from the original Records Center are shown in Fig. 3-6 through Fig. 3-9. The file drawers were used primarily to store paper records. The shelving was used to hold records contained in standard, one cubic foot storage boxes. There were also a number of mobile storage units used to house media such as microfiche and microfilm. Fig. 3-10 and Fig. 3-11 show storage and review of microfilm records in the original Records Center. Each bay typically contained a mix of different types (formats) of records and records storage media/containers. For example, the tops of the rows of file cabinets were used to store boxes and large-sized media such as drawings and blueprints.
Fig. 3-6. Boxes of documents on shelves in the LANL Records Center in 2005

Fig. 3-7. Document review in the LANL Records Center
Fig. 3-8. File drawers used for document storage in the LANL Records Center in 2005

Fig. 3-9. Review of notebooks in a Records Center drawer
Fig. 3-10. One of numerous drawers of microfilm in the LANL Records Center in 2005

Fig. 3-11. Review of microfilm in the LANL Records Center in 2005
All material accessioned by the LANL Records Center is assigned a Transfer Record (TR) Number. TR Numbers are assigned sequentially and are the principal means of identifying, locating, and tracking material in the center. Locations of records in the original Records Center were referenced using a “bay-row-shelf” nomenclature, where “shelf” could have been any number of storage locations, such as a file drawer or a specific box in a vertical stack of boxes. Thus, the location “B-1-2” would refer to material location in B-Bay, Row 1, Location 2.

The LANL Records Center had been operating near its storage capacity for some time, and the space shortage resulted in records frequently being relocated, reconsolidated, transferred to Federal Records Centers, or otherwise dispositioned to free up space to accommodate newly-accessioned material. In 2005 the Records Center began the process of relocating to the NSSB. Many of the records were relocated to the NSSB, and many others were transferred to Federal Records Centers.

The layout of the Records Center in the NSSB is similar to that in the previous facility, though without the individual bays. Otherwise, the storage system is similar, and in fact the file drawer storage units were physically moved from the old facility to the new one.

The systematic search of the Records Center may be described as having occurred in four distinct phases: initial search activities (up to the work stoppage in 2003 prompted by security issues at the Lab), an interim period, resumption of systematic search activities following the work stoppage, and follow-up review activities after the Records Center was relocated to the NSSB.

**Initial Systematic Searches of the Records Center: February 1999 – October 2003** – The initial systematic search for relevant material in the LANL Records Center began in February of 1999 and continued until October of 2003. To facilitate identification of what had and had not been reviewed, records were marked with one of two rubber stamps. One stamp was used to identify records that contain no information pertinent to off-site releases or health effects (Fig. 3-12):

![CDC/NCEH REVIEWED](in green ink)

The other stamp was used to identify boxes or drawers that did contain relevant information, that is at least one document deemed to be Category 1, 2, or 3 (Fig. 3-13):

![★ CDC/NCEH ★ DO NOT DESTROY](in red ink)
Fig. 3-12. A Records Center drawer with a green “CDC Reviewed” stamp affixed

Fig. 3-13. A Records Center box marked with red “Do Not Destroy” stamps
For records stored in boxes, the outside of the box was stamped. For records stored in drawers, an adhesive label was stamped and affixed to the drawer. Originally a log entry was made identifying everything that was reviewed. These logs, referred to as “box logs”, included the document category assigned to the material (i.e., Category 1, 2, 3, or 4), its TR Number, location, the analyst that performed the review, and the review date. This information was recorded for all material, regardless of whether it contained relevant information. If material was selected for copying, an additional entry was made in a separate log identifying the material by its TR Number and location. The purpose of this “review log” as it was known was to provide the classification reviewers a current listing of what they needed to review and to aide them in locating it. This “review log” was a predecessor to the formal document request log initiated later in the project. Material to be copied was flagged using self-stick notes or equivalent to make it easier for the classification reviewers or others to find later. Once material was either confirmed to be unclassified or properly redacted, it was copied and forwarded for an additional series of reviews to confirm it could be released to the public. This purpose of this subsequent review was to screen for information that was protected under the Privacy Act, proprietary, attorney-client privileged, etc. The review log served as a tool to both identify material in need of classification review and that which had been forwarded for the second part of the review process or still needed to be copied.

Early in the initial review it became apparent the tools and methods originally specified for tracking progress and identifying material that had and had not been reviewed were inappropriate for a facility like the Records Center. The large volume of the material coupled with its dynamic nature (i.e., high turnover) meant handwritten logs were of little use. Boxes and drawers that had been stamped by the project team were often re-used to store material that had not been reviewed. This meant the presence or lack of one of the stamps was of limited value. Further, the ever-changing number of storage locations and constant in-flux of new material made asserting a completion percentage problematic, and presented a task that was open-ended. Thus, a more reliable method was needed to keep track of the systematic review of the Records Center.

An electronic database of the Record Center’s holdings was created to allow tracking of what had and had not been reviewed by TR Numbers. The project team adapted the database used by the Records Center staff to track its holdings. Tables, fields, and LAHDRA-specific search criteria were added as needed, including an electronic version of the box log. The box logs and accession/turnover information provided by the Records Center staff provided the two sources of data used to maintain the database. As long as the database was kept current in terms of records locations and TR Numbers, any discrepancies between it and the handwritten box logs gave an immediate indication of either an error in the log or material that
had been moved or otherwise dispositioned. This greatly simplified the task of tracking material that had and had not been reviewed, even for cases where the same locations required review multiple times because of records turnover.

In conjunction with implementing the database for tracking progress, a cutoff accession date was established to define a fixed end point for the initial systematic review of the Records Center. The cutoff accession date chosen was December 31, 1999. The last Transfer Record assigned prior to this date was TR Number 13779. Thus, material in the Records Center having a TR Number 13779 or less was targeted for review under the initial systematic review. Records accessioned after January 1, 2000 were addressed in subsequent review activities. The cutoff accession date was only applied to hardcopy records.

The database used to manage and track the initial systematic review of the LANL Records Center was not used for microform records (that is, microfilm or microfiche). These materials did not suffer from the turnover problems that hindered the review of the hardcopy records, so the review of the microform records was managed and tracked in a manner more consistent with what was originally conceived. Small red or green adhesive dots were applied to microfilm cassettes in lieu of the rubber stamps to indicate material that had been reviewed. For microfiche records, the rubber stamps were applied to either the sleeve the media was stored in (for individual microfiche records) or to the storage container (such as the front of a drawer) if it was a large volume of records.

Interim Search and Retrieval Activities: September, 2004 to March, 2005— A work stoppage prompted by security issues at LANL halted systematic search activities at Los Alamos in October 2003. A large backlog of material selected by the project team for copying and release to the public had accumulated. An interim task to get this material copied, reviewed, and released began in September of 2004.

A listing of outstanding material from the initial systematic review was compiled so it could be located and placed into the review process. By the end of March, 2005 all of this material had been located and submitted for review. By the middle of May, 2005 all of the outstanding material selected by the project team during its initial review activities in the LANL Records Center was in the project’s repository.

In parallel with the task to close out the backlog material during this interim period, a CDC staff member made several trips to the LANL Records Center and the LANL Reports Library to close out some other outstanding items from the initial search activities. Specifically, the review of hardcopy (i.e., non-microform) records at the Records Center and a subset of classified reports in the Reports Library were completed.
Resumption of Systematic Search Activities: February, 2005— Systematic search activities at the LANL Records Center (and for the project as a whole) resumed in February, 2005. Review of hardcopy records accessioned through 1999 had been completed, so the focus upon resumption of systematic searching was completion of the microform records (i.e., microfilm and microfiche). Time was of the essence given the pending relocation of the Records Center to the NSSB.

When work resumed, there were approximately 4,100 cards of microfiche and 2,700 rolls of microfilm in the Records Center remaining to be reviewed. Systematic review of the microfiche was completed by mid-March of 2005. Systematic review of the microfilm (and thus the LANL Records Center itself for the time being) was completed in early June, 2005.

The resumption of systematic review activities saw a significant improvement in throughput over that experienced previously. This was due to a number of important changes that were made to the document review and release process, including analysts being allowed to disposition non-relevant material by title alone and copy relevant documentation as it was identified. Being able to copy the material as it was identified and attach it to the DSF eliminated problems suffered previously with getting copies of what the analysts had selected. Another important, but unfortunately, short-lived change was the near-full-time availability of a contractor to perform the requisite classification reviews that was also authorized to declassify material when appropriate. These changes led to improved throughput of systematic review activities, including short turnaround times between when relevant material was identified and when it was received by the project team. Further, the adoption of the document request log during this time made it easier to confirm that everything the project team had requested was received and to resolve any discrepancies.

Follow-up Reviews in the NSSB— Review of records accessioned after December 31, 1999 took place after the Records Center had completed its relocation to the NSSB. This review was performed by reviewing the information on the individual TRs and identifying records of interest. The scope of this review was limited to records that were stored at LANL, that is, it did not include records that had been transferred to the Federal Records Center.

The LANL Archives

Initially, the LANL Archives was housed primarily in A-Bay of Building TA-21-1001. Some material (motion picture reels, for instance) was housed in B-Bay, and additional material (including some that had not yet been formally accessioned) was stored in G-Bay in Building TA-21-1002. These are where the Archives records were maintained when the project team completed its initial systematic review (with the
exception of film (motion picture) and video records) in early May of 2006. Subsequently, the Archives were relocated to the new National Security Sciences Building in TA-3. Once it was operating in its new location the project team performed follow-up activities there to revisit document collections previously reviewed and to review any records accessioned since the systematic review was completed. The second look at documents previously reviewed was prompted by insights gained from the study of the information from the initial review.

In general, the Archives records were organized into individual folders, which were stored in boxes (see Fig. 3-14 through Fig. 3-17). The boxes and folders were constructed of acid-free paper, making them suitable for archival storage. Most of the boxes were of a clamshell design which allowed easy access to the folders inside. Other types and sizes of boxes were used for some large or odd-sized media, microform records, etc. Some non-paper records were stored in cases or cans on Archives shelves (see Fig. 3-18 and Fig. 3-19).

Archives records were organized into collections, with a collection consisting of records covering a common subject area (e.g., an individual’s memoirs, the records of a particular facility or group, etc.). A collection could be one box or span hundreds of boxes. Each collection was assigned a unique collection number, consisting of the year the material was accessioned and a sequential number starting with 001 for each year. Boxes were numbered sequentially within each collection, and folders were numbered sequentially within each box. Each collection had an inventory listing that gave a brief description of the contents of each folder.

The LANL Archives was a largely static, well-organized collection of records. That plus the availability of the inventory listings provided a framework for systematic document searching that did not exist at other centralized repositories. The project team began systematic review of records in the LANL Archives in June of 2005. The first step in the review process was to obtain the inventory listings for each collection. The Archives staff provided these listings to the LANL LAHDRA project office, which broke them up into “Pages.” The complete listings were broken up into 52 Pages, with a given Page consisting, generally, of hundreds of pages of inventory. (LANL’s choice of “Page” as its nomenclature for the inventory listings tended to be a source of confusion until one became familiar with it. A “Page” of inventory listings covered many different collections and was by no means a single page of information.)
Fig. 3-14. Moveable shelving units in the LANL Archives in 2005

Fig. 3-15. Boxes used to store LANL Archives materials
Fig. 3-16. Boxes used for storage of archived material

Fig. 3-17. A classification officer preparing to review documents selected by LAHDRA analysts
Fig. 3-18. The LANL Archives contain paper documents, audio tapes, video tapes, and microfilm

Fig. 3-19. The LANL Archives includes classified and unclassified motion picture films and videos
The inventory listings were placed in three ring binders and provided to the project team. Project analysts then went through the listings and selected material for review based on the descriptions given. The detail in the inventory listings allowed this selection process to be performed at the folder level rather than the box level. The selection process was rather broad, as often it was not apparent from the description what the material actually was. In such cases the material was always selected for review. Once this selection process was completed, approximately 28,235 folders had been selected for review. This equated to approximately 25% of the total folders in the Archives at that time.

In addition to the records selected by the project team for review, a random sampling of 1% of the folders in the Archives was also performed. The purpose of this sampling was to select material to be reviewed by the analysts to act as a check on both the project team’s document selection process and on the accuracy of the Archives inventory listings. The 1% sampling process did not indicate any problems with the material selection process or the Archives’ inventories.

The review of the material selected by the project team, in general, proceeded one page at a time. A set of boxes from a given collection was pulled and each folder selected from within those boxes (either by the analysts or via the random selection process) was reviewed. Once the review was completed, the appropriate stamp (red or green) was applied to the box and the analyst indicated the material had been reviewed by initialing and dating the inventory listing for that folder. This process was continued until the Page was completed. Deviations from this process were made as needed, such as the advance review of excluded material (discussed below) or completing the review for all material in G-Bay (regardless of what Page it was under). In the latter case, a priority was made to complete the review of material stored in G-Bay under favorable weather conditions. G-Bay was a seldom-used facility with limited climate control, so both LANL and the project team wanted these reviews completed after the summer and before the winter. Review of Archives material in G-Bay (including that not yet accessioned) was completed around the middle of October, 2005.

Prior to review by the project team, all of the material selected (either directly or through random sampling) had to be pre-screened for excluded categories of information by authorized individuals. For the Archives, information determined to be excluded by LANL’s reviewers was dispositioned by an interactive discussion between the reviewer and a project analyst. (Information was excluded at the folder level.) The reviewer gave the analyst a basic description of the contents of the folder and the reason he felt some of the material should be withheld from detailed review. This process gave the analysts enough information to make an informed decision on the relevance of the material for the LAHDRA project. Little of the material selected for review in the Archives was excluded and none of this material was
thought to contain relevant information. Much of the excluded material came out of the random selection process and was not material selected by the project team. The project team went through and addressed most of the excluded material in advance so it did not impede the progress of the systematic review.

As previously discussed, follow-up review activities were completed for hardcopy Archives records following its relocation to the NSSB. In 2007 the project team was provided a listing, several hundreds of pages in length, of films and video tapes held in the Archives collection. This listing was reviewed during 2007 and 2008 and potentially relevant titles were selected for review. In early 2009, a list of 84 titles was submitted to LANL with a request that they be made available for review. It was determined that there was significant duplication within the list, some of the films were old and brittle, and viewing would be problematic for some of the requested titles. A plan was put in place to review as many as possible during remaining visits to LANL within 2009 as budget permits.

**The LANL Reports Collection and Research Library**

Initially, the LANL Reports Collection was housed in a vault facility located beneath the LANL Research Library. Along with the Records Center, Archives, and other collections, it too was eventually relocated to the NSSB. However, since this move took place after the project team had completed its systematic review, this section describes the center as it existed prior to being relocated.

The Reports Collection contained both classified and unclassified reports published by LANL and numerous other entities, in paper copy and on microfiche. The Reports Collection maintained its holdings in three principal collections: classified reports, unclassified reports, and unclassified microfiche. The project team’s systematic review of the Reports Collection approached each of these three collections individually. Fig. 3-20 through Fig. 3-23 show some of the stationary shelving, movable shelving units, and Lektriever units that were used in the Reports Collection.

As with the other systematic document search activities that began early in the project, initially logs were kept of everything that was reviewed in the Reports Collection regardless of whether it contained relevant information. This practice of formally documenting everything that was reviewed was found to be unnecessary and thus was discontinued when document search activities resumed in February of 2005 following the security stand down. This change, plus that of dispositioning material by title, greatly improved the efficiency of the systematic review of the Reports Collection without compromising its effectiveness.
Fig. 3-20. Reports on stationary shelving in the LANL Reports Collection vault

Fig. 3-21. Reports on moveable shelving in the LANL Reports Collection vault
Fig. 3-22. Review of technical reports in the LANL Reports Collection

Fig. 3-23. Microfiche copies of reports are stored in “Lektriever” units such as this in the LANL Report Collection vault
Since there were no complete or reliable finding aides for its holdings, the systematic review of the Reports Collection was performed by reviewing documents shelf by shelf. The largely static nature of the Reports Collection holdings made this an effective procedure.

**Review of the Classified Reports Collection**— The classified reports collection consisted of reports that were classified at the time of publication. The reports were published by LANL and numerous other entities, including other weapons complex sites, military organizations, and contractors. The majority of the reports pertained to weapons program activities (testing in particular) and other large defense programs, such as Rover. The reports published by LANL included those in the LA-series and reports generated by various groups such as SS (material accountability), W-division, X-division, etc. The reports were stored on collapsible shelving in alphabetical order.

The classified reports collection included approximately 3,000 classified report titles issued by LANL as LA- or LAMS- reports. Quantities are reported as titles rather than as individual documents since there can be multiple copies of a given report in the collection. In addition, the classified reports collection contained approximately 32,000 titles from organizations such as other weapons complex sites, other defense-related agencies, academic institutions, and private corporations that conducted research on behalf of DOE or its predecessor agencies.

To address the issue of excluded material, ultimately classified reports were reviewed by a LAHDRA analyst working in tandem with a reviewer authorized by LANL to pre-screen material for excluded information. This arrangement worked well, and the systematic review of the classified reports collection was completed in June of 2005. Additional ad hoc reviews of some of the holdings in the classified reports collection were subsequently performed to follow-up on information learned from the earlier reviews.

**Review of the Unclassified Reports Collection**— The unclassified reports collection was similar to the classified collection, but contained only unclassified documents. As such, the subject areas covered were more broad than those in the classified reports and tended to yield more material of interest to the LAHDRA project.

The Reports Collection contained approximately 10,000 unclassified report titles issued by LANL as LA- or LAMS- reports. In addition, images of approximately 25,000 unclassified LA-, LA-MS-, LA-UR, and LA-PR reports were available as PDF files in the LANL electronic library catalog. Unclassified reports with limited distribution categories, such as OUO (Official Use Only), were not available electronically and had to be reviewed in the vault.
Prior to the heightening of security measures that followed the terrorist attacks of September 11, 2001, the unclassified “LA” reports were available to the public on LANL’s web site. Subsequently, those files could only be accessed from a computer with a LANL IP address or by certain other government computer users. The project team reviewed 100% of the unclassified “LA” reports that were formerly available without restriction on the Internet. Most of these reports were reviewed using LANL computers at an office made available to the project team at TA-35.

In addition to those issued by LANL, there were approximately 90,000 unclassified reports in the Report Library vault issued by non-LANL entities, including:

- DOE sites other than LANL,
- academic institutions,
- private corporations that conducted research on behalf of DOE, and
- other defense-related agencies.

Systematic review of the hard copy holdings of the unclassified reports collection was completed in November of 2006.

**Review of the Unclassified Microfiche Collection**— Historically, LANL subscribed to multiple UC (University of California) distribution codes for DOE-related reports. When the Office of Scientific and Technical Information (OSTI) took over the distribution of DOE-related reports, they began distributing the reports on microfiche instead of paper. As a result, the LANL Reports Collection contained approximately 1.5 million documents on microfiche. In 1999 the LANL Research Library converted to an electronic subscription service, so documents were no longer added to the microfiche collection. Instead, library staff accessed reports via online databases (not hosted by LANL) upon request.

All of the microfiche reports were unclassified, but some were marked for limited distribution. Journals were not included in the microfiche collection due to copyright laws. Many of the reports in the microfiche collection were conference proceedings. The fiche cards were stored in Lektriever™ power filing units in alphabetical order (by document number). The documents in this collection included approximately 22,225 LA reports, according to the Library Catalog. Duplicates of these reports existed between the paper and microfiche collections, so the reports on microfiche did not need to be reviewed again if a paper copy of the same report had already been reviewed. Of the non-LANL agencies represented in the microfiche collection, the three largest (in terms of number of reports) were DOE Energy (~500,000 reports from 1969 to the present), Nuclear Science Abstracts (NSA; ~100,000 reports from 1949 through 1976) and NASA (~20,000 reports).
The Research Library subscribed to two electronic databases, DOE Energy and NSA, and had until recently also subscribed to the NASA electronic database. A search of the DOE Energy and NSA databases showed that Los Alamos was the authoring institution for approximately 11,000 NSA reports and 53,000 DOE Energy reports, or about 10% of the titles in each database.

Like the other collections in the LANL Reports Library, there was no complete finding aide available to allow searching the microfiche collection. The project team and LANL staff members therefore performed a cataloging (mapping) of the numerous entities represented in the millions of pages of reports contained in the microfiche collection. This produced an estimate of approximately 600,000 cards of microfiche in the six Lektrievers. The submitting organizations represented in these cards were differentiated into three broad categories to facilitate developing a search plan for this material. For each category of material, a fraction was reviewed for information relevant to the LAHDRA project. The categories of information and their associated review fractions are given in Table 3-3 below.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Review Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Reports from DOE or DOE sites, LANL-originated reports, and New Mexico-related documents.</td>
<td>100%</td>
</tr>
<tr>
<td>B</td>
<td>Reports from DOD, NASA, other U.S. Govt. organizations, U.S. businesses, or U.S. universities.</td>
<td>1%</td>
</tr>
<tr>
<td>C</td>
<td>Reports from foreign (non-U.S.) organizations.</td>
<td>None beyond that performed in the mapping process</td>
</tr>
</tbody>
</table>

The decision not to review the material from non-U.S. entities any further was based on the sampling of the documents in the microfiche collection intrinsic to the mapping process. Formal review of the microfiche collection was completed in March of 2006. All relevant material identified from the Lektriever collection was received from LANL and entered into the LAHDRA database. The majority of this material was Category 3 information, i.e., that pertinent to sites other than LANL.

Review of the LANL Research Library—LANL’s central research library, in general, did not serve as a central repository for records. However, it did contain some public domain records such as those associated with the “human radiation experiments” initiative and LANL’s annual environmental summary reports. The project team searched these collections and retrieved a number of records from them. In particular, a number of Health Division records were obtained from the Research Library, as they were included among documents associated with DOE’s human radiation experiments project.
The ES&H Records Center and Other ES&H Records

The initial systematic reviews of the holdings in the Environment, Safety, and Health (ES&H) Records Center were completed earlier in the LAHDRA project. More recently the holdings of the ES&H Records Center were relocated to the NSSB and housed in the same area as the primary Records Center. After the documents were relocated the project team completed follow-up review activities of those accessioned since the prior review activities were completed. In all, there were three systematic reviews of the holdings of the ES&H Records Center to ensure that material accessioned since the prior review was evaluated.

This summary of document review activities for the ES&H Records Center reflects group and organization names that were in use at the time review activities began. Since that time LANL went through numerous organizational changes, making the group and organization designations below largely obsolete. However, the previous organizational designations have been retained to preserve the summary of the review activities in sufficient detail.

Description of the ES&H Records Center— Prior to its relocation to the NSSB, the ES&H Records Center was located in Building 46 at TA-35. The center began operating in 1998. Its purpose was to receive records from the various ES&H Groups, catalogue and consolidate them, and eventually forward them to the LANL Records Center. Many of the records stored at the ES&H Records Center were recent, i.e., from the 1990s forward, but older records were found as well.

In Building TA-35-46, the records were stored in a combination of 25 rows of shelving and 9 file cabinets. The shelving units were used to store standard one cubic foot boxes. The file cabinets were used to store a combination of boxes and other items or containers. Often there would also be numerous boxes staged in various areas of the center that had not yet been accessioned. Some of these un-accedioned records would also be placed in the shelving units.

At the time, contents of records stored at the ES&H Records Center were described on CIC Form 170, the Records Transfer Request Form. This form defined a unique transfer record (TR) number for each set of records submitted to the center. The format of the TR numbers used for materials accessioned by the ES&H Records Center differed from those used by the primary Records Center. The ES&H format was TR-120-xxxx, where “xxxx” was a sequential number. The TR numbers were used to track records in a database maintained for that purpose. Hardcopies of the TR forms were kept in binders, with a different binder used for each group. Following its relocation to the NSSB, the holdings of the ES&H Records Center were stored on collapsible shelving units within the main Records Center.
Other ES&H Records—Some ES&H groups held records that had not yet been sent to the ES&H Records Center or the main Records Center. For example, Group ESH-17 (Air Quality) kept records in file drawers that were organized by year. They kept records for the three most recent years and sent those for prior years to the ES&H Records Center. Group ESH-20 (Ecology) stored their records in files organized by topics such as Biology, Contaminate Monitoring, and Cultural Resources. In general, these types of record collections were considered to be active records rather than part of a formal collection. Table 3-4 shows the groups that existed within the ES&H Division when systematic review activities began, and whether they held records independent of the ES&H Records Center.

Table 3-4. Additional Records held within ES&H Groups

<table>
<thead>
<tr>
<th>ES&amp;H Group</th>
<th>Additional Records?</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESH-1: Health Physics Operations</td>
<td>No</td>
</tr>
<tr>
<td>ESH-2: Occupational Medicine</td>
<td>No</td>
</tr>
<tr>
<td>ESH-3: Integrated Risk Analysis, Management and Communication</td>
<td>No</td>
</tr>
<tr>
<td>ESH-4: Health Physics Measurements</td>
<td>No</td>
</tr>
<tr>
<td>ESH-5: Industrial Hygiene and Safety</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-6: Nuclear Criticality Safety</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-7: Occurrence Investigation</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-10: Hazardous Materials Response</td>
<td>No</td>
</tr>
<tr>
<td>ESH-12: Radiation Protection Services</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-13: ES&amp;H Training</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-14: Quality Management</td>
<td>No</td>
</tr>
<tr>
<td>ESH-17: Air Quality</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-18: Water Quality and Hydrology</td>
<td>Yes</td>
</tr>
<tr>
<td>ESH-19: Hazardous and Solid Waste</td>
<td>No</td>
</tr>
<tr>
<td>ESH-20: Ecology</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Since these additional records were considered to be “active”, a detailed review was not performed as part of the initial systematic review for the ES&H Records Center. Instead, the project team generated descriptions of these additional records to identify those to be reviewed in the future. These reviews were performed under the review of records held by the ENV Division, described later in this chapter. These reviews took place following a number of reorganizations and consolidations within the Lab, so the groups described later in this report do not necessarily reflect those above.

Review of the ES&H Records Center—The bulk of the systematic review of the ES&H Records Center took place between January and October of 2000. Records were reviewed at their storage location.
Following review, they were marked using one of the two rubber stamps described earlier based on whether they contained any Category 1, 2, or 3 documents. A log entry was made identifying the material reviewed by its location and its TR number. The log entry included the document category assigned to the material, the analyst whom performed the review, and the review date. A DSF was completed for any document identified as Category 1, 2, or 3.

On several occasions, records that had been reviewed were subsequently replaced with newly accessioned records. In general, these new records were also reviewed, meaning that several locations were reviewed two and even three times as new material displaced older material in the center. Since the ES&H Records Center was an active staging area for records, a cutoff accession date of October 31, 2000 was established as a stopping point for the initial review. The rationale for this date was the fact that all of the accessioned material in the Center had been reviewed by then and the rate at which new material was being accessioned was too slow to justify a continuing effort. Instead, material accessioned after October of 2000 would be reviewed at some point in the future.

A total of 1,187 boxes were reviewed during the initial systematic review of the ES&H Records Center. Of these, 227 (19%) were found to contain relevant material. The majority of the relevant material was designated as Category 2, as it was primarily records from the 1990s that were already readily available in published reports. Examples include AIRNET (NESHAPS) data used in periodic reports required to document exposures to the public from LANL operations, and airborne effluent data reported in the annual environmental surveillance reports.

One of the most useful finds from the initial systematic review of the ES&H Records Center were two notebooks of working notes and document excerpts that contained data on LANL’s historical, site-wide radionuclide releases (Andrews ca. 1973). The first notebook (Volume 1 – Repos. No. 1733) contained data from 1948 to 1972. The second (Volume 2 – Repos. No. 1734) contained data from 1972 to 1996. These compilations had been assembled by LANL as an element of its response to a request from headquarters to assess its historical radionuclide releases.

In July of 2003 the ES&H Records Center was revisited to review material that had been accessioned since the initial systematic review. Copies of all Transfer Requests generated since October of 2000 [TR Numbers 120-186 (11/14/00) through 120-358 (6/20/2003) ] were obtained and the records descriptions were examined to identify any potentially relevant material. Ten boxes were selected for further review, but no additional relevant documents were identified. In early 2009, another follow-up review was performed for material accessioned by the ES&H Records Center since the previous review. This review
was carried out in the same manner as that in July of 2003 and generated the same result: no additional relevant material was identified.

The Engineering Drawings Facility

In February of 2006 the project team began reviewing documents held by the LANL Engineering Drawings Facility at TA-63. This facility housed engineering drawings and associated documents (memos, letters, specifications, etc.) dating back to the 1940s. The documents, which were all on microfilm, included topics such as engineering studies and bases for facility modifications. Modifications were often performed to correct issues encountered after a facility began operating, such as ventilation problems. The documents in the TA-63 facility therefore included information on such problems and their impacts. They also included information such as radionuclide concentrations in soil in the vicinity of release points.

The project team’s review of the TA-63 drawings facility was conducted in a focused, but still systematic, fashion. The goal was to obtain material to support the prioritization of radionuclide and chemical releases from the early LANL facilities. The initial searching, therefore, was for drawings pertinent to Original Technical Area buildings (especially D Building), Omega Site facilities and associated stacks, DP Site facilities and ventilation systems, and the Los Alamos town site.

The TA-63 facility maintained a database of their drawings inventory. The database included fields for TA Number, keywords, titles, etc. Drawings were searched by reviewing titles to identify those of interest. The selected drawings were then physically reviewed, and copies were requested of those deemed relevant to the LAHDRA project. The database was also used to search for drawings by TA Numbers. This included residential areas, as these were designated as TA-0. Approximately 1,000 historical drawings were selected as relevant to the LAHDRA project, obtained from LANL, and scanned to make them available via DocSleuth.

The project team also completed systematic review of the TA-63 microfilm records. As for the drawings, this review was conducted in a focused, systematic fashion with emphasis on documents related to the original Technical Area, Omega Site, DP Site, or the Los Alamos town site.
The TA-21 Library

The TA-21 library was a collection of material housed in a portable building at DP West. Its purpose was to act as a resource for individuals involved in decommissioning activities there. The facility included binders of memoranda, remediation investigation reports, and drawings. Much of this material had already been collected by the project team from its review activities in the Records Center and elsewhere. Nonetheless, a systematic review of this facility was completed and some documents and drawings of interest were retrieved.

The Records Processing Facility

The Records Processing Facility (RPF) managed records of what was formerly the Environmental Restoration (ER) group at LANL. Most of the holdings of the LANL Records Processing Facility, located at the Pueblo School Complex, had been scanned to PDF files and were available through an electronic document management utility. Review of this material is discussed later in this report. In addition to these electronic records, the project team also reviewed some hardcopy records that existed at the RPF earlier in the project, and records that had recently been acquired and not yet scanned.

Division or Group Records and Electronic Databases

As the project team completed its systematic review activities for LANL’s centralized records collections it migrated its focus to records held within division or group offices. These were records that for whatever reason were maintained by their custodial organizations rather than one of the centralized records centers. These records included electronic databases. It was not the goal of the project team to review the records held by every LANL division or group. Rather, the project team selected a subset of LANL’s numerous divisions that it felt had the greatest potential for providing information of interest. In general this selection process focused on divisions responsible for core Laboratory functions, eliminating those that served in only administrative capacities.

The initial focus of the review of division and group records was the Environmental Stewardship (ENV) Division. (As before, the discussions in this section reflect the organization of LANL’s divisions and groups that existed when records review activities took place. The division or group titles may not reflect the current organizational structure due to frequent reorganizations.) The ENV Division consisted of a large number of groups, many of which held records of interest to the project team. Review of these records was therefore a substantial part of the team’s activities once reviews at the centralized collections had largely drawn to an interim close. Review of records within the ENV Division is discussed later in this chapter.
Beyond the ENV Division, project team members also met with representatives of a number of other LANL divisions and groups to inquire about their activities and any records they held. The groups and divisions represented included:

- Associate Directorate for Security and Safeguards
- Chemistry
- Dynamic and Energetic Materials
- Earth and Environmental Science
- Environmental Protection
- Hydrodynamic Experiments
- Industrial Hygiene and Safety
- Materials Science and Technology
- Plutonium Manufacturing and Technology
- Radiation Protection
- Weapons Component Manufacturing
- Weapons Engineering Technology

Review activities that resulted from these discussions are described in the subsections that follow.

**ENV Division Records**

In May of 2006 the project team obtained a summary of records and databases generated by the groups and programs within the LANL Environmental Stewardship (ENV) Division. There were approximately 50 groups and programs listed, along with a number of electronic databases. The function of most of the groups and programs was to collect data needed to demonstrate compliance with state and federal regulations or that was otherwise required by the Compliance Order on Consent that was in place between LANL and the NMED. (At the time the Consent Order was the principal driver of the Laboratory’s environmental remediation and surveillance programs.) Numerous databases had been created within ENV Division to store and manage the data collected by these groups and programs.

The project team met with numerous individuals representing various groups and programs within ENV Division. Team members spoke with these individuals about the types of information collected and maintained by the groups and programs they represented. These discussions were the basis for the team’s approach to selecting what the records to review within ENV Division and for prioritizing these reviews. The groups and programs represented in these discussions included:

- Ambient air sampling
- Cultural Resources
- Direct Penetrating Radiation network (ambient monitoring)
- Environmental surveillance
The Domino and PRS Databases— Of the document collections and other information sources identified within the ENV Division, the largest by far was the Records Processing Facility’s Domino database. The Domino database was an electronic storehouse for historical and current RPF records, i.e., environmental restoration files. These included environmental project case files, remediation management records, regulatory compliance records, and decontamination and decommissioning records. The records were stored as PDF files and managed using the IBM Lotus Domino application. Domino is actually a business collaboration package rather than a database application, but as applied to management of the environmental restoration documents it functioned similar to a database and thus was referred to as such in the vernacular. The Domino application was accessed using a web-based front end that included provisions for searching.

Records in the Domino application were indexed using a unique identifier known as an ERID number. The system contained approximately 100,000 ERIDs, amounting to approximately 250,000 documents. (A record could contain multiple documents.) Systematic review of the Domino records was performed by going through them sequentially by ERID number and reviewing those with titles that were either of interest or too ambiguous to allow a judgment. Documents deemed relevant to the LAHDRA project were printed and a DSF was completed.

The RPF maintained another database called the Potential Release Sites (PRS) database. The PRS database contained documents related to historical activities at so-called “potential release sites”, i.e., solid waste management units or other areas of concern. This database contained far fewer records than the Domino database. Review was performed in the same manner as for the Domino database. A listing
of titles was reviewed to select records of interest for examination. Few records were selected, but some information of interest was obtained.

Other ENV Division Records—Below are other records collection identified within ENV Division that were reviewed by the project team.

NEPA Records: Records pertinent to compliance with the National Environmental Policy Act (NEPA) and associated environmental impact assessments were stored in boxes and file drawers at TA-59. These records included documents associated with LANL’s environmental impact statements and environmental assessments for LANL projects. They also included projects that were not required to have any NEPA documentation beyond a Department Environmental Checklist (DEC), or an Action Declaration Memorandum (ADM) upon which category exclusion declarations were based.

MAQ Records: The LANL Meteorology and Air Quality (MAQ) group maintained air quality and related records at its offices in White Rock, NM, pertaining to open burning activities, beryllium operations, and other laboratory activities involving hazardous air pollutants. In general these were recent records, going back no more than 5 years. Nonetheless a number of relevant documents were identified and retrieved. The review of MAQ records also included meeting with LANL staff responsible for the RADAIR (radioactive air emissions), STACKS (stack parameters), and RMUS (radioactive material usage survey) databases to gain an understanding of the information these resources contained.

Meteorological Data: Project team members met with LANL staff responsible for acquiring and managing meteorological data. Data were gathered from meteorological towers at several locations across the LANL site and from local weather monitors. Several reports were obtained by the project team, on subjects such as atmospheric dispersion modeling for the Los Alamos area, local precipitation data, and other local climatologic data.

Cultural Resources Group Reports: Project team members met with representatives from the LANL Cultural Resources group and reviewed a collection of their reports. Copies were subsequently requested of a number of these, as they included historical information about operations at LANL facilities.
The Litigation Support Database

In early 2000, the LAHDRA project team became aware of a number of small databases created for the Laboratory Counsel’s office. These databases were known collectively as the Legal Counsel Litigation Support Database (LCLSD). Creation of the LCLSD began around 1990 with the scanning of numerous historical documents to image files. The documents selected were those potentially pertinent to the LANL Lab Counsel’s activities. Many of the scanned documents were also subjected to Optical Character Recognition (OCR), creating a searchable file of the text. The database contained approximately 500,000 pages of documents.

During the early stages of the LAHDRA project team members made several attempts to gain access to the LCLSD. While the database itself was not made available, in 2003 the LAHDRA team received a hardcopy listing of the scanned documents available in five of its sub-databases. For each document the listing provided a document number, subject (title), author, addressee, copysta, date, status, and page count. The five sub-databases and the number of scanned documents available in each was as follows:

<table>
<thead>
<tr>
<th>Sub-database</th>
<th>Number of Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Division</td>
<td>1,442 documents</td>
</tr>
<tr>
<td>Human Studies Project Team</td>
<td>4,767 documents</td>
</tr>
<tr>
<td>Central Records Management</td>
<td>11,198 documents</td>
</tr>
<tr>
<td>Others</td>
<td>10,395 documents</td>
</tr>
<tr>
<td>Records Processing Facility</td>
<td>47,922 documents</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>75,724 documents</strong></td>
</tr>
</tbody>
</table>

A description of the information contained in each of these five sub-databases is provided in the following section.

Sub-databases within the Litigation Support Database –

H-Division: The H-Division sub-database of the LCLSD primarily included monthly (1943-1944, 1947-1964), quarterly (1965-1975, 1978-1990) and annual (1943, 1947, 1949-1953, 1957, 1987-1990) Health Division progress reports. It also contained progress reports from groups within the former Health Division, such as H-1, Radiological Monitoring (formerly H-6 and CMR-12), and H-4, Biological and Medical Research. Both of these groups were responsible for monitoring the use of radiological and non-radiological hazardous materials at LANL. Although the H-Division sub-database contained 1,442 documents, this number was a bit inflated given that it typically included three versions of each H-Division progress report: a complete report, a version redacted for Privacy Act information, and an abstract of the complete report.
Human Studies Project Team: The 4,767 documents listed in the Human Studies Project Team (HSPT) sub-database consisted primarily of weekly status reports, fact sheets, press releases, news articles, procedures, phone logs, and other administrative documents generated during the HSPT’s document review activities at LANL. The majority of these documents were generated between 1991 and 1995; however, there were also some historical documents from the 1940s, 1950s, and 1960s. There were also a large number of documents from the 1970s related to the Karen Silkwood case and pion radiotherapy studies, and from the 1958 Cecil Kelley fatality.

Documents in the HSPT sub-database that were of interest to the LAHDRA project were the weekly bibliographies of documents released to the public, inventories of documents in LANL records collections, reports from the LANL autopsy tissue program, and H-Division monthly progress reports. The HSPT sub-database used a classification system for the H-Division reports it contained. The classification categories were 001, Bayo Canyon activities; 002, DOD-related activities; 003, human tissue studies; 004, non-Bayo Canyon releases; 005, other DOE contractor (human studies); 006, tracer studies (plutonium, uranium, radiiodine, tritium, radium, other); 007, history/general; 008, atmospheric testing programs; and 009, pion radiotherapy.

Central Records Management: The 11,198 documents in the Central Records Management sub-database covered the years 1943 to 1965. These documents included

- Monthly hazard and accident reports for month/year (1946-1954)
- Weekly health test data (1950-1956)
- Neutron exposure reports (1946-1958)
- Personnel exposure reports (1957-1958)
- Monthly and weekly reports (1951-1958)
- Monitoring results (1945-1957)
- Minutes from weekly Section Head meetings (1945-1955)
- Air Counts, pencil and ink originals (1950-1962)
- Hand, head, shoe and nose counts (1944-1956)
- Urinalysis/urine counts (1944-1957)
- Film badge exposures (1957-1958)
- Protective Equipment- respirators, clothing (1947-1962)
- Safety meetings (1961-1962)
- Experimental shots at TA-33 (1948-1955)
- Tritium exposures at TA-33
- SL-1 accident
- DP Site explosion (1-14-1947)
- Pajarito accident (1-8-1953)
Others: The 10,395 “Other” documents were primarily administrative records covering the period from 1943 to 1989. Examples of these records are:

- Contracts and contract modifications
- Reimbursement authorizations
- Personnel policies regarding overtime, moving expenses, employee benefits
- Personnel administrative panel meetings
- Organization charts (1945-1989)
- Telephone directories (1944-1989)
- The Atom (1964-1975)
- Annual reports to Congress of the AEC (1948-1973)

However, several other types of documents were also included, such as:

- H-Division progress reports (1943-1980)
- RFI work plans for operable units (1989-1990)
- Glenn Neely Notes
- Dept. of Labor log and summary of occupational injuries and illnesses (1989-1992)
- Occurrence reports
- Newspaper articles

Records Processing Facility: As previously discussed, RPF documents were records from the Environmental Restoration program at LANL. The 47,922 documents in the LCLSD sub-database were also part of the Domino database discussed earlier in this chapter. The smaller number of documents reflects the fact the LCLSD sub-database only contained a subset of the total number of environmental restoration documents. The project team’s review of the RPF sub-database predated its review of the Domino collection.

Review of the Litigation Support Database

Project team analysts reviewed the hardcopy listings of the document titles in each sub-database and selected documents for review. Ultimately, only 5% of the documents available in the five sub-databases were selected. The remainder were either clearly non-relevant or had already been captured by the project team from other collections. A breakdown of the number of documents selected from each sub-database is shown below.

<table>
<thead>
<tr>
<th>Sub-database</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Division</td>
<td>86</td>
</tr>
<tr>
<td>Human Studies Project Team</td>
<td>155</td>
</tr>
<tr>
<td>Central Records Management</td>
<td>1,706</td>
</tr>
<tr>
<td>Others</td>
<td>764</td>
</tr>
<tr>
<td>Records Processing Facility</td>
<td>1,102</td>
</tr>
<tr>
<td>Total</td>
<td>3,813</td>
</tr>
</tbody>
</table>
Project team analysts reviewed the selected documents electronically using commercial information retrieval and viewing software provided by LANL. The software allowed analysts to review the documents in a given sub-database one at a time, establish bookmarks where they left off, or jump to specific documents. Relevant documents were printed using a dedicated printer and attached to the corresponding DSF. Analysts also checked the LAHDRA project database to determine if a selected document had already been retrieved.

Systematic review of the scanned documents in the five LCLSD sub-databases began in May 2005 and was completed in September 2005. Approximately 400 documents (10% of the 3,813 selected for review) were selected and retrieved.

**Weapons Engineering and Manufacturing and Weapons Physics Records**

Systematic records reviews completed by the project team earlier in the project included a review of records held by the Weapons Engineering and Manufacturing (WEM) and Weapons Physics (WP) divisions. However, the nature of these records in conjunction with the information security restrictions imposed on project team analysts at that time meant only a limited review was possible. The reviews were conducted in accordance with a Special Security Plan that was issued in June of 2001.

The reviews focused on the contents of the WEM and WP vault-type room (VTR) located in the Administration Building at TA-3. Most of the documents held by these two divisions were classified and contained nuclear weapon design and testing information. All of the classified documents reviewed in the VTR were published after 1962. Thus, per the Special Security Plan in place at that time, this meant the reviews had to be performed on a restricted-access basis. In other words, project team analysts had to review the documents by title alone. They were prohibited from reviewing the contents.

At the time of the review, the WEM and WP division records consisted of approximately 18,876 classified documents and 1126 classified photographs. There were also classified video media of various formats (e.g. VHS). The project team was not allowed to review the videos. Based on their titles, two documents were identified by the project team as potentially relevant. An appeal was made to DOE for a team member to be able to review the contents of these documents to determine if they were indeed relevant, but it was denied.

Thirty-six classified safes were also reviewed for potentially relevant information. The safes contained 7,056 classified documents. Review of these documents (by title alone) did not identify any relevant to LAHDRA.
LANSCE Records

Earlier in the project team members performed a systematic review of records held at the Los Alamos Neutron Science Center (LANSCE), which is located within TA-53. The reviews focused on files within the Main Administration Building (TA-53-1) and the Radiological Air Monitoring Records Archive located in Sector R, Building 3, Room 3R-4 (TA-53-3). Approximately 10,000 documents were reviewed in the Main Administration Building. Of these, approximately 2,500 were identified as potentially relevant and underwent detailed review. Ultimately 36 of these documents were retrieved. They included shift supervisor logbooks that contained daily beam current and beam-hour data from as far back as 1971.

Forty-five boxes of documents (3,375 documents) located at the Radiological Air Monitoring Records Archive (Building 3R) were reviewed. Approximately 20% of these were identified as duplicates. The documents contained detailed information on radiological monitoring techniques and results from 1971 to the present. Most of them pertained to airborne releases from LANSCE. 97 documents were retrieved by the project team.

Beryllium-Related Records

The project team reviewed records held by the Industrial Hygiene and Safety (IH&S) group at TA-59. The focus of this review was older records from the former H-5 (industrial hygiene) group. H-5 was responsible for monitoring for beryllium and other hazardous materials used in Lab operations. A number of relevant documents were identified.

On several occasions project team members met with the LANL beryllium program coordinator to discuss beryllium operations, releases, and records. This individual provided the project team with a number of useful reports pertaining to beryllium operations and releases at LANL.

On recommendation from other LANL staff members, the project team reviewed reference material used in preparing the environmental impact statement for the DARHT facility. Several documents were retrieved, addressing subjects including releases of aerosolized uranium and beryllium from dynamic experiments and concentrations of these materials in local soils.

Hydrodynamic Testing Records

The project team visited a classified vault in TA-22 that contained records from hydrodynamic testing activities conducted by several LANL groups and divisions. At the time the vault contained approximately 10 rows of collapsible shelving plus a number of flat-file cabinets used to store drawings and radiographs. The hardcopy records stored on the collapsible shelves included chronological files
(sequential memos and reports by date), correspondence files, and shot folders. The shot folders included shot summary reports and other detailed information. Sometimes information on materials included in a shot were given in detail (e.g., the mass of a specific material), and in other cases only part numbers were given (along with their mass).

It was not the goal of the project team to perform a systematic review of this material. Rather, the intent was to conduct a preliminary review of the types of information contained in the shot records and prepare a summary for future reference. Nonetheless, one document was selected for retrieval by the project team during its visit. It was redacted as required to make it unclassified and released. Several other documents that pertained to materials expended in shot activities in the early 1990s were noted. (By this time security restrictions had been relaxed such that appropriately cleared project team members were allowed to access the records in the TA-22 vault as long as they did not contain any Sigma 14 or Sigma 15 information.)

On several occasions project team members met with representatives from the LANL Hydrodynamic Experiments (HX) Division to discuss their activities and records. These discussions led to a box of documents describing materials expended in shot activities being compiled and sent to the LANL Records Center where it was reviewed by the project team. A number of useful documents, akin to some of those seen in the TA-22 vault, were identified and requested. These documents were unclassified, though several of them had to remain Official Use Only given their content.

**Other Sources of Information**

Project team members searched the photographic records of the Los Alamos Historical Society and obtained prints of photographs and maps of interest. More than 50 photographs were obtained, primarily aerial views of LANL facilities and surrounding areas from the 1940s and 1950s. The project team also obtained a title listing of photographic records held by the LANL Environmental Stewardship Division. Prints were obtained of numerous photographs from the early years of LANL operations at TA-1, TA-2, and TA-21. Numerous other photographs were also obtained through records review activities at LANL. The project team also obtained several videotape records from the Broadcast Media Gallery of the LANL Public Affairs Office.

As the LAHDRA project progressed, CDC also supported and benefited from a series of interviews conducted by Peter Malmgren as part of his "Los Alamos Revisited" oral history project. Trained and experienced in anthropology and related fields, Mr. Malmgren has been involved in several oral history projects in New Mexico over a span of many years. In his "Los Alamos Revisited" project, the 30-year
Chimayo, NM resident set out to offer a special perspective on the lives and concerns of retired Los Alamos workers. During the December 2000 to March 2003 period that CDC supported his project, Mr. Malmgren conducted over 100 interviews. Interviews numbered 1 thru 116 (the number 76 was skipped) are summarized briefly, with full names not identified, in Repos. No. 4081 of the LAHDRA document collection (Malmgren 2003). The interviews cover a very wide spectrum of jobs and life experiences of people who worked at Los Alamos and/or lived in the general area. Detailed transcripts were produced by Mr. Malmgren, and the interviews were audio taped.

**Interviews with Past and Current LANL Staff or Other Individuals**

Interviews of current and retired LANL workers and other individuals were conducted by the LAHDRA team to assist in the identification and description of operations possibly associated with off-site releases, identification of relevant collections of records, and development of an understanding of historical operations. Workers sometimes help the document analysts assemble the “big picture” with regard to site operations. Interviewees can also identify additional interview candidates with knowledge about specific subject areas, assist in the interpretation of information from documents or other interviews, and describe record-keeping practices of years gone by.

Interview candidates can be identified from author or distribution lists from key documents, from division rosters or progress reports, or from other interviews. While interviews are typically conducted with individuals, group interviews allow participants to jog each others memories, yielding more information that would otherwise have been provided. All interviews are voluntary, and interviewees have the option to remain anonymous. In these cases, names are excluded from our records. In some cases, people who have held security clearances in the past can receive special authorization to speak freely during an interview, provided it is conducted in an appropriate facility and in accordance with all regulations and guidelines concerning handling of potentially sensitive content.

Summaries of interviews conducted by the project team are included in the project’s information database. The database also includes transcripts and summaries of interviews with cognizant LANL staff that were performed by LANL. These records were obtained from the project team’s systematic search activities, from the Archives in particular.

Some of the individuals who were interviewed by the LAHDRA team included:

- Scott Hughes: graduate student doing research on the evolution of the ES&H program at LANL.
- J. W. Nyhan: LANL staff member re: stack emissions from DP West.
- Jim McInroy: LANL staff member re: human tissue analysis program.
• John Miglio: LANL analytical chemist.
• Jim Lawrence: LANL health physicist.
• Bill Moss: LANL staff member (health physics and industrial hygiene)
• Jay Wechsler: LANL staff member (radionuclides in soils)
• Ron Stafford: LANL staff member re: plutonium handling and releases.
• Scott Miller: LANL staff member (monitoring for airborne releases)
• Gary Whitney: LANL beryllium program coordinator
• Tom Newton: LANL chemist (retired, worked in D Building starting in 1949, then moved to CMR Building)
• Helen Cowan: Former chemist at the Manhattan Project’s “Met Lab.” in D Building at Los Alamos during World War II, and later in LASL’s CMR Building.

D Building Roundtable Discussion

LAHDRA team members worked with LANL personnel to set up a roundtable meeting with current and former Los Alamos workers who were reported to have knowledge of operations and activities D Building. D Building, part of the original Technical Area, was the Lab’s original plutonium processing facility. The meeting was held on July 25, 2006 at LANL to coincide with key project team members being in Los Alamos for a public meeting the following day. Attendance was limited to individuals with the required level of security clearance so that classified information could be discussed freely. The meeting was videotaped, however, and an unclassified version has been made available to the public.

Meeting attendees included:

• Charles D. Blackwell, General Monitoring Section, H-1, retired
• Carl W. Buckland, Leader, General Monitoring Section, H-1, retired
• W. Clarence Courtwright, explosives safety engineer 1955-1991, retired
• Raymond Garde, LANL, retired
• Donald R. Gibbons, LANL, retired
• Joe Vigil, LANL, retired
• Jack Buddenbaum, LAHDRA team member
• Bob Burns, LAHDRA team member
• Joe Shonka, LAHDRA team member
• Tom Widner, LAHDRA Project Director

Plutonium release estimates were not located for D Building so the project team strived to learn as much as possible about the processing that was performed there. The goal was to determine methods for estimating how much plutonium could have been released. At the roundtable meeting, LAHDRA team members described what they had learned about D Building and the activities there. Attendees were
asked if they could address specific questions that remained, such as details of key steps in early plutonium processing, generation of airborne contamination, design of ventilation systems and some filters that were added, and indicators of environmental contamination. Unfortunately the participants knew very little about D Building, but the project team did learn some useful information about other LASL operations.

**Summary Statistics**

Over the course of the LAHDRA project team members reviewed millions of pages of information resulting in the retrieval of approximately 264,000 pages of material relevant to the estimation of offsite releases of chemical or radionuclides from LANL or associated health effects. This information is summarized in the 8,372 records that make up the project’s information database.

Table 3-5 through Table 3-7 below show the breakdown of documents retrieved by the LAHDRA project team by document category, by where the documents were found, and by decade of publication. It should be emphasized these statistics reflect the documents identified by the project team as relevant to the goals of the LAHDRA project during its review activities. By no means do they reflect the overall distribution of documents at LANL, especially where publication dates are concerned.

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<thead>
<tr>
<th>Document Category</th>
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</tr>
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<tbody>
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<td>44%</td>
</tr>
<tr>
<td>Category 2: supporting or confirming information useful in estimation of offsite releases or health effects from LANL operations within New Mexico.</td>
<td>46%</td>
</tr>
<tr>
<td>Category 3: information relevant to estimation of offsite releases or health effects for other DOE or predecessor agency sites</td>
<td>10%</td>
</tr>
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</table>
### Table 3-6. Breakdown of LAHDRA documents by location of origin

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</tr>
<tr>
<td>LANL Reports Collection</td>
<td>19%</td>
</tr>
<tr>
<td>LANL Archives</td>
<td>13%</td>
</tr>
<tr>
<td>Domino Database</td>
<td>10%</td>
</tr>
<tr>
<td>LANL Research Library</td>
<td>5%</td>
</tr>
<tr>
<td>Litigation Support Database</td>
<td>4%</td>
</tr>
<tr>
<td>ES&amp;H Records Center</td>
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</tr>
<tr>
<td>Engineering Drawings Facility</td>
<td>2%</td>
</tr>
<tr>
<td>All other locations</td>
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</tr>
</tbody>
</table>

### Table 3-7. Breakdown of LAHDRA documents by publication date

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<tr>
<td>Unknown</td>
<td>0.1%</td>
</tr>
</tbody>
</table>
References


Chapter 4: Plutonium Processing at Los Alamos

One of the important early roles of the Los Alamos laboratory was the processing of the newly created and largely unknown material plutonium (Hammel 1998). The assignments taken on by Project Y scientists in the mid-1940s were to:

- Perform the final purification of the plutonium received at Los Alamos,
- Reduce the plutonium to its metallic state,
- Determine the metal’s relevant physical and metallurgical properties, and
- Develop the necessary weapon component fabrication technologies.

Los Alamos was the first site in the world to receive quantities of plutonium large enough to manufacture weapon components. Initial plutonium processing was performed in the Original Technical Area, which was located near Ashley Pond and later became known as Technical Area 1 (TA-1) (see Fig. 4-1).

![Map of the Original Technical Area (later called TA-1)](image)

Key to Selected Buildings:
- C- Shops
- D- Plutonium Plant
- E- Theoretical Division Offices
- G- Graphite Fabrication
- J- Research Laboratories
- Q- Medical Offices
- R- Laboratories
- S- Stockroom
- Med Lab = Medical Laboratory
- U- Chemistry and Physics Labs
- V- Shops
- W- Van de Graaff Machines
- X- Cyclotron
- Y- Cryogenics Laboratory
- Z- Cockcroft-Walton Generator

Fig. 4-1. Map of the Original Technical Area (later called TA-1)
Early Plutonium Processing at D-Building

The initial handling and processing of plutonium that took place at the original technical areas involved the following main facilities:

- D Building- housed plutonium chemistry, metallurgy, and processing
- D-2 Building- housed contaminated laundry and glassware decontamination
- D-5 Sigma Vault- storage facility for $^{239}\text{Pu}$ and $^{235}\text{U}$
- ML Building- Housed the Medical laboratory, site of human uptake and excretion studies by H-4 and H-5 groups and urine assay

D Building (see Fig. 4-2) in LANL’s Original Technical Area was the first site in the world in which plutonium was handled in visible quantities, purified, converted to metal, and used to fabricate atomic weapon parts. Because plutonium was a newly discovered element available only in milligram quantities, there was a great deal of pressure on scientists to perform the necessary metallurgical experiments as quickly as possible once gram-scale quantities of plutonium became available. At the time, impurities were of great concern, because $\alpha$-particles are emitted from plutonium at a rate that is over 1,000 times greater than that of uranium. Upon colliding with light-element impurities, these $\alpha$-particles release neutrons, greatly increasing the chance of a premature fission reaction occurring before much of the plutonium reaches a super-critical state. A premature ignition, known as a “fizzle”, would greatly diminish the explosive power of the weapon.

Fig. 4-2. D Building in the original Technical Area on December 4, 1946 (looking north).
*Photo courtesy Los Alamos Historical Society (from LAHM-P1990-40-1-3029).*
D-Building was constructed as an answer to this impurity problem in December 1943. To mitigate light-element dust from settling onto experimental surfaces, D-Building was built with a state-of-the-art air conditioning and ventilation system that provided laboratory conditions that were as dust-free and clean as possible. The building’s air intakes were filtered, but its exhaust vents were not. Starting in late 1943, scientists and engineers in D Building used equipment and procedures that are considered extremely crude by modern-day standards to process the new and largely unknown element plutonium under demanding schedules and extreme wartime pressures. Progress reports indicate that D Building and its roof became highly contaminated, and about 85 rooftop vents released contaminated air without monitoring and for the most part with no filtration. A former Los Alamos plutonium worker wrote that “During the War years, partly because of ignorance and partly because of the stress of wartime conditions, operations with plutonium in D Building were conducted with greater laxity than has ever been tolerated since” and “D Building was known to be hotter than a firecracker” (Coffinberry 1961).

There are no records or LANL estimates of airborne plutonium releases from D Building, which ceased main plutonium production functions when DP West site became operational in late 1945 but remained active until around 1953.

**Flow of Plutonium Operations within D Building**

Operations within D Building can be considered a chemical process with the key objective of converting plutonium nitrate into the highly purified metallic hemispheres used in the Trinity and Nagasaki devices. While many other supporting projects were conducted within D-Building, including uranium chemistry and metallurgy, design of tampers and polonium initiators, as well as the development of various refractory materials, this report focuses specifically on the numerous stages of plutonium processing. These stages are represented generally by the flow diagram shown in Fig. 4-3, which most accurately represents plutonium processing from about December 1944 until D-Building was decommissioned in September 1945. These production-scale processes, in operation for only about 9 mo, were refined from many months of prior chemical and metallurgical research starting in December 1943 when construction of D-Building was completed. It is most likely, however, that the vast majority of plutonium contamination was a direct result of these production-scale operations, as the first few milligrams of plutonium didn’t arrive on site until January 1944, and gram quantities until March 1944 (Hammel 1998). Moreover, by late April 1945, D-Building had produced only about 1 kg of plutonium (see Fig. 4-4), yet would receive about 26 kg of additional plutonium from Hanford Site in Washington (Site W) by the end of August 1945, as shown in Fig. 4-5 (Site Y 1945). Because of this trend, this report focuses mainly on the production-scale processes.
Fig. 4-3. Flow chart of plutonium operations in D Building
Fig. 4-4. Monthly amounts of plutonium produced from plutonium nitrate in D-Building. This graph is not cumulative—by 1 September 1945, purification operations were producing just over 9 kg of purified plutonium per month, roughly ten times what the rate had been on 1 April 1945 (Hammel 1998).

Fig. 4-5. Cumulative amounts of plutonium received from Hanford in 1945 (Site Y 1945)
The bulk of plutonium arrived at D Building in the form of relatively impure plutonium nitrate manufactured at the Hanford Site. Fig. 4-6 shows one of the shipping “bombs” that were used to transport the material known as “49” or “product.” A relatively small amount of the nitrate also arrived from the Clinton pile at Oak Ride, TN (Site X), though this material was used mainly for research purposes. As shown in Fig. 4-3, these nitrates were first converted into plutonium (III) oxalate by wet chemical techniques. This oxalate slurry was then sent to the dry chemistry, or dry conversion, processes in which the oxalate was first thermally converted into plutonium oxide (PuO₂), and then fluorinated using a mixture of hydrogen fluoride (HF) and oxygen, forming plutonium tetrafluoride (PuF₄). This plutonium halide was then reduced in the presence of a more electropositive metal such as calcium, resulting in the formation of plutonium metal. The metal was then remelted and fabricated into a variety of shapes for metallurgical experiments and coated to protect the surface from oxidation. After each metallurgical experiment, the plutonium specimen was returned to the recovery group, converted back to plutonium nitrate, and sent to purification, where it was repurified, re-reduced, remelted, recast, and refabricated. In this way, a very large amount of data was collected using the relatively small amounts of plutonium available at the time. A more detailed description of plutonium processing in D Building that was prepared by the LAHDRA team is available elsewhere (Knutsen and Widner 2007).

By 31 August 1944, J. Robert Oppenheimer stated in a letter that a total of only 51 g of plutonium had been received at Site Y. Remarkably, he noted that this material had been used in “approximately 2500 separate experiments,” and “the overall loss per experiment has been about one per cent” (Hammel 1998). An open hood that was used in D Building for production-scale purification is shown in Fig. 4-7. The associated apparatus, most of which was made of glass, is depicted in Fig. 4-8 (Wahl 1946). Irradiation of glassware caused it to become brittle, and the ether used in the processing was a recognized fire hazard. A furnace used for fluorination and oxidation reactions is shown in Fig. 4-9. The manual transfer of dry powders from one step to the next in platinum “boats” was problematic and led to some dispersal of material in the building. Stationary “bomb” reductions of plutonium tetrafluoride to plutonium metal were conducted in induction furnaces like the one shown in Fig. 4-10, and cylinders of plutonium metal were pressed into hemispheres using heated presses like the one shown in Fig. 4-11.

Between each stage in the process, plutonium compounds were stored in vaults and monitored by the Quantity Control group to prevent critical masses of plutonium from accumulating. Fig. 4-12 documents the processing of plutonium for four weapon cores in D Building during 1945— one for the Trinity test, the first combat bomb (used in Nagasaki), a second combat bomb (not needed in Japan), and the first “composite” core that used active material in addition to plutonium (Wahl 1947).
Fig. 4-6. Plutonium was received from Hanford in 80 g and 160 g batches in "shipping bombs" (right) as a slurry of plutonium nitrate. Shipping bombs were transported in protective cases shown on the left. (Photo IM-9: 1831 courtesy of LANL)

Fig. 4-7. Production-scale purification was conducted in hoods that could be flooded with carbon dioxide in the event of an ether fire. (Photo IM-9: 1829 courtesy of LANL)
Fig. 4-8. Production-scale (160 g) purification apparatus (from Wahl 1946).
Fig. 4-9. A furnace that was used for fluorination and oxidation reactions (Photo IM-9: 1832 courtesy of LANL)

Fig. 4-10. This induction furnace powered by a 20 kW high frequency converter inside a fume hood was used to fire large-scale bomb reductions (from Baker 1946). (Photo IM-9:1824 courtesy of LANL)
Fig. 4-11. Evacuated hot presses like this were used to form hemispheres of plutonium (Photo IM-9:5090 courtesy of LANL)

Fig. 4-12. Graph that documents purification of plutonium for four weapon cores in D Building during 1945 (from Wahl 1947)
Release Estimates for D-Building Plutonium Processing

Because of the lack of effluent measurements for operations in D Building during World War II, plutonium releases were estimated for each plutonium processing step using heuristics and experimental results compiled by the US Department of Energy in a document entitled “DOE Handbook – Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities” (USDOE 1994). Although the Handbook is primarily intended to characterize accidental airborne radionuclide releases, experimental results presented therein lend themselves well to the characterization of releases within D Building, as many plutonium processing operations were conducted in an open environment under similar conditions. The Handbook is broken into a number of sections characterizing releases of plutonium compounds through a number of mechanisms. To estimate plutonium releases from D Building, each processing step was divided into a number of conceptual release mechanisms based on process descriptions contained in original LASL documents. For each conceptual release mechanism, an analogous experiment was identified in the Handbook, which provides estimates of airborne release fractions (ARF) and respirable fractions (RF). These estimates were used to calculate the source term, which is the mass or activity of a radionuclide released during each conceptual release mechanism. While details of this assessment are documented elsewhere (Knutsen 2007), methods and results are summarized below.

Within the release estimation process adopted by USDOE (1994), the source term is a product of a number of parameters:

\[
\text{Source Term} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF}
\]

The material at risk, MAR, is defined as the mass of plutonium present at each conceptual release. For example, fluorination operations were carried out at a nominal scale of 160 g, which represents the MAR for this operation. The Handbook defines the damage ratio, DR, as the “fraction of the MAR impacted by the accident-generated conditions” and notes that a degree of interdependence exists between the DR and MAR, as some analysts choose to exclude radionuclides from the MAR that would not be affected by a given event. In this analysis, the MAR is defined to include only plutonium available for release in each process step, and DR is set to unity in all cases. The airborne release fraction, ARF, is the fraction of plutonium aerosolized during each conceptual release mechanism. This parameter is highly dependant on the release mechanism, and ranges in this analysis from \(1.3 \times 10^{-7}\) for air blowing slowly over a solution of plutonium nitrate to \(2 \times 10^{-3}\), representing a bounding estimate for liquid entrainment resulting from rapidly boiling solutions of plutonium nitrate. The respirable fraction, RF, represents the fraction of
particles in a released aerosol small enough to be inhaled into the human respiratory system. The RF also provides a method of estimating the fraction of aerosolized plutonium that could potentially reach the rooftop of D Building via its ventilation system. The leak-path factor, LPF, is the fraction of aerosolized particles that could be transported through a containment mechanism.

In this analysis, the LPF is used as a means to estimate plutonium released from apparatuses with methods for containment in place. For example, production-scale purification and reduction processes were designed to mitigate aerosolized releases, and the LPFs for these processes were set to a small value based on professional judgment. The authors recognize that a high degree of uncertainty is associated with each of these parameters. Therefore, a Monte Carlo simulation was conducted to assess the sensitivity of each parameter to the overall D-Building source term. While the Handbook notes that estimated parameter ranges “should not be used as a basis for an ARF statistical distribution” and “specifically rejects citation as a defensible basis for such attempts,” a Monte Carlo approach was used in this analysis as a means to assess parameter sensitivity and to provide some context to the range and uncertainty associated with release estimates.

Shown in Table 4-1 are source terms estimated for various plutonium processing steps including purification, dry chemistry, and reduction, in addition to the recovery of plutonium from residues generated by each process. Note that source terms presented in Table 4-1 are calculated from nominal values of ARF and RF for conceptual release mechanisms presented in the Handbook. Thus, the total estimated source term of roughly 0.3 Ci is a nominal estimate, and a distribution of estimates shown in Fig. 4-13 reveals a fairly large uncertainty, with a 95%-ile estimate of over 1 Ci. The details of release estimates from one of the main plutonium process, plutonium recovery, are discussed below to illustrate the process that was used.

**Releases from Plutonium Recovery**

Recovery operations (Recovery) involved some open-air processing steps, and it was one of the most contaminated groups in D Building (Duffy et al. 1945, Hemplemann et al. 1973). Recovery was conducted without effective containment mechanisms because of the large variety of plutonium-containing residues that Recovery received. This large variety of residues also makes it exceedingly difficult in this analysis to characterize releases from all Recovery operations. Instead, releases associated with more routine and well-documented recovery processes were focused on. As shown in Table 4-2, the bulk of the plutonium-containing residues received for recovery were purification supernatants, metallurgical samples (plutonium metal, alloy, skulls, scrap), and materials from reduction/remelting of crucibles and slag (Garner et al. 1945).
Table 4-1. Summary of conceptual release mechanisms and source terms for several plutonium processes conducted from 1943 through 1945

<table>
<thead>
<tr>
<th>Process / Conceptual release mechanism</th>
<th>Number of runs</th>
<th>Mass of Pu entering each run (g)</th>
<th>Mass of Pu processed (kg)</th>
<th>Number of releases per nominal run</th>
<th>Release Fraction</th>
<th>Release Fraction (ppm by mass)</th>
<th>Source term (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purification processes (160 g nominal scale)(^1)</td>
<td>207</td>
<td>151</td>
<td>31</td>
<td>6</td>
<td>6.4E-07</td>
<td>0.6</td>
<td>20</td>
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<tr>
<td>Transfer releases</td>
<td></td>
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<td></td>
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<td></td>
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<td>Evaporation releases</td>
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<tr>
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<td>130</td>
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<td></td>
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<td>Steam releases (simmering)</td>
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<td></td>
<td></td>
<td>2.9E-06</td>
<td>2.9</td>
<td>6</td>
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<td>Liquid entrainment from sparging</td>
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<td>2.5E-05</td>
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<td>6.2</td>
<td>13</td>
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<tr>
<td>Recovery of process &quot;B&quot; and &quot;C&quot; purification supernatants(^1,2)</td>
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<td>16</td>
<td>1.2</td>
<td>16</td>
<td>3.0E-05</td>
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<td></td>
<td>6.1E-06</td>
<td>6.1</td>
<td>7</td>
</tr>
<tr>
<td>Dry Chemistry and Reduction</td>
<td>29.16</td>
<td>7</td>
<td></td>
<td></td>
<td>2.9E-05</td>
<td>29.0</td>
<td>845</td>
</tr>
<tr>
<td>Dry ignition release</td>
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<td></td>
<td></td>
<td></td>
<td>4.6E-07</td>
<td>0.5</td>
<td>13</td>
</tr>
<tr>
<td>Transfer of plutonium oxide powder into fluorination reactor</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2.8E-05</td>
<td>28.0</td>
<td>816</td>
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<tr>
<td>Fluorination of plutonium oxide powder</td>
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<td></td>
<td></td>
<td></td>
<td>3.9E-08</td>
<td>0.0</td>
<td>1</td>
</tr>
<tr>
<td>Transfer of plutonium fluoride into glove box</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3.9E-07</td>
<td>0.4</td>
<td>11</td>
</tr>
<tr>
<td>Transfer of plutonium fluoride within glove box</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>7.8E-08</td>
<td>0.1</td>
<td>2</td>
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<tr>
<td>Removal of plutonium button and transfer of MgO liner to Recovery</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2.0E-08</td>
<td>0.0</td>
<td>1</td>
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<tr>
<td>Recovery of reduction crucibles</td>
<td>0.7</td>
<td>13</td>
<td></td>
<td></td>
<td>3.2E-05</td>
<td>31.6</td>
<td>22</td>
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<td>Transfer of pulverized crucibles</td>
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<td></td>
<td></td>
<td>3.9E-07</td>
<td>0.4</td>
<td>0</td>
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<tr>
<td>Transfer of solutions</td>
<td>8</td>
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<td></td>
<td></td>
<td>1.9E-05</td>
<td>19.1</td>
<td>13</td>
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<td>Steam releases (simmering)</td>
<td>2</td>
<td></td>
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<td>5.8E-06</td>
<td>5.8</td>
<td>4</td>
</tr>
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<td>Filtration releases</td>
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<td></td>
<td></td>
<td>6.3E-06</td>
<td>6.3</td>
<td>4</td>
</tr>
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<td>Peroxide recovery step</td>
<td>7.6</td>
<td>8</td>
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<td></td>
<td>6.1E-04</td>
<td>614.0</td>
<td>4680</td>
</tr>
<tr>
<td>Transfer Releases</td>
<td>5</td>
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<td></td>
<td></td>
<td>1.3E-05</td>
<td>12.8</td>
<td>97</td>
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<td>Steam releases (simmering)</td>
<td>0</td>
<td></td>
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<td></td>
<td>0.0E+00</td>
<td>0.0</td>
<td>0</td>
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<td>Steam releases (boiling)</td>
<td>2</td>
<td></td>
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<td></td>
<td>6.0E-04</td>
<td>598.0</td>
<td>4559</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>3.2E-06</td>
<td>3.2</td>
<td>24</td>
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<td>Total source term:</td>
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<td></td>
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<td>5721</td>
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<td>Total source term (Curies):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.35</td>
</tr>
</tbody>
</table>

\(^1\) Processes combined due to similar release mechanisms
\(^2\) Not including peroxide recovery step
Table 4-2. Types of residues submitted for recovery, April-September 1945 (Garner et al. 1945)

<table>
<thead>
<tr>
<th>Type of Residue</th>
<th>Pu mass (g)</th>
<th>Fraction of Total Pu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purification supernatants</td>
<td>3297</td>
<td>43%</td>
</tr>
<tr>
<td>Reduction liners, slag and remelt crucibles</td>
<td>684</td>
<td>9%</td>
</tr>
<tr>
<td>Metal, alloy, skulls, scrap</td>
<td>3334</td>
<td>44%</td>
</tr>
<tr>
<td>Pickling and plating residues</td>
<td>130</td>
<td>2%</td>
</tr>
<tr>
<td>Analytical and misc. residues</td>
<td>178</td>
<td>2%</td>
</tr>
<tr>
<td>Total:</td>
<td>7623</td>
<td>100%</td>
</tr>
</tbody>
</table>

Fig. 4-13. A distribution of release estimates based on a sum of distributions associated with individual release mechanisms
As shown in Table 4-1 and depicted graphically in Fig. 4-14, the recovery of plutonium from the “A” purification supernatants consisted of 18 conceptual releases. Twelve of these releases consisted of “transfer” releases (Abbreviated “T”), which describe releases resulting from the entrainment of solutions into air while they are pumped from one process step to the next using a centrifugal pump or a steam jet (Duffy et al. 1945). For lack of more representative experimental data, this release was modeled as a liquid spill from a height of 1 m. ARF values for this release were based on experimental results (Sutter et al. 1981). In these experiments, ARF values from $1 \times 10^{-6}$ to $1.6 \times 10^{-5}$ were measured. For the purposes of this analysis, a log-normal distribution was selected with 1% and 99%-ile values set to represent the range of experimental values for ARF. The recommended RF value of 0.8 was chosen to reflect experimental results.

As shown in Fig. 4-14, there were three filtration steps (abbreviated “F”), with release mechanisms assumed to be similar to transfer releases. Some of the most hazardous steps in Recovery involved adding solid sodium hydroxide to solutions of plutonium salts. Because the dissolution of sodium hydroxide is highly exothermic, “considerable steam was released during the neutralization, resulting in a contamination hazard” (Duffy et al. 1945) [p. 17]. This release mechanism (labeled “Simmer” on Fig. 4-14) was modeled using data from experiments (Mishima et al. 1968) in which the fraction of boiling and simmering solutions entrained in flowing air was measured. Mishima et al. (1968) measured ARF values of $1.3 \times 10^{-6}$ to $4.5 \times 10^{-6}$. For this analysis, a uniform distribution across this range was chosen. An RF value of unity was selected based on experimental results published in 2003 that include measurements of size distributions of entrained liquid droplets above boiling solutions and found that over 99% of entrained droplets were smaller than 10 µm (Cosandey et al. 2003).

A fourth release mechanism occurs when plutonium solutions were sparged with sulfur dioxide gas for 15-20 minutes, labeled “Sparge” on Fig. 4-14. This release mechanism was modeled using experimental results published in 1986 that summarize liquid entrainment across a range of superficial gas velocities (Borkowski et al. 1986). The bulk of ARF measurements appear to be log-normally distributed and fall between $10^{-5}$ and $10^{-4}$. To capture these results qualitatively, a log-normal distribution with the 1%-ile and 99%-ile values of $2 \times 10^{-6}$ and $1 \times 10^{-3}$, respectively, was selected for this analysis. The conceptual release mechanisms for recovery of plutonium from residual supernatants from the “B” and “C” purification processes were similar, but contained only one “simmering” release and no releases from sparging, as the sulfur dioxide step was not needed for these residues.
As shown in Table 4-1 and Fig. 4-15, releases from the recovery of plutonium from reduction slag and crucibles are characterized by 13 release points, consisting of eight liquid transfer releases, two releases from simmering, two releases from filtration, and one release associated with the transfer of crushed crucibles and slag. A final step in all recovery processes, peroxide precipitation was used to separate plutonium from a number of rare earth elements. Release mechanisms in this processing step, shown in Fig. 4-16, are associated with five liquid transfer operations, one filtration, and two boilings. There were two significant release mechanisms that occurred during the peroxide process. The first occurred when a 30% solution of hydrogen peroxide was added to a solution of plutonium nitrate. Upon addition, the hydrogen peroxide would effervesce, an effect that scientists tried to mitigate by cooling the mixture to 4°C. It was documented in 1945 that “the spray from the ‘peroxiding’ operation as carried out in Building D was a major source of contamination” (Duffy et al. 1945)[p. 34]. An additional source of contamination presumably occurred in the final Recovery step, which involved boiling solutions of plutonium nitrate over a steam bath in 600 mL beakers, concentrating them into a “thick syrup” (Duffy et al. 1945)[p. 32].

**Release Summary**

Heuristics and experimental results compiled by the USDOE that characterize the accidental release of plutonium compounds were used to estimate the source term associated with plutonium production operations within D Building from 1943-1945. The scope of this was limited to releases occurring from the Purification, Dry Chemistry, Reduction and Recovery groups during documented plutonium production operations. In agreement with anecdotal evidence in several LASL documents, this analysis suggests that the bulk of plutonium releases occurred from the Recovery group, a result of open-air processing with minimal protection. Emissions resulting from the addition of hydrogen peroxide and from boiling of plutonium nitrate solutions were likely to have been particularly severe. This work resulted in a preliminary source term estimate of about 0.4 Ci (median) from processes that were included. This estimate is associated with a high degree of uncertainty, and true releases may have been in excess of 1 to 1.5 Ci. The preliminary 95th percentile value is about 1.05 Ci. The uncertainty is these estimates is mainly due to the relatively sparse and marginally relevant experimental data. If further work on estimation of early airborne plutonium releases from Los Alamos operations is undertaken, a portion of the work should be aimed at obtaining additional experimental data to support this estimate and reducing its uncertainty.
Fig. 4-14. Flow diagram of recovery release mechanisms during recovery of plutonium from residual purification supernatants.
Fig. 4-15. Release mechanisms associated with plutonium recovery from reduction slag and crucibles. “T” = “Transfer” release mechanism (liquid); “TS” = “Transfer” release mechanism (solid powder); “F” = “Filtration” release mechanism; “Simmer” = “Simmering” release mechanism

Fig. 4-16. Release mechanisms associated with the final recovery processes involving precipitation of plutonium nitrate with hydrogen peroxide
Indoor Measurements of Airborne Radioactivity as a Source of Information about Plutonium Releases from D Building during World War II

One of the major operational areas from which plutonium releases were unmonitored was D-Building operations from 1943 until 1954. D Building was the site of the process development, production of the plutonium components of the early nuclear weapons, analytical chemistry operations, and metallurgical research and development. Although major plutonium component production activities were transferred to new processing facilities at DP West Site in late 1945, D Building continued to be an active and expanding facility until the Chemistry and Metallurgical Research (CMR) Building at TA-3 became operational around 1953.

As D Building was the first facility to process plutonium in visible quantities and fabricate weapon components, many environmental safety and health practices considered routine today had not been developed. Work that today would be carried out in glove boxes with multiple stages of HEPA filtration on the exhaust was instead conducted in open hoods or on laboratory benches. Working conditions experienced after multi-gram quantities of plutonium began to arrive at Los Alamos in late 1944 rapidly deteriorated. In May of 1945, Wright Langham made a trip to Chicago to describe what steps were being taken at Los Alamos to protect the workers, including the recently developed monitoring methods utilizing bioassay. The push to develop and test the implosion device was considerable until the war was successfully concluded.

Although LAHDRA team members were unable to locate any stack monitoring records for D Building for any portions of its operational period, workers at Los Alamos frequently took measurements of the airborne concentrations of plutonium in various rooms and locations around D Building. From these concentrations, estimated room volumes, ventilation rates and some other assumptions, a lower bound estimate of plutonium releases can be made. This estimate must be considered a lower bound for several reasons. A large portion of releases apparently occurred from operational activities conducted in hoods, glove boxes, and other enclosures. Releases of the contaminated air in laboratories would be expected to be small compared to the unmonitored releases from work performed in laboratory hoods and other primitive confinement devices that exhausted directly to the environment via roof-top vents. Those releases are the subject of a separate analysis. Also, there were no measurements made during the highly problematic startup period with larger quantities of plutonium, roughly from December 1944 to August 1945. The measurements that were reported were made after the end of the war and after efforts were made to improve operational conditions within D Building. Finally, the rooms that had plutonium
measurements reported had results for less than 14% of all months. Many had only a few measurements
during the entire period.

The monthly reports listed average (and at times, maximum) values recorded over the month. The
reporting of data clearly separated rooms that housed enriched uranium activities from those that housed
plutonium operations, and the room assignments do not appear to have been interchanged significantly
over time. This separation of uranium and plutonium operations must have been intended to simplify the
control and measurement of contamination and was later continued at DP Site.

Measurements were made in 116 unique areas within D Building. Some were rooms with the same
number but differing letters (such as D-116 and D-116A) and other areas were hallways, change rooms,
attics, and conference rooms. One might have had a total of 11,832 room-months of measurements (102
months times 116 rooms); however, a total of only 1,616 monthly measurements were reported for the
entire time period that started in August 1945.

The release of plutonium over time for the room air exhausted was calculated by the LAHDRA team
using the following assumptions:

- 25% of room air volume is contaminated (heuristic estimate)
- 30 air changes per h (based on interview with LANL staff)
- Room Height = 10 ft for all rooms
- Detector intrinsic efficiency of 80%
- Filter Burial Factor of 1.602 (LANL has suggested a value of 2, not yet incorporated into this part
  of the study)
- Counting Geometry Factor of 2

The last three assumptions result in a total factor of 4.005 for the conversion of air sample counting
results from counts per minute per liter (“c/m/l” or c/min/L) to disintegrations per minute per liter
(“d/m/l” or d/min/L).

The following equations were used to estimate the total release in a month for a given room:

\[
\frac{d}{min}/L = \frac{c}{min}/L \times 4.005
\]

\[
\frac{d}{min}/h = \left(\frac{d}{min}/L\right) \times (\text{room volume}) \times 0.25 \text{ of room air contaminated} \times 30 \text{ air changes h}^{-1}
\]

\[
\frac{d}{min} \text{ released in a month} = \left(\frac{d}{min}/h\right) \times (\text{d/month}) \times 24 \text{ h d}^{-1}
\]

\[
\text{Ci released} = \left(\frac{d}{min} \text{ released}\right) / \left(3.7 \times 10^{10} \text{ d s}^{-1} \text{ Ci}^{-1} \times 60 \text{ s min}^{-1}\right)
\]
Room air concentration data were compiled from the CMR-12 monthly reports into a spreadsheet. Room volumes were calculated based on LANL drawings of D Building. For areas with no defined volume, such as hallways, the volume of the section of hallway immediately adjacent to a laboratory was used (with a further reduction associated with the assumption that only 25% of that volume is contaminated). At present, the limitation of the contamination to 25% of the room air and also to a small section of hallway is felt to be non-conservative and produces a lower bound for the calculated releases.

To emphasize the degree of non-conservatism in this estimate, in 1948, LANL began to better understand the nature of releases from D Building and glove boxes. In a study published in 1948, three rooms in D Building were subjected to air sampling for a little more than one year (Kennedy 1948). These rooms were used for processes that are not considered in the earlier section of this Chapter entitled “Release Estimates for D-Building Plutonium Processing.” They included Room 134, which was used in 1947 for preparation of plutonium alloys and samples. The air in this room would have released 1.5 mCi of plutonium in 1947 with the room air model assumptions given above. The releases to room air comprise a small fraction of the total plutonium released, since many of the operations were conducted in dryboxes. The plutonium released to room air largely came from transfers of material through the room to other boxes and from handling the material in the open. Releases from the dryboxes during grinding and polishing to prepare metallurgical samples for analysis were unmeasured and were another significant source of releases.

As mentioned above, the monthly reports yielded a total of 1,616 data points from 116 rooms over 102 months. This means that over 14% of the cells in the spreadsheet have values. All the data in a given year was compiled into a distribution and tested. The data for each year followed a log-normal distribution, with no year showing a smaller residual than 0.93. These distributions could be used, if further evaluation of D-Building releases is undertaken, to stochastically estimate air concentrations for rooms each month for which no measurements were reported.

The sum of estimated releases over all months with reported measurements is 0.0109 Ci of alpha emitting radioactivity. Recall that this calculation is a partial representation of D-Building releases. In order to account for the rooms each month that have no results reported, additional assumptions must be made. This memo considers two possible approaches:

- One method would be to simply assume that the unmeasured rooms have the same average contamination as the average measured room. Using this assumption, a value of 0.08 Ci is obtained. This method essentially increases the total estimated for sampled rooms by a factor of the total of 11,832 room-months divided by 1,616 reported room-months.
• Many rooms have low concentrations reported. An alternate approach is to assume that the average measured concentration in a given room is constant for that room. Under this assumption, a total room air release of 6.12 Ci is obtained. There are rooms with high concentrations and few measurements that result in the larger release estimate under this approach, which assigns higher values to unmeasured periods than the average of measurements across all rooms.

This range of estimates (from 0.08 to 6.12 Ci) does not include the troublesome startup period of D-Building operations. Although this startup period represented 8% of the 102 months for which limited monitoring data are available, improvements in confinement devices might easily have afforded a factor of 10 reduction in air concentrations in a given laboratory by the time monitoring began. Thus, the early 8-month period during which multi-gram quantities of plutonium was being processed might have been an important period for environmental releases that this preliminary assessment does not address.

**TA-21 (DP Site) Historical Plutonium Processing— DP West**

In January 1945, a serious fire that broke out in C Building within the Original Technical Area raised concerns about the possibility of a fire in D Building. This, plus a dramatic increase in the amounts of plutonium handled in D Building and concerns about the need to house plutonium and polonium safely, led to planning of new facility to be called DP Site and later TA-21. DP West took over the plutonium production functions of D Building. Most DP Site facilities were constructed in 1944-1945, and the necessary process equipment was installed during this time as well. Operations appeared to have started near the end of November 1945 (Meyer and Schulte 1944-1956).

The primary functions of DP West were to: 1) produce metal and alloys of plutonium and other transuranic elements from nitrate solution feedstock; 2) fabricate these metals into precision shapes; 3) provide and install protective claddings; 4) measure the chemical and physical properties of these metals and alloys; and 5) recycle scrap or materials used in experiments (Valentine et al. 1982).

Fig. 4-17 shows the early layout of DP West (Christenson and Maraman 1969). Photos of DP West are shown as Fig. 4-18 and Fig. 4-19. Buildings 2 and 3 housed wet chemistry processes, and Buildings 4 and 5 housed dry chemistry processes. Building 12 was the main filter building for exhausted air.
1. Early DP West Site Building Layout and Main Functions

Fig. 4-17. Early DP West Site Building Layout and Main Functions

2. DP West site, looking north, date unknown. Plutonium process buildings 2, 3, 4, and 5 are labeled, as are the filter building (12) and associated ductwork, manifold, and stacks. From photo IM-9:15926 courtesy of LANL.

Fig. 4-18. DP West site, looking north, date unknown. Plutonium process buildings 2, 3, 4, and 5 are labeled, as are the filter building (12) and associated ductwork, manifold, and stacks. From photo IM-9:15926 courtesy of LANL.
Fig. 4-20 presents a flow diagram of process used in early DP West Site operations in processing of plutonium and production of atomic weapon components (Kennedy 1947).

Following are summaries of the activities performed in each major building at DP West:

- **Building 2 (TA-21-2)**—housed gloveboxes for dissolution and recovery of plutonium and storage of $^{241}$Am wastes. The building housed a scrap incinerator, solvent extraction columns, and a liquid-waste loading area. On 30 December 1958, a criticality accident occurred in Building 2 South involving separated phases in a plutonium process tank. The operator (Cecil Kelley) died 36 hours later.

- **Building 3 (TA-21-3)**—housed the oxalate precipitation operations.

- **Building 4 (TA-21-4)**—housed some development laboratories for plutonium research from 1945 to 1948 at which point the laboratories were converted to production areas for enriched uranium hydride. In 1960, the hydride equipment was removed so that a hot cell could be added for the examination of irradiated plutonium and enriched uranium fuel elements. In 1965, two glovebox lines were added to support the $^{238}$Pu metal production. The above programs were part of Rooms 401 and 401E on the north end of the building (Valentine et al. 1982). Rooms 403, 404, 405, 406, and 407 also had gloveboxes that were used for $^{239}$Pu and $^{238}$Pu metal preparation during these early years.
Fig. 4-20. A flowchart of early plutonium processing operations at DP West Site (from Kennedy 1947)
• **Building 21 (TA-21-21)** – was a vault for storage of uranium and plutonium metal.

• **Building 33 (TA-21-33)** – housed research efforts into collecting additional plutonium from waste streams.

• **Building 150 (TA-21-150)** – was built in 1963 as a plutonium fuels development building (Repos. No. 2344). This building was built next to Building 5. Some of the programs the building supported included: 1) the development of $^{238}$Pu heat sources for space electric power applications; 2) investigations of various ceramic materials containing plutonium for use in the Liquid Metal Fast Breeder Reactor (LMFBR) program; and 3) the development of $^{238}$Pu fuels for isotopic powered heat sources for powering artificial organs (Valentine et al. 1982).

In an incident in DP West Building 150 on 7 October 1970, a sealed capillary broke, resulting in the release of a reported 10 ug of $^{238}$Pu up a vent. Resulting concentrations were estimated to be 2,800 times the AEC maximum permissible concentration (MPC) for insoluble $^{238}$Pu. Air samples were analyzed from the DP fence line, near private housing just west of the west end of the airport runway, and at the airport terminal air particulate sampler. Maximum reported air concentrations were \(1.27 \times 10^{-14} \text{µCi mL}^{-1} \) $^{238}$Pu at housing near the airport runway and \(0.29 \times 10^{-14} \text{µCi mL}^{-1} \) $^{239}$Pu at the DP Site fence (Kennedy 1970, Meyer 1970).

• **Building 210 (TA-21-210)** – housed additional research activities on the properties and uses of plutonium.

**DP West Air Handling and Stack Air Sampling**

Buildings 2, 3, 4, and 5 each had an intake air fan. The air was filtered and then distributed by a system of ducts that entered the rooms of the buildings at the ceiling. The exhaust air left the rooms by another system of ducts that lead into a large common duct located on the roof of each building. All dryboxes and hoods for each building were vented into this common exhaust duct (LAB-CMR-12-60).

These common ducts converged into a large manifold in Building 12, where the air was supposed to mix to a uniform concentration. The air then passed through the precipitrons. The precipitrons were electrostatic units that used electric fields to ionize and capture particles. The air then passed through a single bank of American Air Filter Company type PL-24 filters (Christensen et al. 1975). The air was finally discharged by exhaust fans out of four stacks that were approximately 57 feet tall. In the early days of DP West, the exhaust air was sampled in the common exhaust ducts, the Building 12 manifold,
and in each stack. Modified “Filter Queen” vacuum cleaners were used to sample the exhaust air at these locations (Maraman et al. 1975).

The DP West Site exhaust treatment systems were improved over the decades of site operations (Maraman et al. 1975). A single bank of HEPA filters was installed in the DP West Site’s combined process exhaust system in 1959. The process exhaust system was separated from the plant exhaust system at that time. As part of the work during 1959, a cleaning of the room exhaust plenum resulted in a spike in measured airborne releases. The room exhaust plenum was again cleaned in 1973, leading to another spike in releases. Two banks of HEPA filters were installed in the process exhaust system in 1973, the same year in which a single bank of HEPA filters was installed in the room air exhaust system.

More Recent Plutonium Processing

In 1969, the decision was made to build a new facility, TA-55, the Plutonium Facility Site. Processing of plutonium and research on plutonium metallurgy are done at this site, which is also known as “PF Site.” Operations at TA-55 include processing and recovery of $^{239}$Pu from scrap materials, recycle, metal production, metal fabrication, and research & development. This was also the site of special isotope separation research. The SIS-III was designed to provide special plutonium isotopes for LANL weapons research. The site also has responsibility for manufacturing heat sources for weapons-related programs (Cochran et al. 1987).

Plutonium has also been processed at TA-3, the new Core Area: [a.k.a. “South Mesa Site”]. The Lab’s main technical facilities moved here from TA-1 in 1953. Areas at TA-3 that likely involved plutonium processing include:

- TA-3-29 Chemical and Metallurgical Research (SM-29) (has Wings 1-9).
- TA-3-32 Cryogenics
- TA-3-34 Cryogenics
- TA-3-35 Press Building
- TA-3-39 Technical Shops
- TA-3-40 Physics
- TA-3-65 Source Storage (SM-65)
- TA-3-66 Sigma Complex
- TA-3-102 Tech Shops (handles beryllium, uranium, lithium per Repos. No. 225)
- TA-3-141 Rolling Mill
- TA-3-184 Occupational Health
- TA-3-216 Weapons Test Support
- TA-3-700 Acid Neutralization and Pump Bldg (also known as SM-700).
As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Effluents were filtered through Aerosolve 95 filters. Wing 9 contained hot cells handling irradiated uranium and sometimes plutonium. Effluents may also have contained mixed fission products including iodine. HEPA and charcoal filters were reportedly used for treatment. Filters were counted for both alpha and beta radiation.

Stack FE-19 of the CMR Building serves the glove box processes and rooms on the south side of Wing 3. As of March 1980, the exhaust treatment system had a demister, one stage of M-80 prefilters, and one stage of American Air Filter Continental 2000 filters (that is, bag filters with published 85% efficiency for 0.3 μm DOP). Prior to July 1976, the system included Aerosolve 95 filters.

Since early 1974, FE-19 has been major source of plutonium at LASL (up to 99% of the total in 1980). Releases from FE-19 began to increase during Feb 1979, when two filters tore. During filter change-out, flow reversal sent 143 μCi of Pu up FE-20 stack (Stafford et al. 1979-1982). February 1980 testing showed FE-19 filters were only 29.3% efficient. The release from FE-19 from Jan 19 – Jan 26, 1979 was 91 μCi, which was greater than the total release for this stack in 1978.

Alpha activity in liquids flowing into the TA-50 waste treatment plant rose sharply in the years leading up to 1973 because of increased use of 238Pu at the SM 29 building in TA-3. Concentrations at times reached 0.001 μCi/cc [pages from microfiche: TR7831, Envelope 51, dated 5/9/73].

References


Kennedy J. Volume 8, Chemistry of Uranium and Plutonium. Chapters 5 through 7, Section B. Los Alamos, NM: Los Alamos Scientific Laboratory; LA-1017; 1947. Repos. No. 3085.


Chapter 5: Reactor Development and Operations at Los Alamos

When it was first established, Technical Area 2 (TA-2), also known as Omega Site, was used for both nuclear criticality experiments and as the location for the Water Boiler reactor. Assembly of the first Water Boiler (the LOPO model) began in late 1943. In April of 1946, nuclear criticality experimentation was relocated from TA-2 to TA-18 (Pajarito Site). Construction of the plutonium fast reactor (Clementine) began in August of that year, and from then on Omega Site was used primarily as the location for reactors for neutronics experiments and isotope production. Over its history, three reactors have operated at TA-2: the Water Boilers (three different versions), the plutonium fast reactor (Clementine), and the Omega West Reactor (OWR). No reactors have operated at TA-2 since the shutdown of the OWR in December of 1992. The Water Boiler was deactivated in June of 1974, and the Clementine reactor was deactivated in December of 1950 following four years of problematic operation.

The Water Boiler Reactors

[Much of the following was adapted from “Early Reactors” by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983). Other references are as cited.]

During the Manhattan Project, a reactor was needed for confirming critical mass calculations, measuring fission cross-sections, and determining the neutron scattering and absorption properties for materials being considered for moderators and reflectors in the first atomic bombs. Enrico Fermi advocated the construction of a homogeneous, liquid-fueled reactor, using enriched uranium. Three versions were eventually built, all based on this concept. For security reasons, these reactors were all referred to as “water boilers.” The name was appropriate, since dissociation of the fuel solution would occur in the higher-power versions, giving an appearance of boiling.

The first water boiler was assembled in late 1943 at Omega Site. At that time, the fuel for this reactor (14%-enriched uranium) consumed the Nation’s total supply of enriched uranium. Two machine gun posts were therefore placed at the site to ensure its security. The first water boiler was called LOPO (for Fig. 5-1. A view of Omega Site, TA-2, from above
low-power) because its power output was virtually zero. This allowed for a simple design and eliminated the need for shielding. The fuel for the LOPO was an aqueous solution of enriched uranyl sulfate. The fuel was contained in a one-foot diameter spherical shell of stainless steel, surrounded by a reflector consisting of beryllium blocks on a graphite base. Control and safety rods passed through the reflector assembly. The fuel solution (known as the “soup”) was pumped into the steel shell from a conical storage basin located beneath it. Since the system was intended for low power, no provisions for cooling were included. The LOPO achieved initial criticality in May of 1944.

The purpose of the LOPO was to determine the critical mass of a simple fuel configuration and to test the water boiler concept. With these goals met, the LOPO was dismantled to make way for a second design that could be operated at a power level of up to 5.5 kW and thus serve as a neutron source needed for cross-section measurements and other studies. This second version was called the HYPO (for high power). The fuel solution was changed from uranyl sulfate to uranyl nitrate, and cooling coils were added within the shell. A tube passing through the shell (called the Glory Hole) was also added to allow for placing samples in the region of maximum neutron flux. The reactor was surrounded with a concrete shield. The HYPO began operation in December of 1944, and was used for many of the key neutron measurements needed in the early days of atomic bomb design.

In March of 1951, significant modifications to the HYPO were completed in response to demands for higher neutron flux and more research capability. These modifications allowed the water boiler to operate at power levels up to 35 kW. This modified version of the HYPO was dubbed the SUPO. Modifications made in the conversion of the HYPO to the SUPO included:

- Installation of additional cooling coils within the fuel vessel for greater cooling capacity.
- A significant increase in the enrichment of the uranyl nitrate fuel solution, from 14% $^{235}$U to 88.7% $^{235}$U.
- The beryllium oxide portion of the reflector was replaced with graphite to allow for more rapid shutdown.
- A gas recombination system was connected to the reactor vessel to eliminate the explosion hazard posed by the radiolytic dissociation of hydrogen and oxygen from the fuel solution. The water formed in the recombination chamber of this system was returned to the fuel vessel.

To reduce the emission of short-lived radioactive gasses from the Water Boiler, a delay line was installed. Before the installation of the delay line, it reportedly could not be determined how much $^{131}$I was present because of masking by Rb-88. Charcoal samples reportedly showed that essentially no $^{131}$I was present before or after the delay line was installed [3/98 memo J. Margo Clark to Ken Silver].
The SUPO Water Boiler experienced a water leak into its moderator shield, and had to shut down in 1973. Its stack was found to be contaminated with $^{137}$Cs (Site Tour, 1998). Contamination in the reactor had migrated to the bioshield. SUPO was operated almost daily until its deactivation in 1974. Like its predecessors, it was used extensively for cross-section studies and other neutron measurements. However, it was also used for studying reactor physics (perturbation effects) and for biological research.

Planning for Decontamination and Decommissioning (D&D) of the SUPO facility began in July of 1988. The physical decommissioning process was completed in April of 1990, with the facility (TA-2-1-122) subsequently being released to the Isotope and Nuclear Chemistry division (Montoya, 1991; LA-12049).

**The Plutonium Fast Reactor (Clementine)**

[Much of the following was adapted from “Early Reactors” by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983). Other references are as cited.]

The plutonium fast reactor was proposed and approved in 1945 as a high-intensity fission neutron source that could also be used to assess the suitability of plutonium as a reactor fuel. Since a fast reactor requires no moderating material, the reactor could be of small size. The site chosen for the fast reactor was adjacent to the water boiler building at Omega Site. Construction began in August of 1946, during which time the reactor was dubbed Clementine, after the song “My Darling Clementine.” The fuel for the fast reactor was in the form of small rods clad in steel jackets. The rods were installed in a steel cage through which the coolant, liquid mercury, flowed at a rate of approximately 9 liters per minute. Flow was maintained via an electromagnetic pump. The fuel cage was surrounded with a 6-inch thick natural uranium reflector, most of which was plated with silver to reduce corrosion. The uranium reflector was surrounded by an additional steel reflector 6 in thick, and finally by a 4-in thick lead shield. Reactor (reactivity) control was effected via insertion of uranium fuel rods into the cage – a positive reactivity control method as opposed to the negative reactivity control method typically used in reactors.

Initial criticality of the fast reactor was achieved in late 1946, though its design power of 25 kW was not reached until March of 1949. During this interim period, measurements were made at low power, including determination of the neutron energy spectrum, reactivity effects, cross sections, etc. Changes in the control system were also made during this time as experience in the operation of a fast reactor was gained. In March of 1950, following nearly a full year of operation, the fast reactor was shut down to correct a malfunction in the operation of the control and shim rods. During this shutdown, a ruptured uranium rod was discovered and replaced. Operation resumed in September of 1950, and continued until late in December of that year when it was determined that a plutonium fuel rod had ruptured and released plutonium into the mercury coolant. The hazard created by this condition and the identification of serious
abnormalities in the uranium reflector prompted the decision to permanently shut down and disassemble the reactor. One of the lessons learned from experience with the fast reactor was that mercury was unacceptable as a coolant due to its poor heat transfer properties and other concerns.

When Clementine was decommissioned, its parts were stored in a hutment at Area C, and are believed to have been subsequently buried there (Repos. No. 525). The disposal location of the mercury coolant is not known (per Repos. No. 525).

The Omega West Reactor (OWR)

[Much of the following was adapted from “Early Reactors” by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983). Other references are as cited.]

With the early demise of the plutonium fast reactor, a replacement was needed to meet the needs for neutron measurements for various laboratory activities. Evaluation of the options available at that time led to a conclusion that a design patterned after the Materials Test Reactor (MTR) at the Idaho National Laboratory was the most attractive. A reactor designed to use the MTR’s plate-type fuel elements, which had already undergone extensive testing, meant core design and licensing could be expedited. The conceptual design for the new reactor was completed by the end of 1953. The core was to sit at the bottom of a water tank 8 feet in diameter and 24 feet high. The reactor would be cooled by water flowing at 3500 gpm. The proposed power level was 5 MW, but the shield was designed so that a power level of 10 MW could be tolerated. To save time and money, the reactor was built in the same room that had housed the plutonium fast reactor.

The OWR reportedly got an exemption from 10 CFR 100 reactor-siting criteria. The OWR was a small, low pressure, low temperature research reactor. Natural convective circulation of the reactor pool water was reportedly sufficient to cool the reactor. The maximum credible accident that was assessed would release 822 Ci of $^{131}$I to the air, along with 10,900 Ci of other iodines, 168 Ci of $^{131}$Xe, and 153,000 Ci of other rare gases. Doses were calculated at a Residential Area (0.4 mi cross canyon), Skating Rink (1.9 mi up canyon), and State Road 4 (4.0 mi Down Canyon). Maximum doses calculated by LANL personnel for this accident were reportedly 57 rem to thyroid and 22 rem whole body at State Road 4. [”Potential Environmental Issues at Los Alamos Scientific Laboratory” c. Oct. 1979, Repos. No. 615].

Construction of the new reactor began in mid 1954. Initial criticality was achieved in July of 1956, and a few months later the Omega West Reactor (as it became known) was operating at 1 to 2 megawatts. [Repos. No. 2387 states that the OWR achieved initial criticality on June 29, 1956.] In May of 1966, new operating limits were established that allowed the maximum operating power level to be increased to 6.5
A modification to the OWR’s cooling system allowed its maximum operating power level to be increased to 8 megawatts in August of 1967. The technical specifications for the OWR prescribed a Limiting Safety System Setting (LSSS) of 11 MW. The OWR’s safety limit was 14 MW (LA-UR-93-579).

The OWR reportedly had an iodine-125 production loop, and at times the reactor was operated essentially around the clock on an “Iodine Production Loop schedule.” “OWREX” capsules were placed in the reactor (e.g., OWREX-5 insert, OWREX-8 insert around 1966). These capsules evidently contained fuel and sodium. Fission gas traps and sweep-gas monitor detected leaks of capsules on several occasions [e.g., LA-3582-MS].

The combination of an unusual occurrence that resulted in a challenge to a safety system and the discovery of coolant leaks in underground piping prompted the shutdown of the OWR in December of 1992. The unusual occurrence took place on December 11, 1992 when human error resulted in the reactor power rising to an administrative control limit of 9.6 MW, prompting an automatic shutdown of the reactor. The investigation report compiled for this event identified three root causes for the incident, but drew an overall conclusion that conduct of operations at the OWR facility was inadequate (LA-UR-93-579). The three root causes specifically identified in the report were task performance errors on the part of various personnel, inadequate procedures for removal of samples from the reactor, and inadequate procedures and policies for ensuring reactor control is not compromised in the event of off-normal conditions (LA-UR-93-579).

In 1994, all of the fuel and control blades were removed from the OWR and the facility was placed in a safe shutdown mode (Burns et al., 1993; LA-UR-95-4294). Inspection of the fuel elements conducted during the defueling operation showed that no fuel damage had occurred. All coolant was drained from the reactor vessel. A preliminary characterization in support of planning decommissioning activities was conducted in 1995 (Burns et al., 1993; LA-UR-95-4294).

The Omega West Reactor (OWR) operated routinely operated 120 hours a week during its first 16 years. Usage dropped off to around 40 hours per week thereafter until the reactor was permanently shut down. Research conducted at the OWR included: cross-section studies, measurement of weapon yields (via comparison fission counting), neutron radiography, condensed matter studies (via neutron scattering), testing of power reactor components, testing of power reactor fuels, tests of plasma thermocouples, neutron activation analyses, and radioisotope production.
The Omega Stack

A memo from Hornberger to Hoffman dated 25 May 1945 (Repos. No. 510) describes the off-gas line from the Water Boiler (HYPO) and reports exposure rate readings made beneath and to the sides of the line. These readings are given in terms of the time in hours one would need to be at a location to receive an exposure equal to the daily limit at that time. The first part of the line (see Figure 5-2) is described as being hung on tree supports and ascending the canyon wall. The last half of the line had four points where it sagged to the ground. Breaks in the line were noted at 75 yards and 25 yards from its exhaust end. There is no mention of a stack. The memo includes a hand-drawn figure (Figure 5-2) showing the off-gas line relative to the Water Boiler building and the mesas north and south of Los Alamos Canyon.

Los Alamos document LAMD-155-I, “Manhattan District History, Volume II,” states that “External radiation hazards [at LANL] were, for the most part, well controlled. However, arrangements for discharge of fission products from the Water Boiler were most unsatisfactory and represented a potential and serious health hazard. The gaseous materials were merely discharged near ground level at the top of the mesa just to the south of Los Alamos Canyon. Warning signs were inadequate and the area was accessible to any casual visitor. Intensities in excess of 50 r/hr were repeatedly measured near the discharge point when the boiler was in operation.”

![Fig. 5-2. Sketch of the Omega Site off-gas line](image_url)
Repos. No. 510 includes a memo from Blackwell and Littlejohn to Hempelmann dated April 24, 1947 reporting their discovery that the offgas line from the Water Boiler (HYPO) was “shattered” at about 100 feet prior to the “outlet” (stack), which was located in the top of a pine tree. It is surmised that the line became brittle from the off-gas and was broken due to swinging caused by recent high winds.

In later years, a 150-ft tall stack on South Mesa was used to ventilate the OWR thermal column region and experiment. The flow rate in this stack was reportedly 880 ft³ min⁻¹. Approximately 600 Ci of ⁴¹Ar was reportedly discharged per year [Repos. No. 645]. In 1968, a charcoal filter was added in the vent line from the OWR surge tank to the 150-ft stack [Repos. No. 648].

The original stack for OWR effluents was also described as a “flexible pipeline” that ran up the mesa and was attached to a tree. Exposures to a nearby “Trailer Village” were a concern [Repos. No. 510]. This original effluent line was Tygon tubing that was laid on the ground or draped on trees. It led to a pipe that was fastened to a pine tree. Eventually a buried stainless steel line and a stack were put into place.

Repos. No. 177 includes a memo from D. D. Meyer to D. Ritter (ENG-4) dated June 11, 1957 that requests removal of the barbed wire exclusion fence that kept people 50 feet or so away from the Omega stack. It also states that the “old” Omega stack is still located in the top of a dead tree just outside the fence surrounding the current stack. It is requested that the old stack be taken down and sent to the “contaminated waste pit.” A second memo included in Repos. No. 177 (from D. D Meyer to Carl Buckland), also dated June 11, 1957; states that P-2 plans to connect the off-gas system for the OWR to the existing system for the Water Boiler (SUPO). Per Repos. No. 2414, this action was completed between September 20, 1957 and October 20, 1957.

A charcoal filter was installed in the vent line for the OWR surge tank air space in 1968 (Repos. No. 648). The filter was installed as a precaution against a large radioiodine release that might otherwise have occurred in the event of a fuel element or experiment failure.

Hankins (1963) describes the Omega stack as being 150 feet long and having an inside diameter of 8 in. The 2 inch (inside) diameter vent pipe from the reactor to the stack was 1100 ft long. The vent pipe included a settling tank and two water traps to collect water that condensed out of the effluent. The delay time of gas in the vent pipe was originally 2.3 d, but the addition of the vent line from the OWR cut this time to about 8 to 10 hours. The effluent in the vent pipe flowed to the stack at a rate of about 100 to 200 cm³ min⁻¹, resulting in a dilution factor of about 100,000 in the stack. The stack flow rate was measured to be 845 ft³ min⁻¹ at a velocity of 2400 ft min⁻¹.
Per Hankins (1963), the combination of the recombiner, the long length of the vent pipe, and the low flow rates resulted in the particulate component of the effluent consisting of very small particles. It is reported that 65% were less than 0.05 µm, 93% were less than 0.1 µm, and none were larger than 1.0 µm.

A timeline of events of operational significance for Omega Site reactors is presented as Figure 5-3.

LAPRE I and LAPRE II

The Los Alamos Power Reactor Experiment (LAPRE) explored the use of a homogeneous reactor fuel consisting of highly-enriched UO₂ (93.5% ²³⁵U) dissolved in 95% phosphoric acid. Such a reactor system was thought to show promise for portable power sources for military applications if a method for containing the highly-corrosive fuel solution could be found. Consequently, two test reactors (LAPRE I and LAPRE II) were constructed and operated at Ten Site (TA-35) by K-division personnel between 1955 and 1960. LAPRE I was located in one of the hot cells of the main laboratory building. LAPRE II was located outside the main building in an underground enclosure tank. The purpose of the LAPRE I reactor experiment was to study the use of phosphoric acid solutions of uranium for a high-temperature reactor fuel in a simple, compact design in which the reactor core and the heat exchanger were contained in a single vessel (LA-2292). Protection of the reactor internals from the highly-corrosive fuel solution was supposed to have been achieved by coating the exposed surfaces with a thin layer of gold. While it was known that the problem of pinholes in the gold plating could not be completely eliminated (despite the use of multiple layers of gold), it was thought that the corrosion rate of the stainless steel under a pinhole in the plating would be tolerable (LA-2292).

The first critical experiments with LAPRE I began on February 15, 1956 (LA-2292). The reactor power was raised to a level of 20 kW and held there for five hours. Radioactivity was then detected in the steam line, and shortly thereafter criticality could not be maintained without dropping the temperature. The experiment was terminated with the fuel being transferred to an external tank. After nine days, the reactor was disassembled to determine the cause of the failure. It was found that some of the gold plating on the heat exchanger tubes had been damaged during assembly of the reactor, which allowed the hot fuel solution to come into direct contact with the stainless steel tubing. The fuel solution corroded several of the tubes, prompting failure. The corrosion rate observed was unexpectedly high relative to what had been predicted on the basis of laboratory tests (LA-2292). Chemical attack was also noted at imperfections in the plating of the vessel and the boron poison can (LA-2292).
Figure 5-3: Timeline of Operational Events for Omega Site Reactors

- **May 1944**: LOPO initial criticality
- **Dec 1946**: Clementine initial criticality
- **Mar 1951**: SUPO begins operation (max. power = 35 kW)
- **Jul 1956**: OWR initial criticality
- **Jan 1943** to **Jan 1960**: HYPO begins operation (max. power = 5.5 kW) and Clementine reaches design power (25 kW)
- **Dec 1944**: Clementine deactivated
- **Mar 1949**: Clementine reaches design power (25 kW)
- **Dec 1950**: Clementine deactivated
- **Jun 1974**: SUPO deactivated
- **May 1966**: OWR max. operating power raised from 5 MW to 6.5 MW
- **Aug 1967**: OWR max. operating power raised to 8 MW
- **Apr 1990**: SUPO D&D completed
- **Dec 1992**: OWR scram prompts deactivation
Since the failure of LAPRE I was not due to the reactor itself, components were repaired or replaced as thought necessary and a second attempt at operating the reactor was made (LA-2292). This second experiment was conducted on 15 October 1956. The reactor reached a power level of 160 kW and had been held there for approximately 2 hours when radioactivity was detected in the feed water and steam systems, prompting a shutdown. Activity in the steam line rose rapidly, resulting in dose rates of 300 mR h⁻¹ in the control room (LA-2292). This was thought to be due to gaseous activity released from the end of the steam line and drawn into the building ventilation system (LA-2292). Post-mortem inspection of the reactor determined the failure was again due to the heat exchanger tubes having been eaten away by the fuel solution. Since construction of LAPRE II was already underway at this time, further work with LAPRE I was abandoned (LA-2292).

LAPRE II utilized a different fuel solution than LAPRE I. This new solution had a lower vapor pressure than the LAPRE I fuel, at the expenses of less uranium solubility and thus the requirement for a larger vessel to achieve a critical mass. LAPRE II was also to make use of bonded components, in hopes of solving the failures associated with the protective gold plating. Construction of LAPRE II was begun in February of 1956 (Clark, 1960; LA-2465). The reactor was located in an underground enclosure tank on the south side of the main laboratory building at TA-35. This arrangement provided a prudent means by which to provide the necessary radiation shielding. The design thermal power of the reactor was 800 kW. The primary purpose of the LAPRE II experiment was to demonstrate containment of phosphate fuels through suitable corrosion protection techniques.

Operation of LAPRE II was begun in February of 1959 and continued into May of 1959 (Clark, 1960; LA-2465). Full power operation was achieved on April 22, 1959. The fuel solution was kept in the reactor vessel at a temperature above 200 F for 46 days. A maximum temperature of 826 F was achieved. Like LAPRE I, LAPRE II experienced problems with the leakage of volatile fission products into the steam system. At full power, dose rates of several thousand R h⁻¹ were present adjacent to the feed water heater (Clark, 1960; LA-2465). Though it could never be determined for certain, it was suspected that the leakage occurred via containment problems with the heat exchanger, ala LAMPRE I. Dismantlement of LAPRE II began on May 8, 1959 with the transfer of the fuel solution back to the storage tanks (Clark, 1960; LA-2465). The LAPRE program was terminated in 1960.

LAMPRE I

*The following was adapted from “Early Reactors” by Merle E. Bunker (Los Alamos Science, Winter/Spring 1983) except where otherwise noted.*
The purpose of the Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) program was to explore the issues associated with using plutonium fuel in fast breeder reactors using a reactor fueled with molten plutonium and cooled by molten sodium. While the original design of the LAMPRE I reactor called for a design power level of 20 MW, the researchers concluded that the knowledge base required to develop such a system was not yet sufficient. The design of the LAMPRE I therefore underwent substantial changes, going from a 20 megawatt system down to a 1 megawatt test reactor. The LAMPRE I core matrix was such that it could accommodate up to 199 separate fuel elements. Each element consisted of plutonium-iron fuel material in a tantalum thimble. The core matrix allowed several fuel element designs to be tested simultaneously.

The 1 megawatt design power for the LAMPRE I allowed it to be placed in an existing building at Ten Site (TA-35). A gas-fired 2-megawatt sodium cooling loop was also included to gain experience with high-temperature sodium-to-water heat exchangers. LAMPRE I achieved initial criticality in early 1961 and operated for several thousand hours thereafter. One of the problems encountered was corrosion of the tantalum fuel thimbles by both the fuel and the coolant.

By mid 1963 LAMPRE I had achieved its intended purpose and was shut down. LAMPRE II, which was to be the 20 megawatt system first conceptualized for LAMPRE I, was never funded, with the AEC instead opting to pursue uranium-oxide-fueled reactors rather than plutonium-fueled systems. LAMPRE was in the Ten-Site cell adjacent to the one used for $^{140}$La separation. It used molten plutonium contained within dozens of tantalum capsules, located within a sodium-cooled cylindrical core region about 40 cm high by 44 cm diameter. The LAMPRE fuel was transferred to Wing 9 at TA-3 (LA-UR-79-3091). LAMPRE experienced three separate fuel failures during operation; official reports say that these fuel failures did not cause any operational problems. [LADC-5936, CONF-258-1 by Robert A. Clark and Review of LAMPP by Argonne NL (PRO-P-1; 4/20/66)]

**The Rover Program**

In 1955, the United States initiated a program to develop a nuclear rocket engine to be used in defense systems and space exploration (Koenig, 1986; LA-10062-H). The plan was to carry large payloads into deep space, by essentially passing hydrogen through a very high temperature nuclear reactor, where it would expand and be blasted out of the reactor at high velocity. Conducted with NASA, this program was called Project Rover. Los Alamos was given the roles of establishing the basic reactor design and leading the fuel development effort (Koenig, 1986; LA-10062-H). A series of test reactors were designed and built at Los Alamos prior to being tested at the Nevada Test Site. These reactors were intended to
first demonstrate proof of principle, then to establish and test the requisite design considerations. In 1962, Rover was the second largest program at LASL. The Rover program was cancelled in January of 1973.

The Rover reactors were developed by the Los Alamos Critical Experiments Group using the facilities of the Pajarito Site (TA-18). In general, each new Rover reactor was developed following the same basic progression. First, parametric studies were performed using the Honeycomb assembly to establish the appropriate dimensions. The design then proceeded to the mockup phase, where details for controls and internal structures were worked out. Finally, the completed reactors were assembled and checked out prior to being sent to NTS for testing. Adjustments were made if any deviations from specifications were noted during checkout (Paternoster and Kirk, 1991; LA-UR-91-2434). Each Rover program reactor developed at Los Alamos is listed in Table 5-1 below, along with the date the reactor was tested at NTS (Paxton, 1983; LA-9685-H).

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Date(s) Tested at Nevada Test Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiwi-A</td>
<td>July 1, 1959</td>
</tr>
<tr>
<td>Kiwi-A'</td>
<td>July 8, 1960</td>
</tr>
<tr>
<td>Kiwi-A3</td>
<td>October 19, 1960</td>
</tr>
<tr>
<td>Kiwi-B1A</td>
<td>December 7, 1961</td>
</tr>
<tr>
<td>Kiwi-B1B</td>
<td>September 1, 1962</td>
</tr>
<tr>
<td>Kiwi-B2A</td>
<td>test cancelled</td>
</tr>
<tr>
<td>Kiwi-B4A</td>
<td>November 30, 1962</td>
</tr>
<tr>
<td>Kiwi-B4D</td>
<td>May 13, 1964</td>
</tr>
<tr>
<td>Kiwi-B4E</td>
<td>August 28 and September 11, 1964</td>
</tr>
<tr>
<td>Kiwi-TNT</td>
<td>January 13, 1965</td>
</tr>
<tr>
<td>Phoebus-1A</td>
<td>June 25, 1965</td>
</tr>
<tr>
<td>Phoebus-1B</td>
<td>June 26, 1968</td>
</tr>
<tr>
<td>Phoebus-2A</td>
<td>June 26, 1968</td>
</tr>
<tr>
<td>Pewee-1</td>
<td>November 21, 1968</td>
</tr>
<tr>
<td>Pewee-2</td>
<td>test cancelled</td>
</tr>
<tr>
<td>NF-1 (Nuclear Fuel Furnace)</td>
<td>June 29 and July 12, 21, and 27, 1972</td>
</tr>
</tbody>
</table>

Before shipment to NTS, the Kiwi-TNT reactor was operated at Pajarito Site beside the PARKA reactor (essentially a Phoebus 1 reactor set up as a critical assembly) to measure their interactions at various separating distances. A 1969 waste management plan says that the DP East facility processed new Rover fuel elements containing enriched uranium. Air from the exhaust systems handling radioactive materials was reportedly passed through HEPA filters. All four stacks from these systems were monitored but concentrations were below detectable levels [Repos. No. 113].
UHTREX

The Ultra-High Temperature Reactor Experiment (UHTREX) involved the construction and operation of a test reactor to advance the technology of high-temperature, graphite-moderated, gas-cooled reactors. The reactor was constructed in the late 1960s at Technical Area 52, and operated for approximately one year before being shut down in February of 1970 (Salazar and Elder, 1993; LA-12356). The UHTREX was cooled by helium gas in a system consisting of a primary and a secondary loop, and a single heat exchanger. Gas pressure in the two loops ranged from 475 psi to 545 psi, with the secondary loop kept at higher pressure than the primary in case leakage occurred within the main heat exchanger (K-Division, 1967; LA-3556 Revised). Under maximum conditions, the gas temperature at the core inlet was 1600 F, and the exit temperature was 2400 F (Salazar and Elder, 1993; LA-12356). The secondary loop coolant entered the heat exchanger at 200 F and exited at 1000 F (Salazar and Elder, 1993; LA-12356). A regenerative heat exchanger called the recuperator was used to re-heat the primary coolant on its way back to the core. The recuperator also served to lower the primary coolant temperature from 2400 F to 1400 F prior to it reaching the main heat exchanger. The secondary loop rejected heat to the atmosphere in a building outside the main reactor building. This heat dump building housed finned tubes cooled by large fans. The reactor produced no power. The UHTREX utilized 93%-enriched uranium fuel in the form of small spheres of UO₂ coated with 3 layers of pyrolytic carbon and bound in a graphite matrix (K-Division, 1967; LA-3556 Revised). Fuel for the UHTREX was fabricated at the CMR Building (K-Division, 1967; LA-3556 Revised). The UHTREX was designed with a rotating core that allowed the reactor to be fueled while operating. The design thermal power for the UHTREX was 3 MW.

The UHTREX utilized a gas cleanup system on the primary coolant loop to remove fission products and outgases from the (unclad) fuel. The UHTREX reactor, primary cooling system, and the gas cleanup system were contained in a gas-tight secondary containment provided by the main reactor building (Salazar and Elder, 1993; LA-12356). The gas cleanup system consisted of metallic filters (to remove particulate matter), a copper oxide bed (to oxidize reducing agents), molecular sieve beds (to adsorb carbon dioxide and water), and water-cooled beds of activated carbon (to either trap volatile fission products or to delay fission gases to allow for radioactive decay) (K-Division, 1967; LA-3556 Revised). Delay times for the carbon bed were 1.2 h for krypton and 20 h for xenon. Under maximum conditions, 13 kW of decay heat were produced in the charcoal bed. Tritium produced in the primary coolant via the $^3$He $(n,p)\ ^3$H reaction accumulated in the cleanup system in the copper oxide bed and in the molecular sieve beds. This tritium was eventually discharged up the 100 ft high main stack during regeneration of the sieve beds (K-Division, 1967; LA-3556 Revised). This process also resulted in the discharge of entrained fission gases (K-Division, 1967; LA-3556 Revised).
Air from the secondary containment, the fuel handling and gas sampling areas, and the change rooms and other such potentially contaminated areas passed through absolute (HEPA) and activated charcoal filters prior to being exhausted up the main stack (K-Division, 1967; LA-3556 Revised). Stack releases were monitored via a Tracerlab model MAP-1B/MGP-1A combination gas and particulate monitor (K-Division, 1967; LA-3556 Revised). The particulate monitor utilized a moving filter and a plastic scintillation detector. The gas monitor utilized a sodium-iodide detector. A removable charcoal filter was located between the particulate and gas monitors to allow for periodic assay of radioiodine concentrations via gamma-ray spectrometry. The stack monitor did not provide for “real-time” radioiodine monitoring. Air from the control room, offices, laboratories, equipment rooms, and other such “clean” areas was exhausted through rooftop vents. The UHTREX facility was designed so that air flowed from clean areas to potentially contaminated areas.

Spent fuel from the UHTREX was loaded into casks and transported by truck to Wing 9 of the CMR Building where it could be evaluated utilizing the hot cell facilities there (K-Division, 1967; LA-3556 Revised). Liquid radioactive wastes were carried by contaminated waste lines to the TA-50 treatment facility. Decontamination and Decontamination (D&D) of the UHTREX site and facilities began in the late 1980s. All radioactively-contaminated solid waste was buried at the laboratory’s central waste disposal facility (TA-54) (Salazar and Elder, 1993; LA-12356).

References

Chapter 6: Accelerator Operations at Los Alamos

During World War II, accelerators were used to determine the critical masses for each proposed atomic bomb design. Two Van de Graaff accelerators were acquired from the University of Wisconsin, a Cockcroft-Walton accelerator was “borrowed” from the University of Illinois, and a cyclotron was purchased from Harvard (Hoddeson et al., 1993).

The machines supplied neutrons for studying the neutron interactions involved in an explosive fission chain reaction. This was important because these interactions had not been studied at all of the neutron energies relevant to a nuclear explosion, from which fast neutrons are emitted with no slowing down or “moderation” as had been the case in the early graphite reactors. The accelerators also supported the effort to find a way of preventing a “fizzle,” or predetonation, in the gun-assembled plutonium bomb. A circular electron accelerator called a betatron was later procured to obtain sequences of images of spheres of mock fission fuel as they were being imploded by surrounding high explosives (Reichelt, 1993, Los Alamos Science No. 21).

During the postwar years, the emphasis was on building a foundation of basic scientific research with weapons applications. Three wartime accelerators were purchased and retained by the government— the Short Tank, the Cockcroft-Walton, and the cyclotron. The Long Tank was returned to the University of Wisconsin, but was replaced by a high-energy Van de Graaff accelerator with a vertical configuration. The neutrons from that device and those provided by the Cockroft-Walton were used to study neutron interactions relevant to nuclear fusion. The old Harvard cyclotron was upgraded into a variable-energy cyclotron that was used to study the angular distributions of accelerated particles after they scattered off the nuclei of various target elements. (Reichelt, 1993, Los Alamos Science No. 21).

Two electron linear accelerators (linacs) were later built to provide radiographs of the implosion process, in work that led to the 1963 construction of PHERMEX (pulsed high-energy radiographic machine emitting x rays). PHERMEX generates x rays by accelerating an electron beam onto a tungsten target, and the x-ray bursts are sent through model weapons at a remote blasting site to provide three-dimensional images of imploding spheres. (Reichelt, 1993, Los Alamos Science No. 21).

Relatively small accelerators that have been used at Los Alamos include:

- W Building at TA-1 housed a Van de Graaff accelerator. Building W had 2 high-voltage electrostatic generators used to produce variable energy neutrons for cross-section measurements.
Protons were accelerated, hit a target (usually lithium), producing neutrons. Some X rays were also produced. There were also hazards from neutrons and X rays.

- TA-3 Building 16 housed a Van de Graaff accelerator (a.k.a. SM-16). On 24 May 1977, there was a release of up to 800 Ci of tritium from the Van De Graaff accelerator. [Repository Nos. 593, 829]

**Accelerator Operations at Technical Area 53**

The largest accelerator facility at Los Alamos is the one that is housed at TA-53. Following is a list of acronyms that are used in the discussion of TA-53:

$LAMPF = \text{Los Alamos Meson Physics Facility}; \ WNR = \text{Weapons Neutron Research Facility}; \ LANSCE = \text{Los Alamos Neutron Science Center}; \ PSR = \text{Proton Storage Ring}; \ MeV = \text{Million Electron Volt (energy unit)}; \ MAP = \text{Mixed Activation Products}$

The primary facility at TA-53 is a large accelerator complex originally called the Los Alamos Meson Physics Facility (LAMPF). The original sections of LAMPF were later renamed the Clinton P. Anderson Meson Physics Facility. LAMPF is a nominal 800 million electron volt (MeV), 1-milliampere intensity proton linear accelerator. Construction was started on LAMPF in 1968. On June 12, 1972, LAMPF first obtained a full energy beam. Originally constructed to study sub-atomic particles, today LAMPF serves as an accelerator generating intense pulses of neutrons (by sending the protons into targets of high atomic number such as uranium) for scattering research at the WNR and LANSCE facilities. The Proton Storage Ring is used to accumulate protons and provide a short duration pulse of protons for targeting onto uranium and other high atomic number targets for neutron production at WNR.

Today, the complex is called the Los Alamos Neutron Science Center, and includes the linear proton accelerator, the Manuel Lujan Jr. Neutron Scattering Center, and a medical isotope production facility. In addition, the Accelerator Production of Tritium Project Office, including the Low-Energy Demonstration Accelerator, and R&D activities in accelerator technology and high-power microwaves are located at TA-53.

**LANSCE Release Summary**

LANSCE airborne radionuclide releases consist of short-lived radioactive materials that have been activated from air. These radioactive materials are composed of particulates from activated dust in air and gaseous activation products from air constituent gases. Another source of LANSCE radionuclide
releases is the cooling water used for cooling accelerator components. Non-radioactive releases at accelerators include solvents, which are used in large volumes for cleaning vacuum components.

LANL documents refer to the mix of short-lived materials as Mixed Activation Products (MAP). Some other acronyms seen in documents are G/MAP for Gaseous Mixed Activation Products and P/VAP which are Particulate Various Activation Products. These radioactive materials are produced when the proton beam from LAMPF is sent through air, or when a fraction of the proton beam is lost through interactions with accelerator components (such as targets). These interactions generate neutrons, which subsequently activate the air gases and the dust in air.

Radionuclide releases from LANSCE occur in two ways 1) from the four stacks located in the facility which are monitored for both particulates with filters, and for gases with Kanne chambers and 2) via unintentional pathways of diffuse release via doors and other exit points. For some periods of time, these combined emissions are the source of the highest priority releases to the environment. The radionuclide releases reported at LANSCE are among the highest of all DOE operations nation-wide. The amount of radioactivity released from LANSCE increases proportionally as the power levels and beam-on time increase. Principal gaseous radionuclides constituents released were $^{11}\text{C}$ (20 min), $^{13}\text{N}$ (10 min), $^{15}\text{O}$ (2 min). A trace amount of $^{41}\text{Ar}$ (1.8 h) was also released. The particulate releases are too numerous to mention and are only present in trace levels since these consist of activation products from dust in air or disintegrated target material.

Cooling water that services accelerator components, including targets, also becomes radioactive, and also accumulates corrosion products from the target and magnet systems. This water has been released by the site after decay in concrete walled cooling water ponds that have bentonite clay on the bottom. The cooling water is held until no short-lived radionuclides are observed in the water, after confirmation measurements, the cooling water from these ponds is then released and becomes surface water.

**Prioritization of LANSCE Releases**

The releases from LANSCE are cataloged in detail by the LAHDRA team in a two calculations (O’Brien 2003a and O’Brien 2003b). Results of the prioritization assessment for airborne radionuclides are presented in Chapter 17. The calculation of Priority Indices (PI) involves dividing the reported annual release by the maximum effluent concentration from 10 CFR Part 20. The result represents the volume of air required to dilute the releases to the maximum permitted value, and therefore permits comparisons for varying amounts of radioactive material from year to year based on the total quantities of air required to dilute the effluent. The maximum effluent concentration value used for MAP is from the International
Atomic Energy Agency (IAEA 1979) and was $2.0 \times 10^{-7} \, \mu\text{Ci mL}^{-1}$. The prioritization shows that LAMPF dominates site releases to air since the mid-1970s.

**Detailed LANSCE Release Data**

The LAHDRA project team has spent many hours finding and reviewing LANSCE records. The project team has identified two key document resource centers within TA-53 that provide substantial quantities of historical effluent monitoring data for LANSCE. Those records cover operations from the early 1970s to the present. The locations are:

- Building 3, Room 3R-4 (TA-53-3) - Radiological records that contain mostly exhaust stack and water monitoring data for radionuclides.
- Another location for useful records is the operations group in Building 53. Management staff at the accelerator facility generally opted to retain large portions of their records for historical and operational purposes and has stored these records on-site at TA-53.

Monthly and annual air emission reports from 1976 to the present have been located by the LAHDRA team. These reports also present backup information pertaining to how LANL staff performed and collected stack monitoring data and calculated air releases. In related reports, methods for calibration of Kanne “flow-through” ionization chambers and for stack measurements are presented.

Probably the most appropriate method of estimating releases is to use the accelerator operation logs to obtain the milliampere-hours (mA-h) of beam operation, then to use the LAHDRA team’s Off-Site Releases (OSR) Database to obtain the curies released annually at TA-53. The accelerator logs were found by LAHDRA analysts and entered into a spreadsheet (LANSCE Effluents.xls) for 1976 to 1992. Periods of accelerator operation are called “cycles” and each cycle is given a sequence number. These data included operations during cycles 3 through 61. Data for cycle 1 and 2 were not found. Data for cycles above 61 are available, but were not captured. In the LANSCE Effluents spreadsheet, beam current was multiplied by beam-on time to calculate mA-hrs for the beam. These values were summed to yield annual values of beam time in mA-h (see Table 6-1). Curies per mA-h are plotted in Fig. 6-1.
### Table 6-1. Compiled Annual Beam Current Data for LANSCE

<table>
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<tr>
<th>Year</th>
<th>mA-h (from log books)</th>
<th>Annual Activity in Curies (from OSR Database)</th>
<th>Ci/mA-h</th>
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<td>1974</td>
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<tr>
<td>1975</td>
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</table>

Fig. 6-1. Ci/mA-h for LANSCE operations 1975-1993
There were some columns in the beam operation logs that were not used in these informal calculations since it was not known how to apply them. One column was for “Duty Factor” and two contained additional beam information “Beam Current 2” and “Beam Hours 2”. From verbal conversations with LANL employees it was found that the “Beam Current 2” and “Beam Hours 2” were used only when the beam was run at one current for a certain amount of time and then was run for a second amount of time at a different beam current. Since there were not many times this information was supplied it was ignored for this informal calculation. “Duty Factor” was explained as having something to do with the pulsed nature of the output used sometimes during the operation. Since it was not know how to apply a correction factor for “Duty Factor”, the column was not used.

In addition to point release estimates (i.e., exhaust stack releases) LANL began estimating non-point (diffuse) emissions in their annual release and dose estimates. Documents were found for 1993, 1995, 1996, and 1997. The estimates of diffuse releases were 1,418 Ci, 716 Ci, 221 Ci, and 866 Ci for the years listed respectively. These quantities are approximately less than 10% of the annual airborne release values as shown in Table 6-1. The vast majority of these releases were estimated to be $^{11}$C.

Repos. No. 1071 mentions that short-lived activation gases were not reported at LAMPF for the 1974 to 1978 time frame. One of the documents abstracted (Repos. No. 441) refers to a letter to the AEC concerning LAMPF airborne emission in 1970, so limited operations may also have occurred prior to 1972.

The TA-53 data suggest that there are at least four stacks for which data are available. These stack designations include: FE-3 (North Stack, also called main stack in 1981); FE-4 (South Stack); FE-16; and, FE-2. The FE-3 fan serviced the main accelerator tunnel, and was terminated in 1980. The FE-4 fan was added in 1977. FE-3 and FE-4 have reported emissions primarily of short-lived air activation products such as: $^{11}$C, $^{13}$N, $^{15}$O, $^{41}$Ar, and $^{7}$Be. FE-2 services the WNR, and was added in 1981. FE-16 services TA-53-1 D-wing, with releases reported for other longer-lived radionuclides such as $^{7}$Be.

Cooling water was released to floor drains that fed two 2,500-gal carbon steel tanks. These tanks were discharged to the cooling water ponds (Repos. No. 503). The magnitude of releases at LANSCE resulted in continuing studies to estimate the off-site impact. One such study was LA-11150-MS, which documented the releases and modeling of the releases for 1985 (Repos. No. 2145). Laboratory measurements have been found for lagoon and cooling pond waters, and for long-lived activity that can be collected on filtering media. The short-lived MAP was assessed with on-line monitoring and through TLDs located at various locations.
Repos. No. 1556 discusses the diffuse releases from LAMPF for 1990, which were 0.21 Ci, a small fraction of the 120,000 Ci of short-lived gases that were reported. The diffuse emissions were comprised of longer lived nuclides (since the diffuse emissions are completely unfiltered) and a comparison of curies alone might be misleading, but the magnitude of diffuse emissions is clearly less significant than that of the primary release points.

The LANL assessment of the impact of radioactive releases from TA-53 has changed in many ways over the years. Prior to 1991, the site assessed the releases taking credit for estimated occupancy and the inherent shielding provided by residences. In 1992, LANL was told by the USEPA that no credit should be taken for shielding and residency time factors (Repos. No. 713). This resulted in a change in methodology for projecting impacts from the releases. Care should be taken when comparing assessments reported by LANL for different periods.

**Conclusions Regarding LANSCE Operations**

LANSCE is an important major scientific system at LANL. Its operation is important to scientists and researchers from LANL and visiting organizations. Since its inception, LANSCE has been one of the major contributors to airborne releases to the environment. Fortunately, the radionuclides released are short-lived gases or trace amounts of particulates from diffuse emissions. Future iterations that are attempting to create an accurate source term for LANSCE should concentrate on applying the additional beam time corrections, applying the duty factor corrections, locating early operation info (cycle 1 and 2), and ensuring that the curie quantities in the OSR Database are complete and accurate so that Ci/mA-h can be calculated accurately for LANSCE.
Chapter 7: Tritium Processing at Los Alamos and a Screening Assessment of Public Exposures

The benefits of incorporating tritium into nuclear weapons design was recognized early in the Manhattan Project. Facilities and processes for tritium production were a topic of discussion at LANL at least as early as 1944 (Allison 1944). By this time, tritium production efforts had already begun at the X-10 site (now the Oak Ridge National Laboratory) and there were discussions about large-scale tritium production taking place at Hanford. As of late 1945, LANL had installed equipment for the purification and assaying of tritium. The Lab’s CMR Division began using this equipment to supply tritium to groups within P Division and M Division in early 1946. A tritium collection system was being installed in the laboratories of Group P-4 as of March of 1946 (LASL 1946). It is unclear where these operations took place, but small quantities of tritium are reported to have been used in Buildings U, W, and Z in the Original Technical Area (TA-1). As Laboratory operations matured, significant quantities of tritium were released to the atmosphere from facilities in TAs 3, 21, 33, 35, and 41. In addition, tritium was used in some firing site (dynamic testing) activities, at TA-15 for example.

Tritium Facilities at TA-3

The three facilities responsible for the majority of atmospheric tritium releases from TA-3 were the Cryogenics Laboratory (Building SM-34), the Ion Beam Facility (Building SM-16), and the CMR Building (Building SM-29). Both the Cryogenics Laboratory and the IBF used tritium gas generated from uranium tritide\(^a\) beds.

The LANL Cryogenics Laboratory opened in 1955 and is reported to have released 28,000 Ci of tritium from 1976 to 1985 (Morgenstern and Hueske 1995). The Ion Beam Facility (IBF), which housed two Van de Graaff accelerators, began operating in 1951 (Loomis et al. 2005). The accelerators produced neutrons by bombarding tritium gas targets with charged particles. Atmospheric tritium releases for the IBF are reported to have been 14,000 Ci from the 1960s through 1992 (Morgenstern and Hueske 1995). The same reference reports a release of 11,000 Ci of tritium from the CMR Building from when it began operations in 1953. The asserted releases for these three facilities total 53,000 Ci.

\(^a\) A tritide is a hydride (a binary compound formed by the union of hydrogen and one other element) in which hydrogen is in the form of its \(^3\)H isotope.
Tritium Facilities at TA-21

TA-21 has housed the LANL Tritium Handling Facility (THF) and the Tritium Systems Test Assembly (TSTA), as well as earlier tritium operations. The THF was also known as the Tritium Salt Facility (TSF). It was expanded in 1984, and subsequently became known as the Tritium Science Fabrication Facility (TSFF). The THF was activated December 5, 1974 as a replacement for obsolete tritide salt processing facilities at TA-35. It was located at DP East Site in Building TA-21-209. The THF consisted of a large dry box system and a gas purification system. Its purpose was to house processes involving metal tritides, specifically, tritium-bearing lithium salts. As of December 12, 1979 the THF had reportedly processed 3.8 million curies of tritium and had released 704.5 Ci to the atmosphere via its local stack (Nasise 1980).

TSTA was a facility for the integrated testing, in full scale, of the processes and safety systems required for the reprocessing and recycling of plasma exhaust gas from a tokamak fusion reactor. The primary material handled was deuterium-tritium (DT) gas. Tritium was first introduced at TSTA on June 25, 1984 (Jalbert 1985).

Tritium appears to have been in use at DP West since at least the early 1950s. In 1952, J. B. Webber of LASL described sampling of effluent streams for tritium oxide from a beaker of tritiated water placed in various locations in DP West Room 326 (Webber 1952). By 1971, a tritium stack monitor had been installed for DP West Room 513 (Johnson 1971).

Tritium Facilities at TA-33

TA-33 was established in 1947 as primarily a test site for atomic bomb initiators (Garcia et al. 2004). Dynamic testing activities took place there involving polonium and other materials. Shots were fired in underground chambers and at the surface. Large guns were used to fire test projectiles into berms. In the early 1950s, facilities were designed and built at TA-33 for the processing of tritium gas (Coffin 1971). The high pressure tritium gas facilities were housed in Building HP-86 and operated there until late 1990 (Garcia et al. 2004). In addition to its function as a high pressure tritium pumping station, HP-86 also had laboratory areas for conducting tests of tritium gas systems and for material compatibility studies (Tuggle 1983). HP-86 had a 75-foot stack as of late 1962, though apparently the stack height had increased from its original design (Deinken 1962).

On an activity basis, HP-86 is believed to be the largest source of atmospheric releases of tritium at LANL. Coffin (1971) stated routine releases to the atmosphere were 2,000 to 6,000 Ci annually and that
60,000 Ci of gas had been released in ten separate incidents dating back 15 years. These accidental releases were in addition to routine releases associated with the evacuation of lines and vessels containing tritium gas and leakage from the gas system overall. The gas system consisted of a process system and a filling system, with the former used to mix and prepare gases for introduction into the latter (Holmes 1965). The filling system was used to fill a desired container with tritium gas at a desired pressure. Coffin (1971) estimated the contributions from routine and accidental releases to the total atmospheric source term to be approximately equal. The LAHDRA document collection contains numerous references documenting accidental releases of large quantities of tritium gas at TA-33.

Tritium Facilities at TA-35

The original tritium salt facility was located in the basement of Building 2 at TA-35. It was constructed in 1953 (Harper and Garde 1981) and was in use until 1974 when the tritium salt operations moved to DP East Site. The TA-35 tritium salt facility was decommissioned in 1979. The facility was used to handle lithium tritide salts containing kilocurie quantities of tritium. It consisted of two glovebox lines and associated equipment, and had its own exhaust stack (Harper and Garde 1981). Tritium operations began in 1955 (Storm 1972) and ended in 1979 with the decommissioning of the facility. Tritium releases from the TA-35-2 facility did not end when operations were relocated to DP East Site. Releases continued to be monitored and reported through the decommissioning process.

The lithium tritide salts were received from Mound Laboratory in a powdered form and were processed and packaged at TA-35 for transfer to Group W-1 (Storm 1972). As of 1972, the frequency of the operation was 6 to 24 weeks per year. Water reacting with the salt compound would result in the release of tritium. This condition was exacerbated by the high moisture content of the glovebox cover gas and the use of water to clean some of the process equipment (Storm 1972). The fact the tritium was released through the water-salt reaction prompted Ellery Storm of LASL to conclude it was probably released in the oxide form.

Tritium Facilities at TA-41

TA-41 was constructed in the early 1950s for weapons development activities (LANL 1988). It was built at the bottom of Los Alamos Canyon, approximately 300 feet below the mesa tops. A central exhaust system and stack were added in 1962. Prior to that time, process effluents were ventilated by local stacks and exhausts serving individual laboratories. TA-41 consists of a number of structures, including an underground vault for the storage of explosives and special nuclear material. The vault, designated Building W-1, is a reinforced concrete structure constructed by tunneling into the north wall of Los
Alamos Canyon. It was built in May, 1949 (LANL 1991). Materials stored in the W-1 vault included pressure vessels containing tritium gas.

It is unclear when tritium operations first began at TA-41. LANL’s 1973 estimates of atmospheric tritium releases included estimates for TA-41 dating back to 1967 (LASL 1973). In 1976, LANL was evaluating locating a new tritium handling facility at TA-41 (Barnes 1976) to replace operations at the HP-86 facility at TA-33. It is not clear when these activities began, but it appears they continued until approximately the early 1990s. As of 1983, one of the primary activities at TA-41 was the building and testing of equipment and systems for the storage and transfer of high pressure gases, including tritium (Tuggle 1983). In 1992 the Laboratory determined the cost associated with upgrading the TA-41 facilities to allow resumption of programmatic tritium operations involving quantities greater than 1,000 Ci was not justified (Erickson 1993). Those operations were to be transferred to the Weapons Engineering Tritium Facility at TA-16.

TA-41 was also used for plutonium operations, dating back to at least 1957 (Buckland 1957), and uranium. As of 1983 plutonium and uranium were handled only in sealed containers. Experiments with the containers were conducted inside double containment (Tuggle 1983).

Other Tritium Facilities

As of 2001 the largest tritium inventory at LANL was held at the Weapons Engineering Tritium Facility (WETF) at TA-16. Originally constructed as a replacement for the tritium gas facilities at TA-33 (LANL 1990), WETF houses research and development activities in support of nuclear weapons programs and inertial confinement fusion (DNFSB 2001). Consolidation efforts were at that time underway to relocate all of LANL’s tritium processing operations to WETF. WETF is a more modern facility than its predecessors and its tritium releases to the atmosphere are relatively small. Other LANL facilities that contribute to atmospheric tritium releases are waste treatment operations at TA-50 and operations involving tritium-contaminated weapons components at TA-55. There have also been limited tritium operations conducted at a gas boosting test facility housed at TA-9 (Tuggle 1983). With respect to environmental levels, a significant source of atmospheric releases of tritium oxide has been the Lab’s central waste disposal facility at TA-54. Buried, tritium-bearing waste materials result in atmospheric releases of tritiated water vapor via evaporation from the soil. These releases are evident on the local ambient air monitoring stations.
Atmospheric Effluent Data for Tritium

LANL did not begin monitoring tritium stack releases until 1971. In 1973, the Lab prepared estimates of atmospheric releases for 1967 through 1970 based on accountability data (LASL 1973). There are no formal estimates of total tritium releases prior to 1967, though the LAHDRA document collection contains effluent monitoring and other tritium release data for some tritium facilities prior to 1967. How complete a picture this information might represent with regard to LANL’s total atmospheric tritium releases for the pre-1967 period is currently unknown.

Earlier in the project, the LAHDRA team made a limited effort to compile tritium effluent data from its document collection into a database. Specifically, the focus was on the Lab’s formally reported tritium releases for the period from 1967 forward. These data were entered into a database known as the Off-Site Releases (OSR) database. The OSR database was an internal tool used by the LAHDRA project team to support prioritization of historical radionuclide releases from LANL.

Table 7-1 summarizes the atmospheric release data for tritium in the OSR database for TAs 3, 15, 21, 33, 35, and 41 for 1967 through 1991. After 1991, the tritium effluent records used to populate the OSR database began reporting releases on a consolidated basis, that is, releases from multiple TA were combined and reported as a single value. Regardless, the data for the years included in Table 7-1 are believed to encompass the periods of the largest airborne tritium releases from the selected TAs since 1967. In addition, the documents that have been reviewed indicate that these facilities represented the largest contributors to atmospheric tritium releases. In Table 7-1, years for which no data were reported are denoted by “–”. This notation differentiates from the values of 0 for several years for which the database currently shows a release of zero curies.

As the primary charge of the LAHDRA project was information gathering, only limited resources could be dedicated to source term evaluation in support of screening for potential health risks. Thus, the data in the OSR database are known to be incomplete with respect to the totality of tritium release data embedded in the LAHDRA document collection. As an example of the possible magnitude of data not yet captured in the OSR database, compare the total release for TA-3 shown in Table 7-1 (35,414 Ci) with that asserted in 1995 by Morgenstern and Hueske (53,000 Ci). The latter, which includes releases for the period prior to 1967, exceeds the total from the OSR database by a factor of about 1.5. It should be noted than none of the release totals cited here have been independently verified by the LAHDRA team. All values have been used as reported in the available reference material, without adjustment.
Table 7-1. Airborne Tritium Release Data for Selected TAs from the OSR Database (Ci)

<table>
<thead>
<tr>
<th>Year</th>
<th>TA-3</th>
<th>TA-15</th>
<th>TA-21</th>
<th>TA-33</th>
<th>TA-35</th>
<th>TA-41</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>872</td>
<td>3,590</td>
<td>-</td>
<td>11,284</td>
<td>-</td>
<td>12,168</td>
<td>27,914</td>
</tr>
<tr>
<td>1968</td>
<td>10,382</td>
<td>-</td>
<td>23</td>
<td>5,512</td>
<td>-</td>
<td>15,782</td>
<td>31,699</td>
</tr>
<tr>
<td>1969</td>
<td>172</td>
<td>4,500</td>
<td>3</td>
<td>20,098</td>
<td>-</td>
<td>9,750</td>
<td>34,523</td>
</tr>
<tr>
<td>1970</td>
<td>-</td>
<td>11,000</td>
<td>-</td>
<td>670</td>
<td>25,000</td>
<td>438</td>
<td>37,108</td>
</tr>
<tr>
<td>1971</td>
<td>-</td>
<td>2,660</td>
<td>-</td>
<td>4,100</td>
<td>3,100</td>
<td>320</td>
<td>10,180</td>
</tr>
<tr>
<td>1972</td>
<td>-</td>
<td>1,796</td>
<td>-</td>
<td>2,100</td>
<td>2,500</td>
<td>110</td>
<td>6,506</td>
</tr>
<tr>
<td>1973</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>3,880</td>
<td>2,464</td>
<td>118</td>
<td>6,466</td>
</tr>
<tr>
<td>1974</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5,916</td>
<td>1,400</td>
<td>-</td>
<td>7,316</td>
</tr>
<tr>
<td>1975</td>
<td>22</td>
<td>-</td>
<td>306</td>
<td>3,478</td>
<td>2,394</td>
<td>-</td>
<td>6,200</td>
</tr>
<tr>
<td>1976</td>
<td>-</td>
<td>-</td>
<td>95</td>
<td>1,349</td>
<td>1,657</td>
<td>-</td>
<td>3,101</td>
</tr>
<tr>
<td>1977</td>
<td>400</td>
<td>-</td>
<td>133</td>
<td>36,950</td>
<td>786</td>
<td>-</td>
<td>38,269</td>
</tr>
<tr>
<td>1978</td>
<td>100</td>
<td>-</td>
<td>72</td>
<td>17,780</td>
<td>676</td>
<td>-</td>
<td>18,627</td>
</tr>
<tr>
<td>1979</td>
<td>3,015</td>
<td>-</td>
<td>95</td>
<td>10,470</td>
<td>1,300</td>
<td>143</td>
<td>15,024</td>
</tr>
<tr>
<td>1980</td>
<td>5</td>
<td>-</td>
<td>106</td>
<td>6,965</td>
<td>25</td>
<td>414</td>
<td>7,515</td>
</tr>
<tr>
<td>1981</td>
<td>899</td>
<td>-</td>
<td>108</td>
<td>6,085</td>
<td>-</td>
<td>126</td>
<td>7,218</td>
</tr>
<tr>
<td>1982</td>
<td>1,938</td>
<td>-</td>
<td>169</td>
<td>13,600</td>
<td>-</td>
<td>130</td>
<td>15,837</td>
</tr>
<tr>
<td>1983</td>
<td>2,277</td>
<td>-</td>
<td>180</td>
<td>4,410</td>
<td>6</td>
<td>974</td>
<td>7,847</td>
</tr>
<tr>
<td>1984</td>
<td>1,793</td>
<td>-</td>
<td>802</td>
<td>7,110</td>
<td>206</td>
<td>4,780</td>
<td>14,691</td>
</tr>
<tr>
<td>1985</td>
<td>2,119</td>
<td>-</td>
<td>367</td>
<td>4,870</td>
<td>5</td>
<td>1,270</td>
<td>8,631</td>
</tr>
<tr>
<td>1986</td>
<td>1,228</td>
<td>-</td>
<td>448</td>
<td>6,660</td>
<td>48</td>
<td>1,320</td>
<td>9,704</td>
</tr>
<tr>
<td>1987</td>
<td>851</td>
<td>-</td>
<td>596</td>
<td>1,000</td>
<td>155</td>
<td>470</td>
<td>3,072</td>
</tr>
<tr>
<td>1988</td>
<td>8,350</td>
<td>-</td>
<td>528</td>
<td>-</td>
<td>118</td>
<td>1,730</td>
<td>10,726</td>
</tr>
<tr>
<td>1989</td>
<td>291</td>
<td>-</td>
<td>455</td>
<td>1,770</td>
<td>18</td>
<td>11,600</td>
<td>14,134</td>
</tr>
<tr>
<td>1990</td>
<td>496</td>
<td>-</td>
<td>439</td>
<td>854</td>
<td>0</td>
<td>4,440</td>
<td>6,229</td>
</tr>
<tr>
<td>1991</td>
<td>205</td>
<td>-</td>
<td>334</td>
<td>254</td>
<td>0</td>
<td>3,840</td>
<td>4,633</td>
</tr>
<tr>
<td>Total</td>
<td>35,414</td>
<td>23,546</td>
<td>5,262</td>
<td>177,165</td>
<td>41,858</td>
<td>69,923</td>
<td>353,168</td>
</tr>
</tbody>
</table>

To ensure a conservative approach to screening, and to account for the fact the tritium release data in the OSR database were incomplete, the maximum annual atmospheric tritium releases for each of the selected TAs were compiled. These are shown in Table 7-2.

Table 7-2. Maximum reported airborne tritium releases from LANL

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Maximum Release (Ci)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>10,382</td>
<td>1968</td>
</tr>
<tr>
<td>15</td>
<td>11,000</td>
<td>1970</td>
</tr>
<tr>
<td>21</td>
<td>802</td>
<td>1984</td>
</tr>
<tr>
<td>33</td>
<td>36,950</td>
<td>1977</td>
</tr>
<tr>
<td>35</td>
<td>25,000</td>
<td>1970</td>
</tr>
<tr>
<td>41</td>
<td>15,782</td>
<td>1968</td>
</tr>
</tbody>
</table>
For screening purposes, the maximum values should at a minimum be representative of LANL’s atmospheric tritium releases for the period 1967 forward, if not bounding in the case of the earlier data derived from accountability data. For the principal contributors to atmospheric tritium releases, all but two of the maximum values were from the period prior to the onset of stack monitoring, that is, they were derived from accountability data. Such estimates are typically conservative with respect to the true release, though it is reiterated that none of the data used in this evaluation have been independently verified.

Chemical Forms of Tritium

One of the most important factors to consider in evaluating atmospheric releases of tritium for potential health risks is the chemical composition of the release. Specifically, one needs to know if the release was in the form of tritium gas or if it was partially or completely in the form of tritium oxide. Tritium is a radioactive isotope of hydrogen. Tritium gas refers to tritium in the form of diatomic HT or T₂ gas, where T is used in place of H to differentiate between atoms of tritium and protium (normal hydrogen). Tritium oxide refers to molecules of water (normally H₂O) in which a tritium atom has been substituted for one or both of the hydrogen atoms to form HTO or T₂O. The difference between tritium gas and tritium oxide is enormous in terms of radiation dose to a human receiver. If inhaled, tritium gas is not incorporated into the body to any appreciable degree, and the only dose consequence is the direct exposure to lung tissue. Tritium oxide, in contrast, behaves as water and is readily incorporated into body tissues. In terms of radiation dose per unit intake, the dose from tritium oxide exceeds that from tritium gas by four orders of magnitude (ICRP 1996). Dose from tritium gas, therefore, is typically negligible. There is no external dose consequence from tritium in either form, but intakes of tritium oxide can result from absorption through exposed skin in addition to inhalation.

Given its application in the weapons program and accelerator operations, tritium at Los Alamos has primarily been used in the form of tritium gas. However, there are some circumstances where an assumption of the oxide form is appropriate, at least for purposes of initial screening. In addition, as of the late 1970s, LANL had installed catalytic converters on its tritium stacks to convert the gaseous effluent to oxide. This allowed the tritium to be efficiently collected on molecular sieves and thus significantly reduce the overall release. However, anything not captured by the sieve system had taken the oxide form. This system for reducing tritium emissions was described in 1973 by R. R. Dube of LASL’s GMX-4 group and his colleagues (Dube et al. 1973).
There are other chemical forms of tritium possible in addition to gas and oxide. With respect to tritium operations at LANL, tritium could historically be found in the form of metal (uranium) tritides or lithium tritide salts. Unlike gases, any atmospheric emissions of these materials would be in a particulate form and absorption and retention in the body would depend on the characteristic biokinetic behavior for the specific tritide compound. No information has been noted in the LAHDRA document collection regarding the atmospheric release of tritide compounds, and it is believed to be unlikely that tritides would have been a significant component of LANL’s atmospheric tritium releases. From a radiation dose perspective, tritides can represent more dose per unit activity than tritium oxide because they are retained in the body longer. In the case of tritide particulates, with the longer retention characteristics, the dose per unit intake exceeds that for tritium oxide by a factor of 14 (ICRP 1996).

Screening LANL’s Atmospheric Tritium Releases for Potential Health Risks

The NCRP Report No. 123 (NCRP 1996) screening method for radionuclide releases to the environment was used to evaluate atmospheric tritium releases from LANL in terms of their potential risk to local residents. The source term used was the maximum release reported for each of the six TAs that represented the largest contributors to LANL’s atmospheric tritium releases. These maximum values, shown in Table 7-2, were converted to units of becquerels for input into the NCRP Report No. 123 screening models. The converted values are shown in Table 7-3.

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Maximum Release (Bq)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.84×10^{14}</td>
<td>1968</td>
</tr>
<tr>
<td>15</td>
<td>4.07×10^{14}</td>
<td>1970</td>
</tr>
<tr>
<td>21</td>
<td>2.97×10^{13}</td>
<td>1984</td>
</tr>
<tr>
<td>33</td>
<td>1.37×10^{15}</td>
<td>1977</td>
</tr>
<tr>
<td>35</td>
<td>9.25×10^{14}</td>
<td>1970</td>
</tr>
<tr>
<td>41</td>
<td>5.84×10^{14}</td>
<td>1968</td>
</tr>
</tbody>
</table>

The values in Table 7-3 reflect total amounts of tritium released. To ensure a meaningful screening result, they were re-stated in terms of the corresponding tritium oxide activity for each total value. An upper bound for the fraction of a tritium gas source that has converted to an oxide form is 1% (Pan and Rigdon 1996, Mishima and Steele 2002). The small amount of oxide is formed by interactions between residual air in the storage vessel and beta radiation from the tritium. Following a release of tritium gas, additional oxidation occurs slowly, resulting from either additional radiolytic reactions with air (in the case of high activity concentrations) or from photochemical reactions with ultraviolet light. These
secondary oxidation mechanisms result in a conversion rates ranging from approximately 1% per hour, in the case of high activity concentrations, falling off to less than 1% per day as the gas diffuses following release (Mishima and Steele 2002). Tritium gas does not react strongly with water vapor. If there is an ignition, explosion, or similar event involving tritium gas, then an assumption of complete (100%) oxidation is appropriate.

Based on what was known about the processes associated with the maximum atmospheric tritium releases in Table 7-3, conservative assumptions were applied to determine the chemical form of the tritium to be assumed for screening. These are documented in Table 7-4, with tritium oxide being designated HTO.

Table 7-4. Activity and chemical forms of tritium used for screening

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Maximum Release (Bq)</th>
<th>Assumed Chemical Form and Basis</th>
<th>Maximum Release as Oxide (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.84×10^{14}</td>
<td>1% HTO: principal sources were tritium gas.</td>
<td>3.84×10^{12}</td>
</tr>
<tr>
<td>15</td>
<td>4.07×10^{14}</td>
<td>100% HTO: assume tritium was expended in detonation events.</td>
<td>4.07×10^{14}</td>
</tr>
<tr>
<td>21</td>
<td>2.97×10^{13}</td>
<td>100% HTO: assumed releases were the result of water reactions with tritium-bearing salts resulting in an oxide form.</td>
<td>2.97×10^{13}</td>
</tr>
<tr>
<td>33</td>
<td>1.37×10^{15}</td>
<td>1% HTO: HP-86 was a tritium gas facility.</td>
<td>1.37×10^{13}</td>
</tr>
<tr>
<td>35</td>
<td>9.25×10^{14}</td>
<td>100% HTO: assumed releases were the result of water reactions with tritium-bearing salts resulting in an oxide form.</td>
<td>9.25×10^{14}</td>
</tr>
<tr>
<td>41</td>
<td>5.84×10^{14}</td>
<td>1% HTO: operations were similar to those at TA-33.</td>
<td>5.84×10^{12}</td>
</tr>
<tr>
<td>Total</td>
<td>3.70×10^{15}</td>
<td>--</td>
<td>1.39×10^{15}</td>
</tr>
</tbody>
</table>

For screening, the maximum release values in Table 7-4 were considered both on an individual and on an aggregate basis (the six values added). Summing the maximum values, which occurred in different calendar years, is believed to provide a source term that is at worst representative of any specific year and is likely bounding. It is reiterated that the maximum release data for TAs 3, 15, 35, and 41 are based on LANL’s examination of accountability records, and such assessments are typically conservative with respect to actual releases. On an aggregate basis, the source term in Table 7-4 represents 3.70×10^{15} Bq (100,000 Ci) of tritium and 1.39×10^{15} Bq (37,600 Ci) of tritium oxide. The effective oxide fraction for the aggregate source term is 38%.

Screening was performed against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 6% per sievert (Sv) (ICRP 1990). This corresponds to a dose equivalent of
The exposed population selected for each screening assessment was the residential population nearest each release point. The pathways considered for each residential location were inhalation of contaminated air and consumption of contaminated soil and vegetables. Consumption of locally raised meat or milk were not considered.

The first step of the NCRP Report No. 123 screening process is to perform a Level I screening evaluation, which is the simplest and most conservative type of evaluation. The Level I screen does not account for distance from the source to the receiver or the associated atmospheric dispersion. If the Level I screening result exceeds the screening criterion, then one progresses to a Level II approach in which distance to the receiver and atmospheric dispersion are considered. Also, in the Level II screen, the screening criterion is reduced by an order of magnitude to account for uncertainties. If the Level II screening result exceeds the criterion, then a Level III screen is performed. In general, the Level III screen only differs from the Level II in how dose pathways are considered. The approach used here for screening LANL’s atmospheric tritium releases was hybridized in that the appropriate pathways were accounted for from the outset, rather than first screening for all pathways and then removing the non-applicable pathways afterward.

A Level I screen was performed for the TA-3 release first, since it was the smallest contributor to the tritium oxide source term. If the Level I screening evaluation for the TA-3 release exceeded the screening criterion, there would be no need to continue with Level I screening for the other releases. As shown in Table 7-5, the Level I screening evaluation for the TA-3 source term exceeded the screening criterion by a substantial margin. Screening therefore proceeded to Level II/III.

<table>
<thead>
<tr>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Release = 3.84E+12 Bq HTO</td>
</tr>
<tr>
<td>Seconds per year = 3.2E+07</td>
</tr>
<tr>
<td>Annualized Release Rate = 1.2E+05 Bq/sec</td>
</tr>
<tr>
<td>Volumetric Flow Rate = 0.3 m³/sec</td>
</tr>
<tr>
<td>Exhaust vent concentration = 4.0E+05 Bq/m³</td>
</tr>
<tr>
<td>Receiver concentration = 1.0E+05 Bq/m³</td>
</tr>
<tr>
<td>Screening Factor = 7.20E-07 Sv per Bq/m³</td>
</tr>
<tr>
<td>Screening Value = 7.2E-02 Sv</td>
</tr>
<tr>
<td>Screening Criterion = 1.67E-04 Sv</td>
</tr>
</tbody>
</table>

**Table 7-5.** Level I screening for the maximum HTO release from TA-3

Screening criterion exceeded? YES
To proceed to Level II screening, the distance from each release point (Technical Area) to the nearest residential area was estimated. Table 7-6 shows the location of the nearest residential area and the approximate distance in meters from each TA.

Table 7-6. Approximate distances from tritium release points to the nearest residents

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Nearest Residents</th>
<th>Approximate Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Western Area</td>
<td>1,740</td>
</tr>
<tr>
<td>15</td>
<td>Royal Crest Trailer Park</td>
<td>3,050</td>
</tr>
<tr>
<td>21</td>
<td>Town Site Apartments</td>
<td>1,460</td>
</tr>
<tr>
<td>33</td>
<td>White Rock</td>
<td>3,750</td>
</tr>
<tr>
<td>35</td>
<td>Royal Crest Trailer Park</td>
<td>1,740</td>
</tr>
<tr>
<td>41</td>
<td>Town Site Apartments</td>
<td>490</td>
</tr>
</tbody>
</table>

In the Level II screening process, the estimated distances from the release points to the nearest residential locations are used to determine a plume diffusion factor. These factors are determined from plots provided in NCRP Report No. 123. To simplify the process, the bounding value of the diffusion factor was selected for each source-receiver distance. This eliminated the need to account for effective release heights and the possibility of building wake effects. It also added a further degree of conservatism.

Tables 7-7 through 7-12 below show the Level II\textsuperscript{b} screening calculations for TAs 3, 15, 21, 33, 35, and 41, respectively. In each of the six Level II screening calculations, the screening criterion has been reduced by an order of magnitude (factor of ten) for an additional degree of conservatism per NCRP Report No. 123. Thus, the judgments as to whether the screening criterion has been exceeded are made against the adjusted, rather than the actual, screening criterion.

The screening evaluations show that only in the case of TA-35, for which the maximum release was treated as 100% HTO, was the adjusted screening criterion exceeded. In no case was the actual (unadjusted) screening criterion exceeded. If all of the screening results are summed, the result (8.17×10\textsuperscript{-5} Sv) is still less than half of the screening criterion of 1.67×10\textsuperscript{-4} Sv. Note that, in addition to the fact the maximum release values are being treated as if they all occurred in the same time span, summing the individual screening values represents the physical impossibility of a hypothetical population of residents simultaneously living at a location nearest each of the individual release points. The screening dose for the aggregate releases would be much lower for any of the individual residential areas.

\textsuperscript{b} In reality the Level II screening assessments may be thought of as Level III since only the applicable pathways are being considered.
### Table 7-7. Level II screening for the maximum tritium release from TA-3

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Release</td>
<td>3.84E+12 Bq HTO</td>
<td>OSR database Rev. 7, 1% HTO</td>
</tr>
<tr>
<td>Seconds per year</td>
<td>3.2E+07 sec</td>
<td>NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>1.20E+05 Bq/sec</td>
<td>(calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2 m/sec</td>
<td>NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>1740 m</td>
<td>estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>2.5E-05 m²</td>
<td>NCRP 123 Fig. 1.4 (limiting value)</td>
</tr>
<tr>
<td>Receiver concentration</td>
<td>3.75E-01 Bq/m³</td>
<td></td>
</tr>
<tr>
<td>Screening Factor</td>
<td>7.20E-07 Sv per Bq/m³</td>
<td>NCRP 123 Table B.1 (inhalation + vegetables + soil)</td>
</tr>
<tr>
<td>Screening Value</td>
<td>2.70E-07 Sv</td>
<td></td>
</tr>
<tr>
<td>Adjusted Screening Criterion</td>
<td>1.67E-05 Sv</td>
<td>1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5</td>
</tr>
<tr>
<td>Screening criterion exceeded?</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

### Table 7-8. Level II screening for the maximum tritium release from TA-15

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Release</td>
<td>4.07E+14 Bq</td>
<td>OSR database Rev. 7, 100% HTO</td>
</tr>
<tr>
<td>Seconds per year</td>
<td>3.2E+07 sec</td>
<td>NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>1.27E+07 Bq/sec</td>
<td>(calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2 m/sec</td>
<td>NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>3050 m</td>
<td>estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>9E-06 m²</td>
<td>NCRP 123 Fig. 1.4 (limiting value)</td>
</tr>
<tr>
<td>Receiver concentration</td>
<td>1.43E+01 Bq/m³</td>
<td></td>
</tr>
<tr>
<td>Screening Factor</td>
<td>7.20E-07 Sv per Bq/m³</td>
<td>NCRP 123 Table B.1 (inhalation + vegetables + soil)</td>
</tr>
<tr>
<td>Screening Value</td>
<td>1.03E-05 Sv</td>
<td></td>
</tr>
<tr>
<td>Adjusted Screening Criterion</td>
<td>1.67E-05 Sv</td>
<td>1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5</td>
</tr>
<tr>
<td>Screening criterion exceeded?</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>

### Table 7-9. Level II screening for the maximum tritium release from TA-21

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Release</td>
<td>2.97E+13 Bq HTO</td>
<td>OSR database Rev. 7, 1% HTO</td>
</tr>
<tr>
<td>Seconds per year</td>
<td>3.2E+07 sec</td>
<td>NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>9.28E+05 Bq/sec</td>
<td>(calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2 m/sec</td>
<td>NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>1460 m</td>
<td>estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>3E-05 m²</td>
<td>NCRP 123 Fig. 1.4 (limiting value)</td>
</tr>
<tr>
<td>Receiver concentration</td>
<td>3.48E+00 Bq/m³</td>
<td></td>
</tr>
<tr>
<td>Screening Factor</td>
<td>7.20E-07 Sv per Bq/m³</td>
<td>NCRP 123 Table B.1 (inhalation + vegetables + soil)</td>
</tr>
<tr>
<td>Screening Value</td>
<td>2.51E-06 Sv</td>
<td></td>
</tr>
<tr>
<td>Adjusted Screening Criterion</td>
<td>1.67E-05 Sv</td>
<td>1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5</td>
</tr>
<tr>
<td>Screening criterion exceeded?</td>
<td>NO</td>
<td></td>
</tr>
</tbody>
</table>
### Table 7-10. Level II screening for the maximum tritium release from TA-33

<table>
<thead>
<tr>
<th>Total Release</th>
<th>Bq HTO</th>
<th>OSR database Rev. 7, 1% HTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seconds per year</td>
<td>3.2E+07</td>
<td>sec NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>4.28E+05</td>
<td>Bq/sec (calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2</td>
<td>m/sec NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>3750</td>
<td>m estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>7E-06</td>
<td>m² NCRP 123 Fig. 1.4 (limiting value)</td>
</tr>
</tbody>
</table>

Receiver concentration = 3.75E-01 Bq/m³

Screening Factor = 7.20E-07 Sv per Bq/m³ NCRP 123 Table B.1 (inhalation + vegetables + soil)

Screening Value = 2.70E-07 Sv

Adjusted Screening Criterion = 1.67E-05 Sv 1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5

Screening criterion exceeded? NO

### Table 7-11. Level II screening for the maximum tritium release from TA-35

<table>
<thead>
<tr>
<th>Total Release</th>
<th>9.25E+14</th>
<th>Bq HTO OSR database Rev. 7, 100% HTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seconds per year</td>
<td>3.2E+07</td>
<td>sec NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>2.89E+07</td>
<td>Bq/sec (calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2</td>
<td>m/sec NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>1740</td>
<td>m estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>2.5E-05</td>
<td>m² NCRP 123 Fig. 1.4 (limiting value)</td>
</tr>
</tbody>
</table>

Receiver concentration = 9.03E+01 Bq/m³

Screening Factor = 7.20E-07 Sv per Bq/m³ NCRP 123 Table B.1 (inhalation + vegetables + soil)

Screening Value = 6.50E-05 Sv

Adjusted Screening Criterion = 1.67E-05 Sv 1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5

Screening criterion exceeded? YES

### Table 7-12. Level II screening for the maximum tritium release from TA-41

<table>
<thead>
<tr>
<th>Total Release</th>
<th>5.84E+12</th>
<th>Bq HTO OSR database Rev. 7, 1% HTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seconds per year</td>
<td>3.2E+07</td>
<td>sec NCRP 123 I-A-2</td>
</tr>
<tr>
<td>Annualized Release Rate</td>
<td>1.83E+05</td>
<td>Bq/sec (calculated)</td>
</tr>
<tr>
<td>Wind Speed</td>
<td>2</td>
<td>m/sec NCRP 123 II-bi-7</td>
</tr>
<tr>
<td>Distance to receiver</td>
<td>490</td>
<td>m estimated from LAHDRA project map</td>
</tr>
<tr>
<td>Dispersion factor</td>
<td>2E-04</td>
<td>m² NCRP 123 Fig. 1.5 (limiting value)</td>
</tr>
</tbody>
</table>

Receiver concentration = 4.56E+00 Bq/m³

Screening Factor = 7.20E-07 Sv per Bq/m³ NCRP 123 Table B.1 (inhalation + vegetables + soil)

Screening Value = 3.29E-06 Sv

Adjusted Screening Criterion = 1.67E-05 Sv 1E-05 excess risk at 6% per Sv, divided by 10 to account for uncertainties per NCRP 123 II-F-5

Screening criterion exceeded? NO
The NCRP Report No. 123 screening evaluation suggests airborne tritium releases from LANL were unlikely to have been a source of adverse health risks to local residents around Los Alamos. The possibility cannot be ruled out entirely, however, in light of the screening result for TA-35. Further, there are caveats to consider, including the possibility that larger releases could have occurred prior to 1967 (when atmospheric tritium releases were first estimated by LANL) or that some of the releases consisted of a greater fraction as tritium oxide (HTO) than has been considered here. But given the degree of conservatism used in the screening method, it appears the impacts of such effects would have to be substantial before atmospheric tritium releases would have posed a significant health risk.

As a check on the intended conservatism in the screening approach used for atmospheric tritium releases, local environmental monitoring data for tritium oxide (HTO) were compiled for the period July 1970 through December 1979. This period was expected to encompass the largest airborne tritium releases from LANL for the era when environmental monitoring data are available. Table 7-13 shows the maximum annual average concentrations for the on-site and off-site environmental tritium monitoring stations on and around the LANL site for July 1970 to December 1979. The on-site data were included in this evaluation to both be conservative and to allow for the fact that the public historically has had access to many “on-site” locations at LANL.

Table 7-13. Maximum tritium oxide concentrations from the LANL environmental air monitoring stations 1970 – 1979

<table>
<thead>
<tr>
<th>Year</th>
<th>Maximum On-Site Average</th>
<th>Maximum Off-Site Average</th>
<th>LAHTRA Reference (Repos. No)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concentration (µCi mL⁻¹)</td>
<td>Location</td>
<td>Concentration (µCi mL⁻¹)</td>
</tr>
<tr>
<td>1970*</td>
<td>1.80×10⁻¹¹</td>
<td>unknown</td>
<td>3.50×10⁻¹²</td>
</tr>
<tr>
<td>1971</td>
<td>2.40×10⁻¹⁰</td>
<td>Array 156-9.4</td>
<td>1.20×10⁻¹⁰</td>
</tr>
<tr>
<td>1972</td>
<td>1.80×10⁻¹⁰</td>
<td>Array 156-9.4</td>
<td>4.40×10⁻¹¹</td>
</tr>
<tr>
<td>1973</td>
<td>1.51×10⁻¹⁰</td>
<td>TA-21</td>
<td>2.70×10⁻¹¹</td>
</tr>
<tr>
<td>1974</td>
<td>1.41×10⁻¹⁰</td>
<td>TA-33</td>
<td>3.60×10⁻¹¹</td>
</tr>
<tr>
<td>1975</td>
<td>1.74×10⁻¹⁰</td>
<td>TA-52</td>
<td>9.30×10⁻¹¹</td>
</tr>
<tr>
<td>1976</td>
<td>3.30×10⁻¹⁰</td>
<td>TA-54</td>
<td>5.10×10⁻¹¹</td>
</tr>
<tr>
<td>1977</td>
<td>1.87×10⁻¹⁰</td>
<td>TA-54</td>
<td>5.10×10⁻¹¹</td>
</tr>
<tr>
<td>1978</td>
<td>5.70×10⁻¹¹</td>
<td>TA-54</td>
<td>2.60×10⁻¹¹</td>
</tr>
<tr>
<td>1979</td>
<td>4.00×10⁻¹¹</td>
<td>TA-33</td>
<td>6.70×10⁻¹²</td>
</tr>
</tbody>
</table>

*July – December 1970

The elevated HTO concentrations at TA-54 are the result of evaporative losses from soil containing buried, tritium-contaminated wastes. Tritium oxidizes slowly in the environment at a rate of less than 1% per day (Mishima and Steele 2002). The fact the TA-54 sampling station is the location of the maximum measured on-site HTO concentrations for some years shows the importance of TA-54 as a source of
airborne releases of tritium oxide relative to other sources. The tritium oxide concentration for the TA-54 environmental monitoring station for 1976 was the largest of all of the on-site annual averages for July 1970 through December 1979. The largest off-site annual average for this period was at the location designated Array 42-3.1 for 1971. It is difficult to discern the precise location of this monitoring station in the reference, but it appears that it might be at or near the Fuller Lodge location.

From Table 7-13, the maximum annual average airborne tritium oxide concentrations reported by the LANL environmental air monitoring network for July 1970 through December 1979 were $3.3 \times 10^{-10} \mu\text{Ci mL}^{-1}$ (12.2 Bq m$^3$) and $1.2 \times 10^{-10} \mu\text{Ci mL}^{-1}$ (4.4 Bq m$^3$) for on-site and off-site locations, respectively. One can gauge what these concentrations imply in terms of dose to human receivers by applying screening factors for tritium oxide from NCRP Report No. 123. For the on-site locations, the appropriate factor to use is that for inhalation alone. The combined factors for inhalation and consumption of contaminated vegetables and soil are appropriate for the off-site locations. These screening factors are $1.4 \times 10^{-7}$ Sv per Bq m$^3$ for inhalation and $7.2 \times 10^{-7}$ Sv per Bq m$^3$ for the combination of inhalation and consumption of contaminated vegetables and soil.

Multiplying the inhalation screening factor by the maximum on-site concentration value (in consistent units) gives a screening dose equivalent value of $1.7 \times 10^{-6}$ Sv, or 0.17 mrem. Note this calculation requires the extremely conservative assumption of 100% occupancy at the on-site location. The same calculation for maximum average off-site concentration, using the combined factor for inhalation and vegetables, gives a screening dose equivalent of $3.2 \times 10^{-6}$ Sv, or 0.3 mrem. Including the vegetation pathway results in a higher screening dose than the on-site location despite the lower average air concentration. Nonetheless, both of these values are well below the screening criterion of $1.67 \times 10^{-4}$ Sv (16.7 mrem).

As with the screening assessment performed using atmospheric release data for tritium, measured values of tritium oxide concentrations in the local environment around Los Alamos also suggests that airborne releases of tritium from Los Alamos are unlikely to have resulted in any adverse health risks to the local residents. However, as with the effluent data, the environmental monitoring data have been used as reported without any adjustments or verification, and they do not consider the period prior to 1970.
References

Allison SK. April 10, 1944 letter from the Metallurgical Laboratory to X-10 Site concerning tritium production at Oak Ridge. 1944. Repos. No. 3315.


ICRP. Age-Dependent Doses to The Members of the Public from Intake of Radionuclides Part 5, Compilation Of Ingestion And Inhalation Coefficients. Vienna, Austria: International Commission on Radiological Protection; ICRP Publication No. 72; 1996.


Webber JB. Tritium Results on Water Samples, Room 326, DP West; memorandum to Dean Meyer dated 15 May 1952. Los Alamos Scientific Laboratory. 1952. Repos. No. 4881.
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Chapter 8: Hot Cell Facilities and Operations at LANL

Beginning with early operations, LANL processed highly radioactive material, such as fission products, to meet the production and research needs of the Lab and the federal government. Much of the work on radioactive materials at the laboratory was carried out in specialized, shielded enclosures called “hot cells” that provided protection for the workers by reducing their radiation exposures. Remote manipulators, also called mechanical hands, were used to handle the isolated radioactive materials inside the hot cells. The hot cells also provided some level of control in helping to reduce releases of radioactive material to the environment.

In 1944, LANL began receiving its first shipments of multiple curies of $^{140}\text{Ba}$ for use in extracting $^{140}\text{La}$, a radionuclide used as a tracer for hydrodynamic explosive tests conducted during the Radioactive Lanthanum (“RaLa”) program. Due to the high gamma energy and radiation fields associated with these materials, LANL designed and built its first hot cell facility in order to safely extract the $^{140}\text{La}$ for further processing. Over the course of many years, LANL built several additional hot cell facilities to meet the growing needs of the federal government and other customers and by the early 1980s had approximately 36 hot cells in operation.

In addition to $^{140}\text{Ba}/^{140}\text{La}$ operations, hot cells were used for (Wilson et al. 1979):

- handling and manufacturing of nuclear reactor fuels and fuel assemblies,
- chemical separation and analysis of irradiated reactor fuels,
- radionuclide analyses, such as with fission products, supporting nuclear weapon tests,
- accelerator-based production of radionuclides for medical and research applications,
- fabrication and testing of fuels associated with the Rover nuclear propulsion and the Ultra High-Temperature Reactor Experiment (UHTREX) projects,
- storage and processing of materials with high tritium concentrations, and
- chemical separation, isotopic analysis, treatment and volume reduction, and storage of high-level radioactive waste in support of a variety of laboratory and other governmental programs.

LANL’s hot cell facilities were used in the handling of large quantities of fission products, and to a lesser extent plutonium, uranium, and other heavy elements. Because of the higher radioactivity handled in these facilities, the project team collected information on hot cell operations to support potential prioritization of associated releases in the future. This chapter is intended to provide an overview of LANL’s hot cell operations and highlight those that may warrant further investigation. In the preliminary
prioritization analyses that have been performed, fission products were found to be less important than several other classes of other radionuclides. However, the analyses performed to date have been largely dependent on release estimates put forward by LANL, and waste streams associated with hot cell operations appear to have not always been among the top priorities within programs for monitoring and estimation of releases to the environment. Several comments have been made during past LAHDRA public meetings that indicate a belief among some members of the public that releases from hot cell operations have not been adequately disclosed, characterized, or quantified. Some believe that releases of radioiodine and other fission products could have been significantly larger than has been disclosed, and that an independent evaluation of associated historical activities is warranted. A summary of LANL hot cell operations is presented in Table 8-1 at the end of this chapter.

Over 8,000 documents or sets of documents that are included in the LAHDRA project information database were searched by team members for information pertaining to hot cell and associated operations. A summary of related information that has been extracted is presented below.

**The RaLa Program**

Chemical extractions of lanthanum during the initial years of the program for testing the implosion process (1944-1950) were performed using 1.5- to 2- m high, shielded shipping casks and were carried out in a wooden building located in Bayo Canyon, TA-10 (Wilson 1979). Operators located approximately 27 m from the casks using electric cranks, cabling, and remote tongs, along with telescopes and mirrors for viewing, lowered reagents into casks to complete the chemical separation of barium and lanthanum. One hundred and fifty sources of $^{140}\text{La}$ ranging in source strength from 40 to over 3,000 Ci were prepared and used in explosives tests from September 1944 to July 1950. The crude remote handling facility that was used at TA-10 was modest by today’s standards for hot cell design and performance, but it served its purpose until it was phased out of operations in the early 1950s.

In 1947, LANL began construction of a new hot cell facility at Ten Site (TA-35) to process the barium and lanthanum. Completed in 1951 at a cost of nearly $3 million, the facility consisted of two 3-m by 6-m by 2.5-m high hot cells. A crane and trolley system was used to move radioactive materials in and out of the cells. The trolley housed a rotatable spindle with pins on one end to mate with bayonet slots of various tools, vessels, and equipment components inside the hot cells for handling and processing of materials. An operator’s view inside a hot cell was accomplished through shielded glass windows (such as leaded glass) and a series of mirrors and retractable periscopes. A large auxiliary building was used to handle and purify air and house liquid filtration and treatment equipment. Believed to have been the first modern hot cell design to handle high-level radioactive materials, the TA-35 facility contained innovative
features such as exterior, contamination-free lighting, cell wash-down sprays, collimated ports for experiments, and hydraulic rams for opening and handling shipping casks. LANL later added concrete caves with a zinc bromide window above the hot cells to provide flexibility in packaging lanthanum sources. In 1963, these operations terminated after processing about 2 million curies from the Chemical Processing Plant at the Idaho Falls (Wilson 1979).

**Hot Cells Associated with LANL Reactors**

A series of research and production reactors were operated at Los Alamos dating back to 1943. These reactors were largely used in fuel and neutron experimentation and for research and production of fission products and activation products (Wilson, 1979). The first of these reactors were the Water Boiler series reactors– LOPO, HYPO, and SUPO– as described in Chapter 5. The Clementine reactor, located at Omega Site (TA-2) at the bottom of Los Alamos Canyon, was commissioned in November 1946 and was the first reactor to use $^{239}$Pu as its fuel. Hot cells were used to test the fuel and reactor components following neutron irradiation experiments. Corrosion of steel cladding began to release considerable alpha contamination into the mercury coolant which led to the shutdown and decommissioning of the reactor in 1952. According to LANL employees at the time, no detectable radioactivity was released to the environment during these fuel rod failures (Wilson 1979).

The Omega West Reactor was built at the same location where Clementine existed and was operated from 1956 to 1994 to support a variety of research programs. Irradiated fuel from Omega West was transferred to hot cells for chemical processing and testing. In some cases, isotopes were extracted to support or research programs.

LANL used a series of compact reactors that were assembled and tested at Ten Site in the 1950s and 1960s to test new technologies used in reactor and fuel assembly designs. These were called the Los Alamos Power Reactor Experiment (LAPRE) and used plutonium dissolved in phosphoric acid. LAPRE I was a forced-convection, high pressure, water-cooled reactor that was later drained and decommissioned. LAPRE II used natural convection. This operated for short time and then shut down. Irradiated fuel and reactors components and equipment were tested inside the TA-35 hot cells. Typical processes involved chemical separation, analytical measurements of radionuclides, and preparation for waste disposal. A third reactor known as the Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) was operated within the Ten Site hot cell adjacent to the one used to extract $^{140}$La in the RaLa program. The fuels from these reactors were eventually transferred for storage to the CMR Wing 9 hot cell facility at TA-3 for further processing and waste disposal (Wilson 1979).
General Purpose Hot Cells

Since 1951, LANL has operated 36 general purpose hot cells in four separate on-site facilities. These are described as general purpose cells because their designs permitted considerable flexibility for storage, processing, and handling of radioactive materials. This section presents a description for each of these facilities. Hot cell operations are active, or have been active, at the following LANL facilities:

- TA-3, CMR Building, Wing 9 Operations,
- TA-21, DP West Site, Building 4, Room 401,
- TA-48, Radiochemistry Laboratory,
- TA-50, Contaminated Waste Treatment Facility,
- TA-52, UHTREX Facility, and

TA-3; CMR Building Wing 9 Hot Cells

The CMR Wing 9 hot cell facility began operations in December 1961. The facility was used to support the civilian power reactor program from 1961 to 1967, the Rover Nuclear Propulsion Project from 1961 to 1973, and the Liquid Metal Fast Breeder Reactor (LMFBR) from 1967 to the early 1980s. The facility has also provided assistance to numerous LANL programs by performing various experiments involving high levels of gamma radiation associated with irradiated fuel and fission product samples. The facility still supports a variety of LANL programs, including transuranic (TRU) waste treatment and packaging for disposal at the DOE WIPP site in Carlsbad, New Mexico (LANL 1999).

The Wing 9 hot cell facility consists of sixteen 2-m by 2-m by 3.6-m high hot cells arranged in two groups of eight cells separated by shielded corridors. Fig. 8-1 represents a cutaway drawing of the Wing 9 hot cell facility. The ferrophosphorus walls and leaded-glass windows shield up to 30,000 Ci of mixed fission products or 50,000 Ci

Fig. 8-1. Wing 9 hot cell facility at TA-3’s CMR Building (LANL 1999)
of 1 MeV gamma radioactivity (Wilson 1979; Valentine et al. 1968). A storage area consists of 364 shielded holes that are cooled and maintained at negative pressure. Areas within the facility are designed for decontamination activities, mock-up runs, machine shop, manipulator repair, cold laboratory, dark room, and staff offices. Fig. 8-2 is a photograph that shows the exterior work stations and the shielded glass viewing windows, manipulator arms, and control panels for a group of four Wing 9 hot cells located in the CMR Building.

Airborne effluents from the CMR Wing 9 hot cells are filtered and monitored for particulates and radiiodine with fiber and charcoal filters, respectively. Air from three monitored compartments is discharged at a rate of 176,840 ft$^3$ min$^{-1}$ through a 56 ft tall stack. Air samples are collected on a 24-h basis and analyzed for $^{235}$U, $^{238}$U, $^{239}$Pu, $^{241}$Am, fission products, and $^{131}$I. Sampling results and details of the sampling program are reported in LANL reports and were reviewed by the LAHDRA team. Early effluent monitoring results are published in monthly Health Division reports and special reports that present monitoring results for non-routine releases and discussion of general issues related to stack monitoring and airborne emissions and their impact in the environment. Monitoring results are also published in LANL’s Annual Environmental Surveillance reports for the years 1970 to the present.

Stack sampling and filtering of effluents for the Wing 9 hot cells began at the start of operations and underwent number of changes and improvements over the years. In a 1970 memorandum, LANL reports that the CMR stack sampling was not isokinetic, results were therefore not representative of quantities actually discharged, and improvements were needed in order to generate reliable release estimates (Meyer 1970, Enders 1970). Upgrades and new procedures were implemented to improve the exhaust filtration and monitoring program as highlighted in numerous Health Division reports and memorandums (Lawrence 1970). Efforts to reduce emissions were also being emphasized during this period because of the forthcoming reductions in AEC release limits for radioactive isotopes. Other reports also depict LANL’s efforts to improve monitoring and control of airborne releases from other CMR wings and exhaust stacks (LASL 1975).
Solid radioactive waste from these and other hot cell operations were disposed of at the former TA-21 and TA-54 burials grounds. Waste was often treated or consolidated and packaged into a variety of containers (such as 55-gallon metals drums) and transported to the burial grounds for shallow-land burial. Land burial at LANL began during the 1940s and continued up through recent years.

Small volumes of liquid waste from hot cell operations that contain plutonium, americium, uranium, and fission products along with reacted sodium and sodium potassium solutions were placed in 3.8 L or smaller containers and then packed in 7.8 L cans with dry vermiculite for shaft burial at the burial grounds. Other waste containing higher levels of radioactivity were transported to TA-50 for treatment (LASL 1975).

**T-21; DP West Site Room 401 Hot Cells**

Construction of four hot cells began in 1958 in Building 4 at TA-21. These cells were designed to handle kilogram quantities of irradiated plutonium that possessed kilocuries of gamma activity and to support evaluation of plutonium fuel reprocessing schemes up through 1967. The facility then remained idle for the next three years until the cells were used to perform in-depth, post-irradiation examinations of reactor fuel elements. The 2-m by 2-m by 6.5-m high cells were interconnected by a 3-m by 10-m, shielded corridor with rolling steel doors and 22 storage wells located on the floor that are 1.5 m deep. The cells were equipped with manipulators for remote processing, and radioactive material was moved in and out via a transfer can system. This facility was partially decommissioned in the 1980s and has been under a maintenance and preservation program since. The future plans for many of the buildings at TA-21 are currently under review by the laboratory.

The Room 401 hot cells were designed with a negative pressure water circulating system. If there was a breach in the system, air would leak into the system rather than letting water leak into the cells. This minimized the chances of a nuclear criticality accident and reduced the potential for a large amount of contaminated water that would have otherwise flooded the cells. This design did, however, create airborne emission concerns.

As reported in two 1961 Health Division memos regarding the DP West Room 401 Hot Cells, LANL recognized that process air concentrations and releases of $^{131}\text{I}$ had become a concern and needed to be addressed through the use of improved source control and exhaust vent and stack filtration (Dummer 1961). Fig. 8-3 provides an example report of air concentrations above the maximum permissible concentrations (MPCs) that highlighted those concerns. The elevated air concentrations were due to dissolution and analysis processing of an 82-g plutonium foil that had been irradiated in the Omega West
LANL also stated in memos that, before another sample was run, some effort to prevent iodine dispersal should be made— that is, charcoal filters should be installed at the drybox exhaust ports (Dummer 1961). Fig. 8-4 depicts the layout of the DP West, Room 401 hot cell facility and represents the sequence of air samplers and exhaust air filters in relation to the exhaust stack.

**TA-48 Radiochemistry Hot Cell Facility**

The TA-48 Radiochemistry Hot Cell Facility became operational in 1959 and was designed for evaluations and experiments with irradiated fuel and fission products. The facility was also used for other programs such as actinide chemistry experiments, isotope separation and production for medical and research uses, in-depth fuel analyses, and fission product and fuel testing of samples collected following nuclear weapon detonation tests (Wilson et al 1979). The first cell utilized three work stations and was design to store and handle hundreds of curies of radioactivity. TA-48 hot cells are still in use today for processing, testing, and storage of radioactive materials (Hyder 1992).
In 1963, twelve more cells were built in an adjacent building at TA-48 for dissolution and evaluation of graphite fuel used in the Rover program. The cells are 1.5-m by 1.7-m by 2.7-m high and arranged in two rows of six separated by a shielded corridor. The Rover project ended in 1973, and some of the cells were later modified to handle uranium, plutonium, transuranics, and fission products. Releases of $^{131}$I and other fission products gained the attention of LANL staff. While it is unclear how rapid LANL’s response to the issue was, it is clear that Health Division staff published their concerns about the issue during early operations.

Fig. 8-5 presents an example of a LANL document that highlights radioiodine releases and concerns about off-site emissions from the TA-48 hot cells. Much of their concerns focused on residents living in a nearby trailer court (Royal Crest Trailer Park) located approximately 1000 m from the TA-48 exhaust stack. Hot cells at TA-48 were used to experiment with a variety of less commonly used radionuclides such as $^{227}$Ac, $^{76}$Br, $^{77}$Br, $^{82}$Br, and $^{217}$U (Dummer 1979a, b).
OFFICE MEMORANDUM

TO: Distribution

DATE: Oct. 14, 1964

FROM: Carl Buckland, Leader, General Monitoring Section, H-1

SUBJECT: SUMMARY OF I\textsuperscript{131} CONCENTRATIONS FOUND IN AND FROM NEW CELL ADDITION AT TA-48

SYMBOL: H-1

For my own benefit, I felt a need to summarize Don's I\textsuperscript{131} data at TA-48 to determine how we stand (reference his 10-12-64 report). If I have my figures correct, the following conclusions may be drawn:

Room breathing air - No individual air sample exceeded the MPC for occupational exposure. Highest was one-third MPC on October 5 thru 6, Room 334. It should be pointed out, however, that the sampling time included 8 hours in which no work took place (diluted mathematically by additional air flow).

Stack - Highest individual sample, 4.9 x 10^{-8} \mu c/M^3. Exhaust 4, October 5 thru 6, same dates as highest room sample, is about 500 times MPC for non-occupational exposure. Although this appears high, the highest average over a previous 13 week period was only 2.3 x 10^{-4} \mu c/M^3 (twice MPC non-occupational).

Environmental - As I understand, Chapter 0524 or something I read, if the non-occupational MPC over a 13 week period is exceeded at the point of discharge (stack), samples have to be taken at the perimeter fence. Although the sampling is meager, the non-occupational MPC was not exceeded 500 feet in a NE direction from the building. If there was a skip over this sampling point, we have only two H-6 charcoal filter samplers to fall back on, both of which are not in a northeasterly direction from TA-48 (located at SM-43 and TA-50). The highest level for one month when adding the findings for the whole month, was 8.1 x 10^{-3} \mu c/cc, well below the non-occupational MPC of 1.0 x 10^{-10} \mu c/cc on top of SM-43.

All MPC's for air were taken from Chapter 0524 and converted to 9 x 10^{-3} \mu c/M^3 occupational, 1 x 10^{-4} non-occupational soluble I\textsuperscript{131}.

You may want this type of thing for the Progress Report, if my conclusions and calculations are correct. If so, it can be reduced further as a brief summary.

CB/es Distribution:
Dean Meyer, H-1
Donald McKown, H-1
Sixto Maestas, H-1

Fig. 8-5. 1964 H-Division memo addressing airborne iodine releases at TA-48 (Buckland 1964)
LANL took steps to reduce these iodine releases by adding additional charcoal filters to exhaust air systems. They also improved their stack sampling and monitoring systems and practices over time so that results more accurately quantified releases to the environment (Maestas 1967).

Process air from TA-48 hot cells and surrounding areas was consolidated and exhausted through two main exhaust plenums, designated as FE-38 and FE-48, and then vented to the outdoor atmosphere through an elevated stack (Maestas 1969; Maestas 1970; Maestas 1971). The Maestas references cited here are sample reports selected from a series of weekly Health Division reports located in the LAHDRA database.

**TA-50 Contaminated Waste Treatment Plant Hot Cell Facility**

As part of the Chemical Waste Treatment Plant at TA-50, a hot cell facility became operational in 1963 to handle high levels of beta-gamma emitting radioactive material. The hot cell facility was primarily used to neutralize liquid waste and package the treated and consolidated waste for long-term storage and disposal. The facility consisted of a cask unloading dock, transfer and storage area, and one 2-m by 3-m by 4-m high hot cell.

**TA-52 UHTREX Hot Cell**

This hot cell was built in 1965 to provide a properly-shielded place to exchange fuel assemblies and perform testing of irradiated fuel. The facility was shut down in 1968 along with the UHTREX project.

**Fast Reactor Core Test Facility**

Construction of this facility began in 1963 and was completed in 1966. The project and associated use of the hot cell facility for handling plutonium fuel was terminated before any of the systems or structures were tested or used.

**TA-53 LAMPF/LANSCE**

The accelerator complex at TA-53 contains two hot cells with four work stations. These hot cells have been in operation since 1976. The cells are used for radiochemical experiments and medical and research isotope production and separation. Isotope separation was also performed inside the hot cells at Wing 9, CMR Building at TA-3.
Hot Cell Decontamination and Waste Disposal

The largest amount of radioactive waste generated by hot cell operations came from the hot cells located at TA-3 (Wing 9), TA-21 (Room 401), TA-35 (Ten Site Laboratory), TA-48 (Radiochemistry Laboratory), and TA-50 (Waste Treatment Plant). Methods used to decontaminate, treat, and dispose of liquid and solid waste from LANL’s hot cell operations varied according to the levels of radioactivity and types of radioactive materials processed in a given project. Much of the removal, treatment, consolidation, and disposal of highly radioactive residues and wastes generated inside hot cells involved the use of remotely-operated, jet spray washing and dry and wet vacuum systems (Dummer, 1965; LANL 1974). Treatment of highly radioactive liquid waste was performed at the Contaminated Waste Hot Cell facility located at TA-50.

Removal and collection of contamination and subsequent treatment of the radioactive waste for on-site disposal for a typical LANL hot cell involved the following procedures:

- Removable contamination was spray-washed from containment structures, such as bench tops and laboratory exhaust hoods, and from equipment and tools and then vacuumed into holding containers.

- Spray washing to remove loose contamination was repeated until levels allowed personnel to enter the hot cells for short periods to apply more aggressive measures such as acid washing and scrubbing to lower contamination to acceptable levels.

- Soaking highly contaminated, smaller equipment and tools in containers filled with a mixture of CH2Cl2 (dichloromethane or methylene chloride), detergents, and hot water. This was an effective means of removing radioactive residues. The foaming action of the mixture carried off much contamination in precipitates that were collected for treatment and/or disposal.

- Dry solid residues and debris were vacuumed with in-cell vacuum systems and collected in containers. Recovered material considered to be of value was sent for further separation, analysis, and recycle.

- At Ten Site (TA-35 hot cells), highly radioactive residues were evaporated to dryness, placed in a pressure-sealed, aluminum containers, and loaded into uranium casks. The casks were then loaded on trucks and transported to the TA-21 disposal area for burial in 2-ft diameter by 15 ft
deep holes in the ground. When burial activities at TA-21 ceased, LANL began using the burial
grounds at TA-54 to meet their disposal requirements for these wastes.

- Highly radioactive solid waste was loaded into aluminum or stainless steel containers and placed
in uranium casks for burial at the TA-21 disposal area. In later years, these wastes were
transported to the burial grounds at TA-54. During the early period of the 1950s and 1960s,
liquid wastes were mixed with concrete and vermiculite and buried as solid waste.

- At the Wing 9 facility (TA-3 hot cells), cells dedicated to uranium and plutonium fuel work used
open containers inside the hot cells. Dry debris and dust generated from cutting, crushing, and
drilling the fuel were collected with an in-cell vacuum system equipped with a cyclone separator,
a CWS filter, and a charcoal adsorption bed. Liquid and solid wastes were collected, treated, and
consolidated for land burial using similar methods as those described above.

- By the 1970s, liquid wastes with recoverable amounts of radioactive materials were sent to hot
cells at TA-50 for separation (such as cation exchange processing), analyzed, and returned to Lab
generators for reuse and/or further analyses. Waste contents with $10^{-3}$ $\mu$Ci mL$^{-1}$ alpha and/or $10^{-2}$
$\mu$Ci mL$^{-1}$ beta concentrations were disposed of as low-level radioactive waste. If concentrations
were above these values, the waste was placed in portable stainless steel tanks and delivered to
the TA-50 Waste Treatment facility for recovery and consolidation (LANL, 1974).

References

Repos. No. 1181.


Repos No. 4543.


<table>
<thead>
<tr>
<th>TA</th>
<th>Purpose</th>
<th>Dates</th>
<th>Radionuclides/Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radiochemical and radiotracer separation (including RaLa operations) and neutron source preparation. Most of these operations took place in H Building.</td>
<td>1944-1957</td>
<td>$^{140}$Ba, $^{140}$La, $^{90}$Sr, $^{210}$Po, $^{226}$Ra, Be</td>
</tr>
<tr>
<td>3</td>
<td>CMR Building Wing 9 Hot Cell Facility. Used to evaluate irradiated plutonium and uranium fuel and fission products testing and separation and post detonation debris radiochemical analyses. Operations occurred largely in Wing 9 of CMR Building. The facility contained 16 general purpose cells 2m by 2m by 3.6m high.</td>
<td>1961-present</td>
<td>$^{239,238}$Pu, $^{234,235,238}$U, mixed fission products, mixed activation products, TRU</td>
</tr>
<tr>
<td>10</td>
<td>Early RaLa sources were prepared in Bayo Canyon and later in facilities at Ten Site (TA-35). RaLa explosive experiments were completed in Bayo canyon. Remote handling, telescopes, and mirrors were used to aid in the separation and preparation of the $^{140}$La. A few hundred thousands curies were handled during almost 20 y of RaLa explosive testing. Some batches of La reached upwards to 5,000 Ci. Single sources for test shots ranged from 40 to over 3,000 Ci.</td>
<td>1944-1951</td>
<td>$^{140}$Ba, $^{140}$La, $^{90}$Sr, $^{210}$Po, $^{226}$Ra, Be</td>
</tr>
<tr>
<td>18</td>
<td>Rover Program - Hot Cell facility</td>
<td>1955-1973</td>
<td>Pu, U, and fission products</td>
</tr>
<tr>
<td>21</td>
<td>Examination of irradiated Pu and enriched uranium from Omega reactor (such as $^{235}$U impregnated with graphite and $^{239}$Pu in stainless steel casing and a tantalum sheath) and separation of irradiated fuel and fission products. The facility had four primary hot cells that were designed primarily to evaluate plutonium reprocessing schemes. Fuel reprocessing experiments and tests were discontinued in 1967. In the 1970s, the hot cells were used to evaluate irradiated fuel elements associated with the LMFBR program. Operations occurred largely in Bldg 4, Room 401. Rooms 403 through 407 contained gloveboxes used for metal preparation of $^{238,239}$Pu. High exposure rates during material transfers to hot cells. After tests were completed, irradiated fuel was transferred from hot cells to the “hot dump.” On 26 May 1961, special fiberglass filter papers were placed in cell, corridor, and stack exhaust lines in Room 401 to sample air for fission products.</td>
<td>1958-1978</td>
<td>$^3$H, $^{239,238}$Pu, $^{234,235,238}$U, mixed fission products</td>
</tr>
<tr>
<td>33</td>
<td>Tritium handling facilities that contained hot cells for source handling and processing.</td>
<td></td>
<td>$^3$H</td>
</tr>
<tr>
<td>35</td>
<td>Radiochemistry Hot Cell Facility. Used to perform actinide chemistry and isotope production/separation. Facility also used to analyze samples collected from nuclear weapon test shots. In 1963, another hot cell facility was built in an adjacent structure to evaluate and dissolve samples of graphite fuel from the Rover Program. The Rover Program ended in 1973.</td>
<td>1951-1963</td>
<td>$^{140}$Ba, $^{140}$La, $^{90}$Sr, $^{210}$Po, $^{226}$Ra, mixed fission products, Be</td>
</tr>
<tr>
<td>48</td>
<td>Radiochemistry Hot Cell Facility. Used to perform actinide chemistry and isotope production/separation. Facility also used to analyze samples collected from nuclear weapon test shots. In 1963, another hot cell facility was built in an adjacent structure to evaluate and dissolve samples of graphite fuel from the Rover Program. The Rover Program ended in 1973.</td>
<td>1959-present</td>
<td>Pu, U, TRU, mixed fission products, and mixed activation products</td>
</tr>
<tr>
<td>50</td>
<td>Contaminated Hot Cell facility. This facility was designed to handle high-level beta and gamma emitting wastes from several groups at LANL. The hot cells were part of the Contaminated Waste Treatment Plant. The cell was primarily used to neutralize liquid waste and package it for permanent storage.</td>
<td>1963-present</td>
<td>Pu, U, TRU, mixed fission products, and mixed activation products</td>
</tr>
<tr>
<td>52</td>
<td>UHTREX high-level remote handling area consisted of one hot cell for fuel element changing and examination.</td>
<td>1961-1968</td>
<td>Pu and U</td>
</tr>
<tr>
<td>53</td>
<td>LAMPF and LANSCE facilities contain two hot cells used for radiochemical experiments of irradiated targets, isotope production, and mixed activation products.</td>
<td>1976-present</td>
<td>$^3$H, mixed activation products</td>
</tr>
</tbody>
</table>


Chapter 9: Operations with Other Radionuclides

Uranium

As discussed in numerous places in this report, uranium, at various levels of $^{235}$U enrichment, has been used in a wide variety of applications at Los Alamos.

Uses of Uranium in Weapons

To develop and build gun-assembled weapons, Los Alamos personnel initially experimented with use of enriched uranium ($^{235}$U) and plutonium as the fissionable material. The gun-assembled uranium weapon was carried into production, and some implosion-assembled weapons that came along later included uranium as a fissile material. In addition, heavy metals such as uranium were used as “tampers” that confined the explosion, reflected some neutrons that would otherwise escape, and thereby decreased the “critical mass” of fissile material required to achieve an atomic explosion (Serber et al. 1992).

Uses of Uranium in Reactors

Uranium was also used in liquid and solid forms as fuel in various forms of nuclear reactors. More details can be found in Chapter 5. The first Water Boiler reactor was assembled in late 1943 at Omega Site (TA-2), using the nation’s total supply enriched uranium as its fuel in the form of 14%-enriched uranyl sulfate. The Plutonium Fast Reactor (Clementine) used plutonium fuel that was surrounded with a 6-inch thick natural uranium reflector, and reactivity control was achieved via insertion of uranium fuel rods. The LAPRE I reactor experiment studied the use of phosphoric acid solutions of high-enriched uranium in a high-temperature reactor fuel, as did LAPRE II. The Ultra High Temperature Reactor Experiment (UHTREX) used 93%-enriched uranium fuel in the form of small spheres of UO$_2$ coated with pyrolytic carbon and bound in a graphite matrix. That fuel was fabricated at the CMR Building in TA-3. A 1969 waste management plan says that the DP East facility processed new Rover fuel elements containing enriched uranium.

Facilities that Handled Uranium

From 1948 to 1960, DP West Site’s Building 4 housed laboratories for production of enriched uranium hydride. In 1960, the hydride equipment was removed so that a hot cell could be added for the examination of irradiated plutonium and enriched uranium fuel elements.

Facilities at the Original Technical Area (TA-1) that housed uranium operations included:
• **C Building**— housed a normal machine shop with a uranium machine shop in southeast section. Became operational in October 1943.

• **D-Building**— a facility designed to carry out chemistry and metallurgical experiments on plutonium and uranium. Other activities included design of tampers and polonium initiators and development of various refractory materials.

• **G Building**— housed the uranium and graphite “Sigma Pile”, plus leak-testing of radium sources. Removed 6/59.

• **HT Building**— heat treatment and machining of normal and enriched uranium.

• **HT Barrel House**— contained storage areas for $^{239}\text{Pu}$ and $^{235}\text{U}$.

• **M Building**— housed processing, metallurgy, and recovery of enriched uranium.

• **Sigma Bldg**— housed casting, machining, powder metallurgy of normal and enriched uranium, thorium (eastern part was normal; western part was enriched).

• **TU Building**— housed machining of normal uranium (“tuballoy”).

• **TU-1 Building**— housed recovery of enriched uranium.

• **V Building**— contained the original machine shop; uranium and beryllium were machined there.

The Sigma Complex in TA-3, built in the 1950s and 1960s, has housed extensive laboratory areas for materials synthesis, and processing, characterization, and fabrication of materials such as beryllium, uranium, thallium, and aluminum alloys. These activities have included large-scale metallurgy and fabrication of normal and fully enriched uranium. As of 1969, the CMR Bldg, except for its Wing 9, was used for laboratory work on small quantities of uranium and plutonium. Wing 9 contained hot cells for handling of irradiated uranium and sometimes plutonium (see Chapter 8).

**Uses of Uranium in Explosive Testing**

LASL staff estimated in 1971 that between 75,000 and 95,000 kg of uranium had been expended in experimental shots at the Lab from 1949 through 1970 (Drake and Eyster 1971). Normal uranium was used until 1954, after which depleted uranium was used exclusively. A 1952 AEC report states that test shots at LASL routinely dispersed 300 lbs of uranium per month and 200 lbs of barium per month (English 1952). Between 1944 and 1948, eight firing sites (A-H) were established at TA-15 (R-Site). Experiments using from 50 lb up to 2 tons of HE were conducted at these firing points. Firing points E and F were the most active. Up to 65,000 kg of uranium and 350 kg of beryllium were expended at these two firing sites. Hazardous materials, including uranium, beryllium and lead, were largely left in place at these sites where after they were deposited by the explosion (LANL 1992).
The Bayo Canyon Site (TA-10) was used between 1944 and 1962 for experiments using conventional high explosives, radioactive lanthanum (RaLa), and in some cases depleted or natural uranium. The explosions resulted in the dispersion of uranium,$^{140}$La and $^{90}$Sr in the form of aerosols and debris to the atmosphere and onto the ground.

**Use of Uranium at LAMPF / LANSCE**

Originally constructed to study sub-atomic particles, the Los Alamos Meson Physics facility (LAMPF) includes an accelerator that has been used to generate intense pulses of neutrons by sending protons into targets of high atomic number such as uranium.

**Accidents and Incidents Involving Uranium**

In addition to routine, operational releases of uranium, some of the accidents and incidents that are described in LANL documents involved uranium and could have been associated with airborne and/or waterborne releases to the environment. Some of the documented accidents that have involved uranium are summarized in Table 9-1.

**Evaluation of Potential Health Risks from Atmospheric Releases of Uranium**

As summarized above, the main areas where uranium has been used in machining or fabrication include the original technical area (TA-1), TA-3, and TA-21. Considerable quantities of uranium have also been expended in firing site activities conducted at TA-15, TA-36, and others. LANL’s operations have involved a wide range of uranium enrichment, from depleted (primarily $^{238}$U, with very little $^{235}$U) to highly enriched (primarily $^{235}$U).

To gauge what impact LANL’s atmospheric uranium releases may have had in terms of human health risk, the NCRP Report No. 123 screening model was applied to airborne uranium source term information for a given year (NCRP 1996). The year selected was 1972, for which LANL reported a relatively large release of 1,200 µCi of U-234/U-235 from TA-21 (LASL 1973).

The 1972 uranium release was screened against a criterion of a 1 in 100,000 added risk of fatal or non-fatal cancer, assuming a risk factor of 6% per sievert (Sv). This corresponds to a dose equivalent of $1.67 \times 10^{-04}$ Sv (16.7 mrem). The exposed population selected was the residential area nearest the release point. In the case of TA-21 this was the residential apartments within the townsite, at an estimated distance of 1,460 m. The pathways considered for the residential location were inhalation of contaminated air, plume immersion, irradiation from contaminated ground, and consumption of
### Table 9-1. Some accidents and incidents at LANL that involved uranium

<table>
<thead>
<tr>
<th>Date</th>
<th>Description</th>
<th>Repos. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/1/1951</td>
<td>On February 1, 1951 there was a criticality incident involving 2 cylinders of U-235. The cylinders weighted 24.4 kg and 38.5 kg of 93% U-235. The 2 cylinders were in a water reflected system. There was slight oxidation of the uranium. 10^{17} total fissions were involved.</td>
<td>6206</td>
</tr>
<tr>
<td>12/9/1952</td>
<td>On December 9, 1952 in S-104 uranium in a furnace caught fire and was contained in the furnace. Clean-up of S-104 was conducted on December 11 and 12.</td>
<td>3495</td>
</tr>
<tr>
<td>6/26/1953</td>
<td>On June 26, 1953 there was a small fire in a flask containing uranium hydride in D-151.</td>
<td>3491</td>
</tr>
<tr>
<td>12/5/1953</td>
<td>On December 5, 1953 a glass furnace in a vacuum hood exploded releasing 40g of uranium.</td>
<td>3491</td>
</tr>
<tr>
<td>3/9/1955</td>
<td>Uranium was released into the hood of Room 121 at TA-46 on March 9, 1954.</td>
<td>2383</td>
</tr>
<tr>
<td>5/12/1955</td>
<td>On May 12, 1955 a small furnace erupted releasing an unknown quantity estimated at less than one kilogram of uranium in Room 102 of Sigma Building.</td>
<td>2374</td>
</tr>
<tr>
<td>7/21/1955</td>
<td>On July 21, 1955 some normal uranium caught fire in Room 1131.</td>
<td>1184</td>
</tr>
<tr>
<td>8/19/1955</td>
<td>On August 19, 1955 an employee dropped a test tube containing one gram of normal uranium in Wing 2 of CMR Building.</td>
<td>3489</td>
</tr>
<tr>
<td>3/9/1956</td>
<td>On March 9, 1956 a spill of uranium flowed into the bottom of the furnace in Room 21 of the Sigma Building.</td>
<td>2383</td>
</tr>
<tr>
<td>9/27/1957</td>
<td>On September 27, 1957 rags contaminated with sodium and uranium caught fire in Room 133 at Ten Site. Fire was quickly extinguished with CO2.</td>
<td>2414</td>
</tr>
<tr>
<td>4/1/1959</td>
<td>During processing of irradiated U-235 at TA-48 uranium oxide was blown out of the hood when a sample can was opened.</td>
<td>2514</td>
</tr>
<tr>
<td>12/3/1959</td>
<td>On December 3, 1959, a fire broke out in the duct work of Room 313 of DP West where uranium materials are incinerated. The damage was limited to the duct work.</td>
<td>2494</td>
</tr>
<tr>
<td>6/17/1960</td>
<td>On June 17, 1960 there was a criticality incident involving ~48 kg U-235. Uranium cylinders in thick graphite (9-in.) reflected before complete assembly, resulting in trivial damage. 6 x 10^{16} total fissions were involved.</td>
<td>6206</td>
</tr>
<tr>
<td>8/7/1961</td>
<td>On August 7, 1961 a container with a uranium fuel element leaked. Contamination products were detected in the parking lot and around the building. No decontamination was done.</td>
<td>2524</td>
</tr>
<tr>
<td>4/8/1963</td>
<td>On April 8, 1963 there was a uranium spill at TA-46.</td>
<td>2536</td>
</tr>
<tr>
<td>1/10/1964</td>
<td>On January 10, 1964 in SM-66 depleted uranium residue ignited in a drum. The material was allowed to burn out.</td>
<td>2812</td>
</tr>
<tr>
<td>4/22/1964</td>
<td>An explosion occurred following a fire in Room 313 DP West from uranium contaminated rags on April 22, 1964. The fire spread from the drybox to the adjoining hood.</td>
<td>2505</td>
</tr>
<tr>
<td>6/1/1965</td>
<td>At DP East the gas purge line to a recovery furnace became plugged. The operator in charge removed a rubber hose connected to the unit, and uranium-containing dust was blown out into his face and onto his clothing.</td>
<td>NA</td>
</tr>
<tr>
<td>11/16/1966</td>
<td>The air cleaner at one of the enriched uranium shops developed a pin-hole leak, which resulted in high surface contamination of the surrounding area.</td>
<td>NA</td>
</tr>
<tr>
<td>1/15/1969</td>
<td>A glovebox explosion occurred in the uranium recovery operation at DP West, during the incineration of U-235 metal turnings.</td>
<td>NA</td>
</tr>
<tr>
<td>11/2/1971</td>
<td>On November 2, 1971 an explosion in test cell furnace blew uranium contamination onto floor.</td>
<td>1417</td>
</tr>
<tr>
<td>5/4/1979</td>
<td>A stainless steel pot containing uranium tritide was overheated in a laboratory at the Cryogenics Building and ruptured on May 4, 1979. Tritiated water escaped into the laboratory because of inadequate air flow in the hood. Some tritium was released to the atmosphere.</td>
<td>4484</td>
</tr>
<tr>
<td>11/2/1982</td>
<td>On November 2, 1982 approximately 50-100 L of waste liquid escaped from a tank vent at TA-21-257 contaminating the building roof, walls, and surrounding area with low levels of plutonium, americium, and uranium.</td>
<td>NA</td>
</tr>
</tbody>
</table>
contaminated soil and vegetables. Consumption of locally raised meat or milk were not considered. The applicable NCRP 123 screening factors for the selected pathways were 0.31 Sv per Bq per m³ and 0.33 Sv per Bq per m³ for ²³⁴U and ²³⁵U, respectively. Inhalation is the dominant contributor to both factors, being 93% of the total for ²³⁴U and 80% for ²³⁵U. For simplicity the release was screened as 100% ²³⁵U. A bounding value for the air diffusion factor was selected based on the source-receiver difference. This was conservative and avoided the need to account for effective release height and building wake effects.

The NCRP Report No. 123 screening evaluation for the 1972 airborne uranium release from TA-21 gave a screening value of 1.7×10⁻⁶ Sv (0.17 mrem), much smaller than the screening criterion. The screening dose was also compared against screening criterion reduced by a factor of ten, as recommended by NCRP 123 to account for uncertainties. This gives an adjusted screening value of 1.67×10⁻⁵ Sv (1.67 mrem), still much larger than the screening dose. Thus, a significant human health risk (relative to the selected risk criterion) is not indicated for the relatively large uranium release reported for TA-21 for 1972. It should be noted the release value was used as reported by LANL and has not been adjusted in any way or independently verified. Adjustments for biases such as sample line losses or counting losses from the material being buried in the collection media would increase the amount of material released, but not by enough in this case to exceed the screening criteria.

A screening evaluation was also performed for depleted uranium (DU). The effluent data for 1973 were used, with a release of 640 kg of DU from TA-3 (LASL 1974). On an activity basis, this equates to a release of 2.11×10⁵ µCi, assuming the material was 100% ²³⁸U (specific activity = 0.33 µCi/g). The airborne DU release reported for TA-3 was assumed to have originated from the Sigma Complex. The Sigma Complex consists of the Sigma Building (SM-66) and other facilities involved in uranium operations. The nearest residential area was determined to be the Western Area at a distance of about 1,040 m. As with the screening for TA-21, a bounding value of the diffusion factor at that distance was used for simplicity. The NCRP 123 screening factor for ²³⁸U for the applicable pathways is 0.29 Sv per Bq per m³.

The NCRP 123 screening evaluation for the 1973 airborne DU release from TA-3 gave a screening value of 4.4×10⁻⁴ Sv (44 mrem). This value exceeds the screening criterion without adjusting it to account for uncertainties, indicating further investigation into potential health risks is warranted. As with the evaluation for TA-21, the release value was used as reported by LANL and has not been adjusted in any way or independently verified.
It seems counterintuitive that DU releases would screen so much higher than $^{235}$U, but that result reflects the large quantities of DU processed at Los Alamos over its history. DU was also expended in substantial quantities in dynamic experiments at firing sites such as TA-15 and TA-36.

To follow-up on the result of the DU screening, the maximum average air concentration values reported by LANL’s ambient environmental air monitoring network for 1973 were evaluated in terms of the screening dose they represented. The maximum annual average reported for offsite locations was 0.2 ng m$^{-3}$ (LASL 1974). This value was seen at three of the 26 off-site and perimeter monitoring stations: Acorn Street, Bandelier headquarters, and White Rock. The maximum annual average for the on-site monitors was 0.3 ng m$^{-3}$, measured at TA-52 (LASL 1974). Assuming the measured air concentration values reflected $^{235}$U activity (the conservative choice), applying the NCRP Report No. 123 screening factor for $^{235}$U to the maximum offsite average for 1973 (in consistent units) gave a screening dose of $5.4 \times 10^{-6}$ Sv (0.54 mrem). This is well below the screening criterion of $1.67 \times 10^{-4}$ Sv even if the order of magnitude adjustment is applied to account for uncertainties. Treating the measured concentration as $^{238}$U would give an even lower screening dose.

The above evaluations do not paint a clear picture of the potential for health risks to Los Alamos residents from historical atmospheric releases of uranium. NCRP Report No. 123 screening evaluations have indicated enriched uranium releases were not significant in terms of potential risk relative to the 1 in 100,000 criterion selected, and showed releases of depleted uranium warranted further investigation. The ambient air monitoring data for 1973 did not suggest significant risk. None of these evaluations, however, consider releases from earlier in LANL’s history. Earlier releases may have been much larger than those from the 1970s forward for which atmospheric effluent data are conveniently summarized.

Beyond the need to compile data from a large volume of individual references, asserting uranium releases from the earlier years is further complicated by the fact much of the available effluent data were reported in terms of gross alpha or beta activity, rather than for specific isotopes. These data would need to be evaluated using process knowledge to assign the gross measurements to specific isotopes. Further, the fact uranium releases were a chronic source of exposure involving a material strongly retained in the human body may warrant a more detailed evaluation than can be achieved through the screening methods used here. Thus, further investigation would be needed before a more conclusive assessment could be made of the potential for health risks to local residents from atmospheric uranium releases from Los Alamos.
Radioactive Lanthanum (RaLa) Operations

Barium/lanthanum is a mixture of $^{140}\text{Ba}$ and its daughter product $^{140}\text{La}$. $^{140}\text{La}$ is the isotope that was used by LANL in the years between 1944 and 1962 as an aid in “hydrodynamic tests” conducted primarily to perfect the implosion process. $^{140}\text{La}$ has a 40-h half-life, a strong gamma emission, and “grew into” the $^{140}\text{Ba}$ that was produced in large quantities in the Clinton Pile at X-10 Site in Oak Ridge (Widner 2000, Widner and Flack 2002) and later at the Idaho National Engineering Laboratory. RaLa was used in implosion testing from 21 September 1944 through 6 March 1962 (Dummer et al. 1996). All RaLa implosion tests were conducted in Bayo Canyon (TA-10), which is shown in Fig. 9-1. Fig. 9-2 depicts the location of the buildings and firing points within TA-10.

![Fig. 9-1. Bayo Canyon Site, TA-10, in 1950. View is toward the west.](Photo ERID-018982 courtesy of LANL)
From 1944 to 1950, the RaLa sources were prepared at the TA-10 Chemical Processing Building.
Preparation of the RaLa sources was moved to TA-35 ("Ten Site") for the period of 1951 through 1963 and operated by group CMR-10. The $^{140}$La sources were placed in shielded containers and trucked to the firing site where they were remotely loaded to the explosive test assemblies.

In order to obtain data on implosions, laboratory personnel had previously conceived a procedure by placing a gamma ray source at the center of a spherical implosion assembly. The emitted gamma rays would travel outward radially, through both the collapsing shell and the high explosive. The increased compression of the metallic shell during implosion would cause the gamma rays to be increasingly absorbed. The gamma rays would monitored by detectors set around the high explosives. The monitored data would provide data on the density changes in the collapsing shell, the time of collapse, the degree of compression, and symmetry by comparing the gamma rays intensity in different directions. A mixture of $^{140}$Ba and $^{140}$La would be used as the gamma ray source. Due to the potential post-experiment radioactive problems, $^{140}$Ba was removed from the mixture.

$^{140}$La was initially provided by Oak Ridge as a mixture of $^{140}$Ba and $^{140}$La. Chemists at the TA-10 Chemical Process Building prepared RaLa sources by separating a solution containing the parent barium-
140 and other impurities such as $^{89}$Sr and $^{90}$Sr. The separated RaLa, along with unavoidable small amount of barium and strontium, was then encapsulated as specified by each experiment—sometimes in a metal sphere no larger than a match head (a pure 1,000-Ci $^{140}$La source weighs 0.8 mg).

The explosive test assemblies used surrogate materials with mechanical properties similar to plutonium. Uranium, although used, had the disadvantage of being a strong gamma-ray absorber. Metals such as iron, copper, or cadmium were used, and most of the early shots employed cadmium (Dummer et al. 1996). The implosion assembly was surrounded initially by a number of ionization chambers (see Fig. 9-3) and later by scintillation detectors.

![Fig. 9-3. Ionization chambers surrounding a RaLa shot on 13 May 1947](image)

Table 9-2 lists, by year, the number of test shots and the amount of RaLa involved. A total of 254 tests were conducted between 1944 and 1962, with RaLa sources ranging in size from about 25 Ci to 7,090 Ci. The explosions resulted in the dispersion of the metallic shell (uranium or other material such as cadmium) and the radioactive RaLa and residual impurities such as $^{140}$Ba and $^{90}$Sr, in the form of aerosols and debris to the atmosphere and onto the ground.

The preparation of the RaLa conducted at TA-10 generated liquid and radioactive wastes which were disposed of in subsurface pits and leaching fields at the site. Almost 2 million curies of $^{140}$Ba had been handled at TA-10 and TA-35 by the time the RaLa program was terminated in 1963. The TA-10 site was decommissioned by 1963 and transferred to Los Alamos County on July 1, 1967 (Mayfield et al. 1979). In addition to the release of RaLa, about 226 mCi of Strontium-90 was reported released; over 80% of the 226 mCi was released in seven shots in 1945 (Dummer et al. 1996). In a dose assessment conducted by LANL personnel, the highest annual dose from the RaLa shots (17 mrem) was calculated to have
occurred in 1955. The calculated dose for those who were in Los Alamos during the experiments ranges from 110 mrem to 450 mrem (Mayfield et al. 1979, Dummer et al. 1996, Kraig 1997). None of these dose assessments have been independently critiqued by the LAHDRA team.

### Table 9-2. Annual quantities of radioactive lanthanum used in RaLa shots at Bayo Canyon

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity of RaLa Used (Ci)</th>
<th>Number of Shots</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>1,112</td>
<td>10</td>
</tr>
<tr>
<td>1945</td>
<td>18,363</td>
<td>36</td>
</tr>
<tr>
<td>1946</td>
<td>20,556</td>
<td>24</td>
</tr>
<tr>
<td>1947</td>
<td>22,734</td>
<td>27</td>
</tr>
<tr>
<td>1948</td>
<td>12,236</td>
<td>19</td>
</tr>
<tr>
<td>1949</td>
<td>28,255</td>
<td>26</td>
</tr>
<tr>
<td>1950</td>
<td>19,788</td>
<td>12</td>
</tr>
<tr>
<td>1951</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1952</td>
<td>6,370</td>
<td>4</td>
</tr>
<tr>
<td>1953</td>
<td>1,065</td>
<td>4</td>
</tr>
<tr>
<td>1954</td>
<td>15,580</td>
<td>13</td>
</tr>
<tr>
<td>1955</td>
<td>40,763</td>
<td>21</td>
</tr>
<tr>
<td>1956</td>
<td>35,976</td>
<td>21</td>
</tr>
<tr>
<td>1957</td>
<td>17,358</td>
<td>9</td>
</tr>
<tr>
<td>1958</td>
<td>9,845</td>
<td>7</td>
</tr>
<tr>
<td>1959</td>
<td>8,322</td>
<td>8</td>
</tr>
<tr>
<td>1960</td>
<td>5,560</td>
<td>5</td>
</tr>
<tr>
<td>1961</td>
<td>24,312</td>
<td>5</td>
</tr>
<tr>
<td>1962</td>
<td>13,607</td>
<td>3</td>
</tr>
<tr>
<td>Totals</td>
<td>301,802</td>
<td>254</td>
</tr>
</tbody>
</table>

During March and early April 1950, the Air Force sought to conduct independent studies of airborne radioactivity (Dummer et al. 1996). They selected three of the 254 RaLa experiments (Shots 147, 148, and 149) and used a B-17 aircraft to track and measure radioactivity in the cloud resulting from them. In July 1950, LANL provided the Air Force with a static 400 Ci RaLa source for additional analysis. The source was transported to an area near Abiquiu, about 22 air miles north of Los Alamos, and seven passes were made by an airplane over the stationary source (Dummer et al. 1996).

**Polonium Operations**

Polonium was used in atomic bomb initiators, utilizing the \((\alpha, n)\) reaction of \(^{210}\text{Po}\) and \(^9\text{Be}\) to generate neutrons. In February 1945, schedule for polonium delivery from Monsanto to the Original Technical Area was increased to 100 Ci per month by June and 500 Ci per month by December (Hoddeson et al. 2004). At TA-1, polonium was handled in D Building, H Building, and Gamma Building. DP East Site began operation in September 1945 and contained Buildings 151, 152, and 153. Building 155 was
completed in December 1949. It is reported that “the well-designed DP polonium plant went into operation sooner than did the plutonium plant” [DP West site; TR 6704, Box 6 of 8]. The DP East Site facilities were used to process polonium and actinium and to produce initiators.

At DP East, Building 21-153 exhausted air from the main buildings at DP East, was constructed similarly to Building 12, and was in service until March 1970. The primary radioactive contaminant of this filter house was $^{227}$Ac. Bldg. 153 had transitional plenums and filter housings for electromatic filters, two blowers, and two stacks. Stack monitoring data for DP East Site have been located in CMR-12 monthly progress reports starting in August 1945. The data are presented as average counts per minute per liter over each month for DP East Stack 1 and Stack 2. These data are for alpha-emitting radioactivity, with no isotopic composition indicated through at least 1949 (CMR-12 Progress Reports 1945-1949).

Polonium was also expended in explosive testing at Los Alamos. For example, TA-33 (Hot Point or HP) Site was developed in 1947 for the Laboratory’s weapons testing group as a substitute test site for experiments that were being conducted at Trinity Site in southern New Mexico (McLain et al. 2001). These tests used conventional high explosives as well as uranium, beryllium, and polonium radiation sources. Experiments that were conducted primarily to verify designs of nuclear weapon initiators were performed in underground chambers and on surface firing pads. Additional tests were carried out at TA-33 firing sites equipped with large guns that fired projectiles into earthen berms. The documents associated with LAHDRA Repository Numbers 2375, 4519, 6523, and 7021 provide details of events at TA-33 that resulted in releases of polonium from tests at TA-33 in the 1950s.

On 8 January 1953, it was discovered that a mock fission source containing polonium and beryllium had ruptured at Pajarito Site (TA-18) and contamination had spread to the housing area (Shipman 1953). Possibly as much as 2 Ci of polonium was lost, that greater part of which was thought to have remained in and around the laboratory at Pajarito Site. However, “significant amounts [of polonium] were found in a number of homes.” Among the items found to be contaminated in a “large number” of homes were shoes, clothing, floor coverings, vacuum cleaners, children’s toys, and baby diapers. Rugs and upholstered furniture presented serious problems with decontamination.

On 3 August 1955 a Po:Be neutron source ruptured, resulting in the contamination of 150 staff members in Building SM-40 (Shipman 1955). A mock fission polonium source containing 25.2 Ci of polonium exploded in the basement of the Physics Building, and contamination was spread throughout the building. It was 5 days or more before most personnel could return to work. The report states that air
samples for the area never exceeded "3 times tolerance." Although it was said that no activity reached homes or personal vehicles, a "few" government vehicles were contaminated.

References


Chapter 10: The Trinity Test

During the first six months of development work at the Laboratory, the gun method of assembly was the focus of the ordnance program. Up to August 1944, the main focus of activity was the plutonium gun. By August 1944, the high velocity uranium gun had been thoroughly proved in principle but the plutonium gun assembly program was abandoned. The main effort of the Laboratory was now directed to the mounting difficulties of the implosion program. The proposal for implosion assembly was to use a plastic flow tamper and active material under high-explosive impact. The first advantage of the implosion weapon over the gun weapon was its much shorter time of assembly. This was of special importance for the assembly of plutonium due to its expected high neutron background, which would make predetonation a serious danger (Hawkins 1961). The implosion-assembled, plutonium-based design was by far the more complicated than the gun-assembled design. A test of that device was considered necessary because of the “enormous step” from theory and experiments to production of a combat weapon and the realization that, if the device failed over enemy territory, “the surprise factor would be lost and the enemy would be presented with a large amount of active material in recoverable form.”

Document Review

Internal Los Alamos technical reports (many with LA- and LAMS- prefixes) in the LANL Reports Collection and the document holdings of the LANL Records Center and Archives were the primary sources of information about the development of the implosion weapon and the Trinity test program. These collections were reviewed and copies of relevant documents were requested for public release. Information from interviews with Trinity participants, Web sites, the Nuclear Testing Archives in Las Vegas, news archives, and books available from the popular press were also incorporated into this summary of information regarding the Trinity test.

Preparations for the Test

Test Organization

A test of the implosion bomb was considered essential by the director and most of the group and division leaders of the Laboratory. The first preparations for a test were made in March 1944, when Group X-2 was formed in the Explosives Division headed by George Kistiakowsky. The duties of the X-2 group under Kenneth Bainbridge included making preparations for a field test in which blast, earth shock,

\[\text{\textsuperscript{i} Implosion-assembled weapons were designed on the principle of compressing the fissile material to super-criticality by detonation of a high-explosive implosion system.}\]

\[\text{\textsuperscript{ii} “The July 16, 1945 Trinity Bomb Test,” September 1945. LANL Archives Collection A-1984-019.}\]
neutron, and gamma radiations would be studied and complete photographic records would be made of the explosion and any atmospheric phenomena associated with it. This work was initially set up under Section X-2C, with L. Fussell Jr. in charge.

In May 1945, a temporary organization was formed consisting of seven groups designated TR-1 through TR-7 (TR for Trinity). Organizationally, the test was called Project TR, and for reasons of secrecy the test site was referred to as T Site prior to the test. Personnel from R, G, O, F, and X Divisions and military men from the SED (Special Engineering Detachment) were reassigned to this “division” until the test was completed (Bainbridge 1976). Project Trinity was led by K. T. Bainbridge, with Frank Oppenheimer (brother of J. Robert Oppenheimer) serving as his Aide. Responsibilities of the TR groups were as follows:

- **TR-1**, headed by John H. Williams:
  
  construction, procurement, transportation, timing, communications

- **TR-2**, headed by J. H. Manley:
  
  measurements of air blast and earth shock

- **TR-3**, headed by R. R. Wilson:
  
  physics measurements: prompt alpha, delayed neutron and gamma radiation

- **TR-4**, headed by J. M. Hubbard:
  
  meteorology

- **TR-5**, headed by J. E. Mack:
  
  spectrographic and photographic measurements

- **TR-6**, headed by B. Waldman:
  
  air blast airborne measurements

- **TR-7**, headed by L. H. Hempelmann:
  
  medical, including instruments, the monitoring group, and first aid

- **Special Assignments**:
  
  four searchlight crews, an announcer, and weather advisers

J. Robert Oppenheimer and George Kistiakowsky stated in a 1944 memo that “if we do not have accurate test data from Trinity, the planning of the use of the gadget over the enemy territory will have to be done substantially blindly” (Jones 1985).

**Site Selection and Construction**

Bainbridge’s group considered eight sites\(^1\) for testing the first implosion weapon— three in New Mexico, two in California, one in Texas, and one in Colorado. The Los Alamos scientists established the following criteria for the site:

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\(^1\) Besides the Jornada del Muerto, the other sites in New Mexico were the Tularosa Basin near Alamogordo, the lava beds (now the El Malpais National Monument) south of Grants, and an area southwest of Cuba and north of Thoreau. Possible sites outside New Mexico were: an Army training area north of Blythe, California, in the Mojave Desert; San Nicolas Island (one of the
• flat terrain to minimize effects of the blast and to facilitate easy construction of roads and communication lines;
• sufficient distance from populated areas but close to Los Alamos to minimize travel between the two sites;
• clear and sunny weather on average to permit the extensive collection of optical data;
• and convenience to good rail transportation.

The Manhattan Project’s military head, Major General Leslie R. Groves, added conditions that the area be about 17 by 24 mi in size and that it have no Indians on it, the latter being so that he would not have to deal with Secretary of the Interior Harold Ickes, whom he thought would cause difficulties (Groves 1962). The final site selection was made in late August 1944 by Groves. When Groves discovered that in order to use a California location he favored he would need the permission of its commander, General George Patton, Groves quickly decided on the second choice, the Jornada del Muerto. This was because General Groves did not want anything to do with the flamboyant Patton, who Groves had once described as "the most disagreeable man I had ever met" (Szasz 1984).

Bainbridge, a Harvard physicist assigned by J. Robert Oppenheimer to oversee preparations for the bomb test and base camp, chose the 18- by 24-mi tract of land in the northwest corner of the Jornada del Muerto (Journey of Death) valley east of the Rio Grande in the New Mexico desert (Bainbridge 1976, Jones 1985). As soon as the Air Force’s commanding general for the New Mexico district approved Bainbridge’s request to have a section of the Alamogordo Bombing and Gunnery Range turned over to the Manhattan Project, Bainbridge called Oppenheimer to tell him the good news and urged that they pick a code name for the site as soon as possible. Oppenheimer was familiar with a book of John Donne’s poems, and the opening line of the one he recalled was “Batter my heart, three-person’d God; for, you as yet but knock, breathe, shine, and seek to mend...” One theory is that Oppenheimer said “we’ll call it Trinity” based on that poem (Lamont 1965).

Another theory is that Oppenheimer selected the name with reference to the divine Hindu trinity of Brahma (the Creator), Vishnu (the Preserver), and Shiva (the Destroyer). Oppenheimer had an avid interest in Sanskrit literature (which he had taught himself to read), and following the Trinity test is reported to have recited a passage from the Bhagavad-Gita (Radiochemistry Society 2007).

A great deal of time was initially wasted in land surveys due to inadequate maps. Maps were requested through the Security Office in June 1944 but many were never received. The maps that were eventually

Channel Islands) off the coast of Southern California; on Padre Island south of Corpus Christi, Texas, in the Gulf of Mexico; and in the San Luis Valley of south central Colorado, near today's Great Sand Dunes National Monument (USDOE 1994).

¹ This area was a short cut on the Camino Real, the King’s Highway that linked Mexico to Santa Fe, used to avoid a valley that was too narrow for supply wagons. Sixty miles of desert, with very little water and numerous hostile Apaches, led the Spanish conquerors of New Mexico to assign the name.
used were obtained by ordering all the geodetic survey maps and most of the grazing service and county maps for the state of New Mexico; aerial mosaics and land status maps had to be “scrounged”. Aerial photographs of the northwest corner of the Alamogordo Air Base were obtained from the Air Force and assembled into a photo mosaic that was used with a transparent overlay to determine locations for the main instrument shelters that would not be in washes. The selected land tract permitted separation from nearest habitation by a minimum of 12 mi to the north and west. Moreover, the government controlled the land out to 18 miles on the east. The nearest towns in any direction were 27-30 miles away and the prevalent winds were from the west (Bainbridge 1976). A memorandum providing justification for the construction and equipment requirements for the proposed scientific measurements was given to Oppenheimer in October 1944. A construction company contracted by the Army [J. D. Leftwich Company of El Paso, TX] completed the first facilities at the camp by the end of December 1944, and a small Military Police detachment under Lt. Bush arrived from Los Alamos to provide security for the site (Bainbridge 1976). Shortly after, a much larger group of scientists, technicians, medics, civil service personnel, and construction workers arrived.

There was a maze of roads to be built, hundreds of miles of wire to be strung over and under the ground, a complete communication system to be installed, buildings to be erected, supplies, equipment, and personnel to be transported between Los Alamos and Trinity, all under the cloak of extreme secrecy (LASL 1979). By early 1945, there were more than 200 residents at the Trinity Base Camp. Civilian construction crews aided by construction personnel from Los Alamos built additional facilities in the spring of 1945 to ready the site for the bomb test, which was scheduled for early summer (Jones 1985).

As depicted in Fig. 10-1 through Fig. 10-3, facilities at the test site included:

- A Shot Tower (located at “Ground Zero,” the central reference point)
- Base Camp (located 10 miles to the south-southwest)
- South Shelter (located 10,000 yd (about 6 mi) to the south; housed VIPs and the control center for the test)
- North Shelter (located 10,000 yd to the north; housed personnel, instruments, and searchlight crews)
- West Shelter (located 10,000 yd to the west; housed personnel, cameras, and searchlight crews)

The three shelters, which were heavily-built wooden bunkers reinforced with concrete and covered with earth, were code named Able, Baker, and Pittsburgh (National Atomic Museum 2007). Test personnel made use of the McDonald Ranch House for final assembly of the bomb’s plutonium core. Trinity Base Camp included stables, a blacksmith shop, water storage tanks, a hay barn, officers’ quarters, a supply room, mess hall, barracks, latrine, P.X. and day room, coal storage, infirmary, laboratory, technical warehouse, office, garage, gasoline storage tanks, fire station, engineering office, plumbing shop, electrical shop, carpentry shop, and drinking water tanks (Merlan 2001).
The 100-Ton Test

In the summer of 1944, a “100-ton test shot” using conventional high explosives (HE) was proposed to calibrate the blast and earth shock measuring equipment at the Trinity site and to serve as a dress rehearsal for the summer 1945 test. The “first” Trinity test occurred on May 7, 1945 at the New Mexico site 800 yd south of what would be ground zero for the July 16 test. It was the first chance to test experimental data under explosion conditions. Since explosions of more than a few tons of TNT have different characteristics than lesser amounts, 108 tons of HE (Composition B, a mixture of TNT and the explosive RDX) brought in from Fort Wingate and a small volume of radioactive solution (to simulate the radioactive products of the nuclear test) were detonated atop a 20-foot platform (Fig. 10-4) so that dispersion could be characterized and instruments could be calibrated (LASL 1979, Jones 1985, Radiochemistry Society 2007).

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1 Erickson (1946) described the explosive charge for the 100-Ton Test as 3590 wooden boxes (179,500 lbs) of flaked TNT and 744 boxes (32,044 lbs) of pelletized Composition B.
Fig. 10-2. Location of the Trinity Test Site and Nearby Towns (from Jones 1985)
Box after wooden box of HE were stacked until approximately 100 tons were in the pile. An irradiated uranium fuel slug from a Hanford reactor was dissolved using the apparatus shown in Fig. 10-5 and poured into flexible tubing threaded through the high explosive (Sugarman 1945). The solution introduced into the pile had beta activity of 1,000 Ci and gamma activity of 400 Ci.

Fig. 10-4. Boxes of High Explosives Stacked for the "100-Ton Test"

Fig. 10-5. Diagram of the equipment used to dissolve an irradiated uranium fuel slug from a Hanford reactor for dispersion in the 100-Ton Test at Trinity Site (Sugarman 1945). The fuel slug entered the dissolver via the pipe from the left, by which off-gases were also exhausted. The radioactive solution exited via the tubing to the right, into the stack of boxed high explosives.
The blast (Fig. 10-6) compressed and blew the surrounding earth into a saucer-shaped crater, expelling about 40% of the dirt. A scaling up the RaLa shots suggested that 10% of the activity would remain in the soil within a 300-ft radius. However, only 2% of the activity of the dissolved radioactive material was deposited in the crater out to a distance of 450 ft from the center. This indicated that simple scaling didn’t account for the increase in updraft with increased explosive charge.

According to Richard C. Tolman, a physicist who has an advisor to General Leslie Groves, the explosion of the “100-ton test” aroused little comment in neighboring towns, but the illumination and sound were detected at the Alamogordo Air Base 60 mi away by a pre-warned observer. According to Hempelmann, the level of activity in the crater was low enough to be safe for several hours of exposure. The dissolving unit was covered with dirt and surrounded by a guard fence. Suggestions for improvement in facilities and procedure included paved roads to protect personnel and instruments from dust, more vehicles, more vehicle repairmen, and more telephone lines (Bainbridge 1976, Hoddeson et al. 1993).

Date Selection and Meteorology

July 4 was the original target date for the second test at Trinity, the nuclear test. In mid-June, Oppenheimer said that July 13 was the earliest possible date for the test, however, the laboratory’s “Cowpuncher Committee” had primary responsibility for coordination and scheduling for Trinity. The committee was composed of S. K. Allison, former Director of the Metallurgical Laboratory, Kistiakowsky, Captain Parsons, C. C. Lauritsen, Bacher, and Hartley Rowe, a former Technical Advisor to General Eisenhower. It was organized “to ride herd” on the implosion program.

After a review of developments on June 30, the Committee advanced the test date to July 16 to permit inclusion of certain additional vital experiments. The committee held its first meeting in early March 1945. This group met often and published a semimonthly report called “The Los Alamos Implosion
Program” that presented in detail the current status of the work. Since Secretary of War Henry Stimson would be attending the Potsdam Conference starting on July 16, a test date of July 14 was requested by Groves so the results of the test would be known. The bomb test team, however, insisted on a test date of July 17. On July 7, Oppenheimer told Groves the test could take place on the 16th, but no earlier, since all parts of the Gadget (code name for the Fat Man implosion bomb) would not be ready before July 16 (Jones 1985).

The date of the Trinity test depended on the availability of components and on the weather. Haze, dust, and mirage effects would interfere with photographic measurements. Overcast skies would make flying more difficult for the airplanes to drop instruments. Winds had to be favorable to keep the radioactive cloud away from inhabited areas to the east and north. Each group was asked to specify the best weather conditions for their experiment, and meteorologist Jack Hubbard tried to find a date to match their requirements. Hubbard initially projected that the best dates for the Trinity test would be between July 18 and 21, with July 12 through 14 as second best. The preferred time was several hours before dawn (Hoddeson et al. 1993).

Meeting the weather needs of all groups proved impossible, and the groups had to compromise. Optimum winds would draw the radioactive cloud away from the nearby towns and break it up rapidly. Winds from the northwest through southwest were judged best and were typically the driest, therefore keeping thunderstorms from washing additional radioactivity down to the earth’s surface. No one was sure how high the radioactive cloud would go. An inversion layer over nearby towns, which were 27-30 miles away, would prevent material from touching down in those areas. Although thunderstorms were expected for July 16, Hubbard agreed that the shot could be made, even if conditions would not be optimal for all the planned experiments (Hoddeson et al. 1993).

**Scheduling Impacts on Planning of Protective Actions**

After the date for the Trinity test was set at 16 July 1945, Dr. Louis Hempelmann recalled that “there was feverish activity on our part to make the town monitoring program flexible enough to adapt itself to whatever wind conditions prevailed when the test was ready” (Hacker 1987). In anticipation that the people living in towns and on ranches in the immediate vicinity might have to be evacuated to avoid radioactive fallout, army intelligence agents led by Maj. T. O. Palmer searched the countryside trying to locate, list, and map every person living within a 40-mi radius of ground zero in case evacuation became necessary (Hoffman 1947, Bainbridge 1976, Hacker 1987). The Army stationed a detachment of 160 enlisted men with vehicles at Socorro and other strategic points along main highways a few miles north of the site. The Army also detailed 25 Counterintelligence Corps (CIC) members to towns and cities up to
100 mi from the site with instructions to summon evacuation troops if they were needed, and to help manage public reaction to the blast (Jones 1985).

**Instrumentation, Experiments, and Cameras Put into Place**

At a conference in Oppenheimer’s office on December 23, 1944, diagnostic experiments for the Trinity test were categorized as essential, desirable, or unnecessary. Essential experiments include the pressure of the blast wave and the time spread in the firing of the detonators. Desirable experiments included photographic and spectrographic analyses of the fireball, and measurement of the earth’s motion during the explosion in case any lawsuits were brought against the laboratory for blast damage. All other experiments were deemed unnecessary (Hoddeson et al. 1993).

Much emphasis was placed on measuring the energy in the blast wave. This was achieved by using a pair of beryllium-copper diaphragm microphones to record the peak pressure following the explosion because it was suggested that the change in pressure generated by the blast wave was the only quantity that could be measured accurately from 20 miles away during combat use. A more sophisticated method was also used, which consisted of making a precise measurement of the velocity of sound at the site of explosion and comparing it to the velocity of the blast wave. Spring-loaded piston gauges, water-filled pistons, diaphragm box gauges, and ball and cylinder gauges were calibrated to record a range of peak pressures from the blast. The mechanical gauges were insensitive to electrical disturbances and acted as backup to the electrical methods (Hoddeson et al. 1993).

Plans were made to estimate the energy of the bomb in several ways, including determination of the number of fissions by measuring the number and intensity of the gamma rays emitted. Prompt and delayed gamma rays could be measured separately. Ionization chambers were used to measure the prompt gamma rays. The ionization from the delayed gamma rays was measured by “suitable devices” placed within 10 or 20 miles of the gadget. The number and energy of the gamma rays could be used to derive the number of fissions and calculate the efficiency and yield of the bomb (Hoddeson et al. 1993).

The energies and distribution of neutrons from the blast provided another method for calculating yield, but they were difficult to measure since they were more likely to be degraded or absorbed. Plans were made to measure time-integrated neutron flux using gold foils in protective tubes placed between 300 and 1000 meters from ground zero that would be activated by slow neutrons from the blast. Arrangements were also made to perform direct examinations of the soil from the area near the blast for plutonium and fission products to support estimation of the efficiency of the explosion. Two lead-lined tanks (Fig. 10-7) with trap doors on their undersides were equipped to recover soil samples from the Trinity site crater (Hoddeson et al. 1993).
Another essential measurement was the time interval between the detonation of high explosives and the beginning of the chain reaction to determine if the nuclear reaction was started by the initiator or began prematurely. The degree of simultaneity of the detonators required for an efficient implosion was unknown at the time. The presence of an informer switch at each detonator superseded the requirement for the test to be an exact duplicate of the gadget as it would be used in combat (Hoddeson et al. 1993).

A variety of instruments were put into place to measure earth motion, including the change in position of stakes, geophones, and seismographs. Seismograph measurements were made on site at the North Shelter (10,000 yards from ground zero) and at Base Camp and off site at Tularosa, Carrizozo, and San Antonio (Hoddeson et al. 1993).

Fig. 10-7. One of two lead-lined tanks prepared to recover soil samples from near ground zero

The primary purpose of the photography effort was to have a good photographic record for spectrographic and yield analysis. Different stages of the explosion required different film speeds, lenses and exposures, and no one knew the amount or kind of light that would be emitted during the explosion. Fastax cameras taking 10,000 frames per second were put into place to record minute details of the beginning of the explosion. Fastax cameras placed 800 yd from the blast were protected by a steel and glass bunker and were mounted on a sled that could be pulled out of the contaminated area by a chain attached to one of the lead-lined tanks. They would exhaust their film supplies in several hundredths of a second. Rotating-drum spectrograph cameras were positioned to monitor light wavelengths emitted by the fire ball, and pinhole cameras were put into place to recorded gamma rays. The only available well-exposed color photograph of the explosion was taken by Jack Aeby, a 21-year old Los Alamos scientist and amateur photographer (Hoddeson et al. 1993) using his own camera, which Italian physicist Emilio Segre had secured permission for him to carry on site to record the activities of Segre’s group as they studied delayed gamma rays (Savage and Storm 1965).
The “Jumbo” Containment Vessel

The construction of a large pressure vessel to contain the rare and valuable plutonium if the first atomic bomb was a dud was considered in the winter and spring of 1944. Other recovery methods considered included a below-ground sand cone (sand to high explosive weight ratio 15,000:1) and a cylindrical tank of water (water to high explosive weight ratio 50:1 or 100:1). Although a container could possibly allow scientists to recover the plutonium, all proposed blast, earth shock, and optical measurements would be rendered useless by the presence of the vessel, so this idea was not popular with the scientists. The final design for Jumbo was a 25 ft by 12 ft cylinder with hemispherical ends that weighed 214 tons. It was built by Babcock and Wilcox Corporation in Barberton, Ohio and shipped in early April 1945 on a specially fabricated railcar to a railroad siding at Pope, New Mexico (Fig. 10-8). A 64-wheeled trailer pulled by two tractors was used to move the vessel the 25 miles from Pope to the test site (Jones 1985). By March 1945, all recovery methods were abandoned because sufficient plutonium for a second test would be available from Hanford, and Jumbo was never used. However, it was erected 800 yards from ground zero in case it was needed for a second test (Hoddeson et al. 1993).

Fig. 10-8. The "Jumbo" containment vessel being loaded on a specially made, 64-wheel trailer at the Pope, NM railroad siding (left) and making its 25-mi trip to the Trinity site on a road constructed for that purpose (right).

Final Preparations

Two complete sets of high explosive castings were available on July 10. Prior to July 7, there had not been enough lens castings to make a complete charge. Kistiakowsky and Bradbury picked the best looking pieces for the Trinity assembly and designated the rest for the full-scale magnetic Creutz test of the gadget to be conducted at Pajarito Canyon without active material. The Trinity charge was assembled on July 12 at V Site in Los Alamos and started on its journey to the Trinity site at midnight, arriving just
before noon on the 13\textsuperscript{th} (Bainbridge 1976). Kistiakowsky wrote that he chose to leave just after midnight on Friday the 13\textsuperscript{th} because he “believed in unorthodox luck” (Kistiakowsky 1980).

On July 12, two scientists arrived from Los Alamos in an army sedan with the $^{239}$Pu core for the implosion device. An interview with Phillip Morrison revealed that he rode down to Trinity with the weapon core. He and Marshall Holloway, both G Division engineers, were designated as the Pit Assembly team in April 1945 and were responsible for placing the core into the gadget during final assembly. Morrison didn’t remember a great deal about the ride to the Trinity site, but did recall that he was “rather afraid of the fast driving young woman who drove us down there with the convoy, who was really a high-speed… pedal to the floor all the way. That driver was the scariest thing” (Morrison 1999). General Farrell signed a receipt for the active material, formally completing the transfer from the scientists to the Army (Jones 1985). All components were in place except the detonating system at 5:45 pm on July 13. The device was hoisted to a metal shed on a platform atop a 100-ft steel shot tower, a surplus Forest Service fire-watch tower (Fig. 10-9 and Fig. 10-10) (National Atomic Museum 2007).

![The steel shot tower used for the Trinity test](image)

**Fig. 10-9.** The steel shot tower used for the Trinity test
A truckload of mattresses were piled up under the Gadget in case it fell (Hoddeson et al. 1993). The detonator group completed the firing circuit and technicians added an apparatus for experiments. By 5:00 pm on July 14, the device was ready for the test.

Observers including Office of Scientific Research and Development (OSRD) Director Vannevar Bush and National Defense Research Committee Chairman James Conant arrived with General Groves on Sunday, July 15. The large contingent from Los Alamos arrived in three buses around 3:00 am on the morning of July 16, just before the scheduled test time of 4:00 am. The weather was rainy and there were occasional flashes of lightning. General Groves and Oppenheimer decided to delay the shot for an hour and a half. The rain stopped at 4:00 am. Shortly before 5:00 am, with the wind still blowing in the “right” direction, they gave the go-ahead signal for the test (Jones 1985).

Health and monitoring organization preparations addressed issues of cloud and trail contamination. According to Hempelmann, the activity of the cloud would vary with the efficiency of the explosion and it would need to be monitored until it was dispersed since it was a potential hazard to the local population. If loose dust from the crater and the surrounding area rose to 10,000 feet and fell at a normal rate there might be danger to towns 30 miles away, due to a prediction of 7 R h\(^{-1}\) from fission products and the \(^{239}\)Pu tolerance dose being exceeded in 22 h. Hubbard assured all concerned that the meteorological conditions that could affect the cloud were predictable, including low humidity, temperature inversion, winds above the inversion, atmospheric lapse rate, and heating of the earth. Low humidity would exclude a thunderstorm created by the blast and heat effects that could cause precipitation of the active material.
over a small area. The inversion layer would retard particles from falling until the morning thermals mixed the active material more thoroughly. A 30 mph wind to the SE above the inversion layer would carry the cloud beyond the nearby towns. A stable lapse rate would allow the fire ball to ascend until it reached a higher inversion at 20,000 ft and preclude heavy active particles from falling on a small area. The usual heating of the earth would break the inversion layer and move air in an ascending manner. Hubbard predicted that contaminated material thrown into the air could be suspended for weeks (Bainbridge 1976).

A betting pool was started by Los Alamos scientists on what the yield of the Trinity device would be (National Atomic Museum 2007). Yields from zero to 45,000 tons of TNT (45 kilotons) were selected. Bainbridge was furious when he heard discussions of the possibility that the blast would be hot enough to ignite the nitrogen in the atmosphere and would annihilate the human race (Hacker 1987). This possible outcome had been suggested by Edward Teller, but fears were quashed by intensive studies by Hans Bethe and others that were documented by Teller and Emil Konopinski in December 1943. These studies concluded that the safety factor was “at least a factor of 60” (Rosen 2002).

Bus loads of visitors from Los Alamos and elsewhere started arriving near the Trinity Site around 2:00 a.m. on July 16. Many of them who had no duties for the test set up on Campaña Hill (about 32 km to the northwest of ground zero) to watch the event. This included Ernest O. Lawrence, Hans Bethe, Edward Teller, Robert Serber, Edward McMillan, James Chadwick, and Richard Feynman (Merlan 2001).

At the time of the detonation, 99 project personnel (about 76 civilian and 23 military) were in the three shelters: 29 at North, 37 at West, and 33 at South. Harvard president James Conant, General Groves, and Vannevar Bush observed the test from a slit trench at Base Camp; J.R. Oppenheimer, Kenneth Bainbridge, George Kistiakowsky, Thomas Farrell, Donald Hornig, and Samuel Allison watched from the South 10,000 Shelter, which served as the control point (Maag and Rohrer 1982, Merlan 2001). Groves and Oppenheimer purposefully watched the test from different locations, separated by some distance, so that if one were killed, the other could likely continue to manage the project.

**The Trinity Test**

The Trinity “Gadget” was detonated on Monday, 16 July 1945 at 5:29 a.m. Mountain War Time at latitude 33°28’- 33°50’, longitude 106°22’- 106°41’, UTM coordinates 630266 on the Alamogordo Bombing Range, New Mexico. The time is not known with certainty, because scientists experienced difficulty in picking up station WWV for a time check (Bainbridge 1976, Maag and Rohrer 1982).

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1 “Campaña” also appears as “Campania,” “Campagne,” or “Campagna” in various sources. These spellings might have been adopted to help those with little knowledge of the Spanish language pronounce the word.
Observations/Descriptions

The nuclear blast (Fig. 10-11) created a flash of light brighter than a dozen suns (National Atomic Museum 2007). The light was seen over the entire state of New Mexico and in parts of Arizona, Texas, and Mexico. The resultant mushroom cloud rose to over 38,000 ft within minutes, and the heat of the explosion was 10,000 times hotter than the surface of the sun. At 10 mi away, this heat was described as like standing directly in front of a roaring fireplace. Data from hundreds of instruments recorded what occurred that morning. The blast was more powerful than expected, however, and many instruments and experimental devices were ruined (Lamont 1965). A brilliant yellow light was seen as far away as Albuquerque and Los Alamos to the north, Silver City New Mexico to the west, and El Paso Texas to the south. A sensation of heat persisted as a huge ball of fire took shape and transformed into a moving orange and red column. Out of this spectrum rose a narrower column that rapidly spilled over to form a giant white mushroom cloud surrounded by a blue glow. As the glow began to fade, observers at the base camp felt the pressure of the shock wave and its rumble reverberated for more than five minutes in the surrounding hills (Jones 1985). General Thomas Farrell, Deputy to Gen. Leslie Groves, said that “The effects could well be called unprecedented, magnificent, beautiful, stupendous and terrifying. No man-made phenomenon of such tremendous power had ever occurred before.” “I am become Death, the Destroyer of Worlds” was reportedly said by J. Robert Oppenheimer. Dr. Kenneth Bainbridge, Director of Trinity Test, said “Now we are all sons-of-bitches.”

Fig. 10-11. Two images from the only well-exposed color photograph available for the Trinity blast, taken by Los Alamos scientist and amateur photographer Jack Aeby from near Base Camp. As Aeby later said, “It was there so I shot it.”
The crew sent to Searchlight Station L-8 to illuminate and observe the cloud from the blast recorded that, at $t + 15$ minutes, the cloud was divided into three parts—a dense white mushroom cloud, a flat, fairly long red dust cloud, and a reddish-brown column that seemed to come from ground zero (Blair et al. 1945b). The three-man crew was located 19.5 miles from ground zero, to the northeast, as shown in Fig. 10-12. At $t + 30$ minutes, the high mushroom cloud had moved directly toward their position, and had “taken on the shape of the North American part of the western hemisphere” while the “lower red-brown cloud and column took on the shape of a question mark, while the brown dust seemed to be still emanating from position 0.” Radioactive material started to descend upon Searchlight Station L-8 between $t + 90$ minutes and $t + 120$ minutes (Blair et al. 1945b). The radiation level peaked at its highest level at 8:25 a.m., and remained constant through 9:15 a.m., after which it started to decline (Blair et al. 1945b).

Physicist Otto Frisch had been taken to a spot about 32 km from ground zero (probably on Compañía Hill). Because he couldn’t find his assigned dark glasses as the countdown progressed in the dark that early morning, Frisch initially turned away from ground zero but later recorded the following observations (Frisch 1979):

“And then, without a sound, the sun was shining; or so it looked. The sand hills on the edge of the desert were shimmering in a very bright light, almost colourless and shapeless. The light did not seem to change for a couple of seconds and then began to dim. I turned round, but that object on the horizon which looked like a small sun was still too bright to look at. I kept blinking and trying to take looks, and after another ten seconds or so it had grown and dimmed into something more like a huge oil fire, with a structure that made it look a bit like a strawberry. It was slowly rising into the sky from the ground, with which it remained connected by the lengthening grey stem of swirling dust; incongruously, I thought of a red-hot elephant standing balanced on its trunk. Then, as the cloud of hot gas cooled and became less red, one could see a blue glow surrounding it, a glow of ionized air; a huge replica of what Harry Daghlian … [saw just over five weeks later at Omega Site in Los Alamos] when his assembly went critical and signaled his death sentence. The object, now clearly what has become so well known as the mushroom cloud, ceased to rise but a second mushroom started to grow from its top; the inner layers of the gas were kept hot by their radioactivity and. Being hotter than the rest, broke through the top and rose to even greater height. It was an awesome spectacle; anybody who has ever seen an atomic explosion will never forget it. And all in complete silence; the bang came minutes later, quite loud though I had plugged my ears, and followed by a long rumble like heavy traffic far away. I can still hear it.”
Fig. 10-12. Map of areas to the northeast of the Trinity Site where highest off-site radiation levels were measured after the July 1945 shot.
Less than a half hour after the test shot, General Groves called his secretary in Washington, D.C. to pass on word of the test to Secretary Stimson. He reported that the strength of the explosion was at least “satisfactory plus and perhaps far greater than estimated” (Lamont 1965).

**Trajectory of the Cloud and Observations of Fallout**

Up to the time of the shot and for the first half hour after the shot, information about the direction of travel of the cloud was vague. A 20 mi h\(^{-1}\) wind was blowing from the southeast toward Guard Gate 2\(^i\) to the northeast of ground zero. It was thought that the radioactive cloud would move in a line toward the northwest from ground zero, but the cloud did not travel in that direction (Hoffman 1947).

Col. Stafford Warren, Chief of the Manhattan Project’s Medical Section, documented the following in a July 21, 1945 report to Gen. Groves (Warren 1945):

“The energy developed in the test was several times greater than that expected by scientific group. The cloud column mass and top reached a phenomenal height, variously estimated as 50,000 to 70,000 feet. It remained towering over the northeast corner of the site for several hours. This was sufficient time for the majority of the largest particles to fall out. Various levels were seen to move in different directions. In general the lower one-third drifted eastward, the middle portion to the West and northwest, while the upper third moved northeast. Many small sheets of dust moved independently at all levels and large sheets remained practically in situ. By zero plus 2 hours, the main masses were no longer identifiable except for the very high white mass presumably in the stratosphere.

By 0800 hours the monitors reported an area of high intensity in a canyon 20 miles northeast of zero. … Intensities in the deserted canyon were high enough to cause serious physiological effects.

The distribution over the countryside was spotty and subject to local winds and contour. It skipped the nearby highway #380 (20 mi. N.E.) except for low intensities which were equaled at twice and three times the distance. It is presumed that the largest outfall occurred in the N.E. quadrant of the site. This can only be explored by horseback at a later date.”

Between 6:00 and 7:00 am, the wind direction changed from southeasterly to southwesterly\(^ii\), and the cloud was traveling northeast at 15 mi h\(^{-1}\), at altitude 35,000 ft, and rising about 14,000 ft h\(^{-1}\). Monitors found readable gamma radiation 1.7 h after the shot 19 mi from ground zero. This indicated that the active

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\(^i\) Guard Gates or Guard Posts were typically just tents or parked trucks along the roadside used to provide shelter for security guards that controlled access to the various areas of the Trinity Site.

\(^ii\) Although not adhered to in many historical reports, this summary follows the convention of describing wind directions as the directions that the wind is blowing from.
dust falling from high altitudes had been caught by the northwesterly wind near the ground and blown in the direction of Socorro (Hoffman 1947).

The cloud drifted northeastward at about 10 mi h\(^{-1}\), dropping its trail of fission products across a region measuring 100 mi long and 30 mi wide (Lamont 1965). In the deep ravines northeast of the Trinity site, where cattle grazed, the radioactivity settled in a white mist (Lamont 1965). The off-site monitors feared inversions and solar heating of air in the canyons, which could cause thermal updrafts that can lead to sudden wind shifts and carry airborne contamination beyond the expected limits, possibly dumping it in some remote area unknown to the monitors (Lamont 1965).

William Wrye, whose house was 20 mi northeast of Trinity, tells that “for four or five days after that, a white substance like flour settled on everything” (Albuquerque Journal News 1995). And rancher M. C. Ratliff said that “the ground immediately after the shot appeared covered with light snow,” adding that for several days afterward, especially at dawn and dusk, “the ground and fence posts had the appearance . . . of being frosted” (Hacker 1987).

As the cloud drifted beyond Carrizozo, with monitoring teams in full chase, scientists realized that the monitors had overreached the limits of their radio contact with base camp. As fallout was dropping on northern communities like Coyote, Ancho, and Tecolote, the monitors were unable to relay the results to Stafford Warren at Base Camp (Lamont 1965). Even as officials at base camp were advising Washington that the fallout danger was diminishing, the monitors were racing back toward Trinity with reports that fallout had reached a number of areas beyond their jurisdiction, such as Vaughn (Lamont 1965).

The [visible] cloud from the Trinity blast appears to have dissipated over the vicinity of Vaughn, 96 mi from ground zero. It appears that the main cloud wrapped itself around Gallinas Peak, 65 mi north of the site, and broke up (Lamont 1965). There is evidence that fallout from the Trinity test traveled as far as Indiana. In the fall of 1945, the Kodak Company observed some spotting on their film and they traced it back to contamination in their cardboard. Dr. J.H. Webb, a Kodak employee, studied the matter and concluded that the \(^{141}\text{Ce}\) contamination must have come from a nuclear explosion somewhere in the U.S. In fact, it came from the Trinity Test (Webb 1949).\(^1\) Fallout from the explosion had contaminated the river water that the paper mill in Indiana had used to manufacture the cardboard pulp. Recognizing the sensitivity of this information, Dr. Webb kept his discovery secret until 1949 (Webb 1949). Airplanes equipped with filters followed the Trinity cloud across Kansas, Iowa, Indiana, upstate New York, New England, and out to sea (Blair et al. 1945a).

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Witnesses from Outside the Project

Due to the intense secrecy surrounding the test, accurate information of what happened was not released to the public until after the second atomic bomb had been dropped on Japan three weeks later. Without being officially informed, many people in New Mexico were well aware that something extraordinary had happened the morning of July 16, 1945. The blinding flash of light, followed by the shock wave, had made a distinct impression on people who lived within a radius of 160 miles of ground zero. Windows were shattered 120 miles away in Silver City, and residents of Albuquerque saw the bright light of the explosion on the southern horizon and felt the tremor of the shock waves moments later (National Atomic Museum 2007).

In spite of the “no fly” order, pilot John Ellison, a flight engineer, and four trainees took off from Roswell Air Field in a B-29 just before 5 am on July 16, 1945. They were on a training mission for the 9- to 12-h bombing missions planned over Japan, and had been cleared to fly to California. About 42 min into the flight, they were 18,000 ft over the northern part of the Sacramento Mountains bordering the White Sands Missile Range when they saw a searing light and the red fireball of the first atomic bomb test. Ellison estimated that he and his crew were 15-20 mi from ground zero and may have been the closest persons to witness the test from the air. This is likely to be true, as the two B-29 observation planes were unable to take off from Kirtland Field due to bad weather, including heavy clouds and thunder storms (Groves 1945). Ellison radioed the tower in Roswell and they told him to get the plane back. Later he learned that authorities associated with the atomic test overheard his radio transmission and ordered the base to call in the planes (Santa Fe New Mexican 2005).

The “Cover Story”

An officer from General Grove’s headquarters gave the cover story to the commander of the Alamogordo Air Base to be issued as soon as the test had occurred. Another officer was stationed in the Associated Press office in Albuquerque to suppress any stories that might alarm the public. Groves also arranged with the Office of Censorship in Washington, D.C. to keep news of the explosion from getting into newspapers in other parts of the country. The Army issued an order grounding all commercial planes and suspending all flights from nearby military installations (Jones 1985). Groves modified the cover story to fit the exact circumstances of the test and gave permission to the Associated Press at Albuquerque to release it as follows:

“Alamogordo, N.M., July 16. The commanding officer of the Alamogordo Air Base made the following statement today: Several inquiries have been received concerning a heavy explosion which occurred on the Alamogordo Air Base reservation this morning. A remotely located ammunition magazine containing a considerable amount of high explosives and pyrotechnics exploded. There
was no loss of life or injury to anyone, and the property damage outside of the explosive magazine itself was negligible. Weather conditions affecting the content of the gas shells exploded by the blast may make it desirable for the Army to temporarily evacuate a few civilians from their homes” (Jones 1985).

Fig. 10-13 shows an article that resulted from release of the cover story.

**Experimental Results**

Immediately after the test, Sherman M-4 tanks, painted white, equipped with their own air supplies, and lined with two inches of lead went out to explore the crater area. The lead added 12 tons to each tank’s weight, but was considered necessary to protect the tanks’ occupants from the radiation levels at ground zero. The tank’s passengers found that the 100-foot steel tower had virtually disappeared, with only the metal stumps of its legs imbedded in concrete remaining (USDOE 1994).

The most important result was that the implosion device worked. The yield was three times larger than predicted. T-Division’s predictions were between 5 and 10 kilotons. Radiochemical analysis of the soil samples gave an estimated yield of 18,600 tons of TNT, quite close to the currently accepted value of 20 to 22 kilotons. Some of the observers tried to estimate the yield while watching the test. Enrico Fermi performed a fairly simple experiment, in which he tore a sheet of paper into pieces and dropped them as the blast wave passed his location. They moved about 2.5 ft, which Fermi calculated to be equivalent to 10,000 tons of TNT.

The Socorro Chieftain carried the following item after the Trinity Test, but before the true story of what had happened was released:

“An explosives magazine at the Alamogordo air base blew up Monday morning [see ‘The Cover Story,’ below], and the flash, sound and shock were seen, heard and felt in Socorro, more than 100 miles away . . . The flash was intensely white and seemed to fill the entire world. It was followed by a large crimson glow. The flash lasted only a second or so. It was so bright that Miss Georgia Green

![Munitions Explode at AlamoDump](image-url)

*(By The Associated Press)*

An ammunition magazine exploded early today in a remote area of the Alamogordo Air Base reservation, producing a brilliant flash and blast which were reported to have been observed as far away as Gallup, 235 miles northwest.

Col. William O. Eareckson, Alamogordo commandant, declared there was “no loss of life or injury to anyone, and that property damage outside of the explosives magazine itself was negligible.”

His statement said the magazine contained “a considerable amount of high explosives and pyrotechnics,” and that “weather conditions affecting the content of gas shells exploded by the blast” might make it desirable to evacuate temporarily a few civilians.

There is a civilian area on the reservation.

At Alamogordo, 10 miles from the base, Tom Charles said he knew of no damage there from the explosion.

At Silver City, 135 miles southwest, and at Gallup the blast rattled windows. The vivid flash preceding the concussion by several minutes was reported seen near Silver City, Gallup, and on highways around Albuquerque, 150 miles north.

“I saw a flash of fire followed by a violent explosion and smoke,” reported Ranger Ray Smith on duty on the Lookout Mountain tower, near Beaverhead, northwest of Silver City.

He said there were two other smaller explosions, occurring at 5:30 a.m. He said he had no explanation for the blasts.

From Gallup came reports that two explosions rattled windows there this morning and woke a number of persons at 5:45 a.m.

An explosion heard near Socorro “lighted up the sky like the sun,” reported Joe Willis, Socorro theater operator.
of Socorro, blind student at the University of New Mexico, being driven to Albuquerque by her brother-in-law, Lieutenant Joe Wills, asked, "What's that?"

The blast measuring devices performed well, but the gamma ray measuring devices were overloaded. The higher gamma radiation fogged the motion picture films slightly and ruined the measurements of detonator simultaneity. Few neutron detectors survived the blast. Seven of the gold foils were recovered. No gauges with 200 ft of ground zero survived. The seismographs detected a tremor at the North Shelter and at San Antonio 28 mi away. The yield and size of the fire ball prompted scientists to specify the height of the Hiroshima and Nagasaki bombs at 1,850 ft (Hoddeson et al. 1993). According to Bainbridge, 1% of the fission products were left in the crater and its vicinity (Bainbridge 1976). Due to the presence of dust around ground zero “a large region of the countryside was contaminated by fission products.” This is discussed in more detail in a LASL report (Hirschfelder et al. 1945).

Because of the storm conditions on the morning of the 16th, Oppenheimer asked Waldman and Alvarez not to fly over ground zero to drop the gauges that would radio data back to the B-29s because the flight would be too dangerous (Hoddeson et al. 1993).

**Local Conditions**

Fig. 10-14 shows an aerial photograph of the area around ground zero at 28 h after the test. The blackened area shows the radius of intense heat that burned off all the vegetation. The blast effect in this area and resulting updraft of hot gases removed a thin layer of soil and burned debris from the blast area.

![Aerial view of the Trinity ground zero (center) at 28 h after the shot. The circle to the lower right is from the 100-Ton test, with its detonation point exactly 1 mi distant.](image)
Measurement and Management of Off-site Consequences

While not much was said publicly about measurements of off-site fallout from the Trinity test for years after the shot, advance planning and preparation did take place before the test to establish the ability to measure off-site radioactivity and promote public safety to the extent allowed during war time, when many other objectives were competing.

Competing Priorities for Secrecy, Security, Safety, and Avoidance of Litigation

Writing 25 y after the Trinity test, General Groves described what had been six immediate military requirements for adequate Project Trinity security (Hacker 1987). While Groves’ recollections might have reflected 1970 as well as 1945 views, the list of requirements for security is informative:

- Barring strangers from the test site;
- Preventing harm to project members;
- Reducing chances that outsiders could learn of the explosion;
- Safeguarding the public from fallout;
- Planning for emergency evacuation; and
- Forestalling any national press reports that might alert Japan.

Testing an atomic bomb on American soil, no matter how remote the site, clearly threatened the secret of the atomic bomb project— the most violent man-made explosion in history could hardly pass unseen. It was important that the Japanese not be alerted, and elaborate public safety precautions seemed likely only make the event more noticeable (Hacker 1987). But fortunately, it was thought, to some degree the same measures that kept Trinity safe from prying eyes could also help keep the public safe from the test and testers safe from lawsuits (Hacker 1987).

When general Groves visited Los Alamos in April 1945 for a briefing on Trinity plans, his first questions were about legal matters (Hacker 1987). He was concerned about damage or harm from earth shock, air blast, and toxic effects, and felt that valid records would help secure the army against damage claims. This is why, for example, 20 government agents were stationed in towns up to 100 miles from ground zero on shot day, equipped with recording barographs, seismographs, and recording radiation meters to measure remote shock, blast, and radiation (Hoffman 1947, Bainbridge 1976, Hacker 1987).

Until just weeks before the test, fallout simply appeared to be a minor problem. Los Alamos “plans to send out radio equipped cars provided with instruments for measuring alpha particle and gamma ray intensities in outlying areas” met Groves’ approval (Hacker 1987). “On the basis of these measurements, evacuation of inhabitants could be carried out if necessary.” Groves dismissed any thoughts of advance
warning to nearby ranchers and townsfolk, because “the danger seemed modest given the proper weather” (Hacker 1987). Keeping the secret forced some compromises with safety (Stannard 1988).

Shortly before the field test, updated calculations provided indication that fallout could be more substantial and widespread than originally thought (Hacker 1987, Stannard 1988). While there was considerable discussion regarding whether assumptions on which those calculations were based were overly pessimistic, the fallout calculations completed shortly before June 23, 1945, provided predictions that were sobering, and establishment of monitoring and evacuation plans seemed more prudent (Hacker 1987).

Figure 10-15 shows the locations of ranches, farms, towns, camps, and towns within approximately 40 miles of Trinity ground zero that are labeled on USGS 1:250,000 maps issued in 1954.

General Groves and the Manhattan Project’s Medical Director, Stafford Warren, are said to have known that the Army was not eager to pursue too diligently the possibilities of widespread fallout (Lamont 1965). The specter of endless lawsuits haunted the military, and most of the authorities simply wanted to put the whole test and its aftereffects out of sight and mind (Lamont 1965).

**Potential Pathways of Public Exposure**

Members of the public could have been exposed to radiation and radioactive materials from the Trinity event by a number of pathways, including:

1. Direct, prompt radiation from the blast itself
2. Direct, external irradiation from the cloud passing overhead or near by
3. Direct, external irradiation from being immersed in the cloud
4. Direct, external irradiation from contamination deposited on the ground
5. Direct, external irradiation from contamination deposited on the skin, hair, or clothing
6. Internal dose from inhalation of airborne contamination
7. Internal dose from inhalation of resuspended fallout particles
8. Internal dose from ingestion of contaminated food products

Initial radiation from fission and other processes in the explosion ceased in less than a minute, as delayed neutrons lasted only seconds; radiation from the fireball, although substantial, decreased as the square of distance and was further attenuated by air. Ten thousand feet from ground zero, well within site boundaries, radiation was too low to detect (Hacker 1987).
Fig. 10-15. Locations of ranches, farms, camps, and towns within about 40 mi of Trinity Site ground zero based on USGS 1:250,000 maps issued in 1954. Circles are at radii of 10, 20, and 30 mi.

Pathway 1 was apparently relatively insignificant to members of the public. Had it been significant, it would have shown up on the “remote sentinel robot ionization chambers” that spotted the main access roads at distances between 400 and 10,000 yd (Hoffman 1947, Hacker 1987) and the recording gamma meters that were stationed in local towns.
The post-shot radiological monitoring program conducted by Los Alamos scientists with the assistance of military personnel addressed, to the extent possible with the equipment available at the time, pathways 2, 3, and 4 dealing with direct exposure from radioactivity in the cloud or deposited on the ground. This was accomplished by the collection of data by field monitoring crews, which were analyzed and reported in documents assembled by Hoffman and others.

The post-shot radiological monitoring program, however, did not focus on assessment of pathways 5 through 8. No monitoring for contamination on the bodies of members of the public was performed (such as frisking or collection of wipe or wash samples). This pathway was found to be important for livestock, because they stay mostly outdoors, do not wear clothes, and do not bathe. It was reported that cattle that grazed on Chupadera mesa suffered local beta burns and temporary loss of dorsal hair (Hempelmann 1947, Hacker 1987, Stannard 1988). Patches of hair grew back discolored. The Army bought 75 head in all from ranchers; the 17 most significantly marked were kept at Los Alamos, while the rest were shipped to Oak Ridge for long term observation. It was estimated that the doses required to produce such effects were between 4,000 and 50,000 R, most likely around 20,000 R (Hacker 1987).

While there is documentation that samples of airborne particles were taken using ten Filter Queen air samplers (modified vacuum cleaners), and soil samples were reportedly taken using large-mouthed jars provided to monitoring crew members (Hoffman 1947), we have located no analyses of subsequent radiometric or radiochemical analyses of these samples, nor have we located risk assessments that address exposures to Trinity workers or to members of the public from internally deposited radioactivity following inhalation or ingestion of radioactivity from the Trinity blast.

**Dose Limits and Action Levels for Public Evacuation**

The recovery of data from the Trinity test took precedence over general safety standards (Hacker 1987). The 0.1 R d⁻¹ standard for workers in day to day operations at Los Alamos was replaced for Trinity by a statement that “no person should (of his own will) receive more than five (5) r at one exposure” (Hacker 1987). When pressed to decide how high of a radiation exposure to call safe for those with no part in, or knowledge of, the Trinity test (that is, members of the public), Hempelmann and Nolan assured Bainbridge that a total dose of 68 R spread over two weeks “would certainly not result in permanent injury to a person with no previous exposure . . . It would probably not even cause radiation sickness. A normal person could probably stand two to three times this amount without sustaining permanent bodily damage. Fatalities would not result unless ten or more times this dose were delivered” (Hacker 1987, Stannard 1988). Concern focused on immediate hazards, as within the health physics community “the thinking had not yet focused on possible long-term effects” (Stannard 1988). It was clear that evacuation would require an “extreme emergency” (Hacker 1987). Stafford Warren stated that he would begin to worry only if peak exposure rates reached 10 R h⁻¹, and said that the best approach would be to take
“measurements for several hours and consider evacuation if total dose reached final total of 60-100 r” (Hacker 1987).

Two days before the test, Warren and Hempelmann agreed to “set the upper limit of integrated gamma ray dose for the entire body over a period of two weeks (336 hours) as 75 roentgens” and also agreed on an “upper safe limit of radiation … [of] 15 r/hr at peak of curve” (Hacker 1987).

**Off-Site Monitoring Team Staffing and Positioning**

Four two-man, off-site monitoring teams and one five-man team supervised by the chief off-site monitor constituted the off-site monitoring crew led by Joseph Hoffman (Fig. 10-16). The teams were manned as follows, with initial placement as indicated (Hoffman 1947, Maag and Rohrer 1982):

- Alfred Anderson was with Julian Bernacci at Nogal, NM (about 55 mi ESE)
- Joel Greene was with Charles Nally at Roswell, NM (about 110 mi ESE)
- Carl Hornberger was with Richard Foley at Fort Sumner (about 140 mi NE)
- Robert Leonard was with William McElwreath at Socorro, NM (about 30 mi NW)
- Wright Langham, Phillip Levine, John Magee, Joseph Hirschfelder, and Joseph Hoffman (the chief monitor) were at Guard Gate 2.

The five-man team remained at Guard Gate 2 to assist in evacuation of nearby residents if the cloud from the shot drifted toward the northwest. These residents, specifically the Fite Ranch house and the homes in the town of Tokay, were roughly 15 and 20 mi northwest of ground zero, respectively (Maag and Rohrer 1982). From Guard Gate 2, those monitors could also be dispatched toward Carthage, Bingham, Claunch (about 50 mi NE), and Carrizozo.

![Fig. 10-16. Recovery team and radiation monitoring crew members after the Trinity blast](image)
Equipment Used for Off-Site Monitoring

Each off-site monitoring team was provided with the following equipment (Hoffman 1947):

- A methane filled proportional counter for detecting alpha particle radiation in the presence of beta and gamma radiation.
- A Victoreen Model 247 portable gamma ray survey meter with three ranges.
- A Hallicrafter Model 5 portable Geiger-Mueller survey meter for gamma radiation and mixtures of gamma and beta.
- Large-mouthed bottles for collecting soil samples.
- A map showing names and locations of residents within a radius of 40 mi of ground zero.

Landsverk and Wollan quartz-fiber electrometers (“L & W meters”) were also used, at least at Searchlight Station L-8, as were “meters obtained from R. Watts,” also known as Watts-type meters (Blair et al. 1945b, Hacker 1987). All off-site monitoring teams were intended to be in radio or telephone contact with personnel at Base Camp, but communications were problematic and information could not always be shared (Hoffman 1947, Lamont 1965, Maag and Rohrer 1982).

In addition to the instruments carried in automobiles, the following stationary equipment was used (Hoffman 1947):

- The three shelters (North, South, and West) were equipped with an alpha meter, a beta-gamma GM meter, and a survey meter.
- At the Base Camp, a Filter Queen airborne particulate sampler, and a GM recording meter were used.
- At the towns of Tularosa, Hot Springs, San Antonio, and Carrizozo, a Filter Queen, a recording beta-gamma meter, and a seismograph were set up.

Where Off-Site Monitoring Teams Traveled

Based on observed surface winds, it was thought that contamination was blowing in a line toward the northwest from ground zero during the first half hour after the shot. As a result, an early attempt was made to monitor around Fite’s Farm just past Guard Gate 2 (see Fig. 10-3). A Military Police officer refused to allow the monitoring team to enter that area, however, until permission was received from Base Camp. That permission came after it was thought that the cloud had passed, so attention was diverted elsewhere. Around 7:11 am, a monitoring team found detectable gamma radiation 19 mi from ground zero in the direction of Socorro (toward the northwest) (Hoffman 1947).

After the path of the cloud appeared to shift toward the northeast, monitors focused on areas along, or near, Route 380 past Carthage and between Bingham and Carrizozo (see Fig. 10-12). Monitoring teams
visited Adobe and White Store to the east along Route 380, and some traveled all the way to Carrizozo. Teams traveled north from Bingham on Road 146 to monitor ranches in that area, such as the Coker, Lucero, and Sedillo ranches. Just east of Bingham, the highest levels of elevated radioactivity were found around Searchlight Station L-8 and rugged areas to its southeast. About 2 mi east of the 146/161 junction, Road 146 runs through a steep gorge. The highest exposure rates were found there, which led to it being called “Hot Canyon” (see Fig. 10-12 and Fig. 10-17). Hoffman wrote “since the canyon was hot, extensive measurements could not be made there on account of instrument contamination.” (Hoffman 1947)

Puzzled by the high readings reported from Hot Canyon, Drs. Hempelmann and Friedell went to the area on July 17, the day after the shot, and discovered an adobe house hidden from the road, about a mile east of where the highest readings had been taken (Hacker 1987). An elderly couple lived there with a young grandson, several dogs, and assorted livestock (Hoffman 1947, Hacker 1987). The Ratliff ranch had been overlooked by the Army, and it was not on the copies of “Palmer’s map of inhabited localities” that monitoring crews were given. A second ranch unknown to the army was discovered later. As it turned out, a couple with the last name of Wilson lived near the Ratliffs, and early reports confused the two residences (Hemplemann 1947, Hoffman 1947, Hacker 1987).

While there is no record of what the exposure rates were at the Ratliff ranch on shot day, since the exposure rates there on the 17th, the doctors decided, were not high enough to warrant “hasty evacuation” (Hacker 1987). As mentioned earlier, rancher M. C. Ratliff said that “the ground immediately after the shot appeared covered with light snow,” adding that for several days afterward, especially at dawn and dusk, “the ground and fence posts had the appearance . . . of being frosted” (Hemplemann 1947, Hacker 1987).

Fig. 10-17. USGS Topographic map excerpt showing the area around the Ratliff Ranch (Broken Back Crater, N. Mex., 15-min.series, 1948. Contour interval = 25 ft)
Results of Off-Site Monitoring

Results of the off-site monitoring conducted by 44 individuals after the Trinity test are documented in handwritten notes, typed transcripts of these notes, and in summary forms (NTA 1946, Hempelmann 1947, Hoffman 1947, Lamont 1965, Maag and Rohrer 1982, Quinn 1987). Table 10-1 contains a summary of field team monitoring results recorded on 16-17 July 1945 that reached intensities of 100 mR h⁻¹ or higher. After the trajectory of the cloud shifted toward the northeast, monitors focused mostly on areas along, or near, U. S. Route 380 to the east of Carthage and between Bingham and Carrizozo. Measured exposure rates first reached 100 mR h⁻¹ at Searchlight Station L-8 around 7:30 a.m. Measurements in Bingham (30 km northeast of ground zero) reached 1.5 R h⁻¹ by 8:25 a.m. and peaked at 3.3 R h⁻¹ at 8:49 a.m. Gamma radiation levels in Adobe (5.4 km southeast of Bingham) were 6.5 R h⁻¹ at 8:49 a.m. and fell to 1.6 R h⁻¹ by 10:18 a.m. About 3 km farther southeast, in White Store, the highest recorded result was 3 R h⁻¹ at 10:30 a.m.

The highest gamma intensities were found in the “Hot Canyon” area. Monitoring in the area of the canyon found gamma intensities up to “the vicinity of 20 R/hr” at 8:30 a.m. that dropped off to 6.0 R h⁻¹ by 1:30 p.m. and 3.8 R h⁻¹ by 1:57 p.m. (Hoffman 1946, NTA 1946, Hoffman 1947). Teams traveled north from the Bingham/L-8 area on Route 146 to monitor the Coker, Lucero, and Sedillo ranches. Gamma radiation above background was measured in the school yard at Vaughn [96 mi to the northeast of ground zero] 7.6 h after the blast, indicating that the cloud traveled no slower than 12.9 mi h⁻¹ (Hoffman 1947). On the day after the blast, exposure rates as high as 300 mR h⁻¹ were measured near Corona and Claunch, while exposure rates from 3 to 11 mi north of Vaughn ranged between 0.1 R h⁻¹ and “>> 0.1” R h⁻¹ shortly after 3:00 p.m.. At no location greater than 10 mi distant from ground zero was an alpha particle count obtained that could easily be distinguished from background with the instruments the monitors were using (Hoffman 1947).

At about 3:30 p.m. on the day of the blast, the recording G-M counter at Carrizozo began to track upward. About 15 min later, that meter went off scale on its least sensitive scale, and the monitor notified Base Camp by telephone (Hoffman 1946, Lamont 1965). Full scale on that recorder corresponded to 10,000 counts per minute (“cpm”) (Hoffman 1947). After 1 h, the gamma intensity at Carrizozo was measurable on a single-scale Victoreen survey meter that indicated an intensity of 1.5 mR h⁻¹ until the following morning (Hoffman 1946, NTA 1946). By 10:00 a.m., the G-M counter reading had decreased to 3,000 cpm.
Table 10-1. Exposure rates 0.1 R h⁻¹ or greater measured 16-17 July 1945 near Trinity Site

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>Off-Site Location</th>
<th>Recorded Exposure Rate (R h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30 a.m.</td>
<td>Searchlight Station L-8</td>
<td>0.1</td>
</tr>
<tr>
<td>7:45 a.m.</td>
<td>11-16 km W of Carthage on US 380</td>
<td>0.2</td>
</tr>
<tr>
<td>8:00 a.m.</td>
<td>Searchlight Station L-8</td>
<td>0.5</td>
</tr>
<tr>
<td>8:25 a.m.</td>
<td>Bingham</td>
<td>1.5</td>
</tr>
<tr>
<td>8:25 to 9:15 a.m.</td>
<td>Searchlight Station L-8</td>
<td>2.0</td>
</tr>
<tr>
<td>8:29 a.m.</td>
<td>0.4 km W of Hansenburg Ranch</td>
<td>0.25</td>
</tr>
<tr>
<td>8:30 a.m.</td>
<td>Searchlight Station L-8</td>
<td>0.1</td>
</tr>
<tr>
<td>8:30 a.m.</td>
<td>5.6 km SE of L-8 (&quot;Hot Canyon&quot; area)</td>
<td>&quot;vicinity of 20&quot;</td>
</tr>
<tr>
<td>8:35 a.m.</td>
<td>Searchlight Station L-8</td>
<td>2.0</td>
</tr>
<tr>
<td>8:42 a.m.</td>
<td>1.6 km E of Bingham along US 380</td>
<td>1.0</td>
</tr>
<tr>
<td>8:45 a.m.</td>
<td>3.3 km W of Bingham</td>
<td>1.6</td>
</tr>
<tr>
<td>8:45 a.m.</td>
<td>&quot;Cooler spot&quot; retreated to from 8:30 spot in canyon</td>
<td>15</td>
</tr>
<tr>
<td>8:46 a.m.</td>
<td>3.2 km E of Bingham along US 380</td>
<td>2.2</td>
</tr>
<tr>
<td>8:47 to 8:56 a.m.</td>
<td>From Searchlight Station L-8 to Hot Canyon</td>
<td>1.2 to 14.5</td>
</tr>
<tr>
<td>8:49 a.m.</td>
<td>Bingham</td>
<td>3.3</td>
</tr>
<tr>
<td>8:49 a.m.</td>
<td>6.4 km E of Bingham along US 380 (Adobe)</td>
<td>6.5</td>
</tr>
<tr>
<td>8:50 a.m.</td>
<td>4.8 km E of Searchlight Station L-8</td>
<td>15.0</td>
</tr>
<tr>
<td>8:50 a.m.</td>
<td>Hansenburg Ranch</td>
<td>0.45</td>
</tr>
<tr>
<td>8:56 to 9:40 a.m.</td>
<td>From Hot Canyon to Searchlight Station L-8</td>
<td>1.5 to 6.5</td>
</tr>
<tr>
<td>9:05 a.m.</td>
<td>4.8 E of Searchlight Station L-8</td>
<td>15.0</td>
</tr>
<tr>
<td>9:30 a.m.</td>
<td>Searchlight Station L-8</td>
<td>1.0</td>
</tr>
<tr>
<td>9:40 to 10:15 a.m.</td>
<td>N from L-8 to Rte. 41 cutoff to Maxwell Ranch</td>
<td>1.1 to 6.0</td>
</tr>
<tr>
<td>10:00 a.m.</td>
<td>0.8 km S of Hansenburg Ranch</td>
<td>0.8</td>
</tr>
<tr>
<td>10:15 to 10:50 a.m.</td>
<td>From Rte. 41 near Maxwell Ranch back to L-8</td>
<td>1.5 to 4.8</td>
</tr>
<tr>
<td>10:18 a.m.</td>
<td>6.4 km E of Bingham (Adobe)</td>
<td>1.6</td>
</tr>
<tr>
<td>10:22 a.m.</td>
<td>6.4 km E of Bingham along US 380</td>
<td>1.5</td>
</tr>
<tr>
<td>10:25 a.m.</td>
<td>9.7 km E of Bingham along US 380</td>
<td>3.0</td>
</tr>
<tr>
<td>10:25 a.m.</td>
<td>White Store</td>
<td>2.5</td>
</tr>
<tr>
<td>10:30 a.m.</td>
<td>White Store</td>
<td>3.0</td>
</tr>
<tr>
<td>10:30 to 11:30 a.m.</td>
<td>White Store</td>
<td>2.0</td>
</tr>
<tr>
<td>10:33 a.m.</td>
<td>8 km N of Bingham</td>
<td>0.5</td>
</tr>
<tr>
<td>10:40 a.m.</td>
<td>Just W of White Store on US 380</td>
<td>3.3</td>
</tr>
<tr>
<td>10:45 a.m.</td>
<td>8 km N of Bingham and 0.25 mi E (Wrye Ranch)</td>
<td>0.2</td>
</tr>
<tr>
<td>10:49 a.m.</td>
<td>Just W of White Store on US 380</td>
<td>3.2</td>
</tr>
<tr>
<td>10:54 a.m.</td>
<td>14 km E of Bingham along US 380</td>
<td>0.7</td>
</tr>
<tr>
<td>10:55 a.m.</td>
<td>0.8 km E of Bingham</td>
<td>1.3</td>
</tr>
<tr>
<td>11:00 a.m.</td>
<td>Bingham</td>
<td>1.55</td>
</tr>
<tr>
<td>11:00 a.m.</td>
<td>8 km E of Bingham</td>
<td>2.5</td>
</tr>
<tr>
<td>11:00 a.m.</td>
<td>6.4 km E of Bingham</td>
<td>2.0</td>
</tr>
<tr>
<td>11:00 a.m.</td>
<td>Bingham</td>
<td>0.5</td>
</tr>
<tr>
<td>11:30 a.m.</td>
<td>Bingham</td>
<td>1.7</td>
</tr>
<tr>
<td>11:40 a.m.</td>
<td>Bingham</td>
<td>0.65</td>
</tr>
<tr>
<td>11:50 a.m.</td>
<td>6.4 km W of Bingham</td>
<td>0.25</td>
</tr>
<tr>
<td>11:58 a.m.</td>
<td>1.6 km W of Bingham</td>
<td>0.25</td>
</tr>
<tr>
<td>12:00 p.m.</td>
<td>Bingham</td>
<td>0.25</td>
</tr>
<tr>
<td>12:02 p.m.</td>
<td>1.6 km E of Bingham along US 380</td>
<td>0.15</td>
</tr>
<tr>
<td>Date and Time</td>
<td>Off-Site Location</td>
<td>As recorded&lt;sup&gt;b&lt;/sup&gt; (R h&lt;sup&gt;-1&lt;/sup&gt;)</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Monday, July 16, 1945, continued (after blast at 5:30 a.m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:00 p.m.</td>
<td>Bingham</td>
<td>1.5</td>
</tr>
<tr>
<td>1:27 p.m.</td>
<td>6.4 km E of Bingham along US 380</td>
<td>0.95</td>
</tr>
<tr>
<td>1:28 p.m.</td>
<td>0.2 km E of White Store on US 380</td>
<td>2.8</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>White Store</td>
<td>0.15</td>
</tr>
<tr>
<td>1:30 p.m.</td>
<td>&quot;Hot Canyon&quot;</td>
<td>6.0</td>
</tr>
<tr>
<td>1:35 to 1:57 p.m.</td>
<td>1.6 to 4.8 km E of Searchlight Station L-8</td>
<td>0.5 to 3.8</td>
</tr>
<tr>
<td>1:47 p.m.</td>
<td>11 km E of Bingham along US 380</td>
<td>1.6</td>
</tr>
<tr>
<td>1:54 p.m.</td>
<td>2.4 km E of Bingham on US 380</td>
<td>1.5</td>
</tr>
<tr>
<td>2:00 p.m.</td>
<td>At Bingham</td>
<td>0.5</td>
</tr>
<tr>
<td>2:00 p.m.</td>
<td>Rte. 146 just E of junction with Rte. 161</td>
<td>6.0</td>
</tr>
<tr>
<td>2:13 p.m.</td>
<td>8 km N on Rte. 146 from junction Rte. 161</td>
<td>2</td>
</tr>
<tr>
<td>2:30 p.m.</td>
<td>6.4 km W of Bingham along US 380</td>
<td>0.16</td>
</tr>
<tr>
<td>2:30 p.m.</td>
<td>0.27 km E of Sedillo</td>
<td>0.27</td>
</tr>
<tr>
<td>2:30 p.m.</td>
<td>Coker Ranch</td>
<td>0.22</td>
</tr>
<tr>
<td>2:40 p.m.</td>
<td>9.7 km NE of Bingham on Rte. 161</td>
<td>3.5</td>
</tr>
<tr>
<td>2:46 p.m.</td>
<td>13 km NE of Bingham on Rte. 161</td>
<td>7</td>
</tr>
<tr>
<td>2:47 p.m.</td>
<td>0.27 km W of Coker Ranch</td>
<td>0.26</td>
</tr>
<tr>
<td>2:50 p.m.</td>
<td>Lucero Ranch</td>
<td>0.24</td>
</tr>
<tr>
<td>3:00 p.m.</td>
<td>S side of Rte. 161 near junction with Rte. 146</td>
<td>7.0</td>
</tr>
<tr>
<td>3:42 to 3:50 p.m.</td>
<td>11 to 21 km W of Vaughn on Rte. 60</td>
<td>&quot;off scale&quot;</td>
</tr>
<tr>
<td>4:30 p.m.</td>
<td>Cedarvale</td>
<td>0.11</td>
</tr>
<tr>
<td>4:48 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.6 km W of Cedarvale on Rte. 42</td>
<td>0.11</td>
</tr>
<tr>
<td>4:53 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4 km mi W of Cedarvale on Rte. 42</td>
<td>0.15</td>
</tr>
<tr>
<td>4:59 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.2 km mi W of Cedarvale on Rte. 42</td>
<td>0.13</td>
</tr>
<tr>
<td>7:01 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.6 km E of Willard on Rte. 60</td>
<td>0.11</td>
</tr>
<tr>
<td>10:30 p.m.</td>
<td>White Store</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Tuesday, July 17, 1945 (the day after the blast)

<table>
<thead>
<tr>
<th>Date and Time</th>
<th>Off-Site Location</th>
<th>As recorded&lt;sup&gt;b&lt;/sup&gt; (R h&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:39 to 11:54 a.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>25 to 39 km W of Corona toward Claunch</td>
<td>0.10 to 0.15</td>
</tr>
<tr>
<td>12:01 to 12:10 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8 to 0 km E of Claunch on Rte. 42</td>
<td>0.11 to 0.18</td>
</tr>
<tr>
<td>12:14 to 12:21 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.2 to 9.7 km S of Claunch</td>
<td>0.11 to 0.19</td>
</tr>
<tr>
<td>12:26 to 12:54 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>14 to 40 km S of Claunch</td>
<td>0.11 to 0.30</td>
</tr>
<tr>
<td>1:05 to 1:09 p.m.&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.7 to 5.6 km N of Bingham</td>
<td>0.11 to 0.18</td>
</tr>
<tr>
<td>2:00 p.m.</td>
<td>Bingham</td>
<td>0.10</td>
</tr>
<tr>
<td>3:00 p.m.</td>
<td>White Store</td>
<td>0.10</td>
</tr>
<tr>
<td>3:10 to 3:30 p.m.</td>
<td>4.8 to 18 km N of Vaughn on Rte. 285</td>
<td>0.1 to &quot;&gt; &gt; 0.1&quot;</td>
</tr>
<tr>
<td>3:30 p.m.</td>
<td>8 km N of Bingham on Rte. 41 toward Monte Prieto</td>
<td>0.19</td>
</tr>
<tr>
<td>3:30 to 4:02 p.m.</td>
<td>1.6 to 26 km N of Vaughn toward Encino</td>
<td>&gt; 0.1</td>
</tr>
<tr>
<td>4:30 to 6:00 p.m.</td>
<td>24-40 km N of Bingham on Rte. 41 to Monte Prieto</td>
<td>0.19 to 0.30</td>
</tr>
<tr>
<td>5:50 to 6:36 p.m.</td>
<td>42-47 km E of Broadway (Trinity access) on US 380</td>
<td>0.11 to 0.5</td>
</tr>
<tr>
<td>6:30 p.m.</td>
<td>&quot;Hot Canyon&quot;</td>
<td>0.5</td>
</tr>
<tr>
<td>7:30 to 8:00 p.m.</td>
<td>8 to 0 km N of Claunch on road from Gran Quivira</td>
<td>0.10 to 0.19</td>
</tr>
</tbody>
</table>

<sup>c</sup> Measurement time estimated based on odometer readings and times specified for nearby measurements.
Evacuation Policy and Decision Making

Shortly before the Trinity blast, surface winds were blowing toward the North Shelter (Hoffman 1946). About 12 min after the shot, a “Watts’ meter” at North Shelter indicated a rapid increase in radiation intensity because of a faulty zero setting (Hoffman 1946, Hoffman 1947, Maag and Rohrer 1982). When a remote ionization “sentinel” indicated a rapid increase in radiation, immediate evacuation of all personnel at that shelter was advised. Some personnel evacuated with such urgency that their cars were riding their hubs when they reached Base Camp 25 km south (Lamont 1965). While film badges worn by personnel in the shelter showed no exposures over 100 mR, the subsequent detection of radioactivity in the area was seen as evidence that part of the cloud had passed over but deposited little radioactivity on the ground (Maag and Rohrer 1982, Hacker 1987). Gamma intensities of 10 to 20 mR h⁻¹ were measured around North Shelter 2 h after evacuation (Bainbridge 1976).

Most of the Army evacuation detachment and five radiological safety monitors that were stationed near Guard Post 2 northwest of ground zero remained there until a platoon was sent to Bingham while monitors surveyed that area (Maag and Rohrer 1982). When the chief monitor learned of the exposure rates as high as 3.3 R h⁻¹ at Bingham, Adobe, and White Store, he projected that total exposures in that region might approach the allowed limit. The exposure rate of 6.5 R h⁻¹ taken 4 mi east of Bingham at 8:49 a.m. was judged to be “getting close to the evacuation limit.” A message was sent by courier to Base Camp that integrated gamma doses had been projected at 90% of tolerance (Hoffman 1947, Hacker 1987). Medical experts were summoned, exposure rates decreased as the dust dispersed and settled, and no evacuation of the area was conducted. The evacuation detachment was dismissed at 1:00 p.m. on shot day “when it became evident that evacuations would not be undertaken” (Maag and Rohrer 1982).

After the recording beta-gamma meter at Carrizozo went off scale around 4:20 p.m. on test day, scientists and military officials considered whether Carrizozo should be evacuated. They held off taking that action for some additional monitoring and within an hour, fallout readings dropped, it was concluded that the radioactive cloud had passed over, and no evacuation was ordered (Hoffman 1946, NTA 1946, Lamont 1965, Hacker 1987). As the cloud drifted beyond the 15 mi radius, such as north of Bingham and around Carrizozo, monitors often overreached the limits of radio communication with Base Camp (Bainbridge 1976). As officials at Base Camp were advising Washington that the danger from radioactive fallout was diminishing, they were out of communication with monitors that were measuring fallout in areas as distant as 112 mi to the north (Lamont 1965).

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Historical records indicate that pressures to maintain secrecy and avoid legal claims led to decisions that would not likely have been made in later tests. Even though exposure rates, total exposures, and alpha count rates exceeding pre-established limits were measured and projected; a “cover story” was in place that would have provided an avenue for relatively inconspicuous evacuation of selected residents; and evacuation personnel, vehicles, shelters, and supplies were on standby, no evacuations of members of the public were conducted.

In a July 31, 1945 War Department memorandum to Dr. Louis Hempelmann (reproduced in Hempelmann 1947), Lt. Daniel Dailey of the Corps of Engineers refers to requests from Hempelmann that “the health of persons in a certain house near Bingham, N.M. be discretely investigated.” Over the 2 y following Trinity, at least seven visits were made to the Ratliff ranch by LANL and MED medical personnel, health physicists, and Army Intelligence agents, “under suitable pretext,” to check on the visible condition of the residents (Hempelmann 1947, Hoffman 1947). Even after the atomic bombs were dropped, the atomic bomb project and the roles of Los Alamos and Trinity were described publicly, and the need for secrecy diminished, the reasons for these visits were not disclosed to the residents.

Monitoring practices and protective action decision processes after the Trinity blast were clearly focused on the immediate hazards of radiation exposure. In the health physics community of the MED “the thinking had not yet focused on possible long-term effects” (Pierre 1972, Hacker 1987, Stannard 1988). Medical surveillance of ranchers was limited to casual observation of external appearances and veiled, nonspecific questioning regarding any health complaints. Although concern was voiced for the health status of at least one family, no evidence was found of steps being taken to reduce exposures to ranchers who continued to live in the fallout zone after July 1945. This was in spite of the fact that soil and the grasses eaten by grazing livestock were particularly radioactive in the area of Hot Canyon. In retrospect, Hempelmann acknowledged that “a few people were probably overexposed, but they couldn’t prove it and we couldn’t prove it. So we just assumed we got away with it.” (Hempelmann and Henrickson 1986)

After the Trinity test, Los Alamos scientists estimated effective rates of decay and total (external) doses delivered for several public areas (Hoffman 1947). LASL scientists defined the “geometrical dose” as the integrated dose under the maximum exposure rate that preceded the steady decay (Hoffman 1947). The geometrical dose was seen to represent “high intensity, short duration dose” that “can be a severe health hazard because it is delivered in a short time interval.” The integrated dose used by Los Alamos scientists in 1945 did not include the area under the maximum, but corresponded to the “long, low intensity decay that follows [the maximum]” out to a point in time 14 d after the blast (Hoffman 1947). The maximum tolerable values of geometrical dose and integrated gamma ray dose for the entire body over a period of 14 d were 50 and 75 R, respectively (Hoffman 1947).
Table 10-2 shows the geometrical doses, integrated doses, and total doses (geometrical plus integrated) that were reported by Hoffman (1947) for Hot Canyon, White Store, and Bingham. Correction factors for shielding by house structures were based on measurements in Los Alamos (wooden frame) and Bingham (adobe) houses on 19 July and 17 August 1945, respectively (Hoffman 1947). Based on monitoring done on and beyond the day after the blast, Los Alamos scientists estimated doses at the Ratliff residence (Hempelmann 1947). For the first 14 d after the blast, the geometrical dose was estimated to be 15 R, the dose from the ground 32 R, and the total accumulated dose (waist high) 47 R– said to be a factor of 33 above the tolerance. Radioactivity at the nearby Wilson ranch was estimated to be 75% of that at the Ratliff ranch (Hempelmann 1947).

Table 10-2. External gamma ray exposure values calculated for several public areas after the Trinity test by Los Alamos scientists (Hoffman 1947)

<table>
<thead>
<tr>
<th>Location</th>
<th>“Geometrical Dose” (R)</th>
<th>“Integrated Dose” (R)</th>
<th>“Total Dose” after 14 d (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Canyon</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the ground</td>
<td>24</td>
<td>115</td>
<td>139</td>
</tr>
<tr>
<td>Corrected for house shielding</td>
<td>24</td>
<td>62</td>
<td>88</td>
</tr>
<tr>
<td>Corrected to torso level</td>
<td>15</td>
<td>41</td>
<td>56</td>
</tr>
<tr>
<td>Torso level, no house shielding</td>
<td>28</td>
<td>76</td>
<td>100</td>
</tr>
<tr>
<td><strong>White Store</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the ground</td>
<td>8.4</td>
<td>21.8</td>
<td>30.2</td>
</tr>
<tr>
<td>Corrected for house shielding</td>
<td>8.4</td>
<td>11.8</td>
<td>20.2</td>
</tr>
<tr>
<td>Corrected to torso level</td>
<td>4.2</td>
<td>5.8</td>
<td>10</td>
</tr>
<tr>
<td>Torso level, no house shielding</td>
<td>7.8</td>
<td>10.7</td>
<td>19</td>
</tr>
<tr>
<td><strong>Bingham</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On the ground</td>
<td>3.3</td>
<td>24</td>
<td>27.3</td>
</tr>
<tr>
<td>Corrected for house shielding</td>
<td>3.3</td>
<td>0.3</td>
<td>17.3</td>
</tr>
<tr>
<td>Corrected to torso level</td>
<td>1.7</td>
<td>6.5</td>
<td>8.1</td>
</tr>
<tr>
<td>Torso level, no house shielding</td>
<td>3.1</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>

a Estimated at 10 cm above the ground surface.
b Gamma dose reduced by 46% to account for shielding by an adobe house.
c Dose at torso level estimated to 50% of the dose at 10 cm above ground level during the 2 weeks.
d “Corrected to torso level” values divided by 0.54 to estimate torso level with no house shielding.

Assessments of Trinity Fallout Performed by Others

Exposure rate contour lines based on the data collected by the town monitoring crews in 1945 based on modeling by the Weather Service Nuclear Support Office (Quinn 1987) and extended by Lawrence Livermore National laboratory (Cederwall and Peterson 1990) are presented in Figures 10-18 and 10-19. The lines in Fig. 10-18 that extend roughly east-west at five distances from ground zero indicate approximate locations of the edge of the cloud at times from 2 to 14 h after the shot. The extensions of the fallout contours in Fig. 10-19 show the contamination leaving New Mexico into Colorado and the northwest portion of Oklahoma.
**Fig. 10-18.** The 0.01, 0.1, 2, and 10 R h$^{-1}$ contours from the Trinity test at t + 1h, as analyzed by the Weather Service Nuclear Support Office (WSNSO, Quinn 1987). BGZ = ground zero.

**Fig. 10-19.** Extension of Trinity fallout pattern as exposure rate, mR h$^{-1}$ at t + 12 h, based on WSNSO analysis (Quinn 1987) extended (dotted lines) with LLNL modeling (Cederwall and Peterson 1990).
A source term for the Trinity event was calculated by scientists at Lawrence Livermore National Laboratory (Hicks 1985), and fallout patterns were reconstructed on behalf of the USDOE’s Off-Site Radiation Exposure and Review Project (ORERP) (Quinn 1987). Unlike for the nuclear explosions at the Nevada Test Site, doses have not been reconstructed for the Trinity event, due primarily to scarcity of data (Anspaugh 2000).

All evaluations of public exposures from the Trinity blast that have been published to date have been incomplete in that they have not reflected the internal doses that were received by residents from intakes of airborne radioactivity and contaminated water and foods. Some unique characteristics of the Trinity event amplified the significance of those omissions. Because the Gadget was detonated so close to the ground, members of the public lived less than 20 mi downwind and were not relocated, terrain features and wind patterns caused “hot spots” of radioactive fallout, and lifestyles of local ranchers led to intakes of radioactivity via consumption of water, milk, and homegrown vegetables, it appears that internal radiation doses could have posed significant health risks for individuals exposed after the blast.

**Gaps in Information about the Trinity Test**

In retrospect, pioneer health physicist J. Newell Stannard identified two main gaps in the description of Trinity event (Stannard 1988). The first deals with the characterization of residual plutonium, which was present due to the fact that the efficiency of the device was not 100 percent. The Trinity “Gadget” contained 6 kg of $^{239}$Pu as its sole fissile material (USDOE 2001). The 21 kt yield of the blast (USDOE 2000) corresponds, at $1.45 \times 10^{23}$ fissions per kt (Glasstone and Dolan 1977), to $3.05 \times 10^{24}$ atoms or 1.21 kg of $^{239}$Pu fissioned. That indicates that approximately 4.8 kg of $^{239}$Pu remained unfissioned and was dispersed in the environment. It was present in the crater and partly scattered around the environment in the fallout. Monitors did find some plutonium—it was not measured very carefully near shot time, but its presence was hinted at in the initial surveys (Stannard 1988). The instruments used by field monitoring teams were acknowledged to be incapable of measuring alpha contamination in the environment to the desired sensitivities (Hoffman 1947). A full-scale survey of the Trinity site was not conducted until three years later, by a group from the UCLA medical school.

The second gap is the lack of any measures for detection of internally deposited radionuclides, such as bioassay, nose swabs, etc. At the time, nose swab collection and analysis was the main technique at Los Alamos of monitoring for inhalation of radioactive material, including in D Building where the plutonium hemispheres for the Trinity device were manufactured (Hempelmann and Langham 1953). There certainly were instances of inhalation of airborne radioactivity by members of the public who were in the path of the Trinity cloud or were near deposited radioactivity that was resuspended, and water and food products were also contaminated. For example, the Ratliff home in Hot Canyon used its tin roof to collect...
water into a cistern that served as the family’s drinking water supply. This was a common practice in the area (Allen 2008). There was rain in the area the night after the shot, which means that deposited radioactivity was likely carried into their drinking water (Appendix II in Hoffman 1947).

**Some Lessons about Off-site Impacts Learned from the Trinity Test**

From the Trinity test, it was learned that detonating a nuclear explosive device close to the ground increases the radioactive fallout from the event. Detonating devices at higher elevations results in the dispersion of less radioactivity, while yielding more blast power. Based on experience with the Trinity event, and expanded upon in test series conducted in the Pacific during 1946 and 1948, the potential for exposure of workers and members of the public to fallout became known and appreciated (Anspaugh 2000).

It was also learned that “hot spots” are important phenomena when radioactive clouds disperse, and their occurrence can be influenced by local terrain features and air flow patterns.

The Trinity Site was judged to be too small for additional atomic tests to be conducted there. General Groves concluded that the Trinity test site “is too small for a repetition of a similar test of this magnitude except under very special conditions” (Hacker 1987). He proposed finding a larger site, “preferably with a radius of at least 150 miles without population” [compared to about 15 miles at Trinity] for any future test.

**Follow-Up Studies of Trinity Fallout**

After the Trinity blast, several monitoring teams continued through the remainder of 1945 to periodically traverse roads to the northeast of the site to measure and record exposure rates. Records of survey trips were found for excursions on 12 additional days in July, eight in August, two in November, and four in December (Hoffman 1946, NTA 1946, Hoffman 1947).

In August 1947, scientists from the University of California, working with Wright Langham from LANL, conducted a limited survey of a 26,000 ha (100 mi²) area near the Trinity Site (Overstreet et al. 1947). Between 1949 and 1978, teams from UCLA and the U.S. Environmental Protection Agency (USEPA) published reports of studies of larger zones of local Trinity fallout (Warren and Bellamy 1949, Bellamy et al. 1951, Gillicoly et al. 1951, Leitch 1951, Nishita et al. 1957, Douglas 1978). The earliest UCLA surveys were limited to beta-gamma measurements. Measurements of gross alpha radioactivity in airborne particles (assumed to be plutonium) were first reported in 1951, as were alpha measurements of chemically separated plutonium from plants and soil. The first of these studies to include isotopic analyses of plutonium in environmental media (soil and air) was published by Douglas (1978) for samples collected in 1973 and 1974, over 28 y after the detonation.
Characteristics of members of the public near the Trinity Site

Population, ethnicity, diet, housing, and lifestyle characteristics of residents near the Trinity test site around 1945 were described based on, except where noted otherwise, interviews of current residents and historians (Allen 2008) and information from reviewed documents. Based on interviews of local residents and historians, the typical ethnic compositions of ranchers, shepherders, and cowboys near the Trinity Site around 1945 were estimated to be as shown in Table 10-3. Both ranchers and people who lived in towns used the most readily available construction materials. As shown in Table 10-4, adobe was by the far the most common building material for homes and work places. Barn roofs were typically mud while home roofs were usually metal to facilitate water collection. In towns such as Carrizozo, most buildings were adobe, but homes made of wood frame construction and bricks were also present.

Table 10-3. Estimated distribution of ethnicities for residents near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

<table>
<thead>
<tr>
<th>Class of Persons</th>
<th>Anglo(^a)</th>
<th>Spanish</th>
<th>Native American</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranchers</td>
<td>90</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Sheepherders</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Cowboys</td>
<td>80</td>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

\(^a\)Non-Hispanic white persons

Table 10-4. Estimated distribution of construction types for buildings near the Trinity Site circa 1945 based on LAHDRA interviews (percentages)

<table>
<thead>
<tr>
<th>Building Type and Setting</th>
<th>Adobe</th>
<th>Wood</th>
<th>Stone</th>
<th>Brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranch homes</td>
<td>85</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Homes in towns</td>
<td>75</td>
<td>22</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ranch workplaces</td>
<td>80</td>
<td>15</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Workplaces in towns</td>
<td>75</td>
<td>23</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

If it was daylight, ranchers and their hired hands were typically outside working. Breakfast would typically be eaten while it was still dark so work could begin at first light. Meals would have been eaten inside. Since the Trinity test occurred during the summer, children would also have been outside during daylight hours either working or playing. While ranch wives spent the bulk of their time outdoors tending to laundry, gardening, or helping with the livestock, wives typically spent more time inside than men preparing meals, canning food, and processing milk.
Cattle and sheep were commonly raised by ranchers in the area, and each ranch typically had horses, chickens, and a garden. Some ranchers also had hogs for their personal use. The Ratliff ranch maintained a herd of 200 goats and some turkeys and donkeys (Hempelmann 1947, Hoffman 1947). A long-time resident of the area indicated that these goats were raised for their hair, not their milk. If drought caused lack of forage, livestock was sold.

Ranchers and their hired hands had similar diets. Ranchers in the area typically collected rain water off metal roofs into cisterns, like shown in Fig.10-20, as their source of drinking water. Local ground water contained excessive mineral content that made it unsuitable for human consumption, but it was used to water livestock. Beans and potatoes were grown in vegetable gardens, but were often supplemented with purchases made in town. Flour, sugar, and other staples were bought in town. Produce, including peas, root crops, squash, and corn, was grown in gardens. Moreover, some ranchers had fruit trees. Produce that was not eaten fresh was canned in glass jars, with the goal to put up enough to take the family through to the next harvest. The primary fresh meat sources were deer and chickens, which also provided eggs. If the ranchers ate any beef, it was most likely from the grown calf from their dairy cow. Essentially all ranchers had a dairy cow, and ranch wives processed the milk to make other dairy products used on the ranches.

**Fig. 10-20.** A system for collection of water off the roof of a residence on the Black Hills Ranch, formerly the Nalda Ranch, east-northeast of the Trinity Site. The cistern to the left, which was damaged by the Trinity blast then repaired, is still in use today.
The ranches near the Trinity Site did not have electricity until after the war, but most had an icebox. Ice was purchased in town and stored underground at the ranch houses. Some ranchers might have had butane-powered refrigerators or coal-oil-powered refrigerators and stoves. Town dwellers bought their groceries, including milk products, from grocery stores. Town residents had electricity and refrigerators, and water was piped to their homes. Ranchers and historians have little knowledge of local ranchers who drank goat milk, except for one man who reportedly purchased goat milk in Belen, New Mexico. There has been no specific evidence found that indicates that the Ratliff family drank, sold, or shared goat milk.

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Chapter 11: Beryllium Use at Los Alamos

Beryllium has been used at Los Alamos since 1943 in various operations related to nuclear reactors and weapons production, including machining, fabrication and testing of components. The discovery of beryllium in 1798 was credited to the French chemist Louis Nicolas Vauquelin upon formulation of beryllium hydroxide. Elemental beryllium, however, was not isolated prior to two independent experiments in 1828. Beryllium occurs naturally only as the $^9$Be isotope, although five additional isotopes are produced artificially, $^6$Be to $^{11}$Be (IPCS 1990).

Beryllium is the lightest of all solid and chemically-stable substances and has an unusually high melting point of 1287°C (HSDB 2005). The metal has a number of chemical properties in common with aluminum, including a very high affinity for oxygen. On exposure with air, a thin film of beryllium oxide forms on the surface of bare metal, providing the metal with high resistance to corrosion. This film also renders beryllium resistant to water and cold oxidizing acids (IPCS 1990).

Neutron emission upon alpha-bombardment is the most important of the nuclear physical properties associated with beryllium. Its low neutron absorption properties and its high-scattering cross-section distinguish beryllium as a suitable moderator and reflector of structural material in nuclear facilities. While most other metals absorb neutrons from the fission of nuclear fuel, beryllium atoms only reduce the energy of such neutrons and reflect them back into the fission zone (IPCS 1990).

Industrial Uses of Beryllium

Interest in and application of beryllium grew after the discovery in the 1920s that addition of only two percent beryllium to copper resulted in an alloy that was six times stronger than copper alone (IPCS 1990, Becker and Vigil 1999). Metallic beryllium was examined as a possible tamper material as early as 1943 in the U.S. nuclear weapons program. Enough beryllium had been accumulated at Los Alamos by May 1946 to allow for critical mass experiments (Hanson 1995). However, use of large quantities in the nuclear weapons program in the 1940s would have exhausted the entire U.S. supply of the metal. Beryllium was used as a substitute for gold or natural uranium reflectors in early atomic weapons, thereby saving much weight and money (Hanson 1995).

Beryllium metal did not become readily available to American industry until 1957. Since that time, beryllium use has been widespread as an additive to glass, ceramics and plastics; in camera shutters, submarine cable housings, and dental prostheses; and in beryllium-copper alloys in products such as golf
clubs, springs, pivots, and pinions. Beryllium is additionally used in the semiconductor, precision electronics, spacecraft, and missile manufacturing industries (IPCS 1990).

A timeline depicting events of importance regarding uses of beryllium in general and at AEC/DOE facilities, uses at Los Alamos, states of knowledge regarding health effects, and promulgation of guidelines and regulatory limits is presented in Table 11-1.

**Records Searches for Beryllium Information**

The project team has identified few reports written during the period of historical beryllium operations at LANL other than H-Division Progress Reports. Most of the early H-Division reports mention beryllium air sampling in specific LANL buildings, but no details regarding the associated beryllium operations are provided. Several documents were located in the LANL Records Center and Report Collection that provide summaries of historical monitoring activities associated with beryllium metal machining and firing site operations (Mitchell and Hyatt 1957, Becker and Vigil 1999). A Johns Hopkins report (JHSPH 1999) was recommended to the project team by a former LANL worker, and a copy was provided by M. Cadorette, Project Coordinator, after initial contact with the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) office in Española, NM.

Very little historical stack monitoring data for beryllium have been located by the project team. If stack releases of beryllium were not routinely monitored, indoor air monitoring data might be useful for estimating source terms for beryllium releases to the environment.

**Operations Involving Beryllium Release to the Environment**

Two types of operations at LANL, machining and firing tests, have resulted in releases of beryllium to the environment. The machining, grinding, sanding and general handling of beryllium components typically occurred in machine shops or experimental laboratory settings. Dynamic testing has involved use of beryllium and other materials in explosive tests in the open air or with various forms of containment or confinement. Industrial Hygiene records indicate that activities involving beryllium have been performed at 20 different Technical Areas between 1943 and 1980. The main facilities that housed beryllium operations within the Original Technical Area are shown in Fig. 11-1. Beryllium metal was processed in the shops and metallurgical labs, and soluble beryllium salts were handled in the chemical labs (JHSPH 1999).
### Table 11-1. Beryllium timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>First description of acute beryllium disease (Weber and Engelhardt 1993)</td>
</tr>
<tr>
<td>1943</td>
<td>Chemical pneumonia reported in workers extracting beryllium from beryl ore (Van Ordstrand et al. 1943)</td>
</tr>
<tr>
<td>1943</td>
<td>U.S. Public Health Service publishes NIH Bulletin 181 stating that beryllium metal is not toxic (Hyslop et al. 1943)</td>
</tr>
<tr>
<td>~1944</td>
<td>Beryllium machining began in V Shop at LASL’s Original Technical Area</td>
</tr>
<tr>
<td>1946</td>
<td>First cases of chronic beryllium disease (CBD) in fluorescent light bulb workers (Hardy and Tabershaw 1946)</td>
</tr>
<tr>
<td>1947</td>
<td>United States Atomic Energy Commission (USAEC) is formed</td>
</tr>
<tr>
<td>1949</td>
<td>USAEC establishes a 2 µg m⁻³ occupational exposure limit at their facilities (Eisenbud et al. 1949)</td>
</tr>
<tr>
<td>1949</td>
<td>Beryllium machined in V Shop Annex (also known as the “Old Beryllium Shop”) at LASL</td>
</tr>
<tr>
<td>1952</td>
<td>Exhaust system enlarged in Old Beryllium Shop at LASL</td>
</tr>
<tr>
<td>1953</td>
<td>Beryllium is machined in the new beryllium shop at LASL and the old beryllium shop is closed</td>
</tr>
<tr>
<td>1957</td>
<td>ACGIH proposes a 2 µg m⁻³ Threshold Limit Value exposure limit (ACGIH 2006)</td>
</tr>
<tr>
<td>1958</td>
<td>USAEC contracts with Brush Wellman for 200,000 lbs of beryllium per year (Stange 2005)</td>
</tr>
<tr>
<td>1959</td>
<td>Health protection in beryllium facilities; summary of 10 y of experience (Breslin and Harris 1958, Breslin and Harris 1959)</td>
</tr>
<tr>
<td>1971</td>
<td>OSHA adopts the 2 µg m⁻³ permissible exposure limit (PEL) 8-hr TWA (time-weighted average) (OSHA 2008)</td>
</tr>
<tr>
<td>1973</td>
<td>National Emission Standard for beryllium in ambient air 0.01 µg m⁻³ averaged over a 30-d period (USEPA 2004)</td>
</tr>
<tr>
<td>1977</td>
<td>NIOSH recommends a 0.5 µg m⁻³ limit to OSHA, classifies beryllium as a potential occupational carcinogen (USDOE 1999) based on an increased risk for lung cancer associated with exposure to high levels of beryllium in the workplace before the 1950s (ACGIH 2006)</td>
</tr>
<tr>
<td>1984</td>
<td>First case of CBD at the USDOE Rocky Flats Plant (Stange 2005)</td>
</tr>
<tr>
<td>1998</td>
<td>ACGIH proposes a 0.2 µg m⁻³ TLV®-TWA to minimize CBD and sensitization</td>
</tr>
<tr>
<td>1998</td>
<td>USEPA establishes a reference concentration of 0.02 µg m⁻³ based on sensitization and progression to CBD (USEPA 2009)</td>
</tr>
<tr>
<td>1999</td>
<td>USDOE establishes a 0.2 µg m⁻³ action level that triggers workplace precautions and control measures (USDOE 1999)</td>
</tr>
<tr>
<td>2000</td>
<td>Energy Employees Occupational Illness Compensation Program Act (EEOICPA) passed by Congress</td>
</tr>
<tr>
<td>2001</td>
<td>EEOICPA makes first CBD claim award (Stange 2005)</td>
</tr>
<tr>
<td>2007</td>
<td>ACGIH proposes a 0.05 TLV®-TWA and a 0.2 TLV®-STEL (short term exposure limit) (NRC 2008)</td>
</tr>
</tbody>
</table>
Fig. 11-1. December 1946 view, looking south, of the Original Technical Area with buildings that had significant beryllium involvement identified; Buildings Gamma, V, and M on the left, B and Q in the center, and Sigma, I, and Delta toward the right. Based on photo LAHM-P1990-40-1 courtesy of the Los Alamos Historical Society.
Machining and Component Production Operations

The first production job assigned to the metallurgy groups at Los Alamos involved the manufacture of specially-shaped high-density beryllium oxide bricks required for the Water Boiler reactor. Production of these bricks was accomplished by hot-pressing beryllium oxide powder into a graphite die or mold of suitable shape. The die and contents were heated to approximately 1,700 °C using an induction coil connected to a high-frequency converter under a pressure of 1,000 psi. This process consolidated the semi-plastic beryllium oxide powder into a dense coherent mass in the shape of the die. Occasionally, grinding of the bricks to a precise size was required when critical dimensions had to be met (Smith 1945).

Until 1948, beryllium was machined in the center of a large machine shop located in V Building at the Original Technical Area, TA-1, known as V Shop (JHSPH 1999). Flexible exhaust ducts were placed near the cutting tool and the captured dust was exhausted into the shop’s atmosphere. Due to the use of coarse fiberglass filter media, the Industrial Hygiene Group recommended that the filtered air be exhausted outside the shop.

In 1949, an addition was built onto the main shop where only beryllium would be machined. All machines were equipped with local exhaust hoods. Each machine hood was exhausted by a blower-filter unit equipped with a wool-felt filter. The air was exhausted outside the building through a common stack. The quantity of air exhausted by each unit was approximately 200 ft³ min⁻¹. In 1951, the concentrations of beryllium in stack effluent ranged from 0.1 to 2.0 µg m⁻³ (JHSPH 1999).

In 1952, the local exhaust system was enlarged to provide a larger quantity of air for each machine and to add an additional lathe and mill to the shop. The blower was capable of exhausting 2,000 ft³ min⁻¹ through the five local exhaust hoods in the shop, thus providing approximately 400 ft³ min⁻¹ for each hood. A cloth tube filter was installed outside the old beryllium machine shop to maximize collection efficiency for air cleaning prior to release to the environment. The unit consisted of two steel chambers each containing 32 cloth tubes (cotton bags containing asbestos floc as a filter aid) operating continuously with a total capacity of 2,000 ft³ min⁻¹. The collection efficiency determined by isokinetic sampling during normal machining operations was 98.8%. The mass median diameter particle size in samples collected with a cascade impactor in the duct before the filter was 4 microns (µm) (Mitchell and Hyatt 1957).

In August 1953, the shop was closed down and all machines and equipment were cleaned to prepare for the move to a new shops building at TA-3, SM-39 (JHSPH 1999). Operations in the new beryllium shop were started in October 1953 and included two lathes, a mill, a surface grinder, and an index mill used as
a drill press, all in hood enclosures. The cloth tube filter was moved to the filter room above the machine shop in the new building. A dynamic separator was installed before the cloth tube filter and dampers were installed on all machine hoods. Orlon bags with no filter aid were used instead of cotton bags with asbestos floc. The theoretical collection efficiency increased to 99.9% but the Orlon bags were not as effective (Mitchell and Hyatt 1957).

Continuous stack samples were collected downstream of the dust tube filter in both the old and new beryllium shops. Of the 309 samples collected between 1952 and 1956 (44 from the V Shop and 265 from the SM-39 Shop), 53% were below 0.05 µg m⁻³ (the method detection limit), 67% were below 0.10, 77% were below 0.2, 94% were below 1.0, 99% were below 2.0, and 100% were below 25 µg m⁻³.

Although no tolerance for beryllium stack discharge had been recommended, it was the opinion of the Industrial Hygiene Group at that time that the neighborhood tolerance of 0.01 µg m⁻³ was never exceeded based on the results from the exhaust stacks and atmospheric dilution (Mitchell and Hyatt 1957).

Beryllium work was also initially performed at the Delta, Gamma, I, M, and [old] Sigma buildings at TA-1. Work activities at old Sigma included extrusion, welding, heating beryllium in a furnace, and flame plating beryllium onto substrates. Beryllium metal was welded and machined at Delta building, and beryllium oxide materials were used at M Building. V Shop was a foundry and machine shop where a variety of metals, including beryllium were processed (JHSPH 1999)

As summarized in Table 11-2 and Table 11-3, industrial hygiene records indicate that sampling for beryllium has been conducted at numerous buildings at TA-3 and at 19 other Technical Areas. The Sigma Complex at TA-3 is made up of three large buildings and several smaller buildings totaling over 200,000 ft². These facilities, built in the 1950s and 1960s, house laboratory areas for materials synthesis, and processing, characterization, and fabrication of materials such as beryllium, uranium, thallium, and aluminum alloys. The Sigma Complex is home to two groups of the Materials Science and Technology Division—Ceramics (MST-4) and Metallurgy (MST-6).

The three main buildings of the Sigma Complex are:

- Sigma Building (SM-66)– built in 1959 and 170,000 ft² in size;
- Rolling Mill Building (SM-141)– built in the early 1960s and covering 20,000 ft²; and
- Press Building (SM-35)– built in 1953 and 10,000 ft² in size.
### Table 11-2. Beryllium operations at TA-3 buildings

<table>
<thead>
<tr>
<th>Bldg No.</th>
<th>Building Name</th>
<th>Beryllium Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM-16</td>
<td>Van de Graaff Lab</td>
<td>Sanding</td>
</tr>
<tr>
<td>SM-29</td>
<td>New CMR Bldg</td>
<td>chemical synthesis, vaporization, purification</td>
</tr>
<tr>
<td>SM-30</td>
<td>Warehouse</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-39</td>
<td>Shops Bldg</td>
<td>machining, milling, brazing, heat treating, cutting</td>
</tr>
<tr>
<td>SM-32</td>
<td>Center for Material Science</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-43</td>
<td>Admin Bldg</td>
<td>foils, mirrors, BeO rods</td>
</tr>
<tr>
<td>SM-49</td>
<td>Physics Bldg</td>
<td>thin foils</td>
</tr>
<tr>
<td>SM-66</td>
<td>New Sigma Bldg</td>
<td>Casting, etching, brazing</td>
</tr>
<tr>
<td>SM-141</td>
<td>Rolling Mill Bldg</td>
<td>Coating</td>
</tr>
<tr>
<td>SM-184</td>
<td>Old Occupational Health Lab</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-218</td>
<td>Magnetic Energy and Storage</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-287</td>
<td>Scyllac Bldg</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Source: JHSPH 1999.

BeF = beryllium fluoride; BeO = beryllium oxide; Be-U = beryllium uranium alloy

### Table 11-3. Beryllium operations at Technical Areas other than TA-1 and TA-3

<table>
<thead>
<tr>
<th>TA No.</th>
<th>Technical Area Name</th>
<th>Beryllium Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA-6</td>
<td>Two-Mile Mesa</td>
<td>Foils</td>
</tr>
<tr>
<td>TA-8</td>
<td>Anchor Site West</td>
<td>storage of BeF and BeO</td>
</tr>
<tr>
<td>TA-9</td>
<td>Anchor Site East</td>
<td>BeF fusion furnace</td>
</tr>
<tr>
<td>TA-14</td>
<td>Q Site</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-15</td>
<td>R-Site</td>
<td>test firing with kg quantities of Be</td>
</tr>
<tr>
<td>TA-16</td>
<td>S-Site</td>
<td>laundry, burn pit</td>
</tr>
<tr>
<td>TA-18</td>
<td>Pajarito Site</td>
<td>Processing Be-U blocks and BeO rods, ultrasonic cleaning</td>
</tr>
<tr>
<td>TA-21</td>
<td>DP Site</td>
<td>Machining, milling, arc melting, palletizing</td>
</tr>
<tr>
<td>TA-33</td>
<td>HP Site</td>
<td>Machining using a method X machine</td>
</tr>
<tr>
<td>TA-35</td>
<td>Ten Site</td>
<td>high temperature Be salts</td>
</tr>
<tr>
<td>TA-39</td>
<td>Ancho Canyon</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-40</td>
<td>DF Site</td>
<td>milling, test firing</td>
</tr>
<tr>
<td>TA-41</td>
<td>Icehouse</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-46</td>
<td>WA Site</td>
<td>Heating</td>
</tr>
<tr>
<td>TA-53</td>
<td>LANSCe</td>
<td>targets and beam stops</td>
</tr>
<tr>
<td>TA-11</td>
<td>K Site</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-43</td>
<td>Health Research Lab</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-48</td>
<td>Radiochemistry</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

Source: JHSPH 1999.
One-third of Sigma Building space contains the mechanical and ventilation equipment necessary to protect the health and safety of personnel. The remaining area includes laboratories, offices, and administrative areas. The Rolling Mill Building contains laboratories for beryllium processing, powder metallurgy, ceramics research and rapid solidification research. The Press Building houses a 5,000-ton capacity hydraulic press with a 12-foot maximum opening and laboratories for hazardous materials research (LANL 1995).

Two 1992 files regarding permits for beryllium operations mention historical beryllium cutting operations at DP West Site's Building 5 in the 1960s and possibly 1950s, and existing beryllium operations in Sigma building (TA-3-66), TA-16-450, and TA-55-4. The operations at Sigma Building and TA-16-450 had existed since the 1950s (Gutierrez 1992, Tiedman 1992). An H-1 Division notebook discusses procedures for monitoring beryllium in stack effluent from the CMR Building Wing 5 Filter Tower in February 1954 (Enders 1954).

**Dynamic Testing Operations**

Air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, although beryllium was involved in relatively few tests until 1954 (Voelz and Jordan 1974). Becker and Vigil (1999) reviewed the historical beryllium expenditure in dynamic tests conducted by the DX Division at LANL, present data on known beryllium concentrations in soil at firing sites, beryllium air concentrations measure onsite and beyond LANL boundaries, and beryllium concentrations in swipe samples. Records for beryllium use in dynamic testing activities at Los Alamos date back to 1955 and include shot records in the form of internal LANL memoranda, DX Division office records and published annual beryllium expenditures in LANL Environmental Surveillance reports. It is presumed that beryllium was expended in dynamic testing activities before 1955, although there has been no compilation of these data. They assumed that 160 kg of beryllium was used prior to 1955, but no explanation for this estimate is provided.

Becker and Vigil (1999) estimated a total beryllium expenditure of 1,064 kg for the period of 1955 through 1997 (see Table 11-4). Dynamic testing at firing sites is conducted at TA-40, -14, -15, -36, and -39. The evaluation of available records performed by Becker and Vigil (1999) determined that the majority of beryllium expenditure occurred at three firing sites: PHERMEX, E-F, and R-44— all located at TA-15.
Table 11-4. Beryllium expenditure at LANL firing sites 1955-1997

<table>
<thead>
<tr>
<th>Site</th>
<th>Status as of 1999</th>
<th>Beryllium Expended (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-44 (TA-15)</td>
<td>Closed</td>
<td>346</td>
</tr>
<tr>
<td>PHERMEX (TA-15)</td>
<td>Active</td>
<td>332</td>
</tr>
<tr>
<td>E-F Site (TA-15)</td>
<td>Closed</td>
<td>321</td>
</tr>
<tr>
<td>R-306 (TA-15)</td>
<td>Active</td>
<td>43.6</td>
</tr>
<tr>
<td>All other firing sites at TA-15, -36, -39</td>
<td>--</td>
<td>21.4</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>1,064</td>
</tr>
</tbody>
</table>


Using a mass balance approach and the following assumptions, Becker and Vigil (1999) estimated soil concentrations of beryllium for three firing sites.

- 160 kg of beryllium expended prior to 1955
- more shots at E-F Site during years prior to 1955
- 2% of beryllium becomes aerosolized
- uniform soil concentration to a depth of 6 inches

The authors of the study found less beryllium in soil than they predicted, so they give possible explanations for the discrepancy, such as erosion and non-representative sampling. They postulated that the soil sampling might not have been representative of actual onsite contamination, or that other processes such as mass movement and erosion removed contamination from the firing sites.

LANL has conducted open-air dynamic experiments in which weapons components are either detonated or impacted against a target, which results in soil contamination with beryllium (Sauer et al. 2001). Monthly reports written by the LANL Dynamic Testing Division from December 1975 through December 1987 document fugitive emissions from explosive test shots, including quantities of beryllium released. During this 13-y period, 178 kg of beryllium were released as a result of test shots conducted at TA-15, TA-36 and TA-40. According to the monthly reports, 98% of the total beryllium emissions occurred between 1977 and 1982, and in 1984. However, about one-third of the monthly reports for the 13-y period are missing from the collection identified by the project team, and 75% of the missing reports are from the years 1983, 1985, 1986, and 1987. In the reports that are available, 55% of the monthly values are reported as 0 kg. The average monthly release is 1.65 kg with a standard deviation of 2.42 kg. The median monthly release is 0.02 kg, the 95% upper confidence limit on the mean is 2.04 kg, and the maximum monthly release is 10.6 kg (for November 1976).
B Building Annex

LANL Director’s Office Files for 1944 describe a request for four alpha detectors from Chicago for “0.05 d/cc/s” (disintegrations per cubic centimeter per second) in air in a 14" × 25" duct flowing 800 ft³ min⁻¹ and in other ducts (Bainbridge 1944). The detector was apparently for B Building annex, which was used for testing initiators and was an unmonitored release point for beryllium and polonium.

Information regarding the former B Building Annex at TA-1 was located in source material for the book Critical Assembly (LASL 1944-1945, Hoddeson et al. 2004). A folder in the LANL Archives contains draft chapters and LANL memos that were referenced in each chapter and describe the gun device and initiator testing. The B-Building annex, called the “wart on B Building,” was authorized by J. Robert Oppenheimer and constructed by the end of March 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun-assembled atomic weapon components such as initiators. By mid-April of 1944, the annex was in operation. In August 1944, a “coffin” was authorized that was a box that was operated at negative pressure and equipped with a gas mask filter on its exhaust. By the end of September, the gun had been used in nearly 180 experiments at a frequency of one per day. Chapter 7 in Critical Assembly does not mention beryllium, nor did the assembled memos, as beryllium was not viewed as a hazardous material in the early 1940s. About 50 lbs per month of beryllium was used in the fabrication of initiators (LASL 1944-1945).

Quantities of Beryllium Used at Los Alamos

It has been estimated that 1,064 kg of beryllium was used between 1955 and 1997 and another 160 kg was used prior to 1955 at Los Alamos (Becker and Vigil 1999). Ninety-four percent of the beryllium was expended at PHERMEX, E-F, and R-44 firing sites and another 4% was expended at firing site R-306. Detailed information is not available on the remaining 2%, but it is presumed that it can be divided among the other firing sites.

According to Becker and Vigil (1999), the greatest annual expenditure of beryllium, in excess of 100 kg, occurred in 1964 and significant beryllium use occurred between about 1957 and 1971 (see Fig. 11-2). Beryllium use since 1985 has been relatively low, with annual expenditures remaining less than 5 kg.
In a 1977 report, LASL scientists estimated that 2% of the beryllium present in test devices becomes aerosolized during dynamic experimentation (Dahl and Johnson 1977). Based on this estimate, it has been calculated that approximately 1,200 kg of beryllium remains in the soil at Los Alamos and approximately 94% or 1,128 kg remains at the E-F, R-44, and PHERMEX firing sites per LANL records.

Monthly reports written by the LANL M-DO Division document fugitive emissions from explosive test shots conducted during from December 1975 to December 1987 (LANL 1975-1987). The emissions data are shown in Table 11-5. The release locations are the explosive test areas at TA-15, TA-36 and TA-40.

**Workplace and Environmental Monitoring for Beryllium**

Air concentrations of beryllium have been monitored at LANL for both indoor machining and outdoor firing tests operations since 1948 (Voelz 1970). Measures to control beryllium exposure were in place at Los Alamos beginning in 1948 based on recommendations from occupational medicine pioneer Dr. Harriet Hardy of the Massachusetts Institute of Technology (MIT), who collaborated with the AEC in Los Alamos. The Industrial Hygiene Program was introduced at LASL that same year (Mitchell and Hyatt 1957).
Table 11-5. Beryllium released to the environment by shots at TA-15, TA-36, TA-40

<table>
<thead>
<tr>
<th>Year</th>
<th>Beryllium (kg)</th>
<th>Beryllium Oxide (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>1976</td>
<td>25.54</td>
<td>0</td>
</tr>
<tr>
<td>1977</td>
<td>34.7</td>
<td>3</td>
</tr>
<tr>
<td>1978</td>
<td>29.2</td>
<td>0</td>
</tr>
<tr>
<td>1979</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>9.8</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>10.6</td>
<td>0</td>
</tr>
<tr>
<td>1982</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>1983</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>1984</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>1985</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>2.1</td>
<td>0</td>
</tr>
<tr>
<td>1987</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>175</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: LANL 1975-1987

Beryllium Metal Machining

The Industrial Hygiene Group at LASL made periodic surveys of beryllium machining operations from early 1948 through August 17, 1951. After September 1951, daily air samples were collected whenever beryllium was being machined. From September 1951 through 1955, a sampling rate of 20 L min⁻¹ and a filtering velocity of 130 ft min⁻¹ with Whatman #41 filter paper resulted in a collection efficiency of 70%. In 1956, a sampling rate of 10 L min⁻¹ and a filtering velocity of 65 ft min⁻¹ with Whatman #44 filter paper resulted in a theoretical collection efficiency of 99.8%

A continuous air sampler with a sampling rate of 20 L min⁻¹ and a filtering velocity of 130 ft min⁻¹ using Whatman #4 filter paper was used to monitor beryllium air concentrations for short periods of exposure. The sampler was set to collect hourly general air samples in the vicinity of the machining operations. The reported collection efficiency was 80%. Starting in 1954, the hourly samples were only analyzed when an 8-h breathing zone sample approached the tolerance level of 25 µg m⁻³.

Air samples collected to assess beryllium concentrations through June 1950 were collected with an electrostatic precipitator and sent to the University of Rochester for analysis (Mitchell and Hyatt 1957). Although air samples were analyzed by the Industrial Hygiene Group beginning in June 1950, samples continued to be collected by the electrostatic precipitator through August 1951. Starting in September 1951, samples were collected using a portable pump connected to a sampling head equipped with filter paper. Samples collected after June 1951 were analyzed using a method based on the fluorescence of...
morin with beryllium in an alkaline solution (Sax and Kramlich ca 1952). Beryllium concentrations ranging from 0.05 to 300 µg were adequately detected with this method. It is reported that air samples were analyzed by atomic adsorption in the early to mid 1990s, while samples collected in the late 1990s were analyzed by inductively coupled plasma atomic emission spectroscopy (Becker and Vigil 1999).

From 1950 to 1953, filter type respirators were occasionally used on special jobs. In some cases the filters from these respirators were analyzed for beryllium content. Analyses of respirator filters used during filter unit cleaning, and used during drilling operations without local exhaust ventilation, showed beryllium concentrations ranging from 300-400 µg m⁻³.

An experiment performed by the Industrial Hygiene Group in 1951 to determine the greatest sources of exposure during beryllium operations revealed that rough cutting created the heaviest source of dust. One air sample collected in the hood 8 inches from the cutting tool while rough cuts were being made on a piece of bar stock yielded a beryllium concentration of 725 µg m⁻³ (Mitchell and Hyatt 1957).

Routine air samples collected between September 1957 and June 1958 at the machine shop were well below permissible levels (LASL 1957, 1958). A distinct rise in the average beryllium concentration at the beryllium shop in 1957 was tracked to full time work on a crash program to make special beryllium pieces. The number of air samples collected at CMB-6 was also increased greatly during this time frame in association with a research project to determine the best method of joining two pieces of beryllium.

The beryllium machine shop at Los Alamos was washed down weekly and surface swipe tests were performed to ensure that loose beryllium dust levels were maintained below 15 µg ft⁻² (Mitchell and Hyatt 1957)

Firing Sites

A 1970 letter report from the LANL Health Division Leader to the Deputy Director of Military Application, USAEC, describes the historical air sampling of beryllium near explosive tests at LASL from 1948 to 1959 (Voelz 1970). While air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, beryllium was involved in relatively few tests until 1954. In 1954 there was beryllium exposure during test firing of beryllium pieces in conjunction with explosives at TA-39, the Ancho Canyon Site. Most of the samples were collected between 1956 and 1959 when all tests occurred at R Site and were conducted by the GMX-4 group. In 1955, Group W-3 conducted an experiment at TA-33 in which a device exploded and large pieces of beryllium were thrown all over the firing area. Tests involving beryllium after 1959 were conducted at Ancho Canyon by GMX-6 and at
Table 11-6. Beryllium concentrations measured from LASL explosive tests 1948–1959, \( \mu g \text{ m}^{-3} \)

<table>
<thead>
<tr>
<th>Site</th>
<th>No. of Shots</th>
<th>No. of Samples (N)</th>
<th>No. of Samples &gt;MDC of 0.05</th>
<th>Maximum Onsite</th>
<th>Maximum Offsite</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-Site</td>
<td>39</td>
<td>156</td>
<td>11</td>
<td>0.66 (0.34)(^1)</td>
<td>0.05 (^2)</td>
</tr>
<tr>
<td>Ancho Canyon</td>
<td>8</td>
<td>24</td>
<td>1</td>
<td>0.004 (^3)</td>
<td>NR</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>2</td>
<td>NR</td>
<td>0</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

MDC = minimum detectable concentration; NR = Not reported.
\(^1\) Measured 800 y directly downwind from the shot.
\(^2\) Measured at Ten Site (TA-35).
\(^3\) Measured 150 y from the shot.

Air sampling for beryllium was performed by the LANL Environmental Surveillance program in the early 1970s and resumed in the 1990s. Samples collected on the roof of TA-59-1 during 1971 and 1972 yielded beryllium air concentrations between 0.06 and 0.4 ng m\(^{-3}\) (0.00006 and 0.0004 \( \mu g \text{ m}^{-3} \)). Quarterly samples of airborne beryllium collected onsite, at the Lab perimeter, and regionally in northern New Mexico in 1990, 1992, 1993 and 1994 as part of the AIRNET program ranged from 0.002 to 0.061 ng m\(^{-3}\). When quarterly sampling was resumed in 1998, quarterly Airnet beryllium values ranged from 0 to 0.1 ng m\(^{-3}\). Area air samples collected in 1998 at two firing sites during dynamic shots ranged from 0.013 to 0.381 \( \mu g \text{ m}^{-3} \) of beryllium (Becker and Vigil 1999).

Beryllium concentrations in surface water samples collected from the E-F Firing Site (TA-15) in March 1985 ranged from <1 – 2 parts per billion (ppb) in the dissolved fraction, and from 1.2 – 11.5 ppb in the suspended fraction.

The environmental fate of beryllium released from disposal of neutron sources containing beryllium metal that cannot be recycled or reused is a research interest of the Off-Site Source Recovery Program at LANL. A 2000 progress report describes the experimental use of beryllium-contaminated soils obtained from LANL Dynamic Experimentation Division firing sites. Two samples (locations not specified) contained 74 and 29 mg kg\(^{-1}\) of beryllium (Sauer et al. 2000). Table 11-7 summarizes the soil data from six firing sites (Cokal and Rodgers 1985, Vigil and Becker 1999)
### Table 11-7. Beryllium concentrations in soil at firing sites, µg g⁻¹

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>Samples (n)</th>
<th>Range</th>
<th>Mean</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHERMEX</td>
<td>1987</td>
<td>59</td>
<td>1 – 470</td>
<td>31.5</td>
<td>1 – 2.4</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>1993</td>
<td>21</td>
<td>&lt;1 – 218</td>
<td>13.4</td>
<td>NR</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>1998</td>
<td>18</td>
<td>0.14 – 74</td>
<td>7.1</td>
<td>NR</td>
</tr>
<tr>
<td>E-F</td>
<td>1985</td>
<td>9</td>
<td>2.3 – 14.4</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>E-F</td>
<td>1999</td>
<td>60</td>
<td>NR</td>
<td>1.3</td>
<td>NR</td>
</tr>
<tr>
<td>R-44, R-45</td>
<td>1994</td>
<td>44</td>
<td>NR</td>
<td>7.2</td>
<td>NR</td>
</tr>
<tr>
<td>TA-39</td>
<td>1995</td>
<td>22</td>
<td>&lt;1.3 – 9.1</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>TA-40</td>
<td>1995</td>
<td>39</td>
<td>&lt;1.3</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

NR = Not Reported

Aerosolization of beryllium from open-air shots has been studied by groups at LANL (Dahl and Johnson 1977) and at Lawrence Livermore National laboratory (LLNL) (Shinn et al. 1989). Dahl and Johnson (1977) determined that 2% of the beryllium mass became respirable (<10 µm) due to aerosolization. For a shot containing 600 g of beryllium, the concentration of beryllium 4,376 y downwind of the shot would be 0.2 µg m⁻³ 15-30 min after detonation for 1-3 min. Shinn et al. (1989) found that 8% of the beryllium mass became aerosolized, and that the beryllium was largely in the form of insoluble, high-fired beryllium oxide. For a shot containing 900 g of beryllium, the concentration of respirable beryllium 55 y from the shot was 3.2 µg m⁻³ for 10 min. However, measured soil concentrations at three LANL firing sites were less than predicted assuming 2% or 8% aerosolization (Becker and Vigil 1999), suggesting that aerosolization could be greater than 8% (Sauer et al. 2001).

Beryllium resuspension has been evaluated in three studies, two at LANL and one at Sandia National Laboratories. Sandia researchers estimated a resuspension factor of 1×10⁻⁷ m⁻¹ for wind blown soil (1 g Be per m² of soil = 0.1 µg m⁻³ Be in air) (Luna et al. 1983). A LANL researcher predicted that resuspension of beryllium from a firing site could result in worker exposures to 0.6 µg/m³ of beryllium (Maez 1997). However, measured beryllium concentrations during drilling activities at a LANL firing site were four orders of magnitude lower (Mroz 1995).

**Episodic Releases**

In a joint effort with the U.S. Air Force, an experiment was performed at Beta Site (TA-5) to evaluate the potential air or ground contamination that might result from the burning of a plane containing significant amounts of beryllium (LASL 1957). A piece of beryllium was placed above a large quantity of jet fuel and ignited. Air and soil monitoring results failed to reveal detectable quantities of beryllium at a range of distances downwind of the fire.
Waste Disposal

Small quantities of beryllium residues were among the chemical waste disposed of in Areas G and L at LANL. Waste was disposed of in Areas G and L by emplacement in shafts, trenches and pits excavated in the Bandelier Tuff at depths up to 65 ft. In late 1985, 18 boreholes to 100- to 135-ft depths were drilled in Bandelier Tuff from the top of Mesita del Buey. Core samples were collected from seven of the boreholes at about 10-ft intervals. Only two of 70 samples collected contained concentrations of metals, not otherwise specified, were above their detection limits. Both were acquired at shallow depths (20 ft or less) at Area L (LANL 1987). All rags and waste from housekeeping activities in the old and new beryllium shops were disposed of in the burial pit (Mitchell and Hyatt 1957).

Off-Site Area Monitoring

Air samples were collected quarterly between 1990 and 1994 in northern New Mexico, around the Laboratory perimeter in Los Alamos, White Rock and Bandelier National Monument, and within the Laboratory primarily at TA-52, TA-16 and TA-3 (Becker and Vigil 1999). The mean beryllium concentration recorded at the off-site locations during this timeframe was 0.014 ng m$^{-3}$, while the mean concentration reported at the on-site locations was 0.009 ng m$^{-3}$. Additional sampling was performed at off-site and on-site locations in 1998 and the mean air concentration recorded at all sampling locations during this year was 0.021 ng m$^{-3}$.

Exposure Guidelines for Beryllium

The U.S. Atomic Energy Commission issued “Recommendations for Control of Beryllium Hazards” in August 1951 that included three standards: a 2 µg m$^{-3}$ in-plant, 8-hr average beryllium concentration; a 25 µg m$^{-3}$ beryllium air concentration that can never be exceeded; and a 0.1 µg m$^{-3}$ monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt 1957).

The current OSHA permissable exposure limit (PEL) for occupational exposure to beryllium is 2 µg m$^{-3}$ (8-h time weighted average). A ceiling limit of 5 µg m$^{-3}$ must not be exceeded during the work shift, except that a 30-min excursion over the ceiling limit is allowed as long as the air concentration never exceeds 25 µg m$^{-3}$ during the 30-min period (NIOSH 2003).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 µg/m$^{3}$ (USEPA 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of
deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1949 and 1996 (Eisenbud et al. 1949, Kreiss et al. 1996). The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 µg m\(^{-3}\) (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed and included area samples, process breathing-zone samples, and personal lapel samples (the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 µg m\(^{-3}\) in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

**Beryllium Releases and Exposures at Los Alamos**

It has been reported that largest number of men at Los Alamos were exposed during machining of beryllium, although the most difficult processes to control involved the use of powdered beryllium and soluble beryllium compounds (Hyatt and Milligan 1953). Worker exposure to beryllium from dynamic testing was substantially less than that encountered in the machine shop or laboratory settings primarily because beryllium was present during detonations conducted outside under atmospheric conditions, and because during detonation and afterwards, workers were confined to a closed control bunker or detained at road blocks set up ¼ mile or more from the firing site (Becker and Vigil 1999). Post-shot dispersion of beryllium particles caused by wind was expected to occur rapidly and to significantly dilute beryllium concentrations present in air at the firing sites. If exposures to beryllium did occur at firing sites, it is indicated that exposures would have occurred during dust resuspension from soil and vegetation during brush removal.

Secondary occupational exposure of workers’ families significantly increased beryllium intake through dust when clothing of occupationally exposed individuals were not kept at the workplace, as was usually the case in the 1940s (IPCS 1990). Eisenbud et al. (1949) reported that short-term beryllium levels of 125 to 2,000 µg m\(^{-3}\) were measured in the indoor air after clothing from employees at a beryllium-producing plant were shaken. The authors estimated that approximately 17 µg d\(^{-1}\) could be inhaled by a person during the laundering of the same clothing. However, it is documented that Los Alamos provided their workers in the machine shop with a provision of complete protective clothing with adequate showering facilities (Mitchell and Hyatt 1957). This clothing consisted of coveralls, underwear, socks and safety
shoes. Canvas booties were worn over the safety shoes before leaving the machine shop to go to the tool crib. Likewise, it has been noted that employees working at firing sites wore dedicated work shoes that were removed and remained onsite each evening (Becker and Vigil 1999).

**Medical Surveillance of LANL Workers**

Medical surveillance of workers at LANL began in the 1940s (Stefaniak et al. 2003). A memo from Dr. Cleve Beller of LANL dated January 24, 1947 announced that all Sigma Building personnel that handled beryllium were examined or had made arrangements to be examined by the Health Group (LASL 1944-1950). As of completion of a report detailing beryllium use at DX Division Firing Sites (Becker and Vigil 1999), it was noted that nine workers in the DX Division were in the beryllium medical surveillance program. It was reported that none of these individuals had been identified with chronic beryllium disease or beryllium-associated illness.

An internal memo from Dr. Thomas Shipman of LASL in May 1951 suggests that the health effects associated with beryllium were unknown to Los Alamos until November 1947 when Dr. Harriet Hardy of MIT held a meeting to discuss beryllium-related health concerns (LASL 1944-1950). The result of this meeting was a stoppage of certain beryllium operations (not described) and the use of beryllium at LANL was subjected to careful scrutiny from that point forward.

In a series of memos between Dr. Hardy and Dr. Thomas Shipman, a case of apparent chronic beryllium poisoning was discussed (LASL 1944-1950). It was noted that the individual in question worked at Los Alamos from 1946 until 1949 for P Division in Building U, which was documented as being in the vicinity of the beryllium machining shop. However, this individual’s exposure potential was not limited to that alleged at Los Alamos, as he was also employed at other facilities, including Oak Ridge, where beryllium was also used. A memo from Dr. Hardy to Dr. Guy Fortney at Oak Ridge in September 1964 reported that the beryllium content in this individual’s lungs at his time of death was 0.021 µg g⁻¹. Two additional cases of apparent berylliosis among LANL personnel were reported in a memo from Dr. Shipman in February 1953.

As of June 1998, 110 workers have been diagnosed with chronic beryllium disease; the majority of these workers are associated with the Rocky Flats and Y-12 (Oak Ridge) plants (Becker and Vigil 1999). A Former Worker Medical Surveillance Program that included screening for chronic beryllium disease (CBD) was started in 1999 (Stefaniak et al. 2003).
Beryllium Toxicology and Epidemiology

Acute beryllium disease is usually observed at relatively high beryllium exposure levels, has a short period of induction, and is usually resolved within a couple of months of exposure termination. It is believed to be an inflammatory response to beryllium and most regions of the respiratory tract are affected; some reported symptoms include nasopharyngitis, shortness of breath, labored breathing, and chemical pneumonitis (ATSDR 2002).

Chronic beryllium disease is a systemic granulomatous disorder that predominantly affects the lungs. In general, the occurrence of this disease has been confined to workers exposed to beryllium metal and to less soluble beryllium compounds, such as beryllium oxide. However, there have been cases among residents living near beryllium manufacturing facilities and in families of workers who wore contaminated clothing at home. Chronic beryllium disease is caused by an immune reaction to the inhaled beryllium that is deposited in lung airspaces and retained for a prolonged period. In certain individuals who become sensitized to beryllium, the beryllium in the lungs binds to protein/peptides in the lungs and inflammatory cells accumulate in the lungs. This results in the formation of granuloma and the development of fibrosis. Susceptibility to chronic beryllium disease is believed to have a genetic component (ATSDR 2002).

A number of large-scale screening studies have examined beryllium workers and found beryllium sensitization rates of 1–15% in workers involved in the production of beryllia ceramics and nuclear weapons. More than half of the beryllium sensitized workers were diagnosed with chronic beryllium disease. Several studies attempted to establish associations between beryllium sensitization and/or chronic beryllium disease and mean, cumulative, and peak exposure levels and duration of employment. In general, no consistent associations were found. Although the data are insufficient for establishment of concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 μg m⁻³. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels of beryllium (0.03–0.2 ng m⁻³) are very low (ATSDR 2002).
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Chapter 12: Processing and Testing of High Explosives at Los Alamos

Research, development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; LANL 1990). Many new formulations of the conventional explosives HMX, RDX and TNT were synthesized and tested at LANL since the 1940s (Dobratz 1995). Other high explosives such as Baratol, Comp B, Pentolite, Torpex, and Tetryl were tested at firing sites such as those at TA-14 (IT Corporation 1989). The initial plan for the first atomic weapon was for a gun type weapon that would use “slow-burning” propellants. When it became clear in July 1944 that the weapon would have to be an implosion design due to the presence of the $^{240}$Pu isotope in the active material, high explosives became a key component of the plan.

X-Division

The implosion program began in April 1943 with a proposal by S. H. Neddermeyer on an elementary theory of high-explosives assembly, but there was no established art to follow. Implosion research started as the concern of one small group and grew into the Laboratory’s major problem in the early 1940s. The first implosion tests at Los Alamos were made in an arroyo on the mesa just south of the laboratory on July 4, 1943. The test device consisted of tamped TNT surrounding steel spheres. In April 1944, G. B. Kistiakowsky became the leader for the implosion program.

Data from photographing the interiors of imploding devices indicated the need for controlled quality of high-explosive (HE) castings. Special photographic techniques were developed at LANL to study the implosion process, such as rotating pyramid and rotating mirror photography, high-explosive flash photography, and flash x-ray photography. The Anchor Ranch range (TA-9) had been designed for implosion research, but a large casting plant and several widely spaced test sites were needed. Construction of the casting plant was begun in the winter of 1943 at S (Sawmill) Site (TA-16). S-Site was staffed almost entirely by men from the Army’s Special Engineering Detachment (SED), because finding men with experience in handling explosives was nearly impossible (Hawkins et al. 1961). At the end of the war, there were over 1,000 SED men assigned to the X-Division (Kistiakowsky 1975).

In July 1944, a new development in the implosion program involved the use of explosive lenses that would convert a multiple-point detonation into a converging spherical detonation wave thus eliminating troublesome interaction. The design of lens molds was a difficult first step and took several months. In the August 1944 reorganization, Division X was formed under G. Kistiakowsky to experiment with
explosives and their fabrication and to set up a production system. Three groups from the old Ordnance Division (E-Division) in U Building- Implosion Experimentation, HE Development, and S-Site Group, were transferred to the new Explosives (X) Division. Investigation of implosion dynamics and design of the active core were given to the Weapon Physics (G) Division (Hawkins et al. 1961).

**Explosives Production and Testing**

X-Division records indicate that about 20,000 experimental quality castings were produced in an 18-month period, and a much larger number rejected for quality control reasons. The principal types of HE used were Composition B, Torpex, Pentolite, Baranol and Baratol. The use of risers and overcasting to concentrate imperfections and minimize the very dangerous task of machining HE resulted in over 50,000 machining operations without a detonation (Hawkins et al. 1961). According to Kistiakowsky (1975), tens of thousands of castings were made, primarily of Comp B and Baratol. Baratols, with a higher percentage of barium nitrate (76%) than TNT was used for the slow component of the lens system, and cyclotols such as Comp B (60% RDX: 40% TNT) were used for the fast component (Kistiakowsky 1975; Gibbs and Popolato 1980).

As described in Wilder (1973), operations at S-Site consisted of melting HE and pouring it into molds whose shape was determined by theoretical calculations. The initial facilities at S-Site were inadequate especially for machining. As a result, there was continuous planning and construction of new buildings until just before the Trinity test in July 1945. Casting operations in Building 42 used stainless steel candy kettles, jacketed and steam heated. The molten explosive was poured from the kettle into a rubber bucket and then into steel molds. The mold was finished with Cerrotru, a low-melting casting alloy around a master shape supported in the steel weldment. In Wilder’s opinion, development of the explosive component of the bomb was greatly facilitated by the use of self-adhesive tape just about everywhere. Building 27, built in 1945, had larger kettles and the temperature of cooling water could be varied.

After casting, the HE was taken by hand truck to Building 43 to be machined. The equipment in Building 43 consisted of one K&T milling machine and several Delta drill presses. Comp B was machined under water, and Baratol was initially machined dry but later water was used. Building 55 housed the one small high-speed hammer mill used for grinding barium nitrate. Buildings 31, 32 and 33, built in 1945, were machining bays for Fosdick radial-arm drills. As S-Site activities expanded, they moved into V-Site (TA-25). Three methods were used to protect the cast HE from chipping. Castings were sprayed with the best “Bar Top” varnish available, felt was glued to one of two mating surfaces, and blotting paper was glued to the sides, in Buildings 519 and 520. Practice assemblies were made in Gamma Building in the main
Technical Area. The floors were padded with wrestling mats. The Trinity bomb was assembled in Building 516. All explosive operations produced great quantities of scrap that was collected daily and burned in the area where Building 260 was located (Wilder 1973).

According to Hawkins et al. (1961), S-Site at its peak used over 100,000 lbs of high explosives per month. G. Kistiakowsky’s recollection was that about 25 tons (50,000 lbs) were trucked up the hill per month during the most active HE casting period. X-Division Progress Reports indicate that between 140,000 and 170,000 lbs per month of high explosives, primarily Comp B, TNT and barium nitrate (BN), were used during the months of May, June, July and August 1945 (see Table 12-4). Precision molds and machining were required, and according to Kistiakowsky (1975), there were over 500 machinists and toolmakers available during the peak period. A full-size casting weighed about 100 lbs, and 1 g of HE will reportedly blow off a hand. Kistiakowsky expressed his concerns about using S-Site since five tons of HE had to be trucked past Oppenheimer’s office and T-Division every day on its way to S-Site. He requested that a new site be established in Pajarito Canyon but his request was denied by Captain Parsons (Kistiakowsky 1975).

L-Site (TA-12, akaTA-67) was constructed in the spring of 1945 and used for one year as an explosives test facility, then abandoned in the mid 1950s. Soil tests in 1993 identified RDX, TNT and picric acid at the open firing pit and firing pad 1. Q-Site (TA-14) has been used for development and testing of explosives since 1944. HMX and metals were identified in Q-site soils [Harris 1993; RCRA Facility Investigation plans for OU-1082 (S-Site) and OU-1086 (R-Site)].

Sites in the vicinity of TA-16 (S-Site) formerly used in the 1940s for x-ray studies (P and T-Sites) and assembly operations (V-Site), and several storage magazines (TA-28, 29, and 37) were decommissioned and absorbed into the S-Site complex or are still active. S-Site, K-Site and two of the three magazines were still active as of 1994. TA-11 (K-Site) was originally built to study implosion symmetry and was more recently used for drop tests to study impact initiation of explosives. The resulting debris in the immediate vicinity of the drop tower is picked up and removed for disposal at the TA-16 burning ground. These eight sites are the focus of the Remedial Field Investigation for Operable Unit 1082 (LANL 1994).

Between 1944 and 1948, eight firing sites (A-H) were established at TA-15 (R-Site). Experiments using from 50 lbs up to 2 tons of HE were conducted at these firing points. Firing points E and F were the most active. Up to 65,000 kg of uranium and 350 kg of beryllium have been expended at these two firing sites. Hazardous materials, including uranium, beryllium and lead, have largely been left in place at these sites where the materials were deposited by the explosion. Other materials that may have been deposited
include steel, aluminum, mercury, boron, cadmium, gold, and tritium reportedly in small amounts. TA-15 is the focus of the Remedial Field Investigation for Operable Unit 1086 (LANL 1993).

Other Uses of Explosives at LANL

During the VJ Day celebration at the Laboratory, Kistiakowsky reportedly borrowed a military jeep with a driver and gave the LANL scientists a “21-gun salute” by detonating 21 boxes of Comp B explosive, although someone attending the party said there were actually 22 explosions. It was also reported that the Pajarito ski hill was cleared of trees using plastic explosives (Kistiakowsky 1975).

Key Facilities for High Explosives at Los Alamos

S Site (TA-16) was initially called Sawmill Site, after a portable sawmill that had been erected on the site, and left huge piles of sawdust behind. Its name was shortened to S Site. [Martin 1998]. Investigations at S Site have included development, engineering design, prototype manufacture, and environmental testing of nuclear weapons warhead systems. TA-16 is the site of the Weapons Engineering Tritium Facility for tritium handled in glove boxes. Development and testing of high explosives, plastics, and adhesives, and research on process development for manufacture of items using these and other materials are accomplished in extensive facilities.

Facilities include a slurry plant with a capacity of 300 lbs of explosive per batch (Cochran et al. 1987). The material being cast was a two-phased slurry consisting of a dense solid phase dispersed in molten TNT. [Hoddeson et al. 1993] At first Torpex was used, then PTX-2 (Picatinny ternary explosive 2), Comp B, Pentolite, Baranol, and Baratol. Earlier operations centered on using high explosives (HE), and developing HE lenses to bring about implosion. LANL workers melted HE and poured it into molds whose shape was determined by theoretical calculations. Early castings were worked with hand tools, saws, rasps, and planes, to a template. HE compounds used included Comp. B, TNT, and Baratol.

Early explosives processing facilities included:

- S-24 (possibly a.k.a. TA-16-24) A casting building
- TA-16-42 Casting (stainless steel candy kettles, jacketed and steam heated, with agitator; HE was poured into a rubber bucket, then to molds)
- TA-16-43 Machining (K&T milling machine, drill presses, fly cutters. Comp. B was machined under a stream of water. Baratol was initially machined dry because thought water would dissolve the barium nitrate; later machined wet.
- TA-16-44 Physical inspection (dimensional inspection)
• TA-16-48  “gamma-graph” facility (gamma radiography of large or dense objects).
• TA-16-55  Barium nitrate grinding machinery.
• TA-16-81  Used to dry nitrocellulose (spread out on trays).
• TA-16-260  Near the east end of this building was area for daily burning of scrap. Sometimes the material exploded instead of burning.
• TA-16-27  Built in 1945 to make full-scale castings.
• 30 thru 34  Built at same time to machine Baratol and Comp. B castings from Building 27.
• 94 thru 98  Built when it became desirable to machine all surfaces of the HE material.
• 16-515 thru 520  (called V Site) were under a group other than GMX-3; they had a large mechanical shaker that was used to test the first bomb. The Trinity bomb was assembled in 516. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.” “Mechanical Testing” done here per Repository No. 225 (c. 1981)

Some of the early work being done was considered too dangerous to be performed at TA-1, so these operations were placed at remote locations. Alpha Site at TA-4 was used as a firing site for high explosives (HE). It was originally used to fire several charges per day of up to 1000 lbs and was then converted to accommodate studies of small equation-of-state tests that used only a few pounds of HE per shot. Beta Site at TA-5 was used extensively in 1945 as a firing site for the pin or electric method for studying implosions. Larger charges could be safely used at TA-5, and shots of several hundred pounds were used. S-Site at TA-16 was developed for production of HE to be used in the various tests. [LA-UR-97-4765]

In 1944, a small control building and two firing sites were established at TA-15; one for quantities of HE up to 50 lbs and the second for larger amounts. These probably became Firing Sites A and B. Firing Site A was probably in use by the end of 1944 and Firing Site B shortly thereafter. In 1946, TA-15 was made into a permanent location for explosives experiments related to nuclear weapons design, involving experiments with up to 3/4 tons of HE. By 1947, Firing Sites C,D,E, and F were in use. In 1948, E and F were designated as one firing site, E-F, and Firing Sites G and H were added. Today, Firing Sites A through H are not used, and most structures associated with these firing sites have been decommissioned and dismantled. The hazardous materials used in these explosives tests, e.g. U, Be, and Pb, have largely been left in place at the firing sites where the materials were deposited by the explosion or pushed aside to clean the area. Other materials that may have been deposited in very small amounts include steel, Al, Hg, boron, cadmium, gold, and ³H. Many types of HE were used. While they may have left some residues, no unexploded high explosives have been found in the analyses of site soils. Site E-F was most heavily used and reportedly contains the largest quantities of hazardous materials. Up to 72 tons of uranium and approximately 800 lb of beryllium may have been expended in tests at Firing Site E-F. In the 1950s,
Firing Sites R-44 and R-45 were completed. These sites have been used for various explosives tests, R-45 for smaller tests and R-44 for larger ones [1086 RFI Report; 10/30/95].

TA-15, “R-Site,” is currently the home of PHERMEX (the pulsed high-energy radiographic machine emitting x-rays) a multiple-cavity electron accelerator capable of producing a very large flux of x-rays for weapons development testing. It is also the site where DARHT (the dual-axis radiographic hydrotest facility) was constructed. This site is also used for the investigation of weapons functioning and systems behavior in non-nuclear tests, principally through electronic recordings.

TA-9, Anchor Site East, housed exploration of fabrication feasibility and physical properties of explosives. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied. Name refers to Anchor Ranch, a small cattle operation that was in the area when the MED took it over in 1943. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.”

TA-14, Q Site, is a dynamic testing site used for running various tests on relatively small explosive charges for fragment impact tests, explosives sensitivities, and thermal responses. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.”

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Chapter 13: The LANL Health Division

Although the Health Division at LANL (“H Division”) was responsible for monitoring worker health, operations or activities that were associated with potential worker exposures were often also associated with potential off-site releases and public health consequences. The LAHDRA project team examined a large number of health-related progress reports published by the Health Group, Health Division, and successor organizations that carried on programs related to worker and environmental health. This chapter provides an overview of the organizational structure of the Health Division and its subgroups (such as health physics and industrial hygiene) and describes the various health and safety activities that those groups conducted over the years at LANL. A complete listing of the documents issued by the H Division and its successor groups that the LAHDRA team has located and selected as relevant to off-site releases or health effects is presented as an appendix at the end of this chapter.

The project team located and reviewed approximately 430 documents that consisted of Health Division Progress Reports or reports that are known successors to the Health Division. An example of a successor report might be one named under a different title such as Quarterly Progress Report – Group H-1 Health Physics. Many division or group reports were published monthly, although quarterly and annual reports are available for select years and were also reviewed. The oldest reports available are Health Group and Health and Safety reports for 1943 to 1945. In early 1946, Louis H. Hempelmann, MD, then acting director of the Health Division, wrote a report titled History of the Health Group (A-6) (March 1943 – November 1945). That report discusses issues related to the safe handling of plutonium and polonium and monitoring and prevention of worker exposures to these materials. Discussions of hazards associated with the RaLa and Omega Site operations as well as other health and safety issues, including injuries, are also presented in the report (Hempelmann 1946b). Another early Health Group report titled, Health Hazards of LANL Groups by Division, is a compilation of letter reports that provide summaries of early operational hazards and health and safety measures used by LANL to control worker exposures (Hempelmann 1946a). Many of the groups such as occupational medicine, industrial hygiene, health and safety, and health physics remained part of the Health Division up through the 1970s.

In 1975, the Health Division expanded its name to “Operational Environmental Health and Safety” then in 1981 changed it to “Health, Safety, and Environment.” The division has had other name changes since that time. Divisional activities continued to be published in progress reports under these and other health and safety related division or division group names.
History of H Division

According to the report titled “History of the Health Group,” a directive from the laboratory Director J. Robert Oppenheimer, dated 13 November 1943, stated that the medical supervision of technical personnel was to be directed primarily at protection of persons from the hazards of the project (Hempelmann 1946b). The primary function of the Health Group (A-6) at that time was to establish safe tolerance levels, develop monitoring methods, and to ensure that tolerance levels were not exceeded for worker exposures to hazardous materials. The primary concern was the monitoring and control of workers’ exposures to radioactive materials. Preparation of routine monitoring procedures for workers was primarily the function of each operational unit or lead individual during this early period. Effluent or environmental monitoring that would be of interest for a dose reconstruction study are not mentioned in this report.

The original policy of the Health Group was to depend entirely on information gained from health research and development groups elsewhere, such as the “Met. Lab” in Chicago. Because that policy and support from outside organizations did not always provide the needed information in time to establish safe operating procedures for use at Site Y, research sections were set up within the Health Group, such as for development of instrumentation and biological methods for testing for overexposure (Hempelmann 1946b). For example, approximately half of the 25- to 30-page monthly reports of the era describe various areas of research and papers published on the health effects of radiation by H-4, the radiobiology group, and instrument development and testing work conducted by the electronic and biophysics sections of Radiologic Safety, H-1. Accidents were reported in the Occupational Safety group (H-3) section of the division reports.

On 1 June 1947, the Health Group was renamed the Health Division and Louis H. Hempelmann, MD was the Division leader from 1943 until the end of 1948. Thomas L. Shipman, MD, assumed responsibilities from Hempelmann in 1948. In 1943, the Health Group consisted of 10 staff and expanded to 97 by 1949; by 1951, the group had grown to 158 staff (Hempelmann 1946b, LASL 1950b, 1951)

Documentation of H-Division Activities

The reports of the Health Group were typically called Health Reports, and the Division reports were called H-Division Progress Reports. The Health Reports are organized in three sections: radiation problems, chemical hazards, and general safety. By 1951, the Health Division was divided into six groups. Monthly progress reports generally consist of four to seven sections corresponding to the operating groups in the division. The six primary groups that operated under the Health Division included:
• H-1, Administrative and Medical Records later became Radiologic Safety (later renamed H-1 Health Physics); H-Division administrative activities were reported separately but not given an H number; Radiologic Safety included monitoring, electronics, and biophysics sections;

• H-2, Occupational Health included health physics, industrial hygiene, and occupational biochemistry sections; later when Radiologic Safety became a separate group called H-1 Health Physics, Occupational Medical was created to maintain responsibility for general clinical functions such as physicals and first aid;

• H-3, Training of Military personnel and Medical staff (LANL employee care) later became Occupational Safety and the training function was merged into H-Division Administration;

• H-4, Radiobiology conducted research on clinical aspects of exposure to chemicals and radionuclides including monitoring programs and instrumentation;

• H-5, Industrial Hygiene and Occupational Biochemistry sections were split off from H-2 and formed this group in June 1949; and

• H-6, Monitoring (CMR-12) was merged into H-1 and then became Radiologic Physics, including the old Biophysics group (Special Problems) and the Meteorology section.

Many of the activities performed by these groups are still being performed today under different divisional and/or group names.

Constructed during 1952-54, the Health Research Laboratory at TA-43 is adjacent to the Los Alamos Medical Center in the Los Alamos town site. Research performed at this site has included structural, molecular, and cellular radiobiology, biophysics, mammalian radiobiology, mammalian metabolism, biochemistry, and genetics. The Department of Energy Los Alamos Area Office is also located within TA-43.

The reference list located at the end of this chapter presents the most up to date list of Health Division progress or related group reports that were located and reviewed by the project team. The references are grouped by year and title. These reports document and offer insights into LANL’s health and safety program and describe health protection philosophies used to monitor personnel, work areas, and loss of material to the off-site environment. The list indicates which reports are thought to have been generated but for which copies have not been located by the project team as of the writing of this report. Some of the missing reports might be missing because a report was not issued for that period, or copies might have been lost or filed differently than other reports of the same type.
Groups within the Health Division or from other divisions with health and safety responsibilities also published monthly or quarterly progress reports. Relevant information pertaining to off-site emissions discovered during document reviews was noted, summarized, and included as appropriate in other sections of this report. Below is a list of H (Health) Division and group reports and the years for which reports were located and reviewed during the LAHDRA project. This list does not necessarily list reports by their exact titles, but rather is intended to provide an overview of the types of health-related reports for various periods. The reference list at the end of this chapter does identify relevant reports by their actual titles.

- Health Reports of the LASL Health Division (1943 – 1945)
- Health Division monthly and quarterly progress reports (1946 – 1972)
- Summary of Research, Development, and Health Activities in the CMR Division (1944 – 1951)
- H-1 General Monitoring Section (1956 – 1964)
- CMR-12 Monthly Reports (1945 – 1950)
- Air Monitoring Results – DP West (1946 – 1952)
- Weekly Reports of Stack Release Data for DP West (1950 – 1956)
- Monthly and Annual Reports, DP East (1951 – 1955)
- Health, Safety, and Environment quarterly and annual reports (1975 through 1990)
- Environment, Safety, and Health (1990 – 2005)
- Environment, Health, Safety, and Quality (2005 – present)

Health Division Perceptions of Hazards at Los Alamos National Laboratory

In 1943, the hazards of the project were reported to be limited to external radiation from the cyclotron, the Van de Graaff, the D-D source, and the radium sources. There were also hazards attributed to uranium and the usual chemical laboratory hazards, but these were not serious according to Louis H. Hempelmann. Only one accident was noted that occurred during the first year of Site Y operations. It involved overexposure to radiation from the cyclotron. The main concern of the Health Group at this time was the interpretation of blood counts on exposed personnel to radiation. Normal variation in blood counts was not well known at the time (Hempelmann 1946b).

In February 1944, plutonium arrived at LANL in significant quantities. The members of Chemistry and Metallurgy (CM) Division and the Health Group became concerned about the dangers of working with
this material. Control of alpha-emitting radioactive materials was described as rather uneventful for the
first year. After an accident in August 1944 in which a milligram of plutonium blew up in a worker’s
face, a research program to develop tests for detecting overexposure of personnel with plutonium began.
A urine test was developed in January 1945 that required a new (free of alpha contamination) laboratory
(ML Building) to conduct the bioassay tests. Following the first human tracer experiment in April 1945,
results of the urine tests were evaluated with increased certainty. Until the urine test was perfected, nose
counts were the only index used to monitor personnel exposures. Due to the difficult and time consuming
nature of the urine test, the most heavily exposed persons as indicated by nose counts underwent frequent
urinalyses. Available alpha monitoring equipment lacked both sensitivity and portability, so swipe
samples were used to detect contamination of hands, nostrils, and workplaces. A proportional counter
using a methane-filled, thin windowed tube was developed by D. Froman and R. Watts at LANL and
installed in the D-Building washroom as a hand counter in June 1944 (Hempelmann 1946b).

In September 1944, the CM-1 group was reorganized and many members of the monitoring and
decontamination section were transferred to A-6, the Health Group. The new structure did not lead to
cooperation between the two groups, and in January 1945, H-1 (CM-12), was given full responsibility for
the entire alpha contamination problem in the CM Division. At that time it was necessary to redesign the
existing facilities in D Building in order to safely handle the increased amounts of plutonium being
handled there. In July 1945, CM-5 handled amounts of plutonium that exceeded the capacity of its safety
equipment, and four persons exceeded the safe amount of one microgram of plutonium in their bodies
according to urine tests.

According to Louis Hempelmann, polonium was never the hazard that plutonium was. Because it was
less radioactive, easier to test in the urine, and relatively simple technical operations were most often
used, minimal polonium contamination and exposure hazard was recognized. Only two workers
exceeded the tolerance limit for polonium (1500 counts per minute, “cpm,” in a 24-h urine sample) by
1946 (Hempelmann 1946b).

The perceived external radiation hazard at LANL did not change until September 1944, when the Water
Boiler reactor at Omega Site went into operation. Later, when a higher powered version went into
operation (January 1945), there were several instances of overexposure when the exhaust line developed
leaks. There was also an accident that resulted in serious exposure to several chemists during
decontamination of the active material. By the time of Hempelmann’s 1946 early history summary, there
had been two serious accidents in critical assembly work at Omega Site, one that overexposed four
individuals to gamma and neutron radiation, and one fatality. The report does discuss concerns for off-
site emissions, monitoring, or control measures (Hempelmann 1946b).
During the radioactive lanthanum (RaLa) implosion tests that started in September 1944, members of the chemistry group CM-4 received periodic overexposures to beta radiation. The toxicity and accepted methods for prevention of toxicity from exposure to high explosives were more familiar. In certain cases, safe operational procedures were delayed by inadequacies in construction of exhaust systems, washrooms, etc., but no serious trouble was encountered between March 1943 and October 1945 according to some H Division reports (Hempelmann 1946b).

Although monthly H-Division reports from 1947 forward repeatedly mention the hazards of beryllium, there is no mention of beryllium in Hempelmann (1946b). Table 13-1 presents a summary of materials of concern in terms of potential health hazard, based on review of H-Division reports.

<table>
<thead>
<tr>
<th>Material of Concern (Location of Concern)</th>
<th>Examples of H-Division Reports (LAHDRA Project Repos. Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsine</td>
<td>2275, 2392</td>
</tr>
<tr>
<td>Benzol (DP West)</td>
<td>2259, 2266, 2267</td>
</tr>
<tr>
<td>Beryllium (V Shop, Sigma, R-Site, CMR)</td>
<td>2202, 2433, 2434, 2258, 2259, 2262, 2300, 2224, 2392</td>
</tr>
<tr>
<td>Fluorides (D Building)</td>
<td>2266</td>
</tr>
<tr>
<td>Lithium (Sigma, K)</td>
<td>2270, 2275, 2300, 2301, 2298</td>
</tr>
<tr>
<td>Mercury spills (Omega Site, U-14, K bldg)</td>
<td>2433, 2434, 2211, 2259, 2298</td>
</tr>
<tr>
<td>Polynuclear Aromatic Hydocarbons (scintillation fluids)</td>
<td>2209, 2270, 2275, 2216</td>
</tr>
<tr>
<td>Impurities in RaLa source (Bayo)</td>
<td>2207, 2261, 2262, 2263, 2267, 2268, 2301</td>
</tr>
<tr>
<td>Trichloroethylene (TU, Sandia, Omega, S-Site)</td>
<td>2259, 2260, 2265, 2267, 2201</td>
</tr>
<tr>
<td>TNT (S-Site)</td>
<td>2257, 2433, 2434, 2258, 2260, 2264, 2201</td>
</tr>
<tr>
<td>Thorium</td>
<td>2287, 2383</td>
</tr>
<tr>
<td>Uranium (TU, Sigma, HT)</td>
<td>2257, 2211, 2263, 2216, 2224</td>
</tr>
<tr>
<td>Plutonium</td>
<td>2330, 2375, 7188</td>
</tr>
<tr>
<td>Polonium</td>
<td>124, 3049, 7188</td>
</tr>
</tbody>
</table>

**Incidents Documented in H-Division Reports**

Following are examples of the type of information contained in the monthly H-Division reports. These examples come from reports covering a time period of approximately the mid-1950s to the mid-1960s and highlight operational conditions at LANL and effluent monitoring activities that are relevant to the LAHDRA project.

Examples of chronic issues or problems cited include:
• Liquid waste management problems at Ten Site (TA-35) for the liquid waste streams generated by the RaLa program. Problems with plant capacity and equipment lead to several unplanned discharges of large volumes of radiostrontium-bearing wastes to Mortandad Canyon.

• Leakage around improperly installed filtration units site-wide. For example, a report issued on the release of alpha activity from DP West stacks in 1955 states “definitely that the CWS-6 filters are poorly installed and consistently leak contaminated air around the edges of the filters” (Shipman 1955). In 1964, in-place DOP-testing of the filters on top of DP West Building 4 showed their efficiency to be “approximately 15%” (LASL 1964).

• Glove box explosions and fires at DP West Site are reported in numerous reports.

• Emissions of TNT dust from facilities at S Site (TA-16) are reported in numerous reports.

• Beryllium contamination of soil at R-site (TA-15). The magnitude of the contamination and the potential for resuspension prompted remediation activities on several occasions.

• Unsatisfactory media and methods for sampling airborne effluent streams for radioactive iodine due to low and unpredictable collection efficiencies. This was a particular problem for quantifying radiiodine releases from Wing 9 of the CMR Building, but it was also an issue at Omega Site and DP West Site.

• Lack of suitable instrumentation and methods for monitoring airborne effluents from the Omega Stack, and corresponding uncertainty in assessments of exposure to residents of the old trailer court area (most likely the trailer park on DP Road and overlooking Omega Site; see Chapter 15).

• Lack of appropriate monitoring instrumentation was also a chronic issue at Ten Site, where stack effluents during RaLa source preparation activities often could not be assayed due to excessive radioactivity.

• Failures of containment mechanisms for samples being irradiated in the Omega West Reactor. For example, such a failure on 7 August 1961 resulted in contamination being found on cars in the parking lot and in other areas around the building (LASL 1961b). On 23 December 1963, a rather large “sample” was irradiated in the reactor’s vertical port and had to be removed through the roof of the building. The sample was then dragged down the road to its storage location. Afterward, the roof of the building and the road read 50 mR h⁻¹ and 20 mR h⁻¹, respectively, from contamination by ¹²²Sb and ¹²⁴Sb (Shipman 1964).

• Soil and groundwater contamination downstream from the TA-35, TA-45, and (in later years) TA-50 liquid waste outfalls were reported during the 1950s and 1960s in various reports.
Specific examples of contamination being spread to private property include:

- A contamination incident at the Water Boiler on 16 August 1950 resulted in contamination being spread to a private home (LASL 1950a).
- In 1961, a $^{137}$Cs contamination incident at TA-48 resulted in contamination being tracked off site by workers; 28 homes and 47 vehicles were surveyed for contamination (LASL 1961a).
- $^{90}$Sr contamination was spread to a worker’s vehicle on 2 June 1961 from a spill at the H-7 waste treatment laboratory (LASL 1961c).

Specific examples of episodic events and sources of fugitive and unmonitored emissions include:

- On 8 January 1953, LASL discovered that a polonium-beryllium source had ruptured at the Pajarito Site and found that contamination had spread to Los Alamos residential areas. Follow-up monitoring was performed to assess the extent of the unmonitored release (Shipman 1953).
- Dust from the demolition of contaminated buildings in the Original Technical Area (TA-1). Demolition activities included Buildings CM, D, HT, J-2, M, ML, and N. Debris from these demolition projects was often burned at the contaminated dump site.
- In 1956, glass vials containing tritium gas were disposed of at Beta Site (TA-5) by placing ten at a time in a barrel and dropping a weight on them. At one point, a tritium concentration of 15,000 $\mu$Ci m$^{-3}$ was measured at a distance of 100 ft from the barrel.
- Unintentional releases of tritium from Building TA-33-86 required the site to be evacuated and access restricted by road blocks on multiple occasions (Shipman 1958, 1959b).
- A nuclear criticality accident at DP West (Building 2) on December 30, 1958 killed one worker and exposed numerous others (Shipman 1959a).
- A fire in a plutonium-contaminated CWS filter at DP West Room 501 on 15 July 1959. Highly-contaminated ash was found both inside and outside the building (Shipman 1959b). Another fire occurred in the incinerator drybox exhaust system in DP West Room 313 on 8 December 1959. Buildup of residues allowed the fire to spread throughout the exhaust system. It is reported that the exhaust stack was red hot up to 5 ft above the roof (LASL 1959).
- In 1960, hydrogen sulfide emissions from Building TA-46-1 led to complaints from workers about fumes being drawn back into the building through the intake air system (Shipman 1960).
References


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Appendix 13A: Listing of Reports Issued by the Los Alamos Health Group, Health Division, and Successor Groups

The following compilation of reference documents related to LANL’s Health Division highlights those sources of information that contain information relevant to operational activities and effluent monitoring practices, particularly for those early operational years when reporting of source term information (i.e., basic monitoring data, sampling methods) varied in content both in quantity and quality and are presented in a variety of division and group report formats. The reference list is organized chronologically and grouped by report titles.

1943 – 1946 Health Group Reports

Hempelmann, L. H. 1943a – Health Report, LAMS-6, August 9, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7184


Hempelmann, L. H. 1944c – Health Report, LAMS-81, April 14, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7188


Hempelmann, L. H. 1944e – Health Report, LAMS-126, August 30, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 3953


Hempelmann, L. H., 1946b, Health Hazards of LANL Groups by Division, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 136
1944 – 1945 Health and Safety Reports

LASL (Los Alamos Scientific Laboratory), 1944a, Health and Safety Report – CM Division LAMS-87, April, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7189


LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-129, August, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7193

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-143, September, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7194


1947 Health Division Reports


1948 Health Division Reports


Note: H Division Monthly Progress Reports for May 20 – June 20, 1948 and June 20 – July 20, 1948 have not been located at LANL.


Note: An H Division Annual Progress Report for 1948 has not been located at LANL.

1949 Health Division Reports


LASL (Los Alamos Scientific Laboratory), 1949g, H Division Monthly Progress Report, LAMS 929, June 20, 1949 - July 20, 1949, HSPT-REL-94-266, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2301


Note: An H Division Monthly Progress Report for September 20 – October 20, 1949 was not located at LANL.


Note: An H Division Monthly Progress Report for November 20, 1949 - December 20, 1949 was not located during project research activities

LASL (Los Alamos Scientific Laboratory), 1950a, H Division Annual Report 1949, LA-1072, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2270

1950 Health Division Reports

Note: An H Division Monthly Progress Report for December 20, 1949 - January 20, 1950 was not located during project research activities.


Note: An H Division Monthly progress report for November 20 - December 20, 1950 was not located during project research activities.


**1951 Health Division Reports**

Note: An H Division Monthly Progress Report for December 20, 1950 - January 20, 1951 was not located during project research activities.


LASL (Los Alamos Scientific Laboratory), 1951f, H Division Monthly Progress Report, May 20, 1951 - June 20, 1951, HSPT-REL-94-357, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2226

LASL (Los Alamos Scientific Laboratory), 1951g, H Division Monthly Progress Report, June 20, 1951 - July 20, 1951, HSPT-REL-94-360, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2227


1952 Health Division Reports


**1953 Health Division Reports**


**1954 Health Division Reports**


**1955 Health Division Reports**


Note: An H Division Annual Progress Report for 1955 was not located during project research activities.

1956 Health Division Reports


Note: An H Division Monthly Progress Report for July 20 – August 20, 1956 was not located during project research activities.


Note: An H Division Annual Progress Report for 1956 was not located during project research activities.

1957 Health Division Reports


Note: An H Division Monthly Progress Report for March 20 - April 20, 1957 was not located during project research activities.


1958 Health Division Reports


Note: An H Division Annual Progress Report for 1958 was not located during project research activities.

1959 Health Division Reports


Note: An H Division Annual Progress Report for 1959 was not located during project research activities.

**1960 Health Division Reports**


Note: An H Division Annual Progress Report for 1960 was not located during project research activities.

**1961 Health Division Reports**


Note: An H Division Annual Progress Report for 1961 was not located during project research activities.

**1962 Health Division Reports**


Note: An H Division Monthly Progress Report for June 21 - July 20, 1962 was not located during project research activities.


Note: An H Division Monthly Progress Report for October 21 - November 20, 1962 was not located during project research activities.


Note: An H Division Annual Progress Report for 1962 was not located during project research activities.

1963 Health Division Reports


Note: An H-Division Progress Report for September 21 - October 20, 1963 was not located during project research activities.


Note: An H Division Annual Progress Report for 1963 was not located during project research activities.

1964 Health Division Reports


Note: An H Division Monthly Progress Report for January 21 – February 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for March 21 - April 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for May 21 - June 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for September 21 - October 20, 1964 was not located during project research activities.


Note: H Division Monthly Progress Reports for October 21 - November 20, 1964 and November 21, 1964 – December 20, 1964 were not located during project research activities.

Note: An H Division Annual Progress Report for 1964 was not located during project research activities.

1965 Health Division Reports


1966 Health Division Reports


1967 Health Division Reports


**1968 Health Division Reports**


**1969 Health Division Reports**


**1970 Health Division Reports**


Note: Monthly or quarterly H Division Progress reports for the period October - December, 1970 were not located during project research activities.

**1971 Health Division Reports**


1972 Health Division Reports


Note: Quarterly Progress Reports for July – September 1972 and October – December 1972 was not located during project research activities.

1973 and 1974 Health Division Reports

Note: H-Division Quarterly Progress Reports from third quarter of 1972 through 1980 were not located during the project. Quarterly reports were located for 1981 and second quarter 1982. Additional H-Division reports for this time period and later were not located during project research activities.

1981 Health Division Reports


LASL (Los Alamos Scientific Laboratory), 1981c, Health Division Quarterly Report, April - June 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 936

LASL (Los Alamos Scientific Laboratory), 1981d, Health Division Quarterly Report, July - September 1981; Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 5603

LASL (Los Alamos Scientific Laboratory), 1981e, Health Division Quarterly Report, October - December 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 935

1982 Health Division Reports


Note: Quarterly Progress Reports for January – March, 1981 and July – December, 1981 were not located during project research activities.

Note: Starting the third quarter of 1972, LASL began to publish quarterly and monthly Health Physics reports.

1972 Health Physics Reports


1973 Health Physics Reports


1975 Health Physics Reports

Dummer, J.E., 1975a, Quarterly Progress Report – Group H-1 Health Physics, July – September 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392a

Dummer, J.E., 1975b, Quarterly Progress Report – Group H-1 Health Physics, October - December 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448

1976 Health Physics Reports


Dummer, J.E., 1977b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392c

Dummer, J.E., 1977c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392d


1977 Health Physics Reports


Dummer, J.E., 1978b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392g

Dummer, J.E., 1978c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392h

Note: Starting in the third quarter of 1978, Area Heath Physics (Group H-1) began reporting activities in separate monthly and quarterly reports. The last report with these titles that were located during the project is for January 1981 activities.

Note: Starting in the third quarter of 1978, Area Health Physics began reporting activities in separate monthly and quarterly reports.


1979 Health Physics Reports

Dummer, J.E., 1979a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392j

Dummer, J.E., 1979b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392k

Dummer, J.E., 1979c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392l

Dummer, J.E., 1979d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392m.

Dummer, J.E., 1979e, Area Health Physics Monthly Report, January 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5473

Dummer, J.E., 1979f, Area Health Physics Monthly Report, February 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. 5474

Dummer, J.E., 1979g, Area Health Physics Monthly Report, March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5475

Dummer, J.E., 1979h, Area Health Physics Monthly Report, April 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5476


Dummer, J.E., 1979l, Area Health Physics Monthly Report, August 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5480

Dummer, J.E., 1979m, Area Health Physics Monthly Report, September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5481


Dummer, J.E., 1979o, Area Health Physics Monthly Report, November 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5568


1980 Health Physics Reports


Dummer, J.E., 1980b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392o


Dummer, J.E., 1980d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392q

Note: Starting in the third quarter of 1978, Area Heath Physics began reporting activities in separate monthly reports.


1981 Health Physics Reports


Note: Starting in the third quarter of 1978, Area Health Physics began reporting activities in separate monthly reports.


1982 Health Physics Reports


1983 Health Physics Reports


Note: Quarterly Progress Reports – Group H-1 Health Physics for April – June 1983, July – September 1983, and October – December 1983 were not located during project research activities.


Note: September 1983 Health Physics Monthly Activity Reports were not located during project research activities. Miller, J., Gallimore, J., Stafford, R., 1983a, Health Physics Monthly Activity Reports - Operational, October 1983, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5661


1989 Health Physics Reports


1990 Health Physics Reports


1991 Health Physics Reports


1975 EHS Reports


Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for July - September 1975 was not located during project research activities.

Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for October – December 1975 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1975c, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, January - March 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4993
LASL (Los Alamos Scientific Laboratory), 1975d, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, April - June 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4994

1976 EHS Reports


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Chapter 14: Environmental Monitoring at LANL

This chapter presents a summary of environmental monitoring and research data that may be useful for evaluation of historical releases from Los Alamos National Laboratory. The reports and monitoring data reviewed by the LAHDRA project team represent samples or measurements collected in both on-site and off-site areas potentially affected by past contaminant releases from Los Alamos National Laboratory operations. The information presented here is organized chronologically to highlight changes and improvements that have occurred during the evolution of LANL’s environmental monitoring programs since the start of Laboratory operations in 1943. Details on monitoring practices presented in this chapter are more heavily weighted toward pre-1970 monitoring since it was during this time period that the largest releases occurred.

Overall information availability is summarized in the following sections. Brief descriptions are included of several example environmental studies that are tied to past LANL activities. It is important to note that, while this chapter summarizes a number of environmental monitoring studies, it is not a complete historical record of every study conducted to date. Many more environmental studies are described and referred to in documents that were selected by the LAHDRA project team and added to the project information database.

Areas of Investigation

Environmental monitoring and research data reviewed by the LAHDRA project team primarily address sampling and measurement of environmental media such as air, water, soils, sediments, biota, and foodstuffs that were potentially impacted by radioactive and chemical contaminants released from LANL. Monitoring data of interest to this project represent measured concentrations of contaminants at on-site and off-site locations, including areas along the site boundary and residential communities that are nearby, regional, or useful for characterization of background concentrations. Historically, these data have typically been used by LANL to monitor trends in contaminant releases and/or to study the presence, migration, and fate of releases that have occurred or are occurring through transport mechanisms such as air dispersion, leaching, or surface flow to important water resources. Environmental monitoring data are of interest for potentially filling data gaps that exists in historical effluent monitoring data for various discharge points at LANL.

The following section describes the primary geographical areas of interest during the investigation. These areas were selected for investigation based on:
• The LAHDRA project team’s knowledge of the key release sources at the Laboratory,
• Previous environmental studies of on-site and off-site areas,
• Surface waters that have received past LANL emissions,
• Reported areas of contaminant accumulation in surface water, sediments, and surface and subsurface soils,
• Annual airborne releases and indications of how they have been affected by local and regional wind patterns as well as local and regional topography, and
• Historical environmental surveillance and monitoring and a review of environmental data availability.

Some environmental monitoring within the laboratory boundary and surrounding areas began within the first few years after the start of Laboratory operations in 1943. Monitoring was first conducted by members of the Health Group of Project Y, the United States Atomic Energy Agency, and the U.S. Geological Survey (USGS). In more recent years, other LANL divisions and the State of New Mexico have also conducted environmental monitoring and/or environmental studies. Most of the early monitoring involved collection of non-routine air, water, soil, and sediment samples that were analyzed for radioactive and occasionally elemental or chemical contaminants. The early environmental monitoring program was used to identify and characterize the spread of radioactive contamination to surrounding land areas and to estimate potential radiation exposures to workers as a result of laboratory activities and emissions.

Increased monitoring over the years meant the collection of a larger number of routine samples for all types of media and for a growing list of contaminants. The frequencies with which samples were collected also increased over the years. With the advent of new environmental protection and emission standards of the early 1970s, LASL saw the need to further increase their monitoring of the environment both on site and off site and enhance the formats with which they reported measurement results. The need to do more monitoring was also brought to the LASL’s attention by independent reviewers and experts (Parker 1974).

Based on reports reviewed to date, most of the emphasis for environmental monitoring during the early years was placed on measuring radioactive constituents; however, beginning in the late 1950s, some limited sampling was performed for lead, mercury, chromium, beryllium, and other elements and chemicals of interest. Early environmental documents pointed out the need to increase sampling for all media and to perform radiochemical analyses for isotopic plutonium and specific fission products.
associated with fall-out from atmospheric weapon tests to better differentiate between global fallout and impacts from LASL (Parker 1974).

The areas of concern for the investigation of environmental data include:

- Los Alamos community
- Española community
- White Rock community
- Surrounding Native American lands
- Los Alamos Canyon
- DP Canyon
- Pueblo Canyon
- Acid Canyon
- Rio Grande River
- Mortandad Canyon
- Bayo Canyon
- Pajarito Canyon
- Sandia Canyon
- Guaje Canyon
- Area reservoirs

**Conditions at LANL and Surrounding Areas**

The laboratory site and adjacent communities are situated on the Pajarito Plateau, which consists of a series of mesas separated by deep canyons. These canyons were cut by intermittent streams that trend south-eastward from an altitude of about 2,400 meters at the Jemez Mountains to about 1,800 meters at the eastern margin, where they terminate above the Rio Grande Valley. The canyons and mesas areas are underlain by the Bandelier Tuff composed of ashfall and ashflow pumice and rhyolite tuff that form the surface of Pajarito Plateau. The volcanic ash was deposited following an eruption that occurred about 1.2 million years ago (LASL 1980).

Surface waters are primarily intermittent streams that begin on the sides of the Jemez Mountains and supply base flow to the upper reaches of some canyons. The amount of flow in these streams is typically insufficient to maintain flow across the laboratory area before it is depleted by evaporation, transpiration, and infiltration. However, runoff from heavy thunderstorms and significant snowmelts reaches the Rio Grande several times a year. Over portions of LANL’s operational history, effluents from the Laboratory have provided sufficient volume to maintain surface flow in the canyons for distances up to 1.5 km (LASL 1980). Several photographs of LANL discharges to area canyons are shown in Fig. 14-1.
Groundwater occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in the canyons, (2) perched water in basalt, and (3) the main aquifer of the Los Alamos area. Deposited alluvium in the canyons ranges in thickness from 1 to 30 m and is quick permeable in contrast to the underlying volcanic tuff and sediments. This results in a shallow alluvial groundwater that moves down gradient in the alluvium and becomes depleted as it moves into the underlying volcanic deposits. In lower Los Alamos and Pueblo Canyons, a small local body of perched water is formed in the basalts by water filtration. This water discharges in the Los Alamos Canyon west of the Rio Grande. The main aquifer capable of municipal water supply rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the plateau. Depth to the aquifer decreases from 360 m along the western margin of the Plateau to about 180 m at the eastern margin. The water is under water table conditions in the western and central part of the plateau and under artesian conditions in the eastern part and along the Rio Grande (LASL 1980).
Availability of Environmental Data

Much of the environmental monitoring results reported for years prior to 1970 and reviewed by the project team are published in letter-type reports that vary widely in content and detail. In some cases, only a portion of a report was available for review or a report may only contain limited amounts of monitoring data or lack a description of the methods and purpose for a monitoring activity. Information presented in these earlier documents indicates that environmental monitoring was sporadic and generated a smaller amount of data when compared to results for later years, when monitoring activities were much more formalized and comprehensive.

By the late 1950s, attempts were made by the laboratory to formally consolidate environmental monitoring results into one report. One of the first such reports is titled *Los Alamos Environmental Monitoring Program* for the years 1959 and 1960. This report includes results for direct gamma measurements, air particulate sampling for analysis of alpha and beta air concentrations, and water sampling of potable water supplies, surface body waters, and test monitoring wells (Kennedy 1960). However, it was not until 1970, when LANL began to publish their annual environmental surveillance reports, that results of monitoring activities were routinely reported in a unified and comprehensive manner. Monitoring grew substantially over the next 35 years, with results published and documented in the annual environmental monitoring reports. Many of these annual reports are now available to the public on the laboratory’s Web site at [www.lanl.gov](http://www.lanl.gov).

Chronology of Early Environmental Monitoring at LANL (1943 – 1970)

Documents indicate that LANL began their first environmental monitoring activities sometime in 1944 or 1945. Monitoring was designed to measure radioactive and chemical concentrations in water, sediments, and soils with the intent of defining the impacts to the environment from laboratory liquid waste discharges to nearby canyons or burial grounds. The monitoring program evolved in the 1950s and expanded to include additional sampling and radiation surveys. Along with increases in water and soil sampling locations and sample collection frequencies, LANL began routine gamma radiation measurements and air sampling for gaseous and particulate radionuclides or non-radioactive contaminants. LASL periodically reported results for these early sampling and radiation survey activities in brief letter reports. Reports often present combined results for water and soil samples, ambient gamma measurements, and air samples (Tribby 1945; Tribby 1947; Kinsley 1947; LASL 1954a; Kennedy 1965). Occasionally, LASL reported results for radioactive fallout particulates from LANL operations using “Sticky trays” with gummed-paper to collect the radioactive contamination (Kennedy 1958). These early
sampling activities were sporadic and often involved non-routine monitoring to study changes in contaminant concentrations over time and movement of contaminants in the environment.

An independent safety appraisal of the LASL health and safety program conducted in 1947 by the Safety and Industrial Health Advisory Board of the National Safety Council was highly critical of the laboratory’s ability to control and monitor releases of hazardous materials to the environment (Williams 1948). In addition, LASL documents indicate that environmental monitoring lacked continuity and consistency in terms of sampling methods and data analysis and reporting. The use of staff from various groups operating somewhat independently from one another made it difficult to compile routine data into unified and consistent formats with the level of data and reporting quality that was desired (Kennedy 1958). Effluent and environmental monitoring programs were not as well developed as the methods and practices used for monitoring personnel radiation exposures during this time period and it is evident that the health and safety program was primarily directed towards reducing radiation exposures to workers. Documents available to the project team indicate that routine environmental air sampling was almost nonexistent until the mid to late 1950s.

Monitoring of Liquid Waste Releases

During early operations in the 1940s, liquid waste from the DP site (TA-21) and the Original Technical Area (TA-1) were released into Los Alamos Canyon and Pueblo Canyon. Periodic water and sediment samples were collected in the canyon creeks and drainage areas and in off-site areas such as the Rio Grande and analyzed for radioactive and chemical contaminant concentrations. Samples of liquid effluents were also collected at discharge points to determine if the amounts of waste released were within the legal or recommended concentration limits for the time and also used at the Hanford site (Tribby 1948). Many of the samples during this time were analyzed for plutonium, polonium, uranium, beta and gamma, and occasionally for heavy metals and other elements such as lead, bismuth, mercury, chromium, and fluorine (Tribby 1945; Kingsley 1947; Kingsley et al. 1947; Schnap et al. 1948; Shipman 1958).

Area supply wells and other potable water supplies were also sampled and tested (Kennedy 1948). The liquid effluent limits at that time were $6.3 \times 10^{-4}$ µCi L$^{-1}$ for plutonium and polonium and $5.0 \times 10^{1}$ µCi L$^{-1}$ for mixed fission products such as $^{140}$La and $^{140}$Ba. The earliest LANL documents that describe initial monitoring activities and results are for 1945 to 1950 (Tribby 1945; Tribby 1947; Schnap et al. 1948; Schnap 1950). Treatment of the liquid waste was initially minimal, but did increase as production and liquid waste volumes increased (Tribby 1948). The following excerpt from a LANL document depicts the sources of contamination and environmental areas targeted for sampling (Tribby 1945).
Water sampling was usually conducted after heavy rains since creek beds were often dry during seasonal periods of low precipitation. Many of the samples were collected in “pools” which is where liquid waste discharges and rainwater collected in lower-lying or down gradient drainage areas (Kingsley 1947).

Concentrations for radioactive contaminants in water and soil samples were typically elevated at locations near effluent discharge points in the canyons and decreased to undetectable levels within short distances from points of discharge. Elevated levels were often identified during periods of liquid discharge but concentrations would decrease over time due to the decay of short-lived radionuclides such as polonium or from dilution and movement of longer-lived radioactive contaminants dispersed within surface waters during periods of moderate to heavy precipitation (Kingsley 1947; Schnap et al. 1948). Records indicate that LASL began to scale back on their liquid waste discharges to Los Alamos and Pueblo Canyons as additional waste treatment facilities at the laboratory became operational to reduce contaminants levels release to the canyons or burial grounds.

LASL found it necessary to expand their waste treatment capacity as growing production and research demands generated larger and larger volumes of liquid and solid radioactive and chemical waste. H-7 group became part of the H Division in June 1955 and assumed responsibility for liquid waste treatment
and management. The H-7 Group also oversaw a growing environmental monitoring program in those areas potentially impacted by liquid and airborne discharges. Two liquid waste treatment plants used co-precipitation for removal of plutonium and one plant was equipped with an ion exchange unit to remove barium-140 and radioactive strontium isotopes (Shipman 1958).

The Waste Treatment Plant at TA-45 received wastes from TA-1 and TA-3 and discharged treated liquid waste to Acid canyon. For example, 11.5 million gallons of waste was received in 1957. Treatment of the waste removed roughly 94% of the radioactivity and 99% of the plutonium, which allowed them to meet 10% of the NBS 52 Handbook tolerance for plutonium discharge (Shipman 1958). More treatment capacity was added as necessary and releases of contaminants decreased over time.

The Ten Site Waste Treatment Plant at TA-35 handled liquid waste for the RaLa program with four 50,000 gallon tanks. Wastes contained mixtures of $^{140}\text{Ba}$, $^{140}\text{La}$, $^{89}\text{Sr}$, $^{90}\text{Sr}$, $^{90}\text{Y}$ and trace amounts of other radionuclides. Waste treatment removed 93% of radioactivity and discharged roughly 92% of liquid waste volume to Mortandad Canyon after treatment (Shipman 1958).

In coordination with LANL, the United States Geological Survey (USGS) also collected routine water samples from local surface streams, the Rio Grande, supply wells, and monitoring wells and submitted the samples to LANL for radiochemical and water quality analyses. Monthly samples were analyzed for gross alpha, gross beta, plutonium, and uranium. Samples were also analyzed for pH, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO$_3$, and conductivity. Volumetric flow rates for streams located in Pueblo and Los Alamos canyons are also presented in study results. These additional sampling were also used to assess the potential impacts from LANL operations on water resources and to better understand the rate and direction of groundwater flow in the local and regional area (LASL 1959; Shipman 1956).

By the 1970s, LANL was conducting water sampling at various locations at distances of 40 to 50 kilometers away from the main laboratory area (LASL 1971a). Additional examples of early environmental monitoring studies of waterborne contamination are presented in a later section of this chapter.

**Soil Monitoring**

LANL also conducted soil sampling at on-site and off-site locations to further assess impacts from liquid waste discharges from TA-1 and TA-21. Soil samples were collected in areas along canyon creeks or in dry creek beds and drainage areas. Samples were often analyzed for plutonium, polonium, uranium, beta
and gamma heavy metals and other elements such as lead, mercury, chromium, and fluorine (Tribby 1945). Soil sampling results were reported along with results of their water monitoring activities. Concentrations results at on-site locations close to discharge points are often reported above detection limits or background levels. Results for sampling locations at greater from discharge points are often reported as “negative” meaning either concentration levels were below the method detection limits for analytical measurement techniques used at the time or were below an administrative or regulatory control limit (Kennedy 1952).

Results for soil samples collected in Acid Canyon (discharge from TA-45 plant), Mortandad Canyon (discharge from TA-35 plant), Los Alamos Canyon (discharge from TA-21), and at the laundry site were periodically reported in Health Division of reports or memoranda (Shipman 1958). Samples during this time period were analyzed according to location— gross alpha and plutonium at Acid and Los Alamos Canyons and 90Sr and yttrium at Mortandad Canyon.

In 1955, soil sample results showed strontium contamination in upper reaches of Mortandad Canyon that exceeded NBS Handbook tolerance levels (Shipman 1958). Study of plutonium, strontium, and cesium movement in tuff materials was begun during 1957 and reported that very little movement of radioactive material had occurred based upon comparison to sampling results for the previous years. Soil sampling continued throughout the 1950s and beyond. Results consistently showed strontium contamination in the canyon from Ten Site liquid waste discharges (Shipman 1956).

Grab and composite surface water samples were collected at various locations along the Rio Grande River and the Chama River. The rivers had a reported natural uranium background concentration of approximately 10^-9 µCi cm^-3. Water samples are also collected at 7 perennial streams, 13 water supply wells, and 8 test monitoring wells located in various canyons within and surrounding the laboratory (Shipman 1956). In 1957, LANL began a study to evaluate the movement of 90Sr, 137Cs, and 239Pu released from LANL through the local soils, including tuff material (Shipman 1958).

By the 1970s, LANL was conducting soil and sediment sampling at various locations 40 to 50 km away from the site (LASL 1971a). Additional examples of early monitoring of soil contaminants and sampling studies are presented in a later section of this chapter.

**Air Monitoring**

A variety of air monitoring activities and measurements conducted by LANL were also used as another means of assessing impacts from routine or accidental air effluents from laboratory operations or from re-suspension of radioactively-contaminated soils or dry sediments. The primary focus of their early air
monitoring program from 1944 to around 1970 was to detect larger, accidental releases and as such this meant that routine sampling results at or below detection limits were not reported on a regular basis. These early monitoring stations were equipped with thin-walled GM tubes and a scaler/rate meter to record results. By the late 1950s and 1960s, air particulate filters and charcoal canisters were being used at most of these stations to measure gross alpha and beta and radioactive iodine concentrations in air. Routine reporting of these early measurements also appear to be sporadic and limited in the amount of data presented in LANL documents. It appears that only a limited amount of air monitoring results for 1940s and 1950s and, to some extent the 1960s, was published by LANL. It is also possible that results were published in reports that are now missing or were destroyed or simply were not located by the project team. Routine reporting of monitoring results, however, does not appear to have begun in earnest until 1970 based on available documents reviewed by the project team.

LASL did not have a well established network of air monitoring stations until the late 1950s and documents indicate that 25 to 36 monitoring stations were used from 1958 to 1992. Most of these stations were located on-site within the various Technical Areas at LANL or within the Los Alamos town site or the town’s immediate surrounding areas. The two on-site monitoring stations furthest away from the Main Technical area or Los Alamos town site were located in White Rock, New Mexico (approximately 6 miles to the southeast) and at the eastern site boundary. The report entitled *Los Alamos Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, January through June, 1971* (the predecessor report to LANL’s Annual Environmental Surveillance reports) indicates that LANL began to use two remote “off-site” air monitoring stations starting sometime in 1971. One station was placed in Española, New Mexico approximately 14 mi northeast of Los Alamos and the other station was located in Santa Fe, New Mexico, approximately 24 mi southeast of Los Alamos (LASL 1972a).

In 1992 and 1993, LANL expanded the number of on-site monitoring stations to 52 including the addition of regional or remote stations at various locations up to approximately 45 mi northeast of LANL. The collective array of air monitoring stations became known as AIRNET monitoring program. During this expansion of air monitoring stations, LANL also increased the network to six off-site or remote monitoring stations. The remote stations since that time are located in Española, San Ildefonso Pueblo, El Rancho, and Jemez Pueblo New Mexico and still being used by LANL. An additional monitoring station was added within the city limits of Santa Fe. In 2003, LANL added a seventh remote monitoring station at Picuris Pueblo, New Mexico, making it the station furthest away from LANL at roughly 45 mi to the northeast. Most of these AIRNET stations or predecessor monitoring stations are still in operation today although routine or periodic reporting of monitoring results did not begin until the 1970s with the advent of LANL’s Annual Environmental Surveillance reports (LANL 1994; LANL 2008). Starting around the
early to mid-1960s, air filters were measured for gross alpha and beta activities and then made into composite samples once a month for isotopic analyses of long-lived alpha-emitting radionuclides such as plutonium. Charcoal canisters also continued to be analyzed for $^{131}$I by way of gamma measurements and water vapor was measured for tritium concentrations via liquid scintillation counting.

A comparison of environmental air monitoring programs at other DOE sites shows that LANL used similar measurement techniques throughout the years although they did not establish remote, off-site monitoring as early as some DOE sites. For example, the Oak Ridge Reservation (ORR) sites (X-10, Y-12, and K-25) used a formal network of local and perimeter (“on-site”) samplers and monitors during the 1940s and 1950s, but also began using remote (“off-site”) gamma and air monitoring stations in the early 1960s. Eventually, the networks of monitoring stations were officially referred to as the local air monitors (LAMs), perimeter air monitors (PAMs), and remote air monitors (RAMs). ORR’s LAM and PAM monitoring stations used during this early period were equipped with ion-chamber type instruments to measure outdoor ambient gamma radiation levels. These instruments were later modified to measure beta radiation, although laboratory staff discovered the instruments were highly susceptible to weathering and proven to be unreliable for routine measurements. ORR eventually adopted the used of GM tubes with scaler/rate meters to measure both gamma and beta radiation. Charcoal canisters were used at selected stations for iodine measurements and tritium measurements were performed on rain water samples. Similar to the practices used by LANL, ORR also used film badges and TLDs in later years to measure gamma and beta radiation and air samplers to measure particulate and gaseous airborne concentrations of radioactive materials for determining impacts from site effluents and/or global nuclear fallout.

ORR used three remote air monitoring (RAM) stations as far back as 1956. These stations were also equipped with GM Tubes and scalers along with gummed-paper trays and rain collectors for measuring air particulate radioactive contaminants/fallout along with charcoal canisters for measuring radioactive iodine. The first three RAMs used were located in Corryton and Kingston, Tennessee and Berea Kentucky. The Corryton and Kinston stations were only used in 1956 and data for the Berea station is only available for 1957 and 1958. The Berea station was discontinued in 1962. Prior to 1959, seven additional remote air monitoring stations were added at various Tennessee Valley Authority (TVA) dam locations ranging in distance approximately 12 to 75 miles from the ORR (NIOSH 2004). In comparison, LANL’s primary focus during early air monitoring was not on remote locations as much as it was on monitoring impacts to local residential areas and nearby canyons. It wasn’t until around 1970 that LANL began to expand their air monitoring network beyond its site boundary.
Bayo Canyon (TA-10) and TA-35 – RaLa Test Shots

LANL documents from the 1940s and early 1950s indicate that initial air monitoring conducted by LANL was focused on monitoring radioactive fallout from the RaLa test shots conducted in Bayo Canyon. Radiactive and chemical debris from test shots containing $^{140}\text{Ba}$ and $^{140}\text{La}$ was released to the atmosphere at dispersion rates and directional patterns based on weather conditions at the time of each shot. Airborne contaminants would typically migrate beyond Bayo Canyon to surroundings areas. As discussed in a 1945 LANL document, the three primary hazards associated with RaLa shots included external radiation, explosive materials, and airborne contamination. Airborne contamination was monitored at the firing location and at other points in the canyon and on the Los Alamos mesa initially by members of Group A-6 (Steinhardt 1945). Measurements were made with film badges mounted 3 feet above the ground surface on wooden or metal stakes. Direct gamma measurements were also collected with a GM tube and a scaler/rate meter. Later on fallout trays with gummed-paper were used to collect radioactive debris.

Radioactive fallout from most test shots was monitored to the extent practical as LANL acknowledged that some downwind areas surrounding Bayo Canyon were inaccessible due to the rugged terrain in part of New Mexico. Following test shots, the road from the Main Tech area (TA-1) to the East Gate was often closed to vehicle traffic to allow time for removal and/or decay of radioactive contamination to levels deemed acceptable to allow resumption of public access on the roads. For example, the radioactive plume from a RaLa shot conducted on April 20, 1949 passed over and contaminated the area from the East Main Gate to Los Alamos town site. The incident required decontamination of the main road (Highway 285) before the road was reopened to the public or other workers. Because of these incidences, LANL sought to improve their weather and fallout predictions by requesting the assistance from meteorologists from the Kirkland Air Force Base in Albuquerque (LASL 1949a).

Debris from another shot on May 20 of the same year drifted out of the canyon and contaminated the main road to Los Alamos at the Frijoles junction and resulted in maximum gamma-beta readings of 10 mR h$^{-1}$ (LASL 1949b). Throughout this time period, staff from the Biophysics section focused their efforts on further defining and predicting fallout from the RaLa shots to minimize exposures to workers and members of the public. In 1949, the fallout problem became more acute when LANL discovered a new mining operation in Guaje Canyon operated by the Santa Fe Pumice Company located about 3 mi away from Bayo Canyon. To minimize the spread of contamination and better characterize potential environmental and public health impacts from RaLa test shots, LANL increased their efforts to measure wind rose patterns including prevailing wind directions and maximum and average wind velocities of
prevailing winds (LASL 1949c). As reported in a 1949 monthly H Division progress report, the plume from an implosion test shot rose and spread contamination easterly as far away as 10 mi at a location known as “Camp May” (LASL 1949d).

Descriptions in the 1952 H Division annual report indicate that LANL continued to monitor dispersion and fallout of radioactive material from Bayo Canyon test shots. These surveys focused on tracking contamination in areas north and east of Bayo Canyon, White Rock, Totavi, Puje, and Espanola and to address growing concerns about releases from RaLa shots and from other facilities such as DP Site as production increased significantly during this period. In the report it was noted that additional sampling was conducted along East Road to assess impacts and hazards from DP Site as well as from Bayo Canyon releases. Health Division members from the H-1 and H-6 monitoring groups also expanded the on-site and off-site monitoring program to further address the growing concerns about impacts to the environment (Shipman 1953).

Laboratory safety personnel also expressed concerns about personnel and public exposures associated with RaLa test shots as well as airborne effluents from RaLa hot cell operations and operations at TA-2 (Omega), TA-3 (CMR Building), and TA-21 (DP Sites). The TA-35 hot cell facility was used to handle, store, and prepare the RaLa sources for test shots conducted in Bayo Canyon. The excerpt from a 1952 LANL document shown in Fig. 14-3 represents another example of LANL activities used during this time to assess the impacts from the TA-35 radioactive airborne effluents (Buckland, 1952).

The excerpt from a 1952 LANL document shown in Fig. 14-4 further indicates that LASL staff was aware of the importance of predicting weather conditions to minimize the spread of radioactive contamination and conducted periodic surveys to determine impacts of air effluents (Buckland, 1952). Other means of tracking cloud dispersions from the RaLa shots was through the use of air conductivity measurement. This technique proved to have advantages over the use of GM tube instruments, particularly when radiation fields approach saturation levels (LASL 1951). Based on review of project documents, it is not clear to what extent LANL used conductivity measurements in tracking radioactive, explosive cloud dispersions.
In a series of reports and memoranda from 1956 to 1959, monitoring of outdoor air concentrations and radiation levels within and surrounding TA-35 continued to be used to assess impacts from airborne effluents associated with $^{140}$Ba/$^{140}$La source production, LAPRE operations, and irradiated reactor fuel analyses (including fission products) and plutonium experiments in hot cells (LASL 1959). Availability of these environmental monitoring data are limited based on document searches conducted by the project team. These types of data could be useful as a tool for evaluating the accuracy of effluent estimates.
reported by the lab or release estimates derived from basic effluent measurement data. Further research including document searches for these early environmental data is recommended to be part of any future dose reconstruction study of LANL operations.

Main Technical Area and Greater Los Alamos and Surrounding Areas

In 1951, LANL continued to discuss the need to expand their air sampling program to improve the ability to measure contamination in areas outside of the Main Technical Area and DP Site resulting from laboratory activities. Health Division staff were recommending continuous operation of sampling stations at numerous locations adjacent to Los Alamos (LASL 1952).

In 1954, LANL used ten air particulate monitoring stations within the Los Alamos community to measure airborne alpha concentrations during the demolition of D Building (Johnson 1954). Additional on-site stations were also used to study impacts from LANL operations with a focus on detecting and/or measuring radioactive releases from TA-1 (Main Technical Area), TA-2 (Omega reactor), TA-3 (CMR Building), TA-21 (DP Sites), TA-35 (RaLa hot cells, LAPRE, etc), and TA-10 (Bayo Canyon). During that same year, 14 air samplers were used at locations in the Main Technical Area (TA-1), Los Alamos town site including residential areas, and along the site perimeter (LASL 1954a). The locations for the 14 air monitoring stations included:

- 1636 34th Street, South Mesa Road – Contractor Area
- 194 Abbey Street, Adjacent to Foundry Building at TA-1
- 861 43rd Street, Roof of O Building at TA-1
- 2135 35th Street, Roof of V-Shop at TA-1
- 2500B 36th, Roof of HRL Building at TA-1
- 2379B Ivy Street, Roof of Gamma Building at TA-1
- 331A Manhattan Loop, Warehouse 18 at TA-1

Measurement results for 1954 are presented in two data sets (LASL 1954a, LASL 1954b). Monitoring results for previous years were not identified by the project team but further research to locate relevant records would likely be warranted during any future LANL dose reconstruction investigation. A thorough evaluation of the quality of these data is warranted if used in the future for evaluating the accuracy of effluent release estimates.

In 1959, LANL proposed increasing air sampling for particulates to assess impacts from LANL operations on the surrounding communities by placing additional air samples on the rooftops of schools within the Los Alamos community (Kennedy 1959). By 1960, LANL’s air environmental monitoring
program had grown to 15 sampling locations to monitor airborne alpha contamination (including plutonium and polonium) and to assess any environmental impacts from laboratory operations (LASL 1961b). During 1965 the number of sampling locations expanded to 25 air stations positioned within the Los Alamos residential areas and population centers (such as schools) and along perimeter roads throughout the various technical areas at the laboratory. As was the case during previous environmental air sampling activities, these samplers were used to measure airborne particulates and short-lived radioactive gases routinely released from LANL or for detecting large amounts of radioactive material released during accidents (Kennedy 1965).

The air samplers used during this period contained two separate filter media to test for beta and gamma radioactivity. *Mine Safety Appliance (MSA) 4-inch diameter CR-17651* respirator particulate filters were analyzed for beta (fallout) activity using a gas proportional counter calibrated with a $^{90}$Sr/$^{90}$Y standard. Samples were collected on a daily basis and also periodically merged into composite samples for analysis of $^{90}$Sr, $^{137}$Cs, and $^{144}$Ce. A *MSA BM 2306* charcoal canister was mounted behind the particulate filter and used for measuring gamma (radioiodine) activity. The charcoal canisters were measured for iodine activity on a gamma spectrometer calibrated with a $^{131}$I standard (Kennedy 1965).

A second air particulate sampler was used for measuring long-lived alpha activity such as plutonium. Samples were collected on a Gelman AM-3, 2 inch diameter filters and analyzed on a gas proportional counter calibrated to a $^{239}$Pu standard. Samples were held for one week prior to counting to allow for the decay of natural radon and thoron. The lower limit of detection for these air samples was $4 \times 10^{-15}$ µCi cm$^{-3}$, or one-tenth the regulatory limit ($4 \times 10^{-14}$ µCi cm$^{-3}$) used at that time. If results exceeded the regulatory limit, then samples were analyzed for radionuclide concentrations using alpha spectroscopy. A maximum value of $2 \times 10^{-14}$ µCi cm$^{-3}$ was reported for 1959 and 1960 with the average result below the method detection limit. A charcoal canister was also used on a percentage of these air samplers, but documents with a full or partial set of sampling results were not identified during documents performed during the project (Kennedy 1965).

In 1993, LANL expanded the number of monitoring stations to 52 including regional locations as far away as Picuris Pueblo, New Mexico, located roughly 45 mi northeast of LANL (LANL 1994; LANL 2008).
Global Nuclear Fallout Measurements

Around 1958, LANL began specific collection of air particulate and rain water samples for analysis of beta radioactivity concentrations and performed gamma radiation measurements as part of the U.S. Public Health Service (PHS) program for reporting nuclear fallout data. LANL was one of eleven U.S Atomic Energy Commission sites that participated in the monitoring program and used one monitoring station located on the roof of laboratory’s Administration Building, SM-43 at TA-3 to serve this purpose (Kennedy 1960). The PHS program had a total of 44 monitoring stations located throughout the United States. Results were reported for airborne beta activity (pCi m⁻³), rain water radioactivity (pCi m⁻²), and gamma radiation (mR h⁻¹).

Results for the LANL nuclear fallout monitoring station are reported in a series of annual laboratory reports for the years 1958 to 1970 titled *Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico* or *Beta Radioactivity in Environmental Air at Los Alamos, New Mexico* (see Table 14-1). Reports that contain pre-1958 sampling results were not located during this project although it is believed LANL may have conducted these types of measurements prior to these publications. Reported monitoring results for measured concentrations or radiation levels were typically consistent with background radiation levels or expected nuclear fallout amounts and did not show elevated levels from LANL operations. However, the monitoring station was located west or north and most often upwind of LANL’s primary production areas (e.g., TA-3, TA-10, TA-21, TA-35) and would not have been expected to routinely collect and measure activity released from these LANL process operations.

In March of 1963, the H-8 monitoring group relocated their offices to TA-50 and moved the fallout air station to the roof of their new building which was located about 1.5 southeast of the TA-3 Administration Building (Aeby and Kennedy, 1964).

In 1964, LANL published results for long-lived fission products measured in rain water and air particulate samples continuously collected from 1958 through 1963. The purpose of the report was to describe isotopic analyses of composite samples and present concentration values for \(^{90}\text{Sr}\), \(^{137}\text{Cs}\), and radioactive rare earth elements (Graham 1964).
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<th>Table 14-1. LANL publications on nuclear fallout measurements</th>
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<td>• Radioactivity in Environmental Air at Los Alamos, New Mexico for the Period November 17, 1958 - December 31, 1959. LAMS-2397 (Kennedy 1960).</td>
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<td>• Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1960. LAMS-2499 (Kennedy 1961).</td>
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<td>• Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1st Quarter 1961. ER37183. Los Alamos, New Mexico. (Kennedy 1961a).</td>
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<td>• Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1964. LAMS-3245. (Aeby and Kennedy 1965).</td>
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**Gamma Monitoring**

Direct gamma exposure rates or integrated gamma measurements were used to further define changes in environmental conditions as a result of airborne and waterborne releases from LANL operations. As described in a 1948 monthly H Division report, film badges on South Mesa were planted for daily monitoring (see Fig. 14-5) (LASL 1948). No further details on when this monitoring began are provided in the report and a search for these monitoring data did not identify any additional records. These types of data could provide useful, supplemental information regarding impacts from early effluents during the 1940s and could be used to assess direct radiation exposures for periods when effluent amounts are difficult to ascertain due to a lack of effluent monitoring data.
Descriptions in another 1948 monthly H Division progress report indicate that the film badges where placed on top of South Mesa to monitor radioactive cloud dispersion associated with RaLa implosion test shots carried out in Bayo Canyon (LASL 1948).

Sometime during 1949, direct gamma and beta exposure rates were monitored Geiger-Mueller (G-M) instruments with continuous monitoring and telemetry to a central location (see Fig. 14-6). These instruments were deployed in the Los Alamos area at six separate locations to provide another method for monitoring changes in the outside environment from LANL operations (LASL 1950).

Sometime during the 1950s, the six stations were expanded to seven locations as described in a 1959 LANL report. Twenty-four hour continuous readings were transmitted through telephone lines to a central recording station located at the main Administration Building. The transmitted readings were documented on automatic chart recorders. Variations in radiation levels were identified and most often determined to be attributable to variations in natural background radiation (Kennedy 1960b). It appears that these monitors remained in service throughout the 1960s and perhaps longer. A directed search for a complete set of these measurement results was unsuccessful during the project.

During the 1950s, beta and gamma monitor were designed and built at the laboratory to assess impacts from releases from the Omega Water Boiler reactor. Locations of these monitors were not stated in the report (LASL 1950b).
Additional ambient gamma exposure levels were routinely measured with film badges mounted on stakes 1 m above the ground surface. These badges were exchanged on a monthly basis. The film had a reported sensitivity above ambient background levels that approached the Radiation Protection Guide value used during this period. Any measurable dose recorded was then attributable to LANL effluents or other man-made sources of radiation (e.g., nuclear weapon test fallout). For 1960, 2400 gamma measurements were reported, and with the exceptions for 2 locations, all results were less than the 0.5 rem, the public dose limit used at the time and recommended by the Federal Radiation Council (Federal Register; May 18, 1960) (Kennedy 1961b). Records that contain detailed results of these measurements were not identified during the project.

By 1965, LANL used thermoluminescent dosimeters (TLDs) at 100 locations throughout the Los Alamos residential areas and surrounding areas on LANL property. The dosimeters were used to assess ambient gamma radiation levels and detect potential impacts from radionuclide emissions from the laboratory, particularly larger releases associated with accidents or other uncontrolled events (Kennedy 1965). The dosimeters were collected and analyzed on a monthly basis. A directed search for pre-1970 measurement results was unsuccessful during the project. By 1970, LANL reduced the number of TLD stations to 60 locations based on prior measurement experience (e.g., redundancy of adjacent monitoring locations) and the recognition that for future monitoring one location provided adequate spatial coverage in some areas that had used two to three TLDs during prior monitoring periods. However, LANL increased the number of TLD locations again in 1981 and has maintained more than 150 since that time.

**Summary of Annual Environmental Surveillance Reports (1970 – 2007)**

Beginning in 1970, as environmental monitoring increased, LASL began to publish annual reports for environmental monitoring results based on sampling and analyses conducted by laboratory staff and the USGS. These reports contain monitoring results for a variety of environmental sample types, including:

- direct radiation readings for alpha, beta, and gamma radiation,
- outdoor/external thermoluminescent dosimeters (TLDs),
- surface water including drainage ditches, creeks, ponds, rivers, and lakes,
- ground water,
- particulate and gaseous air sampling,
- soil and sediment sampling,
- food sources,
- assorted biota and wildlife, and
- special environmental sampling and research studies.
In the early 1970s, environmental samples were collected and analyzed by the Laboratory’s Environmental Services Group. Table 14-2 identifies the annual reports that have been published and Table 14-3 presents a summary of chemical and radionuclide monitoring data that are available in the annual environmental surveillance reports.

Data contained in the annual reports represent samples routinely collected in air, surface water, groundwater, soils, sediments, a variety of biota, and some food sources. The laboratory did not perform any measurements of food sources until the later part of the 1970s. The annual reports also contain information about special studies conducted to provide better coverage of areas of particular interest or to study in detail individual sources of contamination. For example, a study of radionuclide uptake in garden plants grown in the Mortandad Canyon was initiated in 1976 and reported in the Environmental Surveillance at Los Alamos During 1977 report (LASL 1978). Additional descriptions of the types of monitoring data contained in the annual reports are presented below.

**Examples of Early Environmental Studies of Interest**

This section presents various environmental monitoring and research data that describe the historical presence and behavior of contaminants in off-site areas around LANL. Media addressed include surface water, sediment, ambient air, aquatic and terrestrial foodstuffs, soil, drinking water, and groundwater. Hydrologic and meteorological data are also presented below. Descriptions of additional studies will be added to this section as more information becomes available to the project team.

**Historical Surface Water and Sediment Data**

Sample of available surface water and sediment monitoring data collected in areas of concern described in the above section are presented below. Due to large volumes of data, not all of the available data have been summarized for this report.

**Study #1: Radioactivity in Los Alamos and Pueblo Creek (1945-1947)**– Some of the earliest measurement results for samples collected from wastewaters released from the Technical Area into Pueblo and Los Alamos Canyons are reported. Samples were collected at various points along the creeks and terminated at the Rio Grande River about 0.25 miles downstream of Otowi Bridge (Tribby 1945; Tribby 1947). The samples were analyzed for plutonium and polonium. A detection limit of 20 disintegrations per minute per liter of creek water was reported at that time. One-liter samples were collected at each location and submitted to counting laboratory for analyses.
Starting in 1970, LASL began publishing annual reports that describe annual environmental monitoring results of media sampled both on-site and off-site at the laboratory. The data contained in these reports represent a wide range of sample types and sampling frequencies and to a more or lesser extent vary according to priorities and emphasis placed on monitoring and surveillance during a given year. Annual reports available for review during this and any future health studies are listed below.

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Study #2: Radioactivity in Los Alamos and Pueblo Creek (1947-1949) -- Samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap et al. 1948a; Schnap 1950).

Four liquid discharge pipes that serviced Technical area 2 (TA-2) and two liquid discharge pipes that serviced Technical Area 3 (TA-3) all discharged liquid wastes to separate two seepage pits systems. These pits were designed to hold the liquids for seepage to underlying soils and evaporation, but are reported to have clogged on occasion and resulted in release of waste liquids to Pueblo Canyon.

Monitoring of radioactive contamination within surrounding canyons was performed to determine the impact from these early waterborne releases. Documented in reports as early as 1945, direct alpha, beta, and gamma radiation surveys were conducted by LASL personnel along the discharge drainage areas immediately down-gradient of the discharge pipes (i.e., canyon walls) and throughout drainage areas of the canyons. Water samples from each discharge pipe were collected and analyzed for plutonium, uranium, mixed fission products, fluorine, and toxic metals. Plutonium was measured in effluent waters released from TA-1 and TA-2 operations and ranged up to 1% by weight (Tribby 1947). During these early years, TA-3 did not handle plutonium compounds and concentrations usually averaged around 0.01 dpm L\(^{-1}\). Seepage pits were also surveyed for radioactive contamination and found to be highly radioactive.

Results for selected soil samples collected around TA-1 and TA-2 seepage pits in 1947 revealed levels of plutonium up to 50 dpm g\(^{-1}\). Polonium levels around TA-3 seepage pits were measured up to 3,000 dpm g\(^{-1}\). In 1947, Tribby reported that plutonium levels on canyon walls and canyon beds near discharge points were quite high and that concentration levels drop-off rapidly 100 ft and beyond release points.

Waterborne radioactive waste was released without treatment to Acid Canyon from 1944 to 1951, when a treatment plant at TA-45 became operational. From 1951 to mid-1953, the TA-45 waste treatment facility only treated liquid waste from the Original Technical Area (TA-1). Beginning in the second half of 1953, wastes from TA-1 and TA-3 were treated at TA-45.

From 1953 through the 1960s, wastes from TA-1 and TA-3 were treated at the TA-45 Waste Treatment Facility and discharged to Pueblo Canyon. Ferric sulfate and lime were added to incoming wastes to form a precipitate of ferric hydroxide which contained most of the plutonium which would in turn settle to the bottom of the waste storage tanks. Also during this period, liquid wastes from DP West production area were treated at the DPW Area Waste treatment Plant and released to Los Alamos Canyon.
Study #3: Radioactivity in Los Alamos, Pueblo, and Bayo Canyons (1957–1958) – During 1957 and 1958, the U.S. geological Survey collected water samples from streams located in Los Alamos and Pueblo Canyons. These locations include: 1) Pueblo Canyon at Otowi Ruins, 2) Los Alamos canyon at bridge, 3) Los Alamos Canyon at Totavi, and 4) Bayo Canyon (Abrahams, 1958a; Abrahams, 1958b).

Study #4: Radioactivity in Rio Grande (1957–1958) – During 1957, the U.S. Geological Survey collected water samples from the Rio Grande. Monthly samples were analyzed for gross alpha, plutonium, and uranium, and gross beta. Samples were collected at stations Embudo, Chama, Otowi, and Cochiti (Abrahams 1958a; Abrahams 1958b).

Study #5: Radioactivity, Chromate, and Zinc in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons (1969-1970) – During 1969 and 1970, LASL (H-8 Group) reported measured radioactivity levels for surface water samples collected from streams located in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons. Monthly and quarterly samples were analyzed for gross alpha, gross beta, plutonium-238, plutonium-239, americium, strontium, cesium, tritium, and uranium (Kennedy, 1971). A limited number of samples were also analyzed for hexavalent chromium and zinc.

Study #6: Plutonium in Pueblo and Acid Canyons (1970) – Sediment samples collected along Pueblo Canyon drainage basin show a decreasing trend in plutonium levels as a function of distance from LANL discharge points (Hanson, 1973). Based on a limited number of samples the following plutonium concentrations in sediment are reported:

- 27 pCi g⁻¹ in lower Acid Canyon
- 4.6 pCi g⁻¹ in Pueblo Canyon 1 mi below Acid Canyon
- 1.1 pCi g⁻¹ in Pueblo Canyon 2 mi below Acid Canyon
- 1.0 pCi g⁻¹ in Pueblo Canyon 0.1 mi above the junction with Los Alamos Canyon

Detailed survey results are reported in document LA-4561, and will be reviewed by the project team for the next version of this report. The reported estimate of plutonium releases from TA-1 and TA-45 to Pueblo Canyon from 1944 to 1964 is 170 mCi (Hanson 1973). Plutonium measured in surface water samples collected in Acid and Pueblo Canyons averaged 20 pCi L⁻¹ during this period, compared to 1.5 and 0.22 pCi L⁻¹ in Mortandad and Los Alamos Canyons, respectively.

Study #7: Radioactivity in Bayo Canyon (1977) – During 1977, LASL collected surface water samples from Bayo Canyon. Radiochemical analysis of samples showed that residual ⁹⁰Sr concentrations in soil averaged for the time period was 1.4 pCi g⁻¹ (LASL 1978b).
Historical Soil Monitoring Data

Samples of available soil monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Radioactivity in Los Alamos Canyon (1947) – Soil samples were collected along the canyon walls and at various locations along the canyon floor and analyzed for plutonium, polonium, uranium, other unspecified radionuclides, fluorine, and unspecified toxic metals (Tribby 1947). The available copy of this memo report reviewed by the project team appears to contain limited data for these surveys and/or is missing some of the sample results and warrants further research for data of this time period.

Study #2: Radioactivity in Los Alamos and Pueblo Creek (1947) – Soil samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap et al. 1948a).

Study #3: Radioactivity in Bayo Canyon (1973-1977) – During 1977, LASL collected soil samples from Bayo Canyon and analyzed them for radioactivity. Study results showed that residual $^{90}$Sr concentrations in soil averaged 1.4 pCi g$^{-1}$ (LASL 1978b). Previously reported surveys cited in this report include measured soil concentration results for gross alpha, gross beta, cesium, plutonium, and uranium.

Historical External Radiation Monitoring Data

Samples of available external radiation monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Direct Radiation Readings in Los Alamos Canyon (1947) – Direct radiation measurements with a Geiger Mueller survey meter were collected throughout Los Alamos Canyon as some of the first reported measurements of this type. The discharge line, canyon walls directly below the wastewater discharge point, and the canyon floor exhibited the highest readings up to 20,000 counts per minute of alpha radioactivity (Tribby 1947).

Study #2: Radiation Levels in Mortandad Canyon (1952) – In 1952, LASL scientists conducted a series of radiation surveys throughout Mortandad Canyon following an accidental release of 2000 to 3000 gallons of “hot water” from waste storage tanks located at the TA-35 Liquid Waste Treatment Plant. Survey results indicated that migration of measurable radioactive contamination had occurred several miles downstream in the canyon. Reported radiation dose rate readings ranged from 0.5 milliroentgens (mR) per hour at a distance of three miles to 300 mR h$^{-1}$ at the TA-35 perimeter fence (Aeby 1952). The
report also discusses a planned release to the canyon of 50,000 gallons of radioactive liquid waste with a concentration of 1.5 mCi L\(^{-1}\), significantly above the tolerance limit. Specific isotopes are not stated in the memo report. Based on other information obtained about operations at the TA-35 for this time period, it is assumed the released waste contained \(^{140}\)Ba, \(^{140}\)La, trace amounts of \(^{89}\)Sr-\(^{90}\)Sr, and other radionuclides (LASL 1957);

**Study #3:** Radioactivity in Bayo Canyon (1973-1977) – Direct radiation measurements throughout Bayo canyon were taken with ion chambers and germanium detectors (LASL 1978b).

**Historical Ambient Air Monitoring Data**

Samples of available ambient air monitoring data (including meteorological) collected in areas of concern described in the above section are presented below.

**Study #1:** LANL Meteorological Data (1956 to 1971) – Measured wind, temperature, pressure, humidity, and precipitation collected at various locations throughout the Los Alamos and surrounding areas are presented (LANL 1976).

**Study #2:** Beta/Gamma Concentrations at LANL (1961) – Airborne radioactive particulate samples collected on filter paper are reported for an air sampler located on the roof of the Administration Building SM-43. Air samples were collected every 24 h and 72 h over weekends (LASL, 1961). Report contains sampling results for the first quarter, 1961.

**Historical Groundwater/Water Supplies Monitoring Data**

Samples of available groundwater monitoring data collected in areas of concern described in the above section are presented below.

**Study #1:** Radioactivity in Los Alamos, Pueblo, and Guaje Canyons (1957-1958) – During 1958, groundwater, water supplies, and springs located in the Los Alamos area and in Los Alamos, Pueblo, and Guaje Canyons were sampled by the U.S. Geological Survey. The samples were analyzed for pH, gross alpha, plutonium, uranium, gross beta, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO\(_3\), and conductivity (Abrahams 1958a; Abrahams 1958b).

**Study #2:** Radioactivity and Other Constituents in U.S. Geological Water Samples (1960) – During 1960, groundwater and water supplies were sampled by the U.S. Geological Survey. The samples were
analyzed for pH, gross alpha, plutonium, uranium, gross beta, total hardness, calcium, magnesium, sodium, chloride, fluoride, total solids, and conductivity (USGS, 1961).


References for Environmental Data


Chapter 15: Development of Residential Areas Around Los Alamos

For a radionuclide or chemical that was used at Los Alamos to have posed a health hazard to members of the public, each of the following elements must have existed:

- A contaminant source that released the material into the environment,
- A transport medium that carried the contaminant off site to a location where exposure took place (the most common media being air and water), and
- An exposure route through which the contaminant entered an individual’s body to produce adverse health effects. Examples of exposure routes include inhalation, ingestion, and immersion in airborne contamination.

Evaluation of off-site exposures from activities at Los Alamos technical areas will require documentation of the development of nearby residential areas over time. While it was initially thought that the 31 houses commandeered from the Los Alamos Ranch School and Anchor Ranch would provide sufficient housing for the projected staff of 30 scientists and their families (Martin 2000), it soon became clear that the scope of the challenge to provide housing for Los Alamos residents had been severely underestimated. The scarcity of housing in Los Alamos was problematic during World War II and for years to follow. Hiring at the Lab was at times severely restricted because there was nowhere for new employees to live. This pressure to provide housing and the limited availability of suitable land in the region of finger-like mesas and canyons led to the development of housing that in some cases was much closer to operational areas than has become customary for government facilities that undertake processing of nuclear materials and high explosives and/or operation of devices such as reactors or high-energy particle accelerators.

Development of Housing Areas in Los Alamos

In response to the atomic weapons race of WWII, Los Alamos, New Mexico, home of the Los Alamos Ranch School, was chosen as the location of key Manhattan Project operations in 1943. Initially, the 54 buildings of the private school for boys (27 of which were houses) were thought to be satisfactory to house the projected staff of scientist and their families (Hunner 2004; Martin 2000). Soon after the project began, the need for further housing was inevitable, and construction of the Sundt apartments began to the west and north of the Ranch School buildings (Martin 2000). The population of Los Alamos continued to grow during 1944 and 1945, and in response, several temporary housing developments were erected in the vicinity of the original town site.
The LAHDRA Project Reference Map provided with this report shows the different residential areas of Los Alamos and depicts the periods of their development, the periods they remained in use, and allows one to see the proximity of the different housing areas to operational areas of potential interest. The original Technical Area (TA-1) and wartime and early postwar housing in Los Alamos are shown in Figure 15-1, which is also included as an inset map in the Project Reference Map.

With the success of the Trinity Test in July 1945 and the ultimate ending of WWII in the September that followed, the original mission of the Manhattan Project was accomplished (Martin 2000). Many scientist and their families, unsure of the future of Los Alamos, returned to pre-war careers and lives in different locations. In 1946 over 1,000 residents left the town of Los Alamos (Hunner 2004). The temporary housing constructed during the war was deteriorating, and, in 1946, the laboratory began developing the first permanent housing in the Western Area of Los Alamos to encourage the residents to remain in the town (Martin 2000; Hunner 2004). After realizing that the Los Alamos Laboratory was going to be a permanent location for research, turnover slowed and hiring increased (LASL 1956). Expansion of the Western Area and town site continued through the late 1940s in response to overcrowding. The population in Los Alamos grew from approximately 7,000 people in 1947 to over 8,500 people in 1949 (Hunner 2004). The main areas of residential development in Los Alamos from 1946 through 2000 are shown in Fig. 15-2.

As a result of President Truman’s decision to further research on the creation of the hydrogen bomb in 1949, significant amounts of money flowed into Los Alamos to support new laboratory research and handle the arrival of new personnel (Hunner 2004). The population grew from slightly over 8,500 in 1949 to 12,800 by 1952 (Hunner 2004). Residential areas began to expand northward into the North Community, and expansion continued into the early 1950s. Temporary housing constructed during the war years began to be replaced with permanent housing in the mid 1950s (LASL 1956; Martin 2000). The Los Alamos laboratory facilities began to be moved from the Ashley Pond area to the South Mesa. To support the necessary construction crews and their families, in 1949, White Rock construction camp was erected on a level plain near the rim of White Rock Canyon and Totavi trailer camp was erected on San Ildefonso Pueblo land to the east of Los Alamos along New Mexico Highway 502 (Martin 1998, 2000; Hunner 2004). Both camps were short-lived, however, White Rock nearly closing by 1953 and entirely shutting down in 1957 and Totavi shutting down in 1953 (Martin 1998, 2000).

The government maintained ownership of all property in Los Alamos until 1958, when Barranca Mesa was opened for private ownership on the mesa north of Bayo Canyon (Martin 2000). Development continued on Barranca Mesa through the mid-1960s and continued growth forced expansion onto the
Figure 15-1: The original Los Alamos Technical Area (lower left corner) and wartime and early postwar housing.
**Figure 15-2: Main residential areas of Los Alamos**

[mesa-top areas (above) and White Rock area (right)]

Detail of the area in the rectangle shown above around the center of Los Alamos townsite is shown in Figure 1 for the wartime and early postwar period.

Maps are from the LAHRA Project Reference Map produced by cartography by Andrea Kron. Data source: LANL GISLab.

<table>
<thead>
<tr>
<th>NAME OF AREA</th>
<th>PERIOD OF CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOS ALAMOS</strong></td>
<td></td>
</tr>
<tr>
<td>A Western Area &amp; nearby housing</td>
<td>Built 1945 through late 1940s</td>
</tr>
<tr>
<td>B North Community</td>
<td>Construction began 1946, expanded through early 1950s</td>
</tr>
<tr>
<td>C Replacement Housing</td>
<td>Built 1953–1957</td>
</tr>
<tr>
<td>D Part of “Group 18” Housing</td>
<td>Built 1957–1958</td>
</tr>
<tr>
<td>E Barranca Mesa Community</td>
<td>Land opened in 1958, expanded through 1964</td>
</tr>
<tr>
<td>F Royal Crest Trailer Park</td>
<td>Work began mid-1960, occupied later that year; remains in use</td>
</tr>
<tr>
<td>G North Mesa Community</td>
<td>Construction began in 1977, continued a few years</td>
</tr>
<tr>
<td>H Expansion onto Cielo Mesa</td>
<td>Construction in late 1970s into early 1980s</td>
</tr>
<tr>
<td>I Ponderosa Estates</td>
<td>Constructed mid-1980s</td>
</tr>
<tr>
<td>J Quemazon Community</td>
<td>First occupied in 2000</td>
</tr>
<tr>
<td><strong>WHITE ROCK</strong></td>
<td></td>
</tr>
<tr>
<td>K White Rock Construction Camp</td>
<td>Established in 1940, shut down in 1957</td>
</tr>
<tr>
<td>L White Rock Community</td>
<td>Construction began in 1982</td>
</tr>
</tbody>
</table>
narrow neck of the mesa in the late 1970s and early 1980s (Martin 2000). The area of White Rock re-opened to house low-income families in 1962, and growth continued throughout the 1960s and 1970s (Marin 2000). To accommodate the seemingly continuous shortage of housing, construction on the North Mesa began for both subdivisions and mobile home parks in 1977 (Martin 2000).

Following several years of rapid development, Los Alamos experienced relatively slow growth throughout the 1980s (Martin 2000). New construction returned in the mid-1990s with the development of Ponderosa Estates near the Guaje Pines Cemetery in the northern part of the town. In 2000, the devastating Cerro Grande Fire destroyed over 400 homes in the Western Area and North Community (Martin 2000). Rebuilding of the burned areas continues today and new developments, such as the Quemazon Community in the northwest area of town, are being erected (Kron, personal communication).

**Locations of Interest When Considering Historical Operations**

Based on reviews of historical documents performed to date, the following locations are among the sites where historical operations took place that appear to warrant evaluation in terms of potential off-site releases or health effects:

- D-Building at the original technical area (TA-1)
- DP West (TA-21; with released primarily from Building 12 stacks)
- DP East (TA-21; with released primarily from Buildings 152 and 153)
- Omega Site Reactors (TA-2)
- TA-3, the current main Technical Area
- The LAMPF (now LANSCE) accelerator complex
- High explosives manufacturing areas (example used is S-Site, TA-16)
- High Explosives firing sites (example used is R-Site, TA-15)
- Bayo Canyon firing site (TA-10, site of radioactive lanthanum test shots)

For evaluation of potential health effects from historical releases, each of these locations should be evaluated with regard to its relationship to Los Alamos housing areas and public facilities that were occupied during time periods that correspond to periods when operations of interest were also active. Philomena’s restaurant, which began operating in the late 1970s, has been an area of interest due to its proximity to the LAMPF (now LANSCE) facility. Although not a Los Alamos housing area, San Ildefonso Pueblo land is also considered due to its close proximity to LANL operations. The housing areas and public facilities that will be most important for a given location of operations depend on a number of factors, including:
• The distance from the contaminant source to the housing area,
• The direction from the contaminant source to the housing area, and
• The prevalence of winds from the contaminant source towards the housing area.

Detailed dose assessment typically utilizes air dispersion modeling based on actual locations of release points and potentially exposed people, using meteorological data that reflect any diurnal or seasonal variations in air flow patterns. As preliminary indicators of residential areas that may be of concern, however, it is useful to examine distance, direction, and wind prevalence for relevant source-receptor combinations.

A 16-sector wind direction frequency distribution based on LANL measurements over a ten-year period was used to determine the prevalence of winds from release points of interest towards housing areas and public facilities. That wind frequency distribution is shown in Table 15-1. This table reflects a wide variation in wind direction when all data are included. If you look instead at data from specific times of the day, you will see that there are recognizable diurnal air flow patterns. As observed in many mountainous areas, air flow is typically up-valley during the day (as solar heating causes air to rise) and down-valley at night (as cooling air drains to lower elevations). These patterns are not seen in the general wind direction data shown in Table 15-1, but they are important to consider when evaluating releases that may have only occurred during daylight hours versus those that may have occurred around the clock.

Tables 15-2 through 15-10 summarize information that will be relevant to evaluation of the potential importance of public areas when evaluating releases from the identified locations of interest. In instances where the operational location of interest is large or had numerous release points, the distance was measured from the middle of the complex. This was necessary with the current main technical area (TA-3) and LAMPF (now LANSCE). Distance was measured in increments of 0.25 mile and always rounded down to the closer distance if a point fell between two distances. In most cases, the distance between the location of interest and the various public areas is presented as a range from the closest to the farthest possible points. Direction, however, was determined by using the public area closest to the location of interest.

Housing areas that are not relevant to operations of a particular facility, that is, they did not exist when that facility was operational, are shown in gray in Tables 2 through 10 rather than black to indicate that residential exposures were not possible.
Due to its close proximity to LANL operations, San Ildefonso Pueblo land is also considered an area of interest. The vast lands make it necessary to determine the areas of land that were historically used for residential purposes. Traditionally, Pueblo members lived near their central plaza and had fields which they tended outside of this area (ChemRisk 2006). According to a 1953 USGS map of Espanola, New Mexico, the nearest concentration of San Ildefonso Pueblo people to Los Alamos was north of the current Highway 502 and east of the Rio Grande (ChemRisk 2006).

**Table 15-1.** Wind direction frequency distribution based on 10 years of LANL data

<table>
<thead>
<tr>
<th>Sector</th>
<th>Wind from</th>
<th>Wind towards</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N</td>
<td>S</td>
<td>3.4233</td>
</tr>
<tr>
<td>2</td>
<td>NNE</td>
<td>SSW</td>
<td>3.6218</td>
</tr>
<tr>
<td>3</td>
<td>NE</td>
<td>SW</td>
<td>3.3293</td>
</tr>
<tr>
<td>4</td>
<td>ENE</td>
<td>WSW</td>
<td>3.1224</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>W</td>
<td>3.4616</td>
</tr>
<tr>
<td>6</td>
<td>ESE</td>
<td>WNW</td>
<td>3.3936</td>
</tr>
<tr>
<td>7</td>
<td>SE</td>
<td>NW</td>
<td>3.718</td>
</tr>
<tr>
<td>8</td>
<td>SSE</td>
<td>NNW</td>
<td>6.0108</td>
</tr>
<tr>
<td>9</td>
<td>S</td>
<td>N</td>
<td>8.8439</td>
</tr>
<tr>
<td>10</td>
<td>SSW</td>
<td>NNE</td>
<td>8.2649</td>
</tr>
<tr>
<td>11</td>
<td>SW</td>
<td>NE</td>
<td>7.7308</td>
</tr>
<tr>
<td>12</td>
<td>WSW</td>
<td>ENE</td>
<td>8.1937</td>
</tr>
<tr>
<td>13</td>
<td>W</td>
<td>E</td>
<td>11.4148</td>
</tr>
<tr>
<td>14</td>
<td>WNW</td>
<td>ESE</td>
<td>11.9399</td>
</tr>
<tr>
<td>15</td>
<td>NW</td>
<td>SE</td>
<td>9.2887</td>
</tr>
<tr>
<td>16</td>
<td>NNW</td>
<td>SSE</td>
<td>4.2424</td>
</tr>
</tbody>
</table>
### Table 15-2: D-Building at the Original Technical Area (operational from 1943 to 1953)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from D Building (mi)</th>
<th>Direction from D Building</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>0.1-0.75</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>0.25-1.25</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>0.25-1.5</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>0.75-2</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>0.25-0.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>0.75-1.25</td>
<td>ENE</td>
<td>8.2</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>1.5-2</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>0.75</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>0.75-2.25</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>Late 1970s-present</td>
<td>2.25-3</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>1.5-2</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>2.25</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>7</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>6.25-7</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>5.75-8</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>10.25</td>
<td>E</td>
<td>11.4</td>
</tr>
</tbody>
</table>

### Table 15-3: DP West Site at TA-21 (operational from 1945 to 1973)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from DP West (mi)</th>
<th>Direction from DP West</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>0.75-2</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>0.5-2.5</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>2.25-2.75</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>1.75-3.25</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>0.5-2.25</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>0.25-0.5</td>
<td>NNW</td>
<td>6.0</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>1.5-2.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>0.75</td>
<td>SW</td>
<td>3.3</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>0.75-1.75</td>
<td>NNE</td>
<td>6.0</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>Late 1970s-present</td>
<td>1.5-1.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>2.2-2.5</td>
<td>NNE</td>
<td>6.0</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>1.25</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>5.5</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>5.7</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>9</td>
<td>ENE</td>
<td>8.2</td>
</tr>
</tbody>
</table>
### Table 15-4: DP East Site at TA-21 (operational from 1945 to 1970)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from DP East (mi)</th>
<th>Direction from DP East</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>1.25-2.25</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>1-2.75</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>2.75-3.25</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>2-3.75</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>1-2.75</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>0.5-0.75</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>1.5-2.25</td>
<td>NNW</td>
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</tr>
<tr>
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<td>1960-present</td>
<td>1</td>
<td>WSW</td>
<td>3.1</td>
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<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>0.75-2.25</td>
<td>NNW</td>
<td>6.0</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>Late 1970s-present</td>
<td>1.5</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Townerosa Estates</td>
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<td>2.25-3</td>
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<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
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<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>5</td>
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<td>11.4</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
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<td>SE</td>
<td>9.3</td>
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<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>4.5-7</td>
<td>SE</td>
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</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
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<td>8.25</td>
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<td>8.2</td>
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</table>

### Table 15-5: Omega Site Reactors at TA-2 (operational from 1943 To 1992)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from Omega Site (mi)</th>
<th>Direction from Omega Site</th>
<th>Winds in this direction (%)</th>
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<td>3.4</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
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<td>0.25-1.75</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>1.5-2.25</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>1.25-2.25</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>0.25-0.75</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>0.5-0.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>1.75-2.25</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>0.25</td>
<td>S</td>
<td>3.4</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>1-1.5</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
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<td>2-2.5</td>
<td>NE</td>
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</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>1.75-2.25</td>
<td>NNW</td>
<td>6.0</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>1.75</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>6.25</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>5.75</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>5.25-7.25</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>8.5</td>
<td>ENE</td>
<td>8.2</td>
</tr>
</tbody>
</table>
Table 15-6: TA-3, the current main technical area (operational from 1953 to present)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from TA-3 (mi)</th>
<th>Direction from TA-3</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>0.75-1.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>1-2</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>0.5-1</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>1.25-2.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>0.5-2</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>2-2.5</td>
<td>NE</td>
<td>8.2</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>2.25-3.5</td>
<td>WNW</td>
<td>7.7</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>1.75</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>1.75-3.25</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>late 1970s-present</td>
<td>3.5-4</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>2-2.5</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>3.5</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>7.25</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>6.5-9</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>11.5</td>
<td>ENE</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Note – Distance from TA-3 is measured from middle of complex

Table 15-7: LAMPF (now LANSCE, operational from 1968 to present)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from LAMPF Building (mi)</th>
<th>Direction from LAMPF Building</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>2-3</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>1.75-3.5</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>3.25-4</td>
<td>WNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>2.75-4.25</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>1.75-3.5</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>1.25-1.75</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>2.25-3.25</td>
<td>NNW</td>
<td>6.0</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>1.75</td>
<td>W</td>
<td>3.5</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>1.25-3</td>
<td>NNW</td>
<td>6.0</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>late 1970s-present</td>
<td>1.75-2.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>3.25-3.75</td>
<td>NW</td>
<td>3.7</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>0.5</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>4.5</td>
<td>E</td>
<td>11.4</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>4</td>
<td>SE</td>
<td>9.3</td>
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<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>3.75-6</td>
<td>SE</td>
<td>9.3</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>8</td>
<td>ENE</td>
<td>8.2</td>
</tr>
</tbody>
</table>

Note – Distance from LANSCE building is measured from middle of complex
### Table 15-8: High Explosives Manufacturing Area– S-Site (TA-16, operational 1944 to present)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from S-Site (mi)</th>
<th>Direction from S-Site Building</th>
<th>Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>3-3.75</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>3.25-3.75</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>2.75-3.25</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>3.5-4.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>3-3.75</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>3.75-4</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>4.75-5.25</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>3</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>3.75-4.75</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>late 1970s-present</td>
<td>5.25-5.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>4.25-4.75</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>4.75</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>9.5</td>
<td>ENE</td>
<td>8.2</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>7.5-7.5</td>
<td>ESE</td>
<td>11.9</td>
</tr>
<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>6.25-8</td>
<td>ESE</td>
<td>11.9</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>12.5</td>
<td>ENE</td>
<td>8.2</td>
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</tbody>
</table>

### Table 15-9: High Explosive Firing Site – R-Site (TA-15, operational from 1944 to present)

<table>
<thead>
<tr>
<th>Public Area</th>
<th>Period Occupied</th>
<th>Distance from R-Site (mi)</th>
<th>Direction from R-Site Building</th>
<th>Daytime Winds in this direction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wartime Housing</td>
<td>1943-1945</td>
<td>2.5-3</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Early Postwar Housing</td>
<td>1946-1960s</td>
<td>2.5-3.25</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Western Area</td>
<td>1946-present</td>
<td>2.5-3.5</td>
<td>NNW</td>
<td>3.4</td>
</tr>
<tr>
<td>North Community</td>
<td>1948-present</td>
<td>3.25-4.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Replacement Housing</td>
<td>1953-present</td>
<td>2.5-3</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Group 18 Homes by Airport</td>
<td>1957-present</td>
<td>2.75-3</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Barranca Mesa</td>
<td>1958-present</td>
<td>4.45</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Royal Crest Trailer Park</td>
<td>1960-present</td>
<td>2</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>North Mesa</td>
<td>1977-present</td>
<td>3.25-3.75</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>Otowi Mesa Expansion</td>
<td>late 1970s-present</td>
<td>4.25-4.5</td>
<td>NNE</td>
<td>8.3</td>
</tr>
<tr>
<td>Ponderosa Estates</td>
<td>Mid 1990s-present</td>
<td>3.75-4.25</td>
<td>N</td>
<td>8.8</td>
</tr>
<tr>
<td>East Gate / Philomena’s</td>
<td>Late 1970s-present</td>
<td>3.5</td>
<td>NE</td>
<td>7.7</td>
</tr>
<tr>
<td>Totavi Camp</td>
<td>1949-1953</td>
<td>7.5</td>
<td>ENE</td>
<td>8.2</td>
</tr>
<tr>
<td>White Rock Camp</td>
<td>1949-1953 (1957)</td>
<td>5.25-6.25</td>
<td>ESE</td>
<td>11.9</td>
</tr>
<tr>
<td>White Rock Community</td>
<td>1962-present</td>
<td>4.75-6.25</td>
<td>ESE</td>
<td>11.9</td>
</tr>
<tr>
<td>San Ildefonso Pueblo Lands</td>
<td>1598-present</td>
<td>10.5</td>
<td>ENE</td>
<td>8.2</td>
</tr>
</tbody>
</table>
Based on examination of the information presented in Tables 15-2 through 15-10 and information from historical documents reviewed by the LAHDRA project team, following are discussions of public areas that may be of importance for evaluation of releases from the historical operations of interest listed above:

### a. D Building at TA-1

D Building at the original Technical Area was the site of plutonium processing during the war years. Specifically, D Building housed plutonium purification and recovery, conversion to metal, metallurgy, weapon component fabrication, and application of coatings. After DP West site became operational in late 1945, D Building continued to house activities that involved plutonium, including chemical and metallurgical research and analysis, until a “new D Building” was completed on South Mesa in the form of the CMR Building within Technical Area 3 (Coffinberry and Miner 1961). D Building was razed in 1953 (Ahlquist et al. 1977).

Due to D Building’s period of operation and proximity to the town site, Wartime Housing and Early Postwar Housing would be public areas of interest with regards to historical releases from D Building. Wartime housing ranged from 0.1-0.75 miles from D Building, and the closest occupants were northwest of the D-Building in the Sundt apartments. Wind blew in the northwest direction 3.7% of the time averaged over a 10 year period. Early Postwar Housing ranged from 0.25 (Hanford Houses) to 1 mile (Denver Steel and Ft. Leonard Wood Houses) to the northeast of D Building, with the wind blowing to the northeast 7.7% of the time. Figures 15-3, 15-4, and 15-5 show the original Technical Area with wartime housing in the form of Sundt apartments located nearby.
**Figure 15-3:** This November 1946 aerial photograph, looking south, shows Sundt apartments west (to the right) of the Technical Area, on both sides of Trinity Drive, which crosses from the upper left to the lower right of the photo. Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-1-3028).

**Figure 15-4:** This 12/04/1946 aerial photograph, looking north, shows the Sundt apartments (dark buildings in upper left) immediately west and north of the Technical Area. The large building at the lower right is D Building. The largest white Technical Area building nearest the Sundt Apartments (photo upper center) is C Building, which housed shops and was the site of a January 1945 fire that prompted planning of replacement facilities for processing plutonium. Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-1-3029).
b. DP West (TA-21; with releases from Building 12 stacks)

In response to fire hazard and safety concerns, most plutonium processing operations moved to DP West in late 1945. Building 12 was the filter building for all of the plutonium processing buildings (2, 3, 4, and 5) and continued in service until 1973. A public area of interest with regard to releases from Building 12 stacks is the Group 18 Housing west of the airport. Figures 15-6 and 15-7 show the locations of DP Site and relevant housing areas. The closest of these homes were 0.25 mi from DP West and winds blew in their direction (NNW) an average of 6.0% of the time. Other Los Alamos housing areas of interest include Early Postwar Housing such as the Denver Steel, Ft. Leonard Wood, Hanford, and Wingfoot housing developments. These areas were located 0.5 to 2.5 mi northwest of DP West, and winds blew in this direction 3.7% of the time. The trailer park south of DP Road should be considered since it was located 0.5 mi directly west from DP West, and winds blew in this direction 3.5% of the time. Finally, the Replacement Housing (see symbol C in Fig. 15-6), is an area of interest since it was constructed as close as 0.5 miles west-northwest of DP West, and wind blew in this direction 3.4% of the time.
c. DP East (TA-21; with releases from Buildings 152 and 153)

DP East started up in 1945 and processed polonium and actinium and to produce initiators. Building 153 served as the exhaust building for DP East until it shut down in 1970. A public area for consideration in relation to DP East operations is Group 18 Housing by the airport (see Figures 15-6 and 15-7). These homes were 0.5 to 0.75 miles northwest of DP East, and the wind blew in their direction approximately 3.7% of the time. Before the housing by the airport was established, Wartime and Early Postwar Housing, and Replacement Housing would be areas for consideration. The trailer park south of DP Road was approximately 0.9-mile WNW of DP East, and the wind blows in that direction 3.4% of the time.

d. Omega Site Reactors

Omega Site was established in 1943 and has housed three different reactors: the Water Boilers (three versions), the Plutonium Fast Reactor, and the Omega West Reactor. Due to the perceived danger of the work to be performed, Omega Site was built at the bottom of Los Alamos Canyon away from the original Technical Area (Hunner 2004; SWEIS 1998). Initially, a flexible off-gas line carried reactor effluents from the bottom of the canyon to the top of South Mesa for discharge (LAMD-155 1947). In later years, a more conventional stack was built on top of South Mesa. Royal Crest Trailer Park, which sits on South Mesa 0.25 miles south of Omega Site, and the trailer park just south of DP Road, which from around 1948 through 1963 was situated on Los Alamos Mesa directly above Omega Site, are potential public areas of consideration for the Omega Site releases (see Figures 15-8 and 15-9).

Figure 15-6: Location of DP Site relative to LANL housing areas. Group 18 housing west of the airport (housing symbol D) was established 1957-1958. Replacement housing (symbol C, established 1953-57) took the place of wartime and early postwar housing (See Figure 6-1), of which the closest to DP Site would have been the trailer park south of DP Road. Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.
Figure 15-7: Aerial view of Los Alamos (circa 1947, looking west) shows DP East (lower center), DP West above it, and Los Alamos townsite in the background. Residential area shown include Western Area at the upper left, Eastern Area in the upper center, and the area west of (above) the airport that became the site of Group 18 housing at the upper right. *Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-1-3114).*
Figure 15-8: This 1949 photo shows a mobile home park located south of DP Road close to Trinity Drive. Located directly above the Omega Site reactor buildings in Los Alamos Canyon (upper left corner), the park included both private mobile homes and Wingfoot trailers supplied by the government. This area eventually became known as Royal Crest park. By August 30, 1963 all occupants were required to move out; some relocated to the “new” Royal Crest trailer park on East Jemez Road (Los Alamos Monitor 8/23/63). West of (above) the park are Zia Company warehouses and service buildings that supported TA-1. *Photo courtesy Los Alamos Historical Society (LAHM-P1989-13-1-1917).*
In 1953, Los Alamos National Laboratory’s (LANL) main technical facilities moved from TA-1, across Los Alamos Canyon, to TA-3. Various buildings at TA-3 have housed plutonium, uranium, machining, and accelerator operations over the years. An area of interest for releases from TA-3 is the Western Area, which is located 0.5 to 1 mile north of the center of TA-3 (see Figures 15-10 and 15-11). LANL winds blow toward the north 8.8% of the time. Other possible housing areas to consider with respect to TA-3 are Replacement Housing, of which construction began in 1953, and Royal Crest Trailer Park, which opened in 1960. The closest Replacement Housing to TA-3, which is approximately 0.5 miles northeast of TA-3, lies south of Trinity Drive and east of Diamond Drive. Winds blow in the northeast direction 7.7% of the time as averaged over a 10 year period. Winds blow toward Royal Crest Trailer Park about 11.4% of the time.
Figure 15-10: This aerial photo (circa 1967) looks across TA-3 and Los Alamos Canyon to Western Area and the Jemez Mountains. The “H”-shaped LASL Administration Building and surrounding structures are in the foreground, Diamond Drive runs through the lower right quadrant of the frame, and part of the CMR Building is visible at the lower left edge. Photo courtesy Los Alamos Historical Society (LAHM-P2000-2-1-7144).
f. **LAMPF (now LANSCE)**

LAMPF (Los Alamos Meson Physics Facility), which is now called LANSCE (Los Alamos Neutron Science Center), is a large accelerator complex located on Mesita de Los Alamos (Figure 15-12). Construction began in 1968 and the facility remains in operation today. The location of the off-site maximally exposed (hypothetical) individual in LANL’s annual environmental radiological dose assessments has typically been at the East Gate/Philomena’s area on State Road 502 where it enters the east side of Los Alamos County (LANL 2001). This is because of the area’s proximity to LANSCE, which is reflected in Figure 15-13. Philomena’s restaurant was once located 0.5-mile north-northeast of the center of the LANSCE complex. According to the 10 year average wind rose, the LANL winds blow in this direction 8.3% of the time.

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**Fig. 15-11:** Location of Technical Area 3 (lower left, established 1953) to some Los Alamos housing areas. Western Area (housing symbol A) was established in 1946, "replacement housing" (symbol C) was constructed 1953-1957, and Royal Crest Trailer Park opened in 1960. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*
Figure 15-12: Aerial view of LANSCE looking towards the southwest. *Photo courtesy of LANL.*

Figure 15-13: Location of LANSCE relative to several public areas near LANL. *Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.*
g. High explosives manufacturing areas

Research, development, and testing of high explosives were conducted in over 25 different Technical Areas of LANL since the 1940s. The S-Site was chosen as the high explosive manufacturing area example for the purposes of this report because it was the main site of early explosives processing facilities. S-Site (Figure 15-14) was developed for the production of high explosives in 1943 and continues in operation today. A public area of interest for the S-Site is the Western Area, which is located 2.75 miles north northeast of this site (see Figure 15-15). The winds blow from the S-Site and in the direction of the Western Area 8.3% of the time. Other areas to consider with regards to the S-Site are Wartime Housing, Replacement Housing, and Early Postwar Housing, all which were located approximately 3 miles from S-Site and experienced winds in their direction about 8% of the time.

Figure 15-14: High explosives manufacturing facilities were constructed in areas more distant from residential areas than original Technical Area buildings, and wider separation between buildings reflected the more readily recognized safety hazards of associated operations. This August 1952 aerial view of TA-16 shows Building 260 in the upper right of the image. These buildings for machining high explosives were made of concrete and had special walls in the back that were built to blow out in the event of an accident. The image shows forested land above and below TA-16. Photo courtesy Los Alamos Historical Society (LAHM-P1990-40-3138).
Fig. 15-15: Location of TA-16 (S Site) relative to public areas of Los Alamos. Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.
h. High Explosives firing sites

There have been a number of high explosive firing sites at LANL. R-Site was chosen as the example for the purposes of this report. Eight firing sites (A-H) were established at R-Site between 1944 and 1948, and operations at R-Site continue today. Royal Crest Trailer Park, which is located 2 miles north-northeast of the site, is the closest public area to R-Site and is an area of interest (see Figure 15-16). According to the LANL wind data, winds blow from R-Site towards the trailer park 8.3% of the time. Since R-Site began operations in 1944, earlier housing should also be considered when evaluating R-Site releases. Wartime Housing, Early Postwar Housing, and Replacement Housing were all about 2.5 miles to the north, north-northeast, and north-northeast, respectively. Winds blow in these directions 8% to 9% of the time.

Fig. 15-16: Location of TA-15 (R Site) relative to public areas of Los Alamos. Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.
i. Bayo Canyon firing site

The Bayo Canyon Site (TA-10) was used between 1944 and 1962 for experiments using conventional high explosives, radioactive lanthanum (RaLa), and in some cases depleted or natural uranium. Its location is shown in Figure 15-17. A public area of interest for the Bayo Canyon site is the Totavi Camp, located 5 miles east-southeast of the site down the Bayo Canyon. Since operations at this site were conducted in a canyon that runs approximately east to west, wind tends to blow back and forth down this canyon. The Totavi Camp was located east south east of the Bayo Canyon site and wind travels in this direction 11.9% of the time. Also of interest due to the canyon winds is the North Community, which is located 2.5 miles directly west of the Bayo Canyon site. Winds blow in the direction of the North Community 3.5% of the time.

Figure 15-17: Location of Point Able site that was the location of many RaLa shots between 1944 and 1962. The North Community (established in 1948) is at the left of the figure (labeled with housing symbol B) and San Ildefonso Pueblo lands are east of the LANL boundary at the lower right. Areas associated with housing symbols A, E, G, and H indicate residential areas that were established in 1946, 1958, 1977, and the late 1970s, respectively. Map is based on the LAHDRA Project Reference Map produced by cARTography by Andrea Kron. Data source: LANL GISLab.

References


LAMD-155 (1947) “Manhattan District History: Supplement to Book VIII, LA Project Y.”


LASL (1956). “The Housing Manual for Laboratory Employees and Supervisors.” Los Alamos Scientific Laboratory of the University of California. September 1


Chapter 16: Partial Chronology of Accidents, Incidents, and Events at LANL

An important part of the review of historical records concerning Los Alamos operations focused on the review of records of the Health Division and other records that include descriptions of accidents or incidents that had potential association with off-site releases or health effects. Some of the incidents of interest include chemical releases, fires, explosions, radiation exposures to workers, and other notable accidents that occurred at Los Alamos. The incidents that are potentially relevant to off-site releases or health effects are of particular importance.

Based on review of reports and items of correspondence assembled by the LAHDRA team, a partial chronology of accidents, incidents, and events at Los Alamos was compiled. The information presented in Table 16-1 is a partial chronology because the information was collected from many sources, and it is likely that not all reports documenting accidents and incidents were found. Minor worker contamination incidents were not included. Spills of small amounts of low toxicity materials to a solid surface that was easily cleaned up were not included. The quantity and type of contamination released is reported when available.

First, Health Division reports in the database were reviewed for incidents of interest. Next, the LAHDRA DocSleuth database was searched for selected keywords (such as health report, quarterly, monthly H Division progress reports) to obtain additional documents to review. The additional documents identified via that keywords search were reviewed and incidents of interest were recorded. Next, the search was expanded to include documents relevant to criticality incidents, explosions, and RaLa shots.

In Table 16-1, the first column lists the stated date of the incident or event, or an estimated date based on the date of the source document.

The second column contains a brief description of the incident or event. Any qualitative descriptions or impressions given are those of the original document’s authors, as are any release quantities or off-site measurements. The original document text can be viewed if questions arise or additional information or context is desired.

The third column in the table contains a categorization of each event. Each event was categorized based on the incident type and the potential for off-site release or possible adverse health effects. The categories used were as follows:
• Accident – An incident not involving radioactive or dangerous material
• Air Release – An incident that involved the release of air contamination
• Criticality – An event in which a mass of radioactive material went “critical”
• Equipment Malfunction – An incident that was the result of equipment failure
• Explosion – An incident that involved an explosion
• Fire – An incident that involved fire
• Liquid Release – An incident that involved the release of liquid contamination
• RaLa Shot – Explosive test event involving radioactive lanthanum
• User Error – Event involving a human error
• Contamination Event – Additional unclassifiable contamination events

The fourth column contains the LAHDRA Repository Number of the source document. In some cases, documents contain so many pages that their image files were broken up into pieces to facilitate downloading. In these cases, the Repository Number may be followed by a letter, for example 338f for the sixth part of a large document having at least six PDF image files.

The fifth and final column in Table 16-1 contains the page number at which the description of the described incident or event begins. This is the page number in the PDF file, which in many cases differs from the page number shown on the original document page, as cover pages and early pages of a printed document are often not numbered, or in some cases not all pages from the source document were requested by the LAHDRA document analysts or released by LANL.

Over 30,000 pages in over 500 documents were reviewed in the preparation of the chronology of accidents and incidents, with those documents including:

• Contamination incident reports
• Incident report investigation files
• Miscellaneous laboratory incident memorandums
• Radiation occurrence reports
• A review of criticality accidents
• A survey of liquid waste management problems at LASL
• Monthly and annual reports of DP West Site operations
• Annual reports of the Health Division
• Health physics/radiation protection quarterly reports
• Incidents and accidents involving explosives at Los Alamos National Laboratory
• Reports of the Bayo Canyon/Radioactive Lanthanum (RaLa) Program
• Airborne Contamination Annual Summaries
• Summaries of LASL Health Hazards
<table>
<thead>
<tr>
<th>Date</th>
<th>Incident Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/21/1944</td>
<td>RaLa shot #1 took place on 9/21/1944 at ~1610 hours. The shot involved ~25 to 60 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>10/4/1944</td>
<td>RaLa shot #2 took place on 10/4/1944 at 16:15 hours. The shot involved 120 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>10/14/1944</td>
<td>RaLa shot #3 took place on 10/14/1944 at ~1615 hours. The shot involved 60 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>10/26/1944</td>
<td>RaLa shot #4 took place on 10/26/1944 at 13:30 hours. The shot involved 200 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>11/3/1944</td>
<td>RaLa shot #5 took place on 11/3/1944 at ~1645 hours. The shot involved 113 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>12/1/1944</td>
<td>RaLa shot #6 took place on 12/1/1944 at 16:30 hours. The shot involved 280 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>12/10/1944</td>
<td>RaLa shot #7 took place on 12/10/1944 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>12/14/1944</td>
<td>RaLa shot #8 took place on 12/14/1944 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>12/20/1944</td>
<td>RaLa shot #9 took place on 12/20/1944 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>12/28/1944</td>
<td>RaLa shot #10 took place on 12/28/1944 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>2/7/1945</td>
<td>RaLa shot #11 took place on 2/7/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>2/13/1945</td>
<td>RaLa shot #12 took place on 2/13/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>2/24/1945</td>
<td>RaLa shot #13 took place on 2/24/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>3/3/1945</td>
<td>RaLa shot #14 took place on 3/3/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>4/1/1945</td>
<td>RaLa shot #15 took place on 4/1/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>4/9/1945</td>
<td>RaLa shot #16 took place on 4/9/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>4/10/1945</td>
<td>RaLa shot #17 took place on 4/10/1945 at 16:30 hours. The shot involved 240 Ci of RaLa, with an explosive charge of 201 to 350 lbs. An air sampler was set up on the Los Alamos Mesa as described for shot 5 on 11/3/1944. The results of each sample were negative.</td>
</tr>
<tr>
<td>Date</td>
<td>Incident Description</td>
</tr>
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<td>----------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>4/15/1945</td>
<td>RaLa shot #18 took place on 4/15/1945 at 2035 hours. The shot involved 43.5 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the ESE. An air sampler was run at Technical Area 1 (TA-1, the main technical area) for 24 hours to check for contamination. A reading of 50 counts per minute (cpm) gamma radiation was found. This was the first time that any airborne contamination associated with Bayo Canyon # was picked up on the mesa.</td>
</tr>
<tr>
<td>4/20/1945</td>
<td>RaLa shot #19 took place on 4/20/1945 at 1841 hours. The shot involved 570 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>4/26/1945</td>
<td>RaLa shot #20 took place on 4/26/1945 at 2145 hours. The shot involved 450 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>5/11/1945</td>
<td>On May 11, 1945 an accident occurred in Room B2 of Gamma Building. A rotating shield struck a piece of Po metal, sending contamination out the lab. Contam. Event 3496 all</td>
</tr>
<tr>
<td>5/22/1945</td>
<td>RaLa shot #21 took place on 5/22/1945 at 1547 hours. The shot involved 620 Ci of RaLa with an explosive charge of 601 to 750 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>5/26/1945</td>
<td>RaLa shot #22 took place on 5/26/1945 at 1700 hours. The shot involved 450 Ci of RaLa with an explosive charge of 601 to 750 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>5/30/1945</td>
<td>RaLa shot #23 took place on 5/30/1945 at 1500 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>6/4/1945</td>
<td>RaLa shot #24 took place on 6/4/1945 at 1630 hours. The shot involved 900 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>6/6/1945</td>
<td>On June 6, 1945 there was a criticality incident involving 34.5 kg U-235 in 1/2-inch cubes. The pseudo sphere went critical during water-seeping between the blocks. ~10^16 total fissions were involved. Criticality 6206 all</td>
</tr>
<tr>
<td>6/8/1945</td>
<td>RaLa shot #25 took place on 6/8/1945 at 1545 hours. The shot involved 795 Ci of RaLa with an explosive charge of 601 to 750 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>6/13/1945</td>
<td>RaLa shot #26 took place on 6/13/1945 at 1535 hours. The shot involved 590 Ci of RaLa with an explosive charge of 201 to 350 lbs. A high-capacity air sampler was run at the edge of Los Alamos Mesa in front of civilian dwelling T-843 (probably T-846). Thirteen thousand five hundred (13,500) liters of air were sampled, and the beta plus gamma activity on the filter was less than 10 cpm (background). Results were also negative.</td>
</tr>
<tr>
<td>6/16/1945</td>
<td>RaLa shot #27 took place on 6/16/1945 at 1700 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. A high-capacity air sampler was run at the edge of Los Alamos Mesa in front of civilian dwelling T-843 (probably T-846). Thirteen thousand five hundred (13,500) liters of air were sampled, and the beta plus gamma activity on the filter was less than 10 cpm (background). Criticality 6206 all</td>
</tr>
<tr>
<td>6/22/1945</td>
<td>RaLa shot #28 took place on 6/22/1945 at 1530 hours. The shot involved 1060 Ci of RaLa with an explosive charge of 601 to 750 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>6/26/1945</td>
<td>RaLa shot #29 took place on 6/26/1945 at 1724 hours. The shot involved 342 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>6/29/1945</td>
<td>RaLa shot #30 took place on 6/29/1945 at 1700 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>7/6/1945</td>
<td>RaLa shot #31 took place on 7/6/1945 at 1500 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>7/14/1945</td>
<td>RaLa shot #32 took place on 7/14/1945 at 1715 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>7/16/1945</td>
<td>On August 21, 1945 there was a criticality incident involving 6.2 kg gamma-phase Pu. An experimenter was hand stacking tungsten carbide blocks around a Pu mass. The experimenter accidentally dropped a block allowing the Pu to go critical. 1 death and 1 injury resulted from the accident. Criticality 6206 all</td>
</tr>
<tr>
<td>8/3/1945</td>
<td>RaLa shot #33 took place on 8/3/1945 at 2145 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/6/1945</td>
<td>RaLa shot #34 took place on 8/6/1945 at 1730 hours. The shot involved 1050 Ci of RaLa with an explosive charge of 601 to 750 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/10/1945</td>
<td>RaLa shot #35 took place on 8/10/1945 at 1531 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/13/1945</td>
<td>RaLa shot #36 took place on 8/13/1945 at 1450 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/21/1945</td>
<td>RaLa shot #37 took place on 8/21/1945 at 2145 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/24/1945</td>
<td>RaLa shot #38 took place on 8/24/1945 at 1550 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>8/28/1945</td>
<td>RaLa shot #39 took place on 8/28/1945 at 2145 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>9/1/1945</td>
<td>RaLa shot #40 took place on 9/1/1945 at 1620 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>9/8/1945</td>
<td>RaLa shot #41 took place on 9/8/1945 at 1715 hours. The shot involved 343 Ci of RaLa with an explosive charge of 201 to 350 lbs. RaLa Shot 2 all</td>
</tr>
<tr>
<td>Date of Inc.</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>9/13/1945</td>
<td>RaLa shot # 39 took place on 9/13/1945 at 1615 hours. The shot involved 440 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>9/20/1945</td>
<td>RaLa shot # 40 took place on 9/20/1945 at 1415 hours. The shot involved 380 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>9/25/1945</td>
<td>RaLa shot # 41 took place on 9/25/1945 at 1740 hours. The shot involved 1291 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>9/26/1945</td>
<td>There was a fire in the contaminated pit September 26, 1945. Contamination was found on the fence surrounding the area and on the guard tower next to the dump.</td>
</tr>
<tr>
<td>10/1/1945</td>
<td>RaLa shot # 42 took place on 10/1/1945 at 1716 hours. The shot involved 772 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>10/6/1945</td>
<td>RaLa shot # 43 took place on 10/6/1945 at 1605 hours. The shot involved 446 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>10/12/1945</td>
<td>RaLa shot # 44 took place on 10/12/1945 at 1620 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>11/28/1945</td>
<td>On November 28, 1945 in Room 76 of DP Site a worker noticed that a container of Po had leaked. The room was decontaminated.</td>
</tr>
<tr>
<td>12/28/1945</td>
<td>RaLa shot # 46 took place on 12/28/1945 at 1620 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>1/4/1946</td>
<td>RaLa shot # 47 took place on 1/4/1946 at 1628 hours. The shot involved 954 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>1/11/1946</td>
<td>RaLa shot # 48 took place on 1/11/1946 at 1600 hours. The shot involved 647 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>1/17/1946</td>
<td>RaLa shot # 49 took place on 1/17/1946 at 1530 hours. The shot involved 459 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>1/24/1946</td>
<td>RaLa shot # 50 took place on 1/24/1946 at 1610 hours. The shot involved 1712 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance (mR/h) was 0.046 mR/h at 2 miles.</td>
</tr>
<tr>
<td>1/31/1946</td>
<td>RaLa shot # 51 took place on 1/31/1946 at 1555 hours. The shot involved 1057 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>2/7/1946</td>
<td>RaLa shot # 52 took place on 2/7/1946 at 1537 hours. The shot involved 654 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>2/14/1946</td>
<td>RaLa shot # 53 took place on 2/14/1946 at 1602 hours. The shot involved 454 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>3/21/1946</td>
<td>RaLa shot # 54 took place on 3/21/1946 at 1520 hours. The shot involved 1034 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/28/1946</td>
<td>RaLa shot # 55 took place on 3/28/1946 at 1447 hours. The shot involved 848 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>4/12/1946</td>
<td>RaLa shot # 56 took place on 4/12/1946 at 1535 hours. The shot involved 315 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>4/15/1946</td>
<td>There was a tuballoy fire in the Tech area on April 15, 1946. Firemen were exposed directly to tuballoy smoke without protective equipment.</td>
</tr>
<tr>
<td>4/25/1946</td>
<td>RaLa shot # 57 took place on 4/25/1946 at 1520 hours. The shot involved 1324 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/2/1946</td>
<td>RaLa shot # 58 took place on 5/2/1946 at 1500 hours. The shot involved 890 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/3/1946</td>
<td>There was an explosion in a drybox in Room 107 of D Building on May 3, 1946. The room and adjoining hallway were contaminated.</td>
</tr>
<tr>
<td>5/9/1946</td>
<td>RaLa shot # 59 took place on 5/9/1946 at 1440 hours. The shot involved 600 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>5/16/1946</td>
<td>RaLa shot # 60 took place on 5/16/1946 at 1535 hours. The shot involved 279 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>5/21/1946</td>
<td>On May 21, 1946 there was a criticality incident involving 6.2 kg of delta-phase Pu. An experimenter was holding two hemispheres of Pu apart with a screw driver as a demonstration to a group. When the screw driver slipped, it allowed the spheres to come together to form a critical mass. 1 death and 7 injuries resulted from the accident. ~3X10^13 total fissions were involved.</td>
</tr>
<tr>
<td>5/23/1946</td>
<td>RaLa shot # 61 took place on 5/23/1946 at 1440 hours. The shot involved 1274 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/29/1946</td>
<td>RaLa shot # 62 took place on 5/29/1946 at 1450 hours. The shot involved 931 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>6/6/1946</td>
<td>RaLa shot # 63 took place on 6/6/1946 at 1445 hours. The shot involved 539 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>6/27/1946</td>
<td>RaLa shot # 64 took place on 6/27/1946 at 1440 hours. The shot involved 1494 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>7/3/1946</td>
<td>RaLa shot # 65 took place on 7/3/1946 at 1625 hours. The shot involved 976 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>7/11/1946</td>
<td>Pu metal turnings caught fire in a drybox in Room 317 on July 11, 1946. The room was highly contaminated.</td>
</tr>
<tr>
<td>7/11/1946</td>
<td>RaLa shot # 66 took place on 7/11/1946 at 1423 hours. The shot involved 702 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>7/18/1946</td>
<td>RaLa shot # 67 took place on 7/18/1946 at 1530 hours. The shot involved 516 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>8/1/1946</td>
<td>The first fatality involving energetic materials at Los Alamos was at the Omega-West Reactor Site in August 1946. Three employees mixed potassium chlorate, sugar, magnesium turnings, and red phosphorous. One person died when the mixture ignited, and two others were injured.</td>
</tr>
<tr>
<td>7/11/1946</td>
<td>RaLa shot # 66 took place on 7/11/1946 at 1423 hours. The shot involved 702 Ci of RaLa with an explosive charge of 201 to 350 lbs.</td>
</tr>
<tr>
<td>8/1/1946</td>
<td>There was a fire in the contaminated dump on November 15, 1946.</td>
</tr>
<tr>
<td>12/19/1946</td>
<td>RaLa shot # 69 took place on 12/19/1946 at 1640 hours. The shot involved 1261 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>12/27/1946</td>
<td>RaLa shot # 70 took place on 12/27/1946 at 2202 hours. The shot involved 610 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>1/3/1947</td>
<td>RaLa shot # 71 took place on 1/3/1947 at 1920 hours. The shot involved 467 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>1/16/1947</td>
<td>On January 16, 1947 a worker cutting Pu(NO3)4 spilled approximately 70 mg of solution on their pants and the floor of D-146.</td>
</tr>
<tr>
<td>1/23/1947</td>
<td>On January 23, 1947 a worker with a sledge hammer hit a 5 gallon bottle containing plutonium residue releasing approximately 30 mg of Pu in the basement of D Building. The ground was dug up and buried in the waste disposal pit.</td>
</tr>
<tr>
<td>3/10/1947</td>
<td>RaLa shot # 72 took place on 3/10/1947 at 2200 hours. The shot involved 570 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/14/1947</td>
<td>RaLa shot # 73 took place on 3/14/1947 at 1758 hours. The shot involved 720 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/19/1947</td>
<td>RaLa shot # 74 took place on 3/19/1947 at 1952 hours. The shot involved 630 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>4/11/1947</td>
<td>RaLa shot # 75 took place on 4/11/1947 at 140 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>4/16/1947</td>
<td>RaLa shot # 76 took place on 4/16/1947 at 1832 hours. The shot involved 640 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/6/1947</td>
<td>RaLa shot # 77 took place on 5/6/1947 at 1540 hours. The shot involved 1341 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/13/1947</td>
<td>RaLa shot # 78 took place on 5/13/1947 at 1655 hours. The shot involved 1141 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/21/1947</td>
<td>RaLa shot # 79 took place on 5/21/1947 at 1926 hours. The shot involved 574 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>6/18/1947</td>
<td>RaLa shot # 80 took place on 6/18/1947 at 1438 hours. The shot involved 170 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>6/25/1947</td>
<td>RaLa shot # 81 took place on 6/25/1947 at 1319 hours. The shot involved 1290 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>7/2/1947</td>
<td>RaLa shot # 82 took place on 7/2/1947 at 1800 hours. The shot involved 1320 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>7/10/1947</td>
<td>RaLa shot # 83 took place on 7/10/1947 at 1703 hours. The shot involved 851 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>7/30/1947</td>
<td>RaLa shot # 84 took place on 7/30/1947 at 1850 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>8/6/1947</td>
<td>RaLa shot # 85 took place on 8/6/1947 at 1706 hours. The shot involved 700 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>8/13/1947</td>
<td>RaLa shot # 86 took place on 8/13/1947 at 1545 hours. The shot involved 680 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>8/27/1947</td>
<td>RaLa shot # 87 took place on 8/27/1947 at 2022 hours. The shot involved 1610 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>9/4/1947</td>
<td>RaLa shot # 88 took place on 9/4/1947 at 1655 hours. The shot involved 925 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>9/11/1947</td>
<td>RaLa shot # 89 took place on 9/11/1947 at 1625 hours. The shot involved 670 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>9/18/1947</td>
<td>RaLa shot # 90 took place on 9/18/1947 at 1420 hours. The shot involved 438 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>10/22/1947</td>
<td>A fire was detected on October 22, 1947 in the contaminated dump. The results of monitoring during and after the fire reportedly indicated that there was no significant exposure to radioactive materials.</td>
</tr>
<tr>
<td>10/29/1947</td>
<td>RaLa shot # 91 took place on 10/29/1947 at 1543 hours. The shot involved 1670 Ci of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Incident Type</td>
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</tr>
<tr>
<td>11/5/1947 RaLa shot # 92</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>11/7/1947 On November 7, 1947 pressurized radioactive spray was released from a line of the peroxider unit contaminating one worker.</td>
<td>Equipment Malfunction</td>
</tr>
<tr>
<td>11/12/1947 RaLa shot # 93</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>11/27/1947 RaLa shot # 94</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>12/3/1947 RaLa shot # 95</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>12/10/1947 RaLa shot # 96</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>12/18/1947 RaLa shot # 97</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>1/29/1948 RaLa shot # 98</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>2/5/1948 RaLa shot # 99</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>2/19/1948 RaLa shot # 100</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>2/27/1948 RaLa shot # 101</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>4/1/1948 RaLa shot # 102</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>4/9/1948 RaLa shot # 103</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>4/16/1948 RaLa shot # 104</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>6/16/1948 On June 16, 1948 there was a fire in the drybox of Room D-115. The fire was believed to have been caused by spontaneous combustion of U-235 lathe turnings.</td>
<td>Fire</td>
</tr>
<tr>
<td>8/4/1948 RaLa shot # 105</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>8/12/1948 RaLa shot # 106</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>8/19/1948 RaLa shot # 107</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>9/10/1948 RaLa shot # 108</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>9/14/1948 On September 14, 1948 workers cleaned out a drybox in Room 126. The material was taken to the hood in Room 119 where it was accidentally released. The room was decontaminated the following day.</td>
<td>User Error</td>
</tr>
<tr>
<td>9/21/1948 RaLa shot # 109</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>9/28/1948 RaLa shot # 110</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>10/7/1948 RaLa shot # 111</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>10/14/1948 RaLa shot # 112</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>10/21/1948 RaLa shot # 113</td>
<td>RaLa Shot</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
</tr>
<tr>
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<td>-------------</td>
</tr>
<tr>
<td>12/1/1948</td>
<td>RaLa shot # 114 took place at 1608 hours. The shot involved 480 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the south. H-1 leader T. N. White observed the cloud to drift a few points west of south and most of it appeared to settle down into Pueblo Canyon, just north of main hill road. White also saw a wisp go over Emilio Segre's old laboratory (East Gate Laboratory) at the extreme eastern end of Los Alamos Mesa. White went there with a radiation survey meter and was able to locate activity at the tip of the mesa. A few specks gave a reading that was close to the maximum with the beta shield open (20 mR/h). There was no activity a hundred feet or more to the west of the mesa tip. Following this observation, White expressed concern to D. Mueller, the leader of the Bayo Canyon experimenters, that it was undesirable to set off shots without regard to wind direction and velocity.</td>
</tr>
<tr>
<td>12/8/1948</td>
<td>RaLa shot # 115 took place on 12/8/1948 at 2039 hours. The shot involved 463 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>12/15/1948</td>
<td>RaLa shot # 116 took place on 12/15/1948 at 1345 hours. The shot involved 317 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 10 mph. The maximum radiation measured at distance was 0.76 mR/h at 0.25 miles.</td>
</tr>
<tr>
<td>1/25/1949</td>
<td>RaLa shot # 117 took place on 1/25/1949 at 405 hours. The shot involved 452 Curies of RaLa with an explosive charge of 351 to 600 lbs.</td>
</tr>
<tr>
<td>2/1/1949</td>
<td>RaLa shot # 118 took place on 2/1/1949 at 1630 hours. The shot involved 487 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/4/1949</td>
<td>RaLa shot # 119 took place on 3/4/1949 at 1359 hours. The shot involved 693 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/8/1949</td>
<td>RaLa shot # 120 took place on 3/8/1949 at 1413 hours. The shot involved 604 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>3/31/1949</td>
<td>RaLa shot # 121 took place on 3/31/1949 at 1647 hours. The shot involved 1096 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>4/20/1949</td>
<td>RaLa shot # 122 took place on 4/20/1949 at 1846 hours. The shot involved 422 Curies of RaLa with an explosive charge of 601 to 750 lbs. A monthly progress report of the Health Division stated, “The radioactive cloud from the Bayo shot of April 20 passed over and contaminated the area of the main gate to Los Alamos. The Fire Department washed off the most heavily contaminated section of the road shortly thereafter.” No survey report has been found.</td>
</tr>
<tr>
<td>4/27/1949</td>
<td>RaLa shot # 123 took place on 4/27/1949 at 2045 hours. The shot involved 1244 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/4/1949</td>
<td>RaLa shot # 124 took place on 5/4/1949 at 2045 hours. The shot involved 1740 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/11/1949</td>
<td>RaLa shot # 125 took place on 5/11/1949 at 1950 hours. The shot involved 1393 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>5/17/1949</td>
<td>RaLa shot # 126 took place on 5/17/1949 at 2030 hours. The shot involved 871 Curies of RaLa with an explosive charge of 601 to 750 lbs. A day after the last Bayo Canyon shot (#126) “activity was discovered at a point about two miles north of the Bayo firing site. The general background activity [meaning contamination] in this area was of the order of 1 mR/hr beta plus gamma ...” (presumed to be at waist height).</td>
</tr>
<tr>
<td>5/20/1949</td>
<td>RaLa shot # 127 took place at 1830 hours. The shot involved 588 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the ESE. The wind speed was 10 mph. The cloud from the shot crossed State Road 4 between Station 101 (a temporary guard gate at the access road to Bayo Canyon) and the McKee Trailer Camp on State Road 4. Roadblocks were established at the Main Gate and lower Bayo Canyon road junction with the main hill road. Following the shot, the blocked-off section of the road and a section running about 1 mi. east were monitored and found to be free of contamination; the roadblocks were removed. Shortly thereafter a second monitoring patrol discovered contamination on the road to the east of Frijoles Junction (the White Rock Y at the intersection of main hill road and State Road 4), which had been thought to be clean. Roadblocks were re-established at the Main Gate. The most heavily contaminated stretch of road ran about 0.75 miles east of Frijoles Junction. The highest readings were 5 to 10 mR/h 12 inches from the ground.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>6/2/1949</td>
<td>RaLa shot # 128 took place at 1417 hours. The shot involved 1933 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north. The wind speed was 12 mph. The maximum radiation measured at distance was 1.5 mR/h at 1.5 miles. “Flypaper and pans [adhesive fallout collectors] distributed in Guaje Canyon previous to the shot were collected approximately two hours afterwards and were found to have no contamination. The following afternoon, however, approximately 15 mR/hr beta and gamma background [assumed at 12 inches] was found in the region over which the cloud passed.” Because “the meteorologist estimated that the cloud reached this position about five minutes after the shot,” the conclusion can be reached that the flypaper and pans were not located in the main path of the fallout.</td>
</tr>
<tr>
<td>6/6/1949</td>
<td>RaLa shot # 129 took place at 2206 hours. The shot involved 1630 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The maximum radiation measured at distance was 1.5 mR/h at 2.5 miles. Adverse weather continued until after the shot. “An attempt was made by Health Division personnel to postpone the shot until such time that conditions were more favorable, but the decision was made to continue.” After the shot it became apparent that a portion of the main road to Los Alamos (SR 502) would become contaminated. Road blocks were placed at the west end of the airstrip, the junction of SR 4 and Sandia Canyon, and above Totavi Camp. Monitoring on the main road showed contamination from the pump house at the Bayo Canyon turnoff to 0.5 miles above Totavi, a distance of about 1.5 miles. The highest reading obtained was about 15 mR/h beta plus gamma at the main hill road and SR 4 junction. This measurement was taken at 12 inches above the road surface rather than at the usual 3 feet as was adopted later.</td>
</tr>
<tr>
<td>6/10/1949</td>
<td>RaLa shot # 130 took place on 6/10/1949 at 0933 hours. The shot involved 1280 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 6 mph. “Considerable effort was made by all persons involved to plan this particular operation so that the difficulties encountered in previous operations would not be present.” Continuous weather predictions were done until after the shot. “The cloud drifted off in a northwesterly direction... Although the main portion of the cloud did not pass over any of the previously placed trays and flypaper in Guaje Canyon, a small amount of background was found seven hours later on two of them located at one edge of the cloud path.”</td>
</tr>
<tr>
<td>7/28/1949</td>
<td>RaLa shot # 131 took place on 7/28/1949 at 1204 hours. The shot involved 1387 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.</td>
</tr>
<tr>
<td>8/3/1949</td>
<td>RaLa shot # 132 took place on 8/3/1949 at 1258 hours. The shot involved 936 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.</td>
</tr>
<tr>
<td>8/9/1949</td>
<td>RaLa shot # 133 took place on 8/9/1949 at 0957 hours. The shot involved 713 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE.</td>
</tr>
<tr>
<td>8/18/1949</td>
<td>On June 27, 1949 there was a fire outside of TU Buildings. Fire resulted from the spontaneous combustion of TU shavings stored outside TU Building. Surrounding area was highly contaminated.</td>
</tr>
<tr>
<td>8/31/1949</td>
<td>RaLa shot # 134 took place on 8/31/1949 at 1200 hours. The shot involved 715 Curies of RaLa with an explosive charge of 601 to 750 lbs.</td>
</tr>
<tr>
<td>9/14/1949</td>
<td>RaLa shot # 135 took place on 9/14/1949 at 1202 hours. The shot involved 356 Curies of RaLa with an explosive charge of 601 to 750 lbs. Flypapers placed on North Ridge (the closest northern approach to Bayo Canyon, about 0.5 miles north, a little west, and 400 feet above of the firing site) about 50 paces apart read 3 to 4 mR/h at 1 inch with a closed-shield GM survey meter.</td>
</tr>
<tr>
<td>9/23/1949</td>
<td>RaLa shot # 136 took place on 9/23/1949 at 1018 hours. The shot involved 346 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SE. The wind speed was 8 mph. Nine flypapers placed on North Ridge read 0.15 to 1.0 mR/h at 1 inch with a closed-shield GM survey meter; the maximum reading was recorded 300 paces from the eastern-most station; the pattern appears to be skewed to the west.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>10/19/1949</td>
<td>RaLa shot # 137 took place on 10/19/1949 at 1007 hours. The shot involved 1385 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NE. The wind speed was 15-20 mph. Flypapers placed on North Ridge read from 0.1 to 0.3 mR/h at 1 inch, measured with a closed-shield GM survey meter. The maximum flypaper reading was recorded 150 paces west of the eastern edge of the array. The ground measured 0.07 mR/h near and in good agreement with one of the flypapers, which read 0.1 mR/h. The dose rate recorder at the same location reached 1.5 mR/h as the cloud passed. A survey made the next day in Rendija Canyon about a mile east of the Sportsman's Club showed a maximum of 0.07 mR/h.</td>
</tr>
<tr>
<td>11/2/1949</td>
<td>RaLa shot # 138 took place at 1205 hours. The shot involved 1614 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W. The maximum radiation measured at distance was 0.8 mR/h at 2.5 miles. T. Shipman reported “an abrupt and temporary shift in the wind ... resulted in blowing the cloud ... across the Technical Area [TA-1]. As far as health and safety are concerned, no significant levels of radiation have been found. There is, however, sufficient contamination so that the background in certain counting procedures may be disturbed.” “Demonstrable contamination was found as far away as Camp May, a distance often miles' [west], but at no place were levels of contamination found to be very high.” Levels of radiation were three times background at the Base Radio Station on North Mesa. The tip of Center Mesa read 0.6 mR/h; the Chapel Apartment area on Rose Street read 0.8 mR/h; Manhattan Loop read 0.3 to 0.4 mR/h; the peak at the main gate was 1.0 mR/h gamma (1.5 mR/h, beta plus gamma). Measurements made on North Ridge were all background.</td>
</tr>
<tr>
<td>11/8/1949</td>
<td>RaLa shot # 139 took place on 11/8/1949 at 1243 hours. The shot involved 1064 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 7-9 mph. The cloud moved west up canyon and then northeast, missing the North Ridge flypaper array. No record of radiation measurements in surrounding areas was found.</td>
</tr>
<tr>
<td>11/14/1949</td>
<td>On November 14, 1949 an accident occurred between two security trucks. One truck was carrying wooden crates of steel cylinders that contained plutonium. Only one wooden crate was damaged and no contamination occurred.</td>
</tr>
<tr>
<td>12/1/1949</td>
<td>In December, 1949 there was a criticality incident involving ~1 kg 235U UO2 (NO3)2 in 13.6 liters water during the manual withdrawal of two poison control rods. 3.4x1016 total fissions were involved.</td>
</tr>
<tr>
<td>12/8/1949</td>
<td>RaLa shot # 140 took place on at 1532 hours. The shot involved 2635 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 8-12 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. Readings from the North Ridge flypapers ranged from background to 2.5 mR/h at 1 inch measured with a closed-shield GM survey meter. The maximum radiation reading was found on the station 50 paces from the eastern end of the nine-station array. The Point Pluto (labeled 23) recorder showed cloud passage and the collected air sample was “3X normal = 0.015 mr/ hr.” At Point Claim, the cloud passed, and a sample read “0.6 mr/hr gammas only.” Guaje Canyon was monitored the next day and a maximum of 0.2 mR/h was found &quot;opposite Pt. Claim.&quot; Also recorded are some &quot;GMX-5 data giving 1.2 mr/hr in Rendija Canyon N of 12 and 0.5 mr/hr N of 10.&quot;</td>
</tr>
<tr>
<td>12/16/1949</td>
<td>RaLa shot # 141 took place at 1739 hours. The shot involved 1539 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NW. The wind speed was 2-3 mph. The maximum reading on flypaper on North Ridge read 1 mR/h at 1 inch, measured with a closed-shield GM survey meter. The cascade impactor at Point Claim showed most of the activity to be collected on the final (filter) stage, 0.7-micron particles if density 2.5 is assumed. Another handwritten description of the December 16 shot exists and has some valuable contemporary thinking comparing RaLa with radium and some dimensional help. But, again, all discussion was aimed, as were the previous flypaper measurements, at showing whether providing an asphalt pad under the shots would reduce fallout. It apparently did. The writer calculated the effect of the worst-case (wind conditions, RaLa source size) fallout on the Guaje reservoir (a partial source of Los Alamos water at that time) to be 0.1 uCi/L or 1 mR/day for continuous intake.</td>
</tr>
<tr>
<td>12/22/1949</td>
<td>RaLa shot # 142 took place at 1632 hours. The shot involved 1132 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the SW. The wind speed was 3-5 mph. A “mild degree of contamination” was recorded in some parts of TA-1. No health hazard occurred; however, background activity may have been elevated enough to affect some TA-1 laboratory counting procedures.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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<tr>
<td>1/13/1950</td>
<td>RaLa shot # 143 took place at 1248 hours. The shot involved 2065 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 25 mph.</td>
</tr>
<tr>
<td>1/17/1950</td>
<td>RaLa shot # 144 took place on 1/17/1950 at 1347 hours. The shot involved 1715 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the north and then east. The wind speed was 4-7 mph.</td>
</tr>
<tr>
<td>1/24/1950</td>
<td>RaLa shot # 145 took place on at 1138 hours. The shot involved 1737 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 25-30 mph. The cloud from the shot remained in Bayo Canyon.</td>
</tr>
<tr>
<td>1/31/1950</td>
<td>RaLa shot # 146 took place on 1/31/1950 at 1417 hours. The shot involved 981 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, NE. The wind speed was 9-17 mph.</td>
</tr>
<tr>
<td>3/24/1950</td>
<td>RaLa shot # 147 took place on 3/24/1950 at 1323 hours. The shot involved 1665 Curies of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E. The wind speed was 28-42 mph. A B-17 flight took place.</td>
</tr>
<tr>
<td>3/29/1950</td>
<td>RaLa shot # 148 took place at 1416 hours. The shot involved 1743 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the W, WNW, and NNE. The wind speed was 2-8 mph. The maximum radiation measured at distance was 0.2 mR/h at 3 miles. “...a slight amount of contamination from fall-out was observed throughout the town site and Tech Area [TA-1]” following shot #148. It was obvious that weather conditions would not be ideal at shot time, but there was reluctance to cancel the shot for the day since weather predictions for the remainder of the week were no better. H Division authorized continuation of the operation. “The vast majority of it [the cloud] apparently moved out to the northwest toward the upper portions of Guaje Canyon. A small portion of the cloud… took a southerly course and left detectable contamination in parts of the Los Alamos housing area (particularly in the Denver steel area), [which was the housing area closest to Bayo Canyon] and also in the Tech Area. The average levels of activity found were in the vicinity of 0.2 mr/h [Beta + gamma]... There certainly is no reason to feel that the situation produced any health hazard whatsoever.”</td>
</tr>
<tr>
<td>4/6/1950</td>
<td>RaLa shot # 149 took place at 1330 hours. The shot involved 1306 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NNW, NNE. The wind speed was 18-37 mph. A B-17 flight took place.</td>
</tr>
<tr>
<td>4/20/1950</td>
<td>RaLa shot # 150 took place at 1431 hours. The shot involved 3334 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the N, NW. The wind speed was 4-12 mph.</td>
</tr>
<tr>
<td>4/26/1950</td>
<td>RaLa shot # 151 took place on 4/26/1950 at 1400 hours. The shot involved 2496 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the E, SE. The wind speed was 5-30 mph. The Point Myrtle weather observer was directly under the cloud as it passed over but “he experienced no contamination.”</td>
</tr>
<tr>
<td>5/12/1950</td>
<td>RaLa shot # 152 took place on 5/12/1950 at 1359 hours. The shot involved 1355 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the S, SW. The wind speed was 10-15 mph.</td>
</tr>
<tr>
<td>5/24/1950</td>
<td>RaLa shot # 153 took place on 5/24/1950 at 1152 hours. The shot involved 391 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE. The wind speed was 6-15 mph.</td>
</tr>
<tr>
<td>5/29/1950</td>
<td>On May 29, 1950 the contaminated waste disposal pit caught fire.</td>
</tr>
<tr>
<td>6/27/1950</td>
<td>On June 27, 1950 -250 g of UO2 were spilled during the transfer from a cabinet to the hood.</td>
</tr>
<tr>
<td>7/13/1950</td>
<td>RaLa shot # 154 took place on 7/13/1950 at 1410 DST hours. The shot involved 1000 Ci of RaLa with an explosive charge of 601 to 750 lbs. The cloud tracked toward the NE and N. The wind speed was 8-26 mph. The cloud motion observer's report stated “The cloud track given herein applies to only a small segment of the cloud. The bulk of the cloud seemed to dissipate without ever rising above the canyon walls.”</td>
</tr>
<tr>
<td>8/18/1950</td>
<td>On August 18, 1950 a tank containing contaminated ammonium nitrate was found leaking. The floor and area was decontaminated.</td>
</tr>
<tr>
<td>10/3/1950</td>
<td>On October 3, 1950 a container of PuO2 was opened and contaminated Room 513 of CMR 12.</td>
</tr>
<tr>
<td>2/1/1951</td>
<td>On February 1, 1951 at Pajarito Site an experiment went critical during a remote control operation.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>2/1/1951</td>
<td>On February 1, 1951 there was a criticality incident involving 2 cylinders of U-235. The cylinders weighted 24.4 kg and 38.5 kg of 93% U-235. The 2 cylinders were in a water reflected system. There was slight oxidation of the uranium. 10^16 total fissions were involved.</td>
</tr>
<tr>
<td>9/13/1951</td>
<td>On September 13, 1951 in Room 201 of DP West a drybox caught fire contaminating the room.</td>
</tr>
<tr>
<td>9/29/1951</td>
<td>On September 29, 1951 a bottle containing 10 grams of enriched U-235 was dropped in Room 307 spilling the contents on the floor.</td>
</tr>
<tr>
<td>10/6/1951</td>
<td>An accident occurred on October 6, 1951 and high levels of contamination were spread in Building 52 of DP East. Everyone leaving was monitored and two cars were found to be contaminated and they were cleaned before the employees left for home.</td>
</tr>
<tr>
<td>10/23/1951</td>
<td>On October 23, 1951 a beaker containing 8 hydroxyquinoline and plutonium exploded releasing contamination into Room D-304. The filter queen located in D-304 was changed immediately and very high levels of contamination were found. The amount of Pu present in the solution was not over 1-2 milligrams.</td>
</tr>
<tr>
<td>3/26/1952</td>
<td>Rala shot # 155 took place on 3/26/1952 at 1652 hours. The shot involved 270 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 20 mph. The maximum radiation measured at distance was 0.15 mR/h at 1.5 miles. Radiation monitoring started from Point Weather westward and included the northern part of the Los Alamos housing area; 0.04 mR/h was recorded 0.1 miles from Point Weather. No activity above background was detected elsewhere on return to TA-1. A second monitor started from the Main Hill Road intersection with State Road 4 and found no activity except “0.15 mR/h in the vicinity of the first large bend in the road east of the main guard gate.” No activity was detected in TA-1.</td>
</tr>
<tr>
<td>4/18/1952</td>
<td>On April 18, 1952 there was a criticality incident involving 92.4 kg U metal 93% 235U due to computation error. 1.5x10^16 total fissions were involved.</td>
</tr>
<tr>
<td>6/16/1952</td>
<td>On June 16, 1952 plutonium ignited in an open port drybox in D-138 of D Building. The fire was quickly quenched with water.</td>
</tr>
<tr>
<td>8/11/1952</td>
<td>Rala shot # 156 took place on 8/11/1952 at 1755 hours. The shot involved 2400 Ci of RaLa with an explosive charge of 101 to 200 lbs. Monitoring began from Point Weather, where activity of 0.05 mR/h was recorded. At the picnic grounds (on North Mesa), background activity was recorded. At the Sportsman’s Club and 35th and Diamond Drive, less than 0.1 mR/h was recorded. Throughout North Community, activity was less than 0.05 mR/h. The survey sheet noted “… before shot background was 0.15, after shot 0.1 mr.”</td>
</tr>
<tr>
<td>8/21/1952</td>
<td>Rala shot # 157 took place on 8/21/1952 at 1151 hours. The shot involved 2900 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. High-volume air samplers located at Station 20 (on Puye Road), White Rock, Well #3 (just east of Guaje pumice mine), and Totavi gave the following results: 239, 689, 460, and 931 cpm, respectively. Five-stage cascade impactor data were as follows: at White Rock, all five stages—0 cpm; at Well #3, 4th stage—31 cpm, 5th stage (Whatman #41 paper)—4 cpm; Totavi, 5th stage (molecular filter)—16 cpm.</td>
</tr>
<tr>
<td>8/29/1952</td>
<td>Rala shot # 158 took place on 8/29/1952 at 1259 hours. The shot involved 800 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E, NE. Air samplers run in Espanola and on Puye Road showed activity in the 30- to 100-nCi range. “Good coverage was obtained on the last Bayo shot [#158] and evaluation of these data has been completed showing no hazard in any inhabited areas.”</td>
</tr>
<tr>
<td>12/9/1952</td>
<td>On December 9, 1952 in S-104 uranium in a furnace caught fire and was contained in the furnace. Clean-up of S-104 was conducted on December 11 and 12.</td>
</tr>
<tr>
<td>1/8/1953</td>
<td>On January 8, 1953 a mock fission polonium beryllium source ruptured releasing as much as 2 Ci of Po. Significant amounts of polonium contamination was found in nearby homes.</td>
</tr>
<tr>
<td>1/8/1953</td>
<td>On January 8, 1953 Po contamination was discovered at Pajarito Site Room 119 of Building 30. Employees of W-2 were exposed over a period of at least a week and several employee homes were contaminated. By January 13, 1953 all of W-2 and W-5 and SD houses were decontaminated.</td>
</tr>
<tr>
<td>4/3/1953</td>
<td>On April 3, 1953 the city dump was possibly contaminated with 125 lbs of tuballoy. 26 lbs were recovered, and the remainder was incinerated. The top layer of ashes was removed and three truck loads of dirt were placed over the contamination site.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>6/10/1953</td>
<td>Rala shot # 159 took place on 6/10/1953. The shot was not fired, the explosive burned. Fallout trays on the main hill road and one high-volume air sampler in Guaje Canyon showed measurable activity. The monthly progress report of H-1 (the Health Physics Group) stated, “Although the east project access road [main hill road] was contaminated, the levels were low enough that they did not constitute a health hazard.”</td>
</tr>
<tr>
<td>6/26/1953</td>
<td>On June 26, 1953 there was a small fire in a flask containing uranium hydride in D-151.</td>
</tr>
<tr>
<td>6/29/1953</td>
<td>On June 29, 1953 an employee spilled approximately 40 µg of plutonium nitrate in Z Building on the floor. The area was decontaminated the following day.</td>
</tr>
<tr>
<td>8/10/1953</td>
<td>On August 10, 1953 a dissolver exploded releasing U-235 over the entire room.</td>
</tr>
<tr>
<td>8/14/1953</td>
<td>Rala shot # 160 took place on 8/14/1953 at 1402 hours. The shot involved 600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 10 mph.</td>
</tr>
<tr>
<td>9/10/1953</td>
<td>Rala shot # 161 took place on 9/10/1953 at ~1400 hours. The shot involved 250 Ci of RaLa with an explosive charge of 20 to 100 lbs.</td>
</tr>
<tr>
<td>10/9/1953</td>
<td>Rala shot # 162 took place on 10/9/1953 at ~1300 hours. The shot involved 215 Ci of RaLa with an explosive charge of 20 to 100 lbs.</td>
</tr>
<tr>
<td>11/12/1953</td>
<td>On November 12, 1953 there was an undetermined explosion in Room 501 that contaminated the room.</td>
</tr>
<tr>
<td>12/5/1953</td>
<td>On December 5, 1953 a glass furnace in a vacuum hood exploded releasing 40g of uranium.</td>
</tr>
<tr>
<td>1/28/1954</td>
<td>On January 28, 1954 a fire occurred at the contamination dump.</td>
</tr>
<tr>
<td>2/1/1954</td>
<td>There have been 8 accidental prompt-critical excursions at Pajarito Site to date. The dates of the accidents are February 1951; April 1952, February 1954; July 1956; February 1957; June 1960; December 1962; May 1967. The only notable damage that occurred was in the February 1954 event. During that even there was a slight warping of the U(93) pieces, but no measurable fission-products were released.</td>
</tr>
<tr>
<td>2/1/1954</td>
<td>There was no measurable fission-product release during the worst accidental excursion at Pajarito, the second Lady Godiva accident.</td>
</tr>
<tr>
<td>2/3/1954</td>
<td>On February 3, 1954 there was a criticality incident involving 53 kg U metal 93% 235U due to incorrect operation at the Lady Godiva reactor. There was a slight warping of the pieces. 5.6 x 10^16 total fissions were involved.</td>
</tr>
<tr>
<td>2/8/1954</td>
<td>On February 8, 1954 in CMR-4 tritium was released when a U-tube cracked under a hood.</td>
</tr>
<tr>
<td>2/12/1954</td>
<td>Rala shot # 163 took place on 2/12/1954 at 1620 hours. The shot involved 2730 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. Two air-sampling count data sheets provided the following information: one for Puye [Road], background activity; one for Espanola, 44 net cpm; no conversion to disintegrations per minute are given.</td>
</tr>
<tr>
<td>3/8/1954</td>
<td>Rala shot # 164 took place on 3/8/1954 at 1615 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E.</td>
</tr>
<tr>
<td>3/19/1954</td>
<td>Rala shot # 165 took place on 3/19/1954 at 1130 hours. The shot involved 150 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>3/29/1954</td>
<td>On March 29, 1954 an 800-pound pig slipped and dropped off the tailgate of a pickup dumping a white powder on the truck and the dock. The area became contaminated with Sr-90 and was decontaminated. No one was allowed to wear contaminated clothing home.</td>
</tr>
<tr>
<td>4/14/1954</td>
<td>Rala shot # 166 took place on 4/14/1954 at 1345 hours. The shot involved 190 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. No radiation was detected. Fallout was monitored starting at the main gate. Otowi ruins. White Rock, Mora's Castle (also known as the Duchess' Castle), Otowi Bridge, and 5 miles up Espanola highway (State Road 5) were surveyed from the main hill road. No readings above background were obtained.</td>
</tr>
<tr>
<td>4/19/1954</td>
<td>On April 19, 1954 a mixture containing 5 milligrams of americium exploded.</td>
</tr>
<tr>
<td>7/2/1954</td>
<td>Glass tube holding plutonium covered wire broke releasing Pu at Y Building on July 2, 1954.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>7/31/1954</td>
<td>RaLa shot # 167 took place at 1605 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The maximum radiation measured at distance was 1.5 mR/h at 2.25 miles. The cloud started to the NE with very little velocity; the wind shifted shortly after the shot took place and spread fallout to the SE and S. A rain shower occurred in Bayo Canyon 35 minutes after the shot. Activity was detected between SR 4 and the Sandia Canyon guard station, one-half mile east of SR 4. Measurements in White Rock showed background activity. The next evening, 1 mR/h was measured at Otowi Ruins. A hand-drawn fallout map was made, from which D. Meyer deduces, “Fallout area was approximately 4 square miles... average reading was 0.5 mr/hr with shield open at waist level. This equals to about 1 mr/hr at contact shield open or 0.15 mr/hr shield closed at 6” from ground.”</td>
</tr>
<tr>
<td>8/5/1954</td>
<td>RaLa shot # 168 took place at 1830 hours. The shot involved 1500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 0 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles; 0.15 mR/h at 12 miles. The team made background readings in Rendija Canyon to the north and northeast several hours before the shot, finding elevated background activity from the previous shot (#167). After the shot, a counterclockwise survey began, reaching Totavi at 1845. The team returned up Guaje Canyon, encountering new fallout measuring 0.4 mR/h at the pumice mine (background in the morning was 0.04 mR/h) but found no further increase over the earlier background activity as far as the junction of Guaje and Rendija canyons. The team returned down Guaje Canyon and proceeded toward Espanola, encountering activity 4.5 miles south of Espanola with a maximum of 0.2 mR/h at the Puye Road turnoff. Activity was 0.15 mR/h at Santa Clara Pueblo and 0.1 to 0.15 mR/h in Espanola. The team returned to Puye Road the next morning and found slightly lower readings than the day before.</td>
</tr>
<tr>
<td>9/9/1954</td>
<td>RaLa shot # 169 took place at 1518 hours. The shot involved 265 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The wind speed was 1 mph. The maximum radiation measured at distance was 0.1 mR/h at 1 mile; 0.45 mR/h at 2 miles; 0.3 mR/h at 2.5 miles; 0.18 mR/hr at 4 miles. The survey team passed the Los Alamos airstrip at 1538, where fallout was encountered; a maximum of 1.1 mR/hr was recorded 1.4 miles east of the airport. Team members completed the survey including west up Guaje Canyon; all readings were background, which varied between 0.03 and 0.05 mR/hr. More readings were taken the next day on other roads further south; a fallout map was prepared showing a relatively narrow fallout pattern to the south-southwest over laboratory property, crossing Sandia Canyon, 0.45 mR/hr, and other east-west roads in the laboratory area.</td>
</tr>
<tr>
<td>9/16/1954</td>
<td>RaLa shot # 170 took place at 1458 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW. No radiation was detected. The team started a clockwise survey from TA-1 before 1500 and continued on to Espanola and Riverside (east side of Espanola). No fallout above background was detected. A map was made.</td>
</tr>
<tr>
<td>10/21/1954</td>
<td>An electrode broke within a flask causing tritium to be released into the hood in Room 220 of HRL Building on October 21, 1954.</td>
</tr>
<tr>
<td>10/24/1954</td>
<td>U-235 material ignited spontaneously in the sigma vault on October 24, 1954.</td>
</tr>
<tr>
<td>11/4/1954</td>
<td>RaLa shot # 171 took place at 1335 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 7 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles. The team started a clockwise perimeter survey from TA-1 at 1600; background activity was 0.03 mR/h. All readings were background to State Road 4. The team returned up Guaje/Rendija Canyons and measured 0.3 mR/h for about 0.5 miles beginning 1.5 miles east of the Sportsman’s Club. Apparently the activity was missed or had not yet arrived on the first pass.</td>
</tr>
<tr>
<td>11/16/1954</td>
<td>RaLa shot # 172 took place at 1500 hours. The shot involved 2440 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.3 mR/3.5 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey at 1538 and encountered fallout in Guaje Canyon about 1.1 mile west of State Road 4 with a maximum of 0.2 mR/h at 1 mile west of State Roads 4. The team checked Totavi, background, and then started north on the Espanola Road (State Road 5). Very low readings (0.04 to 0.075 mR/hr) were found in the first 1.9 miles north of State Road 4 and 5 junction. The team returned west up Guaje Canyon; the measured maximum of 0.3 mR/h was again found 1 mile up canyon, essentially the same as before. Background seemed quite variable on this survey.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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<tr>
<td>12/2/1954</td>
<td>RaLa shot # 173 took place at 1645 hours. The shot involved 1585 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1 mR/h at 1.5 miles. Team members began a clockwise survey from TA-1 before 1730; background was 0.04 to 0.05 mR/h. They encountered fallout at the Sportsman's Club, which continued for 2.5 miles; the maximum reading of 1.0 mR/h was recorded 0.5 miles west of the Rendija Canyon gate.</td>
</tr>
<tr>
<td>12/7/1954</td>
<td>On December 7, 1954 Room 5006 of CMR Building was found to be highly contaminated. The exhaust fan for this room is not filtered, contamination was probably released into the environment.</td>
</tr>
<tr>
<td>12/9/1954</td>
<td>RaLa shot # 174 took place on 12/9/1954 at 1604 hours. The shot involved 500 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>12/30/1954</td>
<td>RaLa shot # 175 took place on 12/30/1954 at 1445 hours. The shot involved 320 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. No radiation was detected. The team surveyed Rendija and Guaje canyons. No readings above background were found, though spurious readings were encountered between the Sportsman's Club and the Rendija Canyon gate. These readings were explained as residual from previous shots. Although we have no fallout data on the previous shot, it seems unlikely that this explanation is valid because of the decay time.</td>
</tr>
<tr>
<td>1/1/1955</td>
<td>On one occasion during the year it was suspected that the city water line was contaminated due to corrosion. Tests did not detect contamination, but the repairs were made.</td>
</tr>
<tr>
<td>1/6/1955</td>
<td>RaLa shot # 176 took place on 1/6/1955 at 1415 hours. The shot involved 134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. A clockwise perimeter survey monitored Rendija and Guaje canyons as far as the well-drilling site below the Guaje pumice mine. Readings were 2 times background (0.07 mR/h) from the Rendija Canyon gate to 0.6 miles east of the gate. All other readings were background.</td>
</tr>
<tr>
<td>1/12/1955</td>
<td>RaLa shot # 177 took place on 1/12/1955 at 1415 hours. The shot involved 180 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance (mR/h) was 0.12 mR/h at 1.3 miles. Two surveys were made in Rendija and Guaje canyons to about 1 mile past the pumice mine. Twice background, 0.07 mR/h, was measured from the Rendija Canyon gate about 0.6 miles east. All other readings were background.</td>
</tr>
<tr>
<td>1/13/1955</td>
<td>On January 13, 1955 a ampule of americium curium mixture exploded spreading contamination on two workers. The workers rinsed off in a sink and drove to the hospital. The route to the hospital and the vehicle was decontaminated.</td>
</tr>
<tr>
<td>3/9/1955</td>
<td>Uranium was released into the hood of Room 121 at TA-46 on March 9, 1954.</td>
</tr>
<tr>
<td>3/17/1955</td>
<td>RaLa shot # 178 took place on 3/17/1955 at 1255 hours. The shot involved 3160 Ci of RaLa with an explosive charge of 201 to 350 lbs. The cloud tracked toward the NE. No radiation was detected. A northern perimeter survey was done in Rendija and Guaje canyons, down and back. All readings showed background activity.</td>
</tr>
<tr>
<td>3/23/1955</td>
<td>RaLa shot # 179 took place at 1315 hours. The shot involved 2260 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 8-15 mph. The maximum radiation measured at distance was 0.3 mR/h at 3 miles. A clockwise perimeter survey starting about 1400 found only background activity in Rendija and Guaje canyons. The team encountered fallout just east of Totavi (0.1 mR/h), which increased through Totavi and reached 0.3 mR/h at 0.2 miles west of Totavi and continued for 0.3 miles. The team retraced its route to check further east of Totavi to Otowi Bridge; readings showed background activity. Activity at the White Rock Y (intersection of main hill road and State Road 4) measured 0.1 mR/h; measurements taken towards and in White Rock were all background. A reading of 1 mR/h was recorded at Otowi ruins by another team. A rough map was drawn.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>3/30/1955</td>
<td>RaLa shot # 180 took place at 1315 hours. The shot involved 2642 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 6-10 mph. The maximum radiation measured at distance was 0.6 mR/h at 2 miles. The general background activity in the Los Alamos area was elevated because of fallout from the Nevada Test Site (NTS). Background activity of 0.5 mR/h was measured in TA-1, 0.1 to 0.2 mR/h on State Road 4 to Totavi, and 0.1 to 0.15 mR/h on North and Tank (Barranca) mesas. The Guaje-Rendija survey passed the Sportsman's Club at 1415, where the background due to NTS fallout was 0.3 mR/h. The team found readings in excess of this background and attributed these readings to activity from this shot for about 1 mile west of the Guaje pumice mine to the mine.</td>
</tr>
<tr>
<td>4/7/1955</td>
<td>RaLa shot # 181 took place at 1522 hours. The shot involved 2080 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 5 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.2 miles. The team stalled the Rendija and Guaje canyons survey from TA-1 at 1600; encountering activity 1.9 miles past the Sportsman's Club. This activity continued for about 1 mile, with a maximum of 0.07 mR/h measured 0.1 miles east of the Rendija Canyon gate to 0.5 miles past the Guaje pumice mine. Here the team turned around and retraced its path. At 1654, the reading at the Sportsman's Club had increased to 0.075 mR/h. It was noted that “residual readings of 0.04 to 0.06 mr/hr from NTS test fallout a week ago prevailed throughout the survey area.”</td>
</tr>
<tr>
<td>4/22/1955</td>
<td>RaLa shot # 182 took place at 1810 hours. The shot involved 700 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.5 miles. The team began to survey Rendija and Guaje canyons from TA-1 at 1600; encountering activity 1.9 miles past the Sportsman's Club. This activity continued for about 1 mile, with a maximum of 0.4 mR/h 2.3 miles past the Sportsman's Club.</td>
</tr>
<tr>
<td>4/28/1955</td>
<td>RaLa shot # 183 took place at 1515 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs.</td>
</tr>
<tr>
<td>5/5/1955</td>
<td>RaLa shot # 184 took place at 1540 hours. The shot involved 1470 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. A team surveying Rendija and Guaje canyons passed the Sportsman's Club at 1625; background was 0.02 to 0.04 mR/h. The team encountered fallout 2 miles further at Rendija Canyon gate; fallout continued to 0.7 miles past the Guaje pumice mine. A maximum reading of 0.2 mR/h was measured 0.4 miles east of the junction of Rendija and Guaje canyons. All other readings were background.</td>
</tr>
<tr>
<td>5/12/1955</td>
<td>On May 12, 1955 a small furnace erupted releasing an unknown quantity estimated at less than one kilogram of uranium in Room 102 of Sigma Building.</td>
</tr>
<tr>
<td>5/12/1955</td>
<td>There was a tuballoy fire in Sigma Building, Room 103 on May 12, 1955.</td>
</tr>
<tr>
<td>5/12/1955</td>
<td>RaLa shot # 185 took place at 1625 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. No radiation was detected. Rendija and Guaje canyons were surveyed. All readings were background activity.</td>
</tr>
<tr>
<td>5/20/1955</td>
<td>RaLa shot # 186 took place at 1845 hours. The shot involved 1470 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. A team surveying Rendija and Guaje canyons passed the Sportsman's Club at 1625; background was 0.02 to 0.04 mR/h. The team encountered fallout 2 miles further at Rendija Canyon gate; fallout continued to 0.7 miles past the Guaje pumice mine. A maximum reading of 0.2 mR/h was measured 0.4 miles east of the junction of Rendija and Guaje canyons. All other readings were background.</td>
</tr>
<tr>
<td>5/26/1955</td>
<td>RaLa shot # 187 took place at 1154 hours. The shot involved 520 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 4-7 mph. The maximum radiation measured at distance was 1 mR/h at 1.2 miles. Rendija and Guaje canyons were surveyed. Activity at the Rendija Canyon gate was 0.18 mR/h. At 0.2 miles east of the Rendija Canyon gate, the reading was 0.5 mR/h. All other readings were 0.08 to 0.1 mR/h.</td>
</tr>
<tr>
<td>6/2/1955</td>
<td>RaLa shot # 188 took place at 1345 hours. The shot involved 490 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. Rendija and Guaje canyons were surveyed. The path of fallout extended 0.3 miles west of the Rendija Canyon gate to 0.8 miles east. The highest reading was 0.16 mR/h. D. Meyer's handwritten note says, “no fallout found”, we assume he interpreted the fallout as resulting from previous shot(s).</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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<tr>
<td>------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>7/21/1955</td>
<td>On July 21, 1955 some normal uranium caught fire in Room 1131.</td>
</tr>
<tr>
<td>8/3/1955</td>
<td>On August 3, 1955 a mock fission polonium source containing 25.2 curies of Po exploded in the basement of the Physics Building. Contamination was spread through out the Physics Building.</td>
</tr>
<tr>
<td>8/19/1955</td>
<td>On August 19, 1955 an employee dropped a test tube containing one gram of normal uranium in Wing 2 of CMR Building.</td>
</tr>
<tr>
<td>9/6/1955</td>
<td>On September 6, 1955 a radiation contamination incident occurred in Room 1 of ML Building.</td>
</tr>
<tr>
<td>9/16/1955</td>
<td>RaLa shot # 189 took place at 1455 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.2 mR/h at 2 miles. The team began a clockwise perimeter survey from Point Weather at 1500; background was 0.03 mR/h. The highest reading of 0.2 mR/h was measured at Point Weather (which must have been direct radiation from the firing pad, reading 65 R/h at a meter above the firing pad after the shot). Fallout was encountered in Guaje Canyon at the pumice mine, continuing for 1.2 miles with a maximum of 0.2 mR/h recorded 0.3 miles east of the pumice mine.</td>
</tr>
<tr>
<td>9/28/1955</td>
<td>RaLa shot # 190 took place at 1631 hours. The shot involved 2600 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 10 mph.</td>
</tr>
<tr>
<td>10/7/1955</td>
<td>RaLa shot # 191 took place at 1515 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was light. The maximum radiation measured at distance was 2 mR/h at 1.5 miles. The team began a clockwise survey from TA-1 at 1555; background was 0.03 mR/h. Fallout was encountered 1.4 miles east of the Sportsman's Club, which continued about 0.6 miles down Rendija Canyon. The team continued west up Guaje Canyon, encountering fallout 0.2 miles west up canyon; this fallout continued for about 1.1 miles with a peak of 1 mR/h recorded 0.8 miles west up canyon. The team completed the survey down Guaje Canyon and returned through Totavi. All activity was background.</td>
</tr>
<tr>
<td>10/19/1955</td>
<td>RaLa shot # 192 took place at 1720 hours. The shot involved 2000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.5 mR/h 6 miles. The team began a counterclockwise survey past the main gate at 1800; background was 0.01 to 0.03 mR/h. The team encountered activity 0.4 miles north on Espanola Road (State Road 5), which continued for about 3 miles. A maximum reading of 0.5 mR/h was measured. The team surveyed around the gravel pits near the Rio Grande, south of Pajarito Village; a maximum of 2 mR/h probably was influenced by several particles, judging from the lower readings on State Road 5. One particle read 1.4 mR/h beta plus gamma at “contact,” and another read 11 mR/h gamma at 6 inches, using a Cutie Pie ion-chamber survey instrument. Later, photomicrographs, autoradiographs, and activity determinations of two particles were made; each particle measured over 300 microns in the longest dimension.</td>
</tr>
<tr>
<td>10/26/1955</td>
<td>RaLa shot # 193 took place at 1630 hours. The shot involved 3987 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 1 mR/h at 3 miles; 0.1 mR/h at 10 miles. The team began a counterclockwise perimeter survey from TA-1 at 1725; background was 0.03 mR/h. All readings showed background activity until 5.4 miles past Totavi on Espanola Road (State Road 5), where fallout was encountered that continued to Santa Clara Pueblo; a maximum of 0.15 mR/h was found at Puye Road. The team returned up Guaje Canyon, encountering fallout 1.8 miles west up canyon, which continued for about 1 mile. The maximum radiation of 1.0 mR/h was recorded 1 mile east of the Guaje pumice mine. The remainder of the perimeter survey readings showed background activity.</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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</tr>
<tr>
<td>11/3/1955</td>
<td>RaLa shot # 194 took place at 1605 hours. The shot involved 3500 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.6 mR/h at 1.5 miles; 3.0 mR/h at 2 miles; 0.2 mR/h at 5 miles. The team began a clockwise perimeter survey from TA-1 at 1645; background activity was 0.04 mR/h. Fallout was encountered 2.1 miles past the Sportsman's Club and continued for about 1 mile. A maximum reading of 1.6 mR/h was recorded 0.3 miles further on. The team went west up Guaje Canyon, encountering fallout 0.3 miles up canyon. The fallout continued for about 1 mile, with a maximum of 3.0 mR/h recorded between 0.6 to 0.7 miles west up canyon. The remainder of the perimeter survey was completed down Guaje Canyon, through Totavi, and back to TA-1. All readings showed background activity. The following morning Puye Road was surveyed, with readings fluctuating between 0.1 and 0.2 mR/h from the Espanola Road (State Road 5) to the Puye Ruins.</td>
</tr>
<tr>
<td>11/17/1955</td>
<td>RaLa shot # 195 took place at 1354 hours. The shot involved 1600 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 8-10 mph. The maximum radiation measured at distance was 0.65 mR/h at 1.5 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1430; background was 0.03 mR/h. Fallout was encountered 0.7 miles past the Sportsman's Club and continued for 1.4 miles, with a maximum of 0.65 mR/h recorded 1.7 miles past the Sportsman's Club. The team surveyed west up Guaje Canyon; a maximum of 0.3 mR/h was recorded 2 miles up the canyon.</td>
</tr>
<tr>
<td>11/29/1955</td>
<td>RaLa shot # 196 took place at 1535 hours. The shot involved 780 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5-7 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.4 mR/h at 2 miles. The team began a clockwise perimeter survey from TA-1 at 1625; background was 0.03 mR/h. Fallout was encountered at the Rendija Canyon gate and continued for 0.8 miles, with a maximum of 0.7 mR/h measured 0.4 miles beyond. The fallout pattern also crossed upper Guaje Canyon with a maximum of 0.4 mR/h about a mile west up canyon. Above-background readings were recorded for about 3 miles to Guaje Canyon gate, where the team completed the survey through lower Rendija and Guaje canyons to Totavi. Only background activity was found.</td>
</tr>
<tr>
<td>1/27/1956</td>
<td>RaLa shot # 197 took place at 1443 hours. The shot involved 1300 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. No radiation was detected. The team began a special survey from TA-1 at 1500; background activity was 0.05 mR/h. Since the cloud remained in Bayo Canyon, the team surveyed only in the eastern part of the canyon to the Otowi ruins, recording a maximum of 0.4 mR/h at 0.3 miles west up Bayo Canyon from State Road 4. A rough sketch was made.</td>
</tr>
<tr>
<td>2/1/1956</td>
<td>In 1956 approximately 1 Ci of Sr was released into Mortandad canyon when a line broke on a full tank of waste.</td>
</tr>
<tr>
<td>2/11/1956</td>
<td>During the week of February 11, 1956 a pipe carrying water near Ten Site developed a leak releasing 35,000 gallons of contaminated water into Mortandad canyon.</td>
</tr>
<tr>
<td>2/21/1956</td>
<td>RaLa shot # 198 took place at 1400 hours. The shot involved 2100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.7 mR/h at 3 miles. The team began a clockwise perimeter survey from TA-1 at 1830; background activity was 0.05 mR/h. The picnic grounds and stables (on North Mesa), and Tank Mesa (Barranca Mesa) were surveyed; background activity was recorded. Fallout was encountered 1.1 miles past the Guaje pumice mine and continued for 1.3 miles with a maximum of 0.7 mR/h recorded 0.6 miles past the mine.</td>
</tr>
<tr>
<td>3/1/1956</td>
<td>RaLa shot # 199 took place at 1540 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance was 1.0 mR/h at 2 miles. The team began a counterclockwise perimeter survey from TA-1 at 1830; the background activity was 0.03 to 0.05 mR/h. Fallout was encountered in Guaje Canyon just east of the pumice mine and continued for almost 3 miles. A maximum of 1.0 mR/h was recorded about 0.2 miles past the Rendija/Guaje Y. The team returned west up Rendija Canyon, measuring 0.1 to 0.2 mR/h for about 0.8 miles. Tank Mesa (Barranca Mesa) and North Mesa were surveyed; only background activity was noted.</td>
</tr>
<tr>
<td>3/9/1956</td>
<td>On March 9, 1956 a spill of uranium flowed into the bottom of the furnace in Room 21 of the Sigma Building.</td>
</tr>
</tbody>
</table>
### Table 16-1. Partial Chronology of Accidents, Incidents, and Important Events at LANL

<table>
<thead>
<tr>
<th>Date of Incident</th>
<th>Description</th>
<th>Incident Type</th>
<th>Repos. No.</th>
<th>Initial Page of Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/9/1956</td>
<td>RaLa shot # 200 took place at 1730 hours. The shot involved 435 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 8-12 mph.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/14/1956</td>
<td>RaLa shot # 201 took place at 1345 hours. The shot involved 560 Ci of RaLa with an explosive charge of 101 to 200 lbs. No radiation was detected. The team began a counterclockwise perimeter survey from TA-1 at 1408; the background activity was 0.05 mR/h. All measurements were background.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/22/1956</td>
<td>RaLa shot # 202 took place at 1330 hours. The shot involved 389 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The maximum radiation measured at distance was 0.15 mR/h at 2.2 miles. The survey team left TA-1 at 1420; background radiation was 0.03 mR/h. A reading of 0.04 mR/h was recorded at the picnic grounds (on North Mesa), 0.15 mR/h at “overlook of Bayo” [tip of Otowi Mesa, called also “North Ridge”—probably direct radiation from the firing pad, which was reading 40 R/h waist high above the pad shortly after the shot]. Readings on the “mesa north of previous measurement (0.15 mR/h),” (Deer Trap Mesa, northeastern-most Barranca Mesa) were background. At 2.7 miles east of the Sportsman's Club, fallout of 0.12 mR/h was encountered. At 2.9 miles, fallout was 0.15 mR/h, and at Booster #1 (near Guaje/Rendija Y) it was 0.08 mR/h. About 0.5 miles up Guaje Canyon, fallout was 0.13 mR/h.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/7/1956</td>
<td>RaLa shot # 203 took place at 1730 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The wind speed was 8 mph. The maximum radiation measured at distance was 1.0 mR/h at 4 miles. The team departed TA-1 at 1812; background activity was 0.03 mR/h. Background activity was measured until the team reached the “tip of Tank Mesa [Barranca Mesa],” where the reading was 0.3 mR/h (direct radiation from the firing pad may have affected this measurement). A clockwise perimeter survey was continued. Background activity was recorded until the Guaje Canyon road junction with State Road 4; at that point, the reading was 0.10 mR/h. Background activity was recorded further east to the junction of State Roads 4 and 5. Readings increased to 1.0 mR/h at Roy's Service Station (Totavi); continuing 0.6 miles west, only background activity was found to TA-1. The cloud did not rise above the Bayo Canyon walls and apparently followed the canyon to Totavi.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/12/1956</td>
<td>RaLa shot # 204 took place at 1455 hours. The shot involved 3740 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 12 mph. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles; 0.07 mR/h at 5.5 miles. The team began a clockwise survey from TA-1 at 1555; background activity was 0.03 mR/h. Down Rendija Canyon, 2 miles past the Sportsman's Club, the team encountered fallout measuring 0.05 mR/h, with a maximum of 0.7 mR/h recorded 2.5 miles beyond. Activity slowly decreased to background activity within half a mile. The team continued down Guaje Canyon to State Road 4 and north to Puye Road junction and then west, encountering 0.07 mR/h 6 to 6.4 miles west on Puye Road, essentially directly in line with the previous encounter in Guaje Canyon. The next morning the team monitored in Espanola, Riverside, and Fairview (areas east and north of Espanola); only background activity was detected.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/20/1956</td>
<td>RaLa shot # 205 took place at 1436 hours. The shot involved 3200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNE. The wind speed was 8 mph. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a clockwise survey from TA-1 at 1506; background activity was 0.03 mR/h. Team members encountered fallout about 0.7 miles past the Sportsman's Club. Activity was 0.09 mR/h, falling to 0.05 mR/h in the next 0.3 miles. Only background activity was found at Booster #1 (3 miles east past the Sportsman's Club) and for 2.3 miles west up Guaje Canyon. At 2.3 miles, fallout was encountered, which increased to a broad maximum of 0.4 mR/h for 0.4 miles, continued at this level for 0.4 miles, and then decreased to 0.15 mR/h at the Guaje Canyon gate.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/26/1956</td>
<td>RaLa shot # 206 took place at 1140 hours. The shot involved 2195 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NE. The wind speed was 5 mph. No radiation was detected. The survey team left TA-1 at 1223; background activity was 0.03 mR/h. The team made the complete perimeter survey and found no readings above background. The cloud was observed to start to the north and then spread east along the canyon rim.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>5/10/1956</td>
<td>RaLa shot # 207 took place at 1145 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The survey team left TA-1 at 1310; background activity was 0.03 mR/h. The perimeter survey was completed with no readings above background recorded.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
<td>Incident Type</td>
<td>Repos. No.</td>
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<tr>
<td>5/21/1956</td>
<td>RaLa shot # 208 took place at 1300 hours. The shot involved 4,000 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW. The maximum radiation measured at distance was 0.16 mR/h at 1.5 miles. The team began a clockwise perimeter survey from the Administration Building (TA-3, SM-43) at 1340 (note the new starting point); background activity was 0.03 mR/h. Fallout was encountered from 0.9 to 1.2 miles east of the Sportsman's Club, and the maximum activity was 0.15 mR/h beyond the Sportsman's Club. The team completed the survey route, finding only background activity. The cloud was observed to move to the south Bayo Canyon wall and then rise and move north.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>5/25/1956</td>
<td>RaLa shot # 209 took place at 1155 hours. The shot involved 4195 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles; 1.2 mR/h at 2 miles. The survey team left Point Weather at 1200 (only 5 minutes after the shot) and immediately measured 13 mR/h (probably direct radiation from the cloud, not fallout). On the continuing clockwise perimeter survey, fallout (0.1 mR/h) was encountered 1.4 miles east of the Sportsman’s Club and continued above background with peaks of 0.8 mR/h at the Barranca (Rendija) gate and 1.2 mR/h 0.4 miles west up Guaje Canyon. The remainder of the survey found no activity above background.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/7/1956</td>
<td>RaLa shot # 210 took place at 1455 hours. The shot involved 2907 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The maximum radiation measured at distance was 0.7 mR/h at 1.5 miles. The team left the Administration Building (SM-43) at 1416; background activity was 0.03 mR/h to Point Weather, where the reading was 0.07 mR/h (probably a direct reading from the firing pad). Fallout was encountered 0.6 miles past the Sportsman's Club, with a maximum of 0.7 mR/h recorded 1.8 miles east. It continued above background for another 0.6 miles. The team completed surveying the rest of the perimeter, encountering only background activity.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/14/1956</td>
<td>RaLa shot # 211 took place at 1305 hours. The shot involved 1840 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the WSW. The wind speed was light (5) mph. No radiation was detected. The survey team left the Administration Building (SM-43) at 1315; background activity was 0.03 mR/h; activity at Point Weather was 0.07 mR/h. Only background activity was encountered on the perimeter survey. The section of State Road 4 road toward White Rock was also checked and background found.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>7/3/1956</td>
<td>On July 3, 1956 there was a criticality incident involving 58 kg U in the form of 93% U-235 as 2- and 5-mil foils. Changes were made in the reflector and graphite moderator and criticality was reached too quickly. $3.2 \times 10^{16}$ total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>10/5/1956</td>
<td>RaLa shot # 212 took place at 1428 hours. The shot involved 2200 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NW and N. The wind speed was 13 mph. The maximum radiation measured at distance was 1.3 mR/h at 1.5 miles; 1.3 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1555; background activity was 0.03 mR/h; activity at Point Weather was 0.5 mR/h. Fallout was encountered 1.3 miles east of the Sportsman’s Club and continued for 3.1 miles, with a peak between 1.0 and 1.3 mR/h recorded 2.1 miles east of the Club. Fallout also crossed Guaje Canyon beginning 0.5 miles west up Guaje Canyon and continuing above background for 2.1 miles. A maximum reading of 1.3 mR/h was recorded 1.1 miles west up canyon.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>10/16/1956</td>
<td>RaLa shot # 213 took place at 1534 hours. The shot involved 1400 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The wind speed was 5 mph. The maximum radiation measured at distance was 0.8 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1605; background activity was 0.03 mR/h. Fallout was encountered 2.4 miles east of the Sportsman's Club (0.1 mR/h) and 0.8 miles west up Guaje Canyon (0.8 mR/h). During the remainder of the clockwise perimeter survey, only background activity was detected.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>10/23/1956</td>
<td>On October 23, 1956; 100 mg of plutonium hexafluoride exploded in a drybox in Room 5122 of CMF 2. The material entered the exhaust system of the drybox and was vented into the filter tower for Wing 5. The filter tower filters were changed and monitored for contamination.</td>
<td>Explosion</td>
<td>4055</td>
<td>6</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
<td>Incident Type</td>
<td>Repos. No.</td>
<td>Initial Page of Interest</td>
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<tr>
<td>10/27/1956</td>
<td>RaLa shot # 214 took place at 1420 hours. The shot involved 300 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 10 mph. The maximum radiation measured at distance was 0.5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1501; background activity was 0.04 mR/h. Fallout was encountered 1.3 miles east past the Sportsman's Club, with a peak of 0.5 mR/h occurring 0.5 miles further on. The peak reading was caused by a one-foot-square contaminated area measuring 6 mR/h at 6 inches (probably one or more particles).</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>11/1/1956</td>
<td>RaLa shot # 215 took place at 1023 hours. The shot involved 200 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The wind speed was 9 mph. The maximum radiation measured at distance was 0.3 mR/h at 1.5 miles; 0.15 mR/h at 2.3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1100; background activity was 0.03 mR/h. Fallout was encountered 0.5 miles east of the Sportsman's Club, with a peak of 0.3 mR/h occurring 1.7 miles past the Sportsman's Club. Above-background readings continued to the Rendija/Guaje canyons junction and then increased west up Guaje Canyon, with a peak of 1.5 mR/h occurring 1.8 miles up the canyon and continuing above background for about 1 mile. The team completed the perimeter survey down Guaje Canyon to Highway 4 and returned to the Administration Building; only background activity was detected.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>12/5/1956</td>
<td>RaLa shot # 216 took place at 1500 hours. The shot involved 800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 17 mph. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1515; background activity was 0.03 mR/h. Fallout was encountered 1 mile past the Sportsman's Club and continued for 0.8 miles, with a peak of 1.0 mR/h occurring 1.4 miles past the Sportsman's Club. The perimeter survey was completed with positive readings recorded 1 mile east of the main gate. Peak activity of 0.4 mR/h occurred at the entrance to the East Gate Lab. No explanation was offered for these later readings, which are in the opposite direction from which the main cloud was detected. Operations at the East Gate Laboratory are suspected (see shots #238, 240, and 242).</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>12/20/1956</td>
<td>RaLa shot # 217 took place at 1450 hours. The shot involved 225 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the W and SW. The wind speed was 3 mph. The maximum radiation measured at distance was 1 mR/h at 0.6 miles; 0.3 mR/h at 1 mile; 0.5 mR/h at 2 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1510; background activity was 0.05 mR/h. A reading of 0.3 mR/h was recorded at the dump site near the Los Alamos Airport. The team completed the perimeter survey; all readings showed only background activity. A town site survey began at 1700; a peak of 0.15 mR/h was recorded at the eastern end of Manhattan Loop (eastern residential area). Activity up to 0.075 mR/h was recorded at the DP Road trailer court (south of the airport). At 0.1 miles west of Point Weather, activity from 1 mR/h to 0.5 mR/h was recorded to the ballpark (on North Mesa), where background activity was measured.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>2/7/1957</td>
<td>On February 7, 1957 an explosion and fire occurred in the pure metal drybox in Room 406 of DP West. The only contamination found was on the outside of the air intake filters.</td>
<td>Explosion</td>
<td>4056</td>
<td>16</td>
</tr>
<tr>
<td>2/8/1957</td>
<td>On February 8, 1957 tinners disconnected the exhaust duct on the wooden drybox line in Room 500. Highly contaminated dust spread throughout the south part of the room.</td>
<td>Air Release</td>
<td>3490</td>
<td>11</td>
</tr>
<tr>
<td>2/12/1957</td>
<td>At 3 pm on February 12, 1957 the Godiva assembly located at Kiva 2 at Pajarito Site went supercritical. Filters in the heating system were found to be highly contaminated. The exhaust system was not running at the time of the incident.</td>
<td>Criticality</td>
<td>2817</td>
<td>1-2</td>
</tr>
<tr>
<td>2/12/1957</td>
<td>On February 12, 1957 there was a criticality incident involving 54 kg U metal 93% U-235 due to incorrect operation at the Lady Godiva reactor. There was warping oxidation near melting close to center. $1.2 \times 10^{17}$ total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>3/7/1957</td>
<td>On March 7, 1957 a worker in Room 2125 Wing 2 of CMR Building was working with 20 grams of plutonium in a glovebox when they noticed that there was a leak in the glove.</td>
<td>Air Release</td>
<td>3490</td>
<td>19</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
<td>Incident Type</td>
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<tr>
<td>3/16/1957</td>
<td>RaLa shot # 218 took place at 1245 hours. The shot involved 2140 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 15 mph.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/27/1957</td>
<td>On March 27, 1957 an explosion occurred in the machine lathe drybox in Room 500. The operator of the lathe was highly contaminated. After showering no contamination was detected.</td>
<td>Explosion</td>
<td>3490</td>
<td>23</td>
</tr>
<tr>
<td>3/29/1957</td>
<td>RaLa shot # 219 took place at 1250 hours. The shot involved 3079 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 6 mph. The maximum radiation measured at distance was 0.1 mR/h at 3 miles; 0.07 mR/h at 7 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1330; background activity was 0.03 mR/h. A reading of 0.1 mR/h was recorded at the stables (on North Mesa), but it was questioned on the survey sheet as not being reasonable, probably because the cloud was reported to have gone to the east. Fallout of 0.07 mR/h was encountered in Guaje Canyon 0.7 miles past the pumice mine, continuing for about 0.5 miles, with a peak of 0.1 mR/hr halfway between. Activity between 0.5 and 0.07 mR/h was recorded north on State Road 5, 3.2 miles from the junction.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/17/1957</td>
<td>RaLa shot # 220 took place at 1630 hours. The shot involved 3249 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The wind speed was 12 mph. The maximum radiation measured at distance was 0.4 mR/h at 4.5 miles. The team left the Administration Building (SM-43) at 1650; background was 0.03 mR/h. During the counterclockwise perimeter survey, fallout (0.04 mR/h) was encountered at the junction of the Main Hill Road/ White Rock cutoff. It increased to a maximum of 0.4 mR/h at 0.3 miles before the junction of Guaje Canyon and State Road 4. At Otowi Bridge, activity was 0.08 mR/h; at the Espanola Highway (State Road 5) to Puye Road, it was 0.08 to 0.09 mR/h for 3 miles. At the entrance to Guaje Canyon, activity was 0.2 mR/h and persisted to the Guaje pumice mine, where the 0.08 mR/h reading was attributed to contamination on the vehicle since the reading continued at this level until the team returned to the Administration Building. Weather observations confirmed that the cloud did not rise above the canyon walls to reach the southwest winds.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>5/9/1957</td>
<td>RaLa shot # 221 took place at 1600 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the SE. The wind speed was 7 mph. No radiation was detected. The team began a clockwise survey from Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. A clockwise perimeter survey was completed that included Puye Road; no measurable fallout was detected. Weather observations of the cloud support these findings. The cloud remained in Bayo Canyon.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/5/1957</td>
<td>There was a fire in the back of a contaminated dump truck on June 5, 1957.</td>
<td>Fire</td>
<td>3490</td>
<td>23</td>
</tr>
<tr>
<td>6/13/1957</td>
<td>On June 13, 1957 there was a contamination incident in Room 513 of DP West. The contamination occurred during the cleaning out of a Lucite casting tunnel.</td>
<td>Contam. Event</td>
<td>3490</td>
<td>49</td>
</tr>
<tr>
<td>6/20/1957</td>
<td>RaLa shot # 222 took place at 1540 hours. The shot involved 1000 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. No radiation was detected. The team left the Administration Building (SM-43) at 1625; background was 0.03 mR/h. A counterclockwise survey included the Puye pumice mine; the survey team returned through Guaje Canyon. The recorded instrument readings fluctuated between 0.02 and 0.05 mR/h but were considered negative. Weather observations confirmed that the cloud remained in the canyon.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>7/10/1957</td>
<td>RaLa shot # 223 took place at 1625 hours. The shot involved 2257 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNE. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles. The team began a clockwise survey from Administration Building (SM-43) at 1640; background activity was 0.05 mR/h. Fallout was encountered 0.4 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded just beyond and falling to background 0.8 miles past the Sportsman's Club.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>7/11/1957</td>
<td>On July 11, 1957 a leak was discovered in the buried acid waste tank outside Building #35 DP West. The contaminated ground was dug up and put into metal containers to be disposed of in the contamination dump.</td>
<td>Liquid Release</td>
<td>721</td>
<td>49</td>
</tr>
<tr>
<td>Date of Incident</td>
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<tr>
<td>7/23/1957</td>
<td>RaLa shot # 224 took place at 1306 hours. The shot involved 1520 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The wind speed was 8 mph. The maximum radiation measured at distance was 0.6 mR/h at 1.5 miles; 1.0 mR/h at 2.2 miles; 0.08 mR/h at 4 miles. The team began a clockwise survey from Administration Building (SM-43) at 1335; background activity was 0.05 mR/h. Fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 0.6 mR/h recorded 1.4 miles past the Sportsman's Club. The same reading was recorded 2.0 miles past the Sportsman's Club. A reading of 1.0 mR/h was recorded 1.6 miles west up Guaje Canyon; 0.08 mR/h was recorded at the Puye pumice mine, although the same reading was recorded at the Administration Building, which does not seem reasonable. Contamination on the detector or the vehicle is suspected.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>8/15/1957</td>
<td>On August 15, 1957 an explosion occurred in a glove box chain in Room 500. 18 rubber gloves were torn and three safety windows were cracked. Five men were contaminated, no skin contamination was detected after showering.</td>
<td>Explosion</td>
<td>4056</td>
<td>8</td>
</tr>
<tr>
<td>8/16/1957</td>
<td>On August 16, 1957 an explosion occurred in a glovebox chain in Room 500. Five men were contaminated with Pu.</td>
<td>Explosion</td>
<td>3490</td>
<td>53</td>
</tr>
<tr>
<td>8/30/1957</td>
<td>On August 30, 1957 large quantities of plutonium contamination were dispersed over the floor, hood and sink in three labs in J-11, contamination was also detected in the J-2 Building hallway.</td>
<td>Air Release</td>
<td>2413</td>
<td>4</td>
</tr>
<tr>
<td>9/27/1957</td>
<td>On September 27, 1957 rags contaminated with sodium and uranium caught fire in Room 133 at Ten Site. Fire was quickly extinguished with CO2.</td>
<td>Fire</td>
<td>2414</td>
<td>3</td>
</tr>
<tr>
<td>9/27/1957</td>
<td>RaLa shot # 225 took place at 1607 hours. The shot involved 1960 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.8 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1707; background activity was 0.05 mR/h. Fallout was encountered 1.4 miles east past the Sportsman's Club, with a maximum of 0.8 mR/h recorded 1.5 miles past the Sportsman's Club.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>10/10/1957</td>
<td>RaLa shot # 226 took place at 1726 hours. The shot involved 1153 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 7 mph. The maximum radiation measured at distance (mR/h) was 0.3 mR/h at 2.2 miles. The team began a clockwise survey and reached the Sportsman's Club at 1814; background activity was 0.03 mR/h. Fallout was encountered 0.2 miles past the Rendija/Guaje junction, with a maximum of 0.3 mR/h recorded 0.4 miles down canyon. Activity continued above background until past the Guaje pumice mine. During the rest of the survey, only background activity was recorded.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>11/12/1957</td>
<td>On November 12, 1957, a vial containing 14,000 c/m of plutonium was dropped at the stairs leading from the first floor of HRL Building.</td>
<td>User Error</td>
<td>2489</td>
<td>3</td>
</tr>
<tr>
<td>1/30/1958</td>
<td>RaLa shot # 227 took place at 1302 hours. The shot involved 1340 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the E. The wind speed was 13 mph. The maximum radiation measured at distance was 0.16 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1343; background activity was 0.02 mR/h. Fallout was encountered at Well #1 and continued for 1.8 miles, with a maximum of 0.16 mR/h recorded 1.3 miles west up canyon from State Road 4.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>2/19/1958</td>
<td>RaLa shot # 228 took place at 1545 hours. The shot involved 1850 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NWW. The wind speed was 5 mph. The maximum radiation measured at distance was 5 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1625; background activity was 0.02 mR/h. Fallout was encountered at the Sportsman's Club, with a maximum of 5 mR/h recorded one mile east past the Sportsman's Club. Above background readings continued to Booster #2 at the junction of Rendija and Guaje canyons.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
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<tr>
<td>3/7/1958</td>
<td>RaLa shot # 229 took place at 1655 hours. The shot involved 1800 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the NNW. The maximum radiation measured at distance was 1.0 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1743; background activity was 0.03 mR/h. Fallout was encountered 1.9 miles east past the Sportsman's Club, with a maximum of 1.0 mR/h recorded 2.1 miles past the Sportsman's Club. Above-background activity was recorded to the junction of Rendija/ Guaje canyons.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/3/1958</td>
<td>RaLa shot # 230 took place at 1505 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NW, NE. The wind speed was 5 mph. No radiation was detected. The team began a clockwise survey from the Administration Building (SM-43) at 1535 for a clockwise perimeter survey. All readings showed background activity.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>5/1/1958</td>
<td>RaLa shot # 231 took place at 1430 hours. The shot involved 1134 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NNW. The wind speed was 10 mph.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/3/1958</td>
<td>RaLa shot # 232 took place at 1450 hours. The shot involved 1316 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the NE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.18 mR/h at 2 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1535; background activity was 0.05 mR/h. Fallout was encountered at the Rendija/Guaje junction, with a maximum of 0.18 mR/h recorded 0.7 miles down canyon. The remainder of the survey recorded background activity.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>7/25/1958</td>
<td>On July 25, 1958 at TA-33, a leak occurred in Building 86 causing tritium to be released. The site was evacuated and road blocks were set up.</td>
<td>Air Release</td>
<td>2422</td>
<td>4</td>
</tr>
<tr>
<td>7/25/1958</td>
<td>Large quantities of tritium were released in the filling chamber of Room 9 at TA-33 on July 25, 1958. It was estimated that 13,000 curies were lost.</td>
<td>Air Release</td>
<td>4057</td>
<td>20</td>
</tr>
<tr>
<td>10/28/1958</td>
<td>A fire was detected on October 28, 1958 in pit #6 of the contaminated dump.</td>
<td>Fire</td>
<td>4057</td>
<td>27</td>
</tr>
<tr>
<td>11/6/1958</td>
<td>On November 6, 1958 K Division members were removing a plutonium pilot plant from the air filter building, contamination was spread to the floor, wheels of the fork lift, and the dirt east of the building.</td>
<td>Contam. Event</td>
<td>2510</td>
<td>3</td>
</tr>
<tr>
<td>12/8/1958</td>
<td>RaLa shot # 233 took place at 1545 hours. The shot involved 1305 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 1.4 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1600; background activity was 0.03 mR/h. Fallout was encountered, twice background, in the “new housing area” (Barranca Mesa), and 1.0 mR/h was recorded at the end of Tank Mesa (Barranca Mesa, overlooking the firing site). Back on the clockwise perimeter survey route, fallout was encountered 1.2 miles east past the Sportsman's Club, with a maximum of 1.4 mR/h recorded at the Guaje Canyon gate. The remainder of the survey route showed background activity.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>12/30/1958</td>
<td>On December 30, 1958 there was a criticality incident involving 3.27 kg Pu Pu02(N03)2 in ~168 liters of water. The cylinder contained dissolved Pu, when the agitator was started it created critical geometry. One death resulted from the accident. 1.5 x 1017 total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>2/20/1959</td>
<td>RaLa shot # 234 took place at 1335 hours. The shot involved 1250 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.18 mR/h at 1.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1405; background activity was 0.04 mR/h. Fallout was encountered 0.5 miles past the Sportsman's Club and continued for 2 miles, with a maximum of 0.18 mR/h recorded at Booster #2, which is 1.2 miles east of the Sportsman's Club.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/13/1959</td>
<td>RaLa shot # 235 took place at 1405 hours. The shot involved 1070 Ci of RaLa with an explosive charge of 20 to 100 lbs. No radiation was detected. The team left the Administration Building (SM-43) at 1426; background activity was 0.05 mR/h. The team completed the counterclockwise survey; all readings showed background activity.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
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<tr>
<td>3/17/1959</td>
<td>On March 17, 308 curies of tritium were released to the outside when a valve on a Van de Graff was left open.</td>
<td>Air Release</td>
<td>2739</td>
<td>3</td>
</tr>
<tr>
<td>4/1/1959</td>
<td>During processing of irradiated U-235 at TA-48 uranium oxide was blown out of the hood when a sample can was opened.</td>
<td>Explosion</td>
<td>2514</td>
<td>4</td>
</tr>
<tr>
<td>4/2/1959</td>
<td>RaLa shot # 236 took place at 1635 hours. The shot involved 980 Ci of RaLa with an explosive charge of 20 to 100 lbs. The cloud tracked toward the ESE. The maximum radiation measured at distance was 0.6 mR/h at 3 miles. The team left the Administration Building (SM-43) at 1750 to conduct a clockwise survey; background activity was 0.03 to 0.04 mR/h. Fallout was encountered at the intersection. The fallout continued west along State Road 4 for 3 miles, with a maximum of 0.6 mR/h recorded 1.5 miles west of the Guaje/State Road 4 intersection (12 mR/h was recorded at an isolated spot). The remainder of the survey showed background activity. The cloud was observed to go over the north Bayo Canyon wall.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/14/1959</td>
<td>RaLa shot # 237 took place at 1250 hours. The shot involved 1140 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N. The maximum radiation measured at distance was 0.4 mR/h at 1.7 miles. The team left the Administration Building (SM-43) at 1401; background activity was 0.03 to 0.04 mR/h. Fallout was encountered 1.2 miles past the Sportsman's Club, and readings remained elevated to the White Rock junction on State Road 4. A maximum of 0.4 mR/h was recorded 2 miles past the Sportsman's Club.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>5/1/1959</td>
<td>During the operation of LAMPRE II radioactive gas was released through the exhaust system, causing an increase in background levels around the town site. High background levels were detected in the water boiler reactor room due to a disconnected exhaust pump in the valve house, the incident increased background levels around the town site.</td>
<td>Air Release</td>
<td>2515</td>
<td>4</td>
</tr>
<tr>
<td>5/15/1959</td>
<td>RaLa shot # 238 took place at 1547 hours. The shot involved 1040 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ESE. The team left the Administration Building (SM-43) at 1640; background activity was 0.03 to 0.05 mR/h. A clockwise survey was conducted; only background activity was recorded until fallout was encountered on the Main Hill Road 0.8 miles east of the main gate for about 0.6 miles. A maximum of 1.5 mR/h was recorded beyond the East Gate Laboratory at the entrance to the Camp Hamilton Trail. Because the cloud was reported to go down canyon (east-southeast), the readings are not believed to be related to the Bayo Canyon activity. During this period, a large 120-curie cobalt-60 source located about 400 feet directly north of the Main Hill Road at the East Gate Laboratory (TA-19) was in intermittent use and is believed to explain these readings (see also shots #240 and #242).</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/4/1959</td>
<td>RaLa shot # 239 took place at 1527 hours. The shot involved 995 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 0.4 mR/h at 2.7 miles. The team left the Administration Building (SM-43) at 1630; background activity was 0.04 mR/h. During the clockwise survey, above-background activity was encountered at Booster #1, 3 miles east of the Sportsman's Club. It continued for 1.4 miles, with a maximum reading of 0.4 mR/h recorded 3.8 miles past the Sportsman's Club.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>6/26/1959</td>
<td>RaLa shot # 240 took place at 1400 hours. The shot involved 954 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the E. The maximum radiation measured at distance was 0.12 mR/h at 2.5 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1419; background activity was 0.02 mR/h. Fallout was encountered at the Guaje pumice mine and continued for 1.6 miles, with a maximum of 0.12 mR/h recorded 0.8 miles past the mine. Fallout was encountered again on the Main Hill Road 1.3 miles east of the main gate, with a maximum of 1.3 mR/h recorded 0.5 miles east of the gate. Because the cloud was reported to have gone over the north wall of Bayo Canyon, this reading is again attributed to the gamma source at the East Gate Laboratory (see shots #238 and #242).</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>7/15/1959</td>
<td>On July 15, 1959 a fire broke out in a plutonium contaminated CWS exhaust filter during welding of a new section of exhaust duct on the discharge side of the filter unit.</td>
<td>Fire</td>
<td>19</td>
<td>55</td>
</tr>
<tr>
<td>7/15/1959</td>
<td>On July 15, 1959 a fire broke out in a plutonium contaminated CWS exhaust filter in Room 501 DP West. Highly contaminated ash was dispersed through out the room. The clothes of 12 firemen were held for decontamination.</td>
<td>Fire</td>
<td>2425</td>
<td>5, 6</td>
</tr>
<tr>
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<tr>
<td>7/17/1959</td>
<td>Tritium gas was released from a storage tank reservoir in Building 86 at TA-33 on July 17, 1959. Road blocks were established and 69 people were evacuated from the area. No appreciable radiation was measured outside the fence of Building 86.</td>
<td>Air Release</td>
<td>2425</td>
<td>5, 6</td>
</tr>
<tr>
<td>8/14/1959</td>
<td>On August 14, 1959 a tritium leak occurred at P-9 Van de Graaff area when an &quot;o&quot; ring allowed tritium to be released.</td>
<td>Air Release</td>
<td>2426</td>
<td>3</td>
</tr>
<tr>
<td>10/7/1959</td>
<td>RaLa shot # 241 took place at 1438 hours. The shot involved 893 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The wind speed was 12 mph. The maximum radiation measured at distance was 0.12 mR/h at 3 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1603; background activity was 0.05 mR/h. Questionable activity (only 0.01 mR/h over background) was encountered at Booster #1 for 4.2 miles, with a maximum of 0.12 mR/h recorded 1.5 miles past the Guaje pumice mine. During the remainder of the survey, only background activity was recorded.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>10/14/1959</td>
<td>Explosion occurred while disposing of scrap and waste explosives</td>
<td>Explosion</td>
<td>NA</td>
<td>58</td>
</tr>
<tr>
<td>12/3/1959</td>
<td>On December 3, 1959 a fire broke out in an incinerator dry box exhaust system. A neoprene duct connection had burned out releasing contamination to the roof.</td>
<td>Fire</td>
<td>19</td>
<td>57</td>
</tr>
<tr>
<td>12/3/1959</td>
<td>On December 3, 1959, a fire broke out in the duct work of Room 313 of DP West where uranium materials are incinerated. The damage was limited to the duct work.</td>
<td>Fire</td>
<td>2494</td>
<td>3</td>
</tr>
<tr>
<td>12/3/1959</td>
<td>A fire occurred on December 3, 1959 in the drybox exhaust ductwork in Room 313 of DP West during the burning of U-235 contaminated rags. The exhaust stack discharged black smoke toward the west for approximately 15 minutes. Alpha contamination was detected downwind of Room 313.</td>
<td>Fire</td>
<td>4058</td>
<td>1</td>
</tr>
<tr>
<td>12/16/1959</td>
<td>On December 16, 1959 a filter in the vent line of the neutralization tank at the waste treatment operation at DP West failed allowing plutonium and americium to run down the roof and contaminate the ground.</td>
<td>Liquid Release</td>
<td>2494</td>
<td>3</td>
</tr>
<tr>
<td>1/15/1960</td>
<td>On January 15, 1960 in Room 308 of DP West a bottle containing plutonium solution had shattered. Contamination was tracked into the main hallway and into Room 206 and 363. Airborne contamination spread into 313, 322 and 326. The air supply room on the south side of Building 3 was monitored and found to be highly contaminated.</td>
<td>Liquid Release</td>
<td>3971</td>
<td>18</td>
</tr>
<tr>
<td>2/3/1960</td>
<td>Two different explosions occurred in the rag incinerator in Room 313 of DP West on January 28, 1960 the other on February 3, 1960.</td>
<td>Explosion</td>
<td>2496</td>
<td>3</td>
</tr>
<tr>
<td>2/3/1960</td>
<td>On February 3, 1960 in Room 313 of DP West an explosion occurred during the burning of U-235 contaminated rags. The area was monitored and no surface contamination was detected.</td>
<td>Explosion</td>
<td>3971</td>
<td>14</td>
</tr>
<tr>
<td>3/8/1960</td>
<td>RaLa shot # 242 took place at 1648 hours. The shot involved 908 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the S. The maximum radiation measured at distance was 0.4 mR/h at 2.5 miles. The team began a counterclockwise survey from the Administration Building (SM-43) at 1717; background activity was 0.03 mR/h. Since the cloud was observed to travel down canyon, the activity that was encountered 1.7 miles east of the airstrip and continued for about 0.5 miles, with a maximum of 1.5 mR/h recorded 1.9 miles past the airstrip, is believed to be due to the gamma source at the East Gate Laboratory (see shots #238 and #240 above). The remaining readings, beginning about 1.5 miles west of Roy's Service Station (Totavi) and continuing for about 1.3 miles, are attributable to this shot. A maximum reading of 0.4 mR/h was recorded 0.9 miles west of Roy's Service Station.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>4/13/1960</td>
<td>On April 13, 1960 in Building HP 21 there was widespread plutonium contamination when 100mg of plutonium was released during an experiment.</td>
<td>Contam. Event</td>
<td>2498</td>
<td>4</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>RaLa shot # 243 took place at 1618 hours. The shot involved 957 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the ENE. The maximum radiation measured at distance was 1.3 mR/h at 2.1 miles. The team began a clockwise survey from the Administration Building (SM-43) at 1645; background activity was 0.02 to 0.03 mR/h. Fallout was encountered 0.7 miles west of Well #1 and continued for 2.5 miles, with a maximum of 1.3 mR/h recorded 1.3 miles past Well #1. At Well #1, a particle was collected reading 1100 mR/h at “contact” with a Cutie Pie (an ionization chamber instrument). Background readings during this survey seemed to fluctuate. The environmental group reported results of two film badge dosimeters planted at the airstrip, about 1 mile southwest of the firing site, for a period beginning 22 days before and ending 30 days after this shot. They reported the readings averaged 200 mR/mr over this period and attributed the dose to a possible particle from the main cloud, although the main cloud went in the opposite direction.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
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</tr>
<tr>
<td>6/17/1960</td>
<td>On June 17, 1960 there was a criticality incident involving ~48 kg U-235. Uranium cylinders in thick graphite (9-in.) reflected before complete assembly, resulting in trivial damage. 6 x 10^16 total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>9/1/1960</td>
<td>RaLa shot # 244 took place at 1300 hours. The shot involved 1120 Ci of RaLa with an explosive charge of 101 to 200 lbs. The cloud tracked toward the N and NW. The maximum radiation measured at distance was 0.3 mR/h at 1.2 miles; 0.3 mR/h at 2 miles. The team began a clockwise perimeter survey from the Administration Building (SM-43) at 1325; background activity was 0.05 mR/h. Fallout was encountered 0.8 miles east past the Sportsman’s Club and continued for 0.8 miles, with a maximum of 0.3 mR/h recorded 1.1 miles past the Sportsman’s Club; 2.1 miles west up Guaje Canyon the maximum was 0.3 mR/h. A resurvey the next morning found a “speck” reading of 1.1 mR/h at “contact” on Guaje Road, where the maximum reading was found the day before.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>9/14/1960</td>
<td>September 14, 1960 15-30 gallons of americium raffinate spilled from a tank at Building 35 DP West. A trailer and the ground outside of the americium treatment Building were contaminated and cleaned.</td>
<td>Liquid Release</td>
<td>2429</td>
<td>5</td>
</tr>
<tr>
<td>9/16/1960</td>
<td>On September 16, 1960 approximately 15-30 gallons of Am raffinate spilled in Building 35 DP West. The equipment trailer and the south side of the Building and ground surrounding the trailer were contaminated.</td>
<td>Liquid Release</td>
<td>3971</td>
<td>8</td>
</tr>
<tr>
<td>9/21/1960</td>
<td>On September 21, 1960 a small explosion occurred in the Room 201 incinerator. The room was decontaminated the following day.</td>
<td>Explosion</td>
<td>3971</td>
<td>7</td>
</tr>
<tr>
<td>10/11/1960</td>
<td>RaLa shot # 245 took place at 1408 hours. The shot involved 1100 Ci of RaLa with an explosive charge of 20 to 100 lbs. The team started a survey on Barranca Mesa, completing a clockwise route. All readings were recorded as “00.”</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>11/22/1960</td>
<td>RaLa shot # 246 took place at 1214 hours. The shot involved 1475 Ci of RaLa with an explosive charge of 101 to 200 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>2/17/1961</td>
<td>RaLa shot # 247 took place at 1650 hours. The shot involved 7090 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/24/1961</td>
<td>On March 24, 1961 a contamination incident occurred during the disassembly of a drybox on a milling machine. The turntable was taken to the contaminated truck for wrapping. The turntable was opened to facilitate further wrapping and in doing so plutonium dust was released. A strong gust of wind blew spread contamination to the truck, the adjacent building, and surrounding ground. A large airborne count of alpha contamination was measured in Building 54 during the incident.</td>
<td>Air Release</td>
<td>19</td>
<td>85</td>
</tr>
<tr>
<td>3/24/1961</td>
<td>On March 24, 1961 a contamination incident occurred in Building 54 of DP Site, resulting in the spread of plutonium dust contamination. The incident occurred during the removal of a glove box from a milling machine.</td>
<td>Air Release</td>
<td>4059</td>
<td>15</td>
</tr>
<tr>
<td>5/19/1961</td>
<td>RaLa shot # 248 took place at 1314 hours. The shot involved 3902 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
<td>Incident Type</td>
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<tr>
<td>6/20/1961</td>
<td>RaLa shot # 249 took place at 2019 hours. The shot involved 5300 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>8/7/1961</td>
<td>On August 7, 1961 a container with a uranium fuel element leaked. Contamination products were detected in the parking lot and around the building. No decontamination was done.</td>
<td>Air Release</td>
<td>2524</td>
<td>4</td>
</tr>
<tr>
<td>9/28/1961</td>
<td>On September 28, 1961 a spill occurred in the liquid waste sampling room located in the northeast of Building 2, DP West. The drain line stopped up and contaminated liquid flowed down the storm drain. Workmen from Room 326 had walked through the area. Their homes and personal shoes were monitored and no contamination was detected.</td>
<td>Liquid Release</td>
<td>4059</td>
<td>10</td>
</tr>
<tr>
<td>10/11/1961</td>
<td>RaLa shot # 250 took place at 1302 hours. The shot involved 3870 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>11/17/1961</td>
<td>RaLa shot # 251 took place at 1430 hours. The shot involved 4150 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>11/28/1961</td>
<td>On November 28, 1961 a spill was discovered on the ground north of the pump house of Building 700. The spill was monitored and contamination was found.</td>
<td>Liquid Release</td>
<td>4059</td>
<td>4</td>
</tr>
<tr>
<td>12/10/1961</td>
<td>The GNOME nuclear test, the first test in the Plowshare Program, was conducted near near Carlsbad, NM. The device was placed at a depth of 1,185 ft in a shaft drilled in salt. The objectives of the 3 kiloton test were isotope recovery, neutron physics experimentation, examination of heat recovery, seismic measurements, and explosive development. The shot also had a Vela Uniform Program objective to determine how the seismic signals and effects of a 3-kiloton device detonated underground in salt beds differed from the outputs of detonations of different yields in other geologic formations such as tuff and granite and from signals caused by earthquakes. [Ref: <a href="http://www.nv.doe.gov/library/films/fulltext/0800034.htm">http://www.nv.doe.gov/library/films/fulltext/0800034.htm</a> and <a href="https://www.osti.gov/opennet/reports/plowshar.pdf">https://www.osti.gov/opennet/reports/plowshar.pdf</a>]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/30/1962</td>
<td>RaLa shot # 252 took place at 1908 hours. The shot involved 6077 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>2/2/1962</td>
<td>RaLa shot # 253 took place at 1341 hours. The shot involved 1590 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/6/1962</td>
<td>RaLa shot # 254 took place at 1330 hours. The shot involved 5940 Ci of RaLa with an explosive charge of 20 to 100 lbs. For this experiment, the configuration was such that the RaLa source remained intact. There was no dispersion of radioactive material.</td>
<td>RaLa Shot</td>
<td>2</td>
<td>all</td>
</tr>
<tr>
<td>3/9/1962</td>
<td>On March 9, 1962 .8 g of tritium were released into the atmosphere during an experiment at TA-41.</td>
<td>Air Release</td>
<td>4060</td>
<td>8</td>
</tr>
<tr>
<td>12/11/1962</td>
<td>On December 11, 1962 there was a criticality incident involving U-235 foils in graphite. The assembly went critical when it was ran due to inadequate communication between work crews. 3 x 10^{15} total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>2/27/1963</td>
<td>On February 27, 1963 approximately 48 millicuries if radioactive iodine was release out the stack of Cell 9, Wing 9, CMR Building.</td>
<td>Air Release</td>
<td>4061</td>
<td>18</td>
</tr>
<tr>
<td>4/8/1963</td>
<td>On April 8, 1963 there was a uranium spill at TA-46.</td>
<td>Contam. Event</td>
<td>2536</td>
<td>2</td>
</tr>
<tr>
<td>6/1/1963</td>
<td>A glovebox was torn in a drybox at DP West during a routine operation, releasing plutonium into air.</td>
<td>Fire</td>
<td>2538</td>
<td>3</td>
</tr>
<tr>
<td>6/1/1963</td>
<td>During maintenance, a spark from a welding operation started a fire in the filter of a plutonium drybox, releasing plutonium into air.</td>
<td>Fire</td>
<td>2538</td>
<td>3</td>
</tr>
<tr>
<td>6/6/1963</td>
<td>On June 6, 1963 a fire occurred in a drybox air intake filter in Room 213 of DP West. No contamination was detected in the vicinity of the drybox.</td>
<td>Fire</td>
<td>4061</td>
<td>16</td>
</tr>
<tr>
<td>7/31/1963</td>
<td>On July 31, 1963 an employee spilled some contaminated material from a U-235 rag incinerator onto the hood and floor of Room 313 DP West.</td>
<td>Contam. Event</td>
<td>4061</td>
<td>9</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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<td>Repos. No.</td>
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</tr>
<tr>
<td>11/26/1963</td>
<td>On November 26, 1963 a worker was found to have contamination on his clothing. His personal car and home were monitored and no contamination was found.</td>
<td>User Error</td>
<td>4061</td>
<td>2</td>
</tr>
<tr>
<td>1/10/1964</td>
<td>On January 10, 1964 in SM-66 depleted uranium residue ignited in a drum. The material was allowed to burn out.</td>
<td>Fire</td>
<td>2812</td>
<td>3</td>
</tr>
<tr>
<td>2/11/1964</td>
<td>Omega Site was contaminated when a sample reading 4.5 R/hr at 1 m was removed from OWR vertical port and dragged down the road (because of its weight) to the storage area.</td>
<td>Contam. Event</td>
<td>2812</td>
<td>3</td>
</tr>
<tr>
<td>4/12/1964</td>
<td>An explosion occurred in Room 313 rag incinerator drybox following ignition of a batch of U-235 contaminated rags on April 12, 1964. The fire spread from the drybox into the adjoining hood and ignited another batch of rags. The fire was quickly extinguished.</td>
<td>Explosion</td>
<td>11</td>
<td>297</td>
</tr>
<tr>
<td>4/22/1964</td>
<td>An explosion occurred following a fire in Room 313 DP West from uranium contaminated rags on April 22, 1964. The fire spread from the drybox to the adjoining hood.</td>
<td>Fire</td>
<td>2505</td>
<td>4</td>
</tr>
<tr>
<td>4/22/1964</td>
<td>On April 22, 1964 an explosion occurred in an incinerator drybox in Room 313 of DP West during the incineration of U-235 contaminated rags.</td>
<td>Explosion</td>
<td>4062</td>
<td>5</td>
</tr>
<tr>
<td>7/2/1964</td>
<td>Explosion attributed to accumulation of unburned gas in area of stagnant air movement in furnace upper passageways, damaged boiler furnace</td>
<td>Explosion</td>
<td>NA</td>
<td>78</td>
</tr>
<tr>
<td>7/31/1964</td>
<td>On July 31, 1964 high levels of contamination were detected in a hood after an accidental plutonium release. The hood was decontaminated, but the stack was likely contaminated.</td>
<td>Air Release</td>
<td>2507</td>
<td>4</td>
</tr>
<tr>
<td>10/3/1965</td>
<td>On October 3, 1965 there was a tritium release at P-9. Approximately 100 curies of tritium was released.</td>
<td>Air Release</td>
<td>4063</td>
<td>3</td>
</tr>
<tr>
<td>11/1/1964</td>
<td>On November 11, 1964 there was a fire in pit 3 of area G (Mesita del Buey). The cause of the fire is unknown.</td>
<td>Fire</td>
<td>4062</td>
<td>5</td>
</tr>
<tr>
<td>2/16/1965</td>
<td>On February 16, 1965 approximately two liters of tritium gas were released up the stack during an experiment.</td>
<td>Air Release</td>
<td>4063</td>
<td>12</td>
</tr>
<tr>
<td>2/17/1965</td>
<td>On February 17, 1965; 10 curies of tritium was released into Room 4130 during an experiment.</td>
<td>Air Release</td>
<td>2072</td>
<td>261</td>
</tr>
<tr>
<td>2/17/1965</td>
<td>An estimated 10 Ci of tritium were released on February 17, 1965 from the hood in Room 4130 of CMF-4.</td>
<td>Air Release</td>
<td>4063</td>
<td>12</td>
</tr>
<tr>
<td>4/14/1965</td>
<td>On April 14, 1965 in Building 35 sludge filtering room, approximately 25 gallons of contaminated sludge spilled when a pipefitter disconnected a flange in the sludge filtering tank. The area was quickly decontaminated.</td>
<td>Liquid Release</td>
<td>4063</td>
<td>12</td>
</tr>
<tr>
<td>5/28/1965</td>
<td>On May 28, 1965 at White Sands Missile Range there was a criticality incident involving 96 kg enriched U-Mo alloy, due to incorrect operation. The assembly bolts broke, and there was minor damage to coating. 1.5 x 10(^{17}) total fissions were involved.</td>
<td>Criticality</td>
<td>6206</td>
<td>all</td>
</tr>
<tr>
<td>6/1/1966</td>
<td>At DP East the gas purge line to a recovery furnace became plugged. The operator in charge removed a rubber hose connected to the unit, and uranium-containing dust was blown out into his face and onto his clothing.</td>
<td>User Error</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>12/1/1965</td>
<td>During the removal of a rod coated with Am-241 from an experimental apparatus, personal clothing of the operator was contaminated.</td>
<td>User Error</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>4/15/1966</td>
<td>On April 15 and 16, 1966 there was a &quot;large spill&quot; of tritium at P-9 due to a diaphragm failure.</td>
<td>Air Release</td>
<td>4064</td>
<td>6</td>
</tr>
<tr>
<td>5/11/1966</td>
<td>An explosion occurred in a rag incinerator glove box in the U-235 recovery area at DP West. The explosion cracked the window of the glove box.</td>
<td>Explosion</td>
<td>NA</td>
<td>4-5</td>
</tr>
<tr>
<td>6/9/1966</td>
<td>On June 9, 1966 there was a tritium spill at P-12.</td>
<td>Air Release</td>
<td>4064</td>
<td>6</td>
</tr>
<tr>
<td>11/16/1966</td>
<td>The air cleaner at one of the enriched uranium shops developed a pin-hole leak, which resulted in high surface contamination of the surrounding area.</td>
<td>Air Release</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>Date of Incident</td>
<td>Description</td>
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<tr>
<td>7/14/1967</td>
<td>A fire occurred on July 14, 1967 in Room 313 of DP West. Sparks from the incinerators escaped and ignited the pre-filter located in a well in the loading drybox floor. The flames swept up the exhaust line and ignited the HEPA filter in the drybox. The Building 3 roof was monitored and no contamination was detected.</td>
<td>Fire</td>
<td>4065</td>
<td>10</td>
</tr>
<tr>
<td>12/1/1967</td>
<td>An explosion occurred in the rag-incinerator drybox in Room 313 DP West on Dec. 1, 1967 during the incineration of U-238 contaminated rags.</td>
<td>Explosion</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>12/10/1967</td>
<td>The GASBUGGY nuclear test was conducted in the San Juan Basin, 55 miles east of Farmington, New Mexico. The device was placed at a depth of 4,240 ft in a shaft drilled in a gas-bearing sandstone formation. The objective of the test was to investigate the feasibility of using nuclear explosives to stimulate a low-permeability gas field. GNOME was the first Plowshare joint government-industry nuclear experiment to test an industrial application. [Ref: <a href="https://www.osti.gov/opennet/reports/plowshar.pdf">https://www.osti.gov/opennet/reports/plowshar.pdf</a>]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/1/1968</td>
<td>In early January 1968 members of group J-11 were working with Pb-210 at TA-48. During routine monitoring one employee's shoes were found to be contaminated. The homes of several employees were monitored and one was found to be contaminated. The home was decontaminated.</td>
<td>Contam. Event</td>
<td>4066</td>
<td>12</td>
</tr>
<tr>
<td>2/1/1968</td>
<td>Four days after a Pb-210 spill in February 1968, Pb-210 contamination was detected in the home of an employee, the area was decontaminated.</td>
<td>Contam. Event</td>
<td>817</td>
<td>13-14</td>
</tr>
<tr>
<td>2/7/1968</td>
<td>On February 7, 1968 approximately 100 cc of tritium gas was released in Room 4136 Wing 4 of CMR Building.</td>
<td>Air Release</td>
<td>4066</td>
<td>36</td>
</tr>
<tr>
<td>2/8/1968</td>
<td>100 cc of tritium gas may have been released from the exhaust system to the environment on February 8, 1968.</td>
<td>Air Release</td>
<td>1180</td>
<td>8</td>
</tr>
<tr>
<td>3/1/1968</td>
<td>An employee broke a charcoal trap which contained approximately 100 cc of tritium, which was released into the exhaust system In March of 1968.</td>
<td>Air Release</td>
<td>817</td>
<td>13</td>
</tr>
<tr>
<td>4/26/1968</td>
<td>At TA-48 some Pb-210 was spilled on the floor and tracked out of the laboratory. The spill was not detected until 4 days later when Pb-210 was detected during routine surveys. One home had spots reading up to 1500 cpm of alpha radiation on the rug. The rug in the home was removed.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>5</td>
</tr>
<tr>
<td>6/4/1968</td>
<td>The sidewalk, driveway, and rug in the home of an employee were contaminated with Pb 210 sometime around June 14, 1968.</td>
<td>Contam. Event</td>
<td>4066</td>
<td>10</td>
</tr>
<tr>
<td>9/17/1968</td>
<td>There was an air duct fire in Building 3 between the exhaust blower near Room 313 and the main stack at DP West on September 17, 1968. The fire was due to a welding operation.</td>
<td>Fire</td>
<td>817</td>
<td>2-3</td>
</tr>
<tr>
<td>9/17/1968</td>
<td>On September 17, 1968 there was a fire in Building 3 main exhaust duct of DP West. No contamination was detected on the roof or duct work.</td>
<td>Fire</td>
<td>4066</td>
<td>2</td>
</tr>
<tr>
<td>1/2/1969</td>
<td>On January 2, 1969 a contamination accident occurred in Room 606 DP West resulting in the release of plutonium dust.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>6-7</td>
</tr>
<tr>
<td>1/15/1969</td>
<td>A glovebox explosion occurred in the uranium recovery operation at DP West, during the incineration of U-235 metal turnings.</td>
<td>Explosion</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>1/15/1969</td>
<td>During the removal of Pu-239 contaminated waste materials from a glovebox line at DP West, the transfer bag ruptured.</td>
<td>Explosion</td>
<td>NA</td>
<td>3</td>
</tr>
<tr>
<td>2/27/1969</td>
<td>On February 27, 1969 a fire occurred in the #2 glovebox line in Room 500 DP West, resulting in the release of plutonium dust contamination.</td>
<td>Fire</td>
<td>NA</td>
<td>6-7</td>
</tr>
<tr>
<td>6/26/1969</td>
<td>On June 26, 1969 an explosion occurred in the rag incinerator box in Room 313 DP West during the burning of U-235 turnings. The explosion scattered contamination through out the room.</td>
<td>Explosion</td>
<td>NA</td>
<td>5</td>
</tr>
<tr>
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</tr>
<tr>
<td>8/21/1969</td>
<td>On August 21, 1969 approximately 5.73 liters of tritium gas was released into the atmosphere at TA-33.</td>
<td>Air Release</td>
<td>4067</td>
<td>4</td>
</tr>
<tr>
<td>10/1/1969</td>
<td>&quot;High levels&quot; of airborne plutonium were detected in the room when a CMF-5 employee dropped a plutonium containing sample.</td>
<td>User Error</td>
<td>4182</td>
<td>3,4</td>
</tr>
<tr>
<td>10/14/1969</td>
<td>On October 14, 1969 plutonium dust was released from a trash bag during the transfer from a glovebox in Room 308 DP West.</td>
<td>Air Release</td>
<td>4182</td>
<td>3</td>
</tr>
<tr>
<td>10/14/1969</td>
<td>On October 14, 1969 a contamination incident occurred in Room 308 DP West, resulting in the release of plutonium dust contamination. The incident occurred during the transfer of trash from a glove box in a plastic bag. The bag ruptured resulting in the contamination of the floor. A CMF-5 staff member accidentally dropped a container with plutonium inside. The lid of the container cam off resulting in a high level of airborne Pu contamination.</td>
<td>Air Release</td>
<td>NA</td>
<td>4-5</td>
</tr>
<tr>
<td>1/16/1970</td>
<td>On January 16, 1970 ZIA craftsmen pumped a caustic solution into the negative water pressure circulating tank in the Building 150 stairwell DP West. Highly contaminated foam escaped through a vent pipe, contaminating the tank, grill, west wall, and stairwell.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>7</td>
</tr>
<tr>
<td>6/10/1970</td>
<td>On June 10, 1970 a tri-state tractor trailer was found to be contaminated with Co60. The trailer was decontaminated, but the source of the contamination is a mystery.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>7/1/1970</td>
<td>A minor fire occurred in the hood of a rag incinerator in Building 3 of TA-21 which was associated with recovery of U-235 oxide.</td>
<td>Fire</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>7/1/1970</td>
<td>On May 1, 1970 a ruptured exhaust filter allowed for an increase in air activity. The filter was replaced and no background contamination was found outside of SM-35.</td>
<td>Air Release</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>9/17/1970</td>
<td>On September 17, 1970 a fire started in a dust collection jar of a vacuum in Room 104 of TA-3-35. The fire started as a result of a spark during the cutting of U-235 fuel elements.</td>
<td>Fire</td>
<td>NA</td>
<td>9</td>
</tr>
<tr>
<td>10/7/1970</td>
<td>On October 7, 1970 a capillary tube containing $^{238}$PuO$_2$ broke in an open-faced hood in Room 605a of Building 150 of DP West. The hood exhausted directly to the roof without filtration. The room under the stack was contaminated in an area of approximately 100 square feet. Areas of contamination were found on the roof of the office trailer parked northwest of Building 150. No other contamination was found. The areas were decontaminated.</td>
<td>Air Release</td>
<td>4068</td>
<td>6</td>
</tr>
<tr>
<td>10/7/1970</td>
<td>A sample of radioactive tritiated salt was lost at Los Alamos Scientific Laboratory. The sample was reported missing 9-29-70 after routine inventory. An exhaustive search failed to turn up the missing sample.</td>
<td>User Error</td>
<td>NA</td>
<td>120</td>
</tr>
<tr>
<td>3/29/1971</td>
<td>On March 29, 1971 a worker was emptying a dempster dumpster in pit 6, area G, TA 54 when a strong gust of wind blew contamination onto the truck and the container.</td>
<td>Air Release</td>
<td>3972</td>
<td>106</td>
</tr>
<tr>
<td>3/29/1971</td>
<td>On March 29, 1971 Pu238 became airborne during the unloading of a dumpster containing radioactive waste at the disposal pit. The truck carrying the waste was contaminated and the contamination did not escape the disposal pit.</td>
<td>Air Release</td>
<td>4705</td>
<td>4</td>
</tr>
<tr>
<td>3/29/1971</td>
<td>On March 29, 1971 during the emptying of a dumpster of radioactive waste at TA-54 Pu-238 became airborne and contaminated the truck carrying the dumpster. The decontamination did not escape the disposal pit.</td>
<td>Air Release</td>
<td>NA</td>
<td>5</td>
</tr>
<tr>
<td>7/31/1971</td>
<td>On July 31, 1971 Pu 238 was released during the disassembly of a transit heat source containing 26,092 Ci of plutonium. Some contamination was released into Wing 9 of CMR Building. 55 microcuries escaped the building over a period of 16.5 hours.</td>
<td>Air Release</td>
<td>3972</td>
<td>5</td>
</tr>
<tr>
<td>7/31/1971</td>
<td>On July 31, 1971 employees were working with a capsule containing Pu-238 in Room 9130, Wing 9, CMR Building. Contamination was released into the room and the workers were contaminated.</td>
<td>Contam. Event</td>
<td>5442</td>
<td>1</td>
</tr>
<tr>
<td>10/7/1971</td>
<td>On October 7, 1971 a release of Pu-238 oxide occurred in 605 DP West contaminating 200 sq ft of the building, the roof and the surrounding ground.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>10/15/1971</td>
<td>There was a fire in exhaust filter SM-102 on October 15, 1971.</td>
<td>Fire</td>
<td>1417</td>
<td>3</td>
</tr>
<tr>
<td>11/2/1971</td>
<td>On November 2, 1971 an explosion in test cell furnace blew uranium contamination onto floor.</td>
<td>Explosion</td>
<td>1417</td>
<td>3</td>
</tr>
<tr>
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<tr>
<td>12/17/1971</td>
<td>On December 17, 1971 high Pu-238 air counts were detected due to contamination from an exploding bottle.</td>
<td>Explosion</td>
<td>1417</td>
<td>3</td>
</tr>
<tr>
<td>8/1/1973</td>
<td>XO-2 cooling loop leaks at TA-53 allowed 1.5 Ci of tritium to be transferred along with 25,000 L of waste water from the waste tanks in the experimental area to the sewage lagoons at TA-53 between July 1, 1978 and September 30, 1978.</td>
<td>Air Release</td>
<td>NA</td>
<td>32</td>
</tr>
<tr>
<td>7/9/1974</td>
<td>On July 9, 1974 it was discovered that a pipe conveying radioactive wastes to TA-50 was leaking north of Pajarito road east of TA-3-184. The section of pipe was repaired.</td>
<td>Liquid Release</td>
<td>515</td>
<td>6</td>
</tr>
<tr>
<td>8/14/1975</td>
<td>On Aug. 14 approximately 10 gallons of reactor water went down the drain to the dry creek bed.</td>
<td>Liquid Release</td>
<td>392a</td>
<td>16</td>
</tr>
<tr>
<td>8/27/1975</td>
<td>On Aug. 27, 1975 approximately 960 gallons of regenerate material spilled out of a sludge holding tank contaminating Room 60A, TA-50. Approximately 500-700 gallons was lost outside. The solution contained Cs, Pu, St, Am. The spill area was roped off, covered with wet sand to minimize airborne contamination, and cleaned.</td>
<td>Liquid Release</td>
<td>392a</td>
<td>15</td>
</tr>
<tr>
<td>1/1/1976</td>
<td>In 1976 approximately 3271 Ci of tritium was release into the environment (this does not include 22,000 Ci released from TA-3-34 on July 15, 1976).</td>
<td>Air Release</td>
<td>NA</td>
<td>13</td>
</tr>
<tr>
<td>7/15/1976</td>
<td>On July 15, 1976 there was a tritium release from TA-3-34 of 22,000 Ci.</td>
<td>Air Release</td>
<td>NA</td>
<td>15</td>
</tr>
<tr>
<td>1/1/1977</td>
<td>In 1977 approximately 6417 Ci of tritium was released into the environment (this does not include 30,800 Ci released from TA-33-36 on October 6, 1977).</td>
<td>Air Release</td>
<td>NA</td>
<td>13</td>
</tr>
<tr>
<td>10/6/1977</td>
<td>On October 6, 1977, 3.08 x 10¹⁰ μCi of tritium gas was released from Room 9 TA-33-86 due to a loose high pressure fitting. Averaged over 24 hours the stack concentration was 0.104 uCi/ml.</td>
<td>Air Release</td>
<td>1232</td>
<td>5</td>
</tr>
<tr>
<td>10/6/1977</td>
<td>On October 6, 1977 there was a tritium release from TA-33-86 of 33,217 Ci.</td>
<td>Air Release</td>
<td>NA</td>
<td>18</td>
</tr>
<tr>
<td>10/6/1977</td>
<td>On October 6, 1977 there was a tritium release of 30,800 Ci from TA-33-86.</td>
<td>Air Release</td>
<td>NA</td>
<td>15</td>
</tr>
<tr>
<td>8/22/1978</td>
<td>On August 22, 1978 SM-102 a drum of depleted U-238 chips ignited while being moved to the outside.</td>
<td>Fire</td>
<td>NA</td>
<td>18</td>
</tr>
<tr>
<td>10/30/1978</td>
<td>It was discovered on October 30, 1978 that a large amount of tritium was released when a glass ballast valve was left open.</td>
<td>Air Release</td>
<td>3462</td>
<td>3</td>
</tr>
<tr>
<td>12/1/1978</td>
<td>An LASL employee contaminated the sleeve of his shirt, which was not detected until the employee returned to work following day. No contamination was detected at his home or in his automobile.</td>
<td>User Error</td>
<td>NA</td>
<td>10</td>
</tr>
<tr>
<td>5/4/1979</td>
<td>On May 4, 1979 approximately 3000 Ci of tritium was released from SM-34.</td>
<td>Air Release</td>
<td>3462</td>
<td>102</td>
</tr>
<tr>
<td>5/4/1979</td>
<td>A stainless steel pot containing uranium tritide was overheated in a laboratory at the Cryogenics Building and ruptured on May 4, 1979. tritiated water escaped into the laboratory because of inadequate air flow in the hood. Some tritium was released to the atmosphere.</td>
<td>Liquid Release</td>
<td>4484</td>
<td>1-2</td>
</tr>
<tr>
<td>5/4/1979</td>
<td>On May 4, 1979 there was a tritium release of ~3,000 Ci from TA-3-34.</td>
<td>Air Release</td>
<td>NA</td>
<td>18</td>
</tr>
<tr>
<td>5/7/1979</td>
<td>Tritium exposure incident at SM-34 on May 4, 1979.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>5/18/1979</td>
<td>On May 18, 1979 during the transfer of 1500 gallons of contaminated water from the north holding tank to LAMPF Site sewage lagoons. The area A parking lot and area A shop floor were flooded, procedures to prevent the spread of contamination were used and the areas were quickly decontaminated.</td>
<td>Liquid Release</td>
<td>4154</td>
<td>91</td>
</tr>
<tr>
<td>5/25/1979</td>
<td>On May 25, 1979 approximately 3000 Ci of tritium were released from SM-34.</td>
<td>Air Release</td>
<td>4154</td>
<td>94</td>
</tr>
<tr>
<td>8/22/1979</td>
<td>On August 22, 1979 approximately 200 grams of UF6 was released at Building 23 TA-18 Pajarito Site. Approximately 0.0038 grams was released into the environment. The majority of the ~200 grams (~180 grams) was caught in the HEPA filter.</td>
<td>Air Release</td>
<td>4154</td>
<td>20</td>
</tr>
<tr>
<td>9/17/1979</td>
<td>A dempster dumpster fire occurred at TA-33-86 on September 17, 1979. The only radioactive isotope believed to be present at the time of the fire was tritium.</td>
<td>Fire</td>
<td>4154</td>
<td>6</td>
</tr>
<tr>
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<tr>
<td>12/12/1979</td>
<td>On December 12, 1979 150 to 200 gallons of slightly radioactive primary reactor system water was released at TA-2 inside Building 44. Approximately 50 gallons drained to a nearby creek via a floor drain in Building 44.</td>
<td>Liquid Release</td>
<td>4154</td>
<td>1</td>
</tr>
<tr>
<td>11/1/1980</td>
<td>In November 1980 there was a release of 16 curies of tritium gas and a total of 10 minor radiation releases of plutonium in labs reported internally.</td>
<td>Air Release</td>
<td>933</td>
<td>19</td>
</tr>
<tr>
<td>2/1/1981</td>
<td>In February 1981 a total of 11 minor radiation accidents were reported internally.</td>
<td>Contam. Event</td>
<td>936</td>
<td>17</td>
</tr>
<tr>
<td>3/19/1981</td>
<td>On March 19, 1981 liquid from an industrial waste line serving TA-48 was inadvertently pumped into Mortandad canyon.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>128-129</td>
</tr>
<tr>
<td>3/24/1981</td>
<td>On March 24, 1981 several curies of gaseous tritium were released from the Van de Graaff Building at TA-3.</td>
<td>Air Release</td>
<td>NA</td>
<td>128-129</td>
</tr>
<tr>
<td>10/14/1981</td>
<td>On October 14, 1981 ten samples contaminated with PuO2 were opened in a laboratory where Pu is not normally handled. Contamination was spread into several laboratories, a small shop, the analyst and several other workers before it was detected. One vehicle and two homes were contaminated with a small amount of material. All employees and contaminated areas were readily decontaminated.</td>
<td>Contam. Event</td>
<td>2057</td>
<td>8</td>
</tr>
<tr>
<td>11/1/1981</td>
<td>In November 1981 ten minor radiation releases were documented and investigated internally at LANL.</td>
<td>Contam. Event</td>
<td>935</td>
<td>20</td>
</tr>
<tr>
<td>3/19/1982</td>
<td>On March 19, 1982 a section of the industrial waste line carrying fission products from hot cells serving TA-48 had been found leaking. A limited area of soil was contaminated within Laboratory boundaries. The affected soil from the areas along both sides of the road behind TA-48 were removed (down to bedrock) up to the edge of Mortandad Canyon, and replaced with clean soil.</td>
<td>Liquid Release</td>
<td>4412</td>
<td>1</td>
</tr>
<tr>
<td>8/10/1982</td>
<td>On August 10, 1982 a furnace at TA-55 ignited and over pressurized a glovebox. Two glovebox windows ruptured releasing alpha contamination into the room and adjacent corridor.</td>
<td>Air Release</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>11/2/1982</td>
<td>On November 2, 1982 approximately 50-100 liters of waste liquid escaped from a tank vent at TA-21-257 contaminating the building roof, walls, and surrounding area with low levels of plutonium, Americium, and uranium.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>1/10/1983</td>
<td>An accidental release of chromium oxychloride occurred at the Van de Graaff facility on January 10, 1983. The accident occurred when an employee removed a valve from one end of a pipe which allowed for the liquid stored in the pipe to spill on the floor.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>6/1/1983</td>
<td>On June 1, 1983 high airborne plutonium levels were detected in Room 429 at TA-55 Building PF-4. The high levels were caused by a leak in the dry vacuum line to a glovebox.</td>
<td>Air Release</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>6/1/1983</td>
<td>Radiation material was discovered in the salvage yard and reported during the report period.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>8/25/1983</td>
<td>On August 25, 1983 a puff release of 104 Ci of tritium occurred at TA-33. This was followed by a slow release of an additional 45 Ci in the subsequent 24 hour period.</td>
<td>Air Release</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>11/28/1983</td>
<td>On November 28, 1983 a fire occurred in the well house at Pajarito water supply well no. 2. Two large PCB capacitors were involved in the fire emitting PCB when the heat caused them to rupture releasing their contents. Air and ash samples confirmed significant PCB contamination inside the building.</td>
<td>Fire</td>
<td>NA</td>
<td>3-4</td>
</tr>
<tr>
<td>12/6/1983</td>
<td>On December 6, 1983 two plutonium containing shipping containers were inadvertently opened, contaminating the clothing and skin of eight workers.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>3-4</td>
</tr>
<tr>
<td>2/17/1984</td>
<td>Fire at TA-50 Building 1 in a ventilation exhaust plenum on February 17, 1984, filter bags were ignited.</td>
<td>Fire</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>4/10/1984</td>
<td>Hydrogen fluoride release on April 10, 1984 from Room 5096 at TA-3-29 through a hole in an exhaust flex hose of the gas centrifuge.</td>
<td>Air Release</td>
<td>NA</td>
<td>4-5</td>
</tr>
<tr>
<td>7/1/1984</td>
<td>There was a fire at the lithium hydride shop TA-3, SM-39 on June 6, 1984. Lithium hydride dust ignited in a section of exhaust duct.</td>
<td>Fire</td>
<td>NA</td>
<td>4-5</td>
</tr>
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</tr>
<tr>
<td>7/26/1984</td>
<td>Equipment failure to contain plutonium solution resulting in significant area contamination and high nose swipes for three employees on July 26, 1984 at TA-55-4-401.</td>
<td>Equipment Malfunction</td>
<td>NA</td>
<td>2-3</td>
</tr>
<tr>
<td>10/19/1984</td>
<td>Inadequate procedures when handling packaged Pu-238 resulted in widespread area contamination and contamination of personal clothing of two employees on October 19, 1984 at TA-54.</td>
<td>Contam. Event</td>
<td>NA</td>
<td>2-3</td>
</tr>
<tr>
<td>1/1/1985</td>
<td>On January 1, 1985 a failure to comply with established procedures resulted in a release of radioactive materials along a public roadway (report no. LAMPF-85-1).</td>
<td>Contam. Event</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>6/1/1985</td>
<td>60 gallons of tri-methyl benzene were spilled in the neutrino area at the L.A. Meson Physics Facility, no serious injuries resulted form this accident.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>6/12/1985</td>
<td>On June 12, 1985 the improper transfer of radioactive material resulted in an employee's home being contaminated (Report no. AHP-85-8).</td>
<td>Contam. Event</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>7/1/1985</td>
<td>On July 1, 1985 activated cooling water was discharged outside facility (Report no. LAMPF-85-5).</td>
<td>Liquid Release</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>9/12/1985</td>
<td>On September 12, 1985 there was a fire in a glove box at TA-55-4-429 which resulted in high airborne activity and area contamination (Report no. CHEM-HP-85-20).</td>
<td>Fire</td>
<td>NA</td>
<td>6</td>
</tr>
<tr>
<td>2/2/1986</td>
<td>On February 2, 1986 there was an unexpected release of tritium oxide at TA-41-4-236A.</td>
<td>Air Release</td>
<td>NA</td>
<td>11</td>
</tr>
<tr>
<td>10/30/1986</td>
<td>On October 30-31, 1986 an estimated 633 Ci of tritium were released at TA-33, mostly in the form of tritiated water.</td>
<td>Air Release</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>11/14/1986</td>
<td>On November 14, 1986 11.5 Ci of tritium was released from TA-33 in the form of elemental tritium.</td>
<td>Air Release</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>11/1/1987</td>
<td>Low level liquid waste from TA-55 showed higher than normal levels of plutonium in Nov. and Dec. There was a pinhole leak in a stream coil in a cascade dissolver process at TA-55.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>4</td>
</tr>
<tr>
<td>2/22/1988</td>
<td>On Feb 22, approximately 5800 Ci of tritium were released from TA-33.</td>
<td>Air Release</td>
<td>1246</td>
<td>8</td>
</tr>
<tr>
<td>2/27/1990</td>
<td>On February 27, 1990 cooling water overflowed in the exhaust system of TA-55-4.</td>
<td>Liquid Release</td>
<td>NA</td>
<td>8</td>
</tr>
<tr>
<td>3/1/2000</td>
<td>An incident occurred in March 2000 when eight workers at TA-55 were exposed to airborne plutonium.</td>
<td>Air Release</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>3/1/2000</td>
<td>An incident occurred in 1998 when a worker at TA-55 was exposed to airborne plutonium.</td>
<td>Air Release</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>5/4/2000</td>
<td>On May 4, 2000 a wild fire was ignited which ultimately burned nearly 50,000 acres in and around Los Alamos New Mexico.</td>
<td>Fire</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>7/27/2005</td>
<td>A small amount of americium-241 was found to have contaminated a package that was shipped from Los Alamos to Pennsylvania. The contamination was spread to homes in Colorado, Kansas, and New Mexico.</td>
<td>Contam. Event</td>
<td>6204</td>
<td>all</td>
</tr>
</tbody>
</table>
Chapter 17: Prioritization of Radionuclide Releases

The LAHDA team identified the following steps to be completed to prioritize radionuclide releases:

1) Review the history of operations at Los Alamos,
2) Find relevant data concerning air and liquid releases,
3) Correct or adjust older data with appropriate factors based on current state-of-the-art methods,
4) Fill in gaps in data with justifiable methods for estimation of air and liquid releases, and
5) Prepare a prioritized list of radionuclides for both operational and episodic releases.

The prioritization of historical releases focused on providing a relative ranking of radionuclide releases that may have impacted public health and to limit attention to radionuclides that did not impact human health. Prioritization to date has been accomplished using a method based on the volume of air or water required to dilute the radionuclide in question down to maximum effluent concentrations for public areas—this is defined to be “Priority Index”. This simple method does not require the definition of a specific “receptor” nor does it require use of an exposure pathway model. For certain historical releases, namely airborne plutonium from DP West Site, it was determined that more developed evaluation based on the screening methods of National Council on Radiation Protection and Measurements (NCRP) Report No. 123 should be used (NCRP 1996). That screening evaluation is described in Chapter 18.

Priority Indices were calculated based on estimated quantities released and maximum effluent concentrations documented in Title 10 of the Code of Federal regulations, Part 20 (USNRC 2003). They are intended to be guidelines to determine the relative rank of a release in comparison with others. The prioritization methods described herein require that some estimates of quantities of each radionuclide or radionuclide class released to the environment be available. In some cases, these data are not available for all facilities or for all years of operations at Los Alamos.

The prioritization of releases from LANL has been problematic. During the Manhattan Project era and continuing well into the post-1946 AEC era, LASL did not measure many of their release points and did not systematically archive and compile effluent data. No effort has been made to characterize the magnitude of the releases from non-point source emissions that have been shown to be particularly important at other DOE sites such as Rocky Flats. Unlike most DOE sites, LANL’s compilations contain well-documented effluent data for only the post Clean Air Act (post-1969) era. Only summary-level information for certain facilities is given in LANL’s compilations prior to this period. In addition, potentially important release sources such as D Building (Fig. 17-1), which housed processing of plutonium during World War II and remained active until around 1953, were not subjected to stack sampling programs and have no effluent data available.
Unlike any other AEC/DOE site studied thus far with regard to historical releases, there was nothing approaching a comprehensive compilation of releases available at LANL to establish a simple, initial prioritization. The best available compilation was one assembled in the early 1970s to support preparation of the first site-wide final environmental impact statement (FEIS) that LANL published in response to the requirements of the Clean Air Act (USDOE 1979). The LAHDRA team has found that compilation to have numerous errors and omissions. Despite these errors and omissions, the preliminary prioritization used data assembled for that report as well as other information, such as estimates of the quantities of uranium expended in explosive test shots, to augment the LANL compilation.

Prioritization of Airborne Radionuclide Releases

LANL operations started in 1943 and have continued to the present. In the early years, radiation science, environmental science, and occupational health were all disciplines that were in their infancy. As time progressed, LANL has, by their own volition and by pressure from the public and government, increased monitoring, documentation, and reporting.

Data Sources

There are six main data sources for the airborne radionuclide effluent information at LANL:

- (Andrews ca. 1973) – “Joe Graf Binders” 1 and 2– Two binders of documents assembled by LANL Environment, Safety, and Health (ES&H) staff for group leader Joe Graf in the early 1970s that document releases from LANL before 1973. This was done to support development of a draft
site-wide Final Environmental Impact Statement (FEIS). The FEIS was finally published in 1979. The documents assembled in these binders include records of room air concentrations, stack monitoring data, ES&H reports, and miscellaneous memos.

• (Miller 2001) - Scott Miller, also an ES&H group member, compiled stack release data from 1973 to 1990. These data were assembled in a three-ring binder that was shared with the LAHDRA team and entered into the LAHDRA project information database. A Microsoft Excel® spreadsheet file containing the associated data was also provided to the project team.

• (Dummer et al. 1996) – A detailed study of all the RaLa shots conducted in Bayo Canyon at Los Alamos and the quantities of RaLa involved in those explosives tests from 1944 to 1962.

• (Drake and Eyster 1971) – A memo that details estimated quantities of uranium that were expended in explosive testing at LANL from 1944 to 1970.

• (Jordan and Black 1958) – An article in the American Industrial Hygiene Association Journal that speaks of airborne radioactive effluents from LANL. This work is one of the most important early studies on releases. LANL has considered the Jordan and Black publication to be the best-available scientific data identified on possible early emissions. As discussed later in this chapter, the LAHDRA project team disagrees with that assessment.

• (Hyatt 1956) – A 1956 memorandum prepared by an alternate group leader of the LASL industrial hygiene group that documents results of a 1955-1956 study that yielded corrected plutonium release estimates for DP West Building 12 stacks on a monthly basis for 1948 through 1955.

Summary of Results for Prioritization of Airborne Radionuclide Releases

During the period of LANL’s existence, many operations involving radionuclides have been performed, and effluents containing various radioactive constituents have been released. This section outlines the calculation of priority indices for six airborne radionuclide sets (plutonium, uranium, tritium, Radioactive Lanthanum (RaLa), Mixed Fission Products (MFP), and Mixed Activation Products (MAP)) for off-site airborne releases from LANL.

A Priority Index (PI) (in units of liters, L) for airborne radionuclide releases is calculated by computing the air volume required to dilute the annual activity released to be equal to the worst-case maximum effluent concentration per 10 CFR 20 (USNRC 2003). This priority index is intended to be a guideline to determine if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other nuclides (O'Brien J. and Burmeister R. 2004). For example, a PI of $10^6$ L indicates that $10^6$ (or one million) liters of air would be required to dilute the released material to a
concentration equal to the maximum effluent concentration. The priority index does not consider environmental transport and dilution. Although the lowest available (most conservative) maximum effluent concentration is used, the priority index does not otherwise address uptake factors. It does not consider decay in transport, which means the priority index would tend to overstate the importance of short-lived materials. Within these limitations, it provides a simple tool for establishing the relative importance of various airborne releases.

For the years 1944 to the present, LANL summary data were reviewed to collect available information for air releases and inventories used in explosions. This effort did not include an independent source term reconstruction; rather it relied on LANL compilations of releases with some adjustments by the LAHDRA team. Not all the data compiled herein are measurements of stack releases. A Microsoft Access® Off-Site Releases (OSR) Database was created to tabulate the available information and to link it to existing LANL documents that have been located and assembled by the LAHDRA project team. In most cases, these documents are available as image files in Adobe Acrobat® Portable Document Format (PDF) files that are linked to records containing bibliographic information the LAHDRA DocSleuth database.

**Radionuclide “Sets” and “Collections”**

The summary data for airborne radionuclide prioritization is grouped by radionuclide “collections” or “nuclide sets” because of the conventions used by LANL staff in quantifying and reporting concentrations and releases. These “sets” are as follows: plutonium, uranium, tritium, Radioactive Lanthanum (RaLa), Mixed Fission Products (MFP), and Mixed Activation Products (MAP). Certain collections of nuclides are grouped in LANL documents. For instance, in many cases, effluent data reports have the radionuclides $^{239}\text{Pu}$, $^{238}\text{Pu}$ and $^{235}\text{U}$ associated. In some cases no mention of the analysis type is made, and so the analysis result can be attributed to several nuclides. In these cases, the nuclide collection would have all of these radionuclides listed in it as a string. During the analysis, when separating the nuclides, “nuclide sets” were created that are simply the nuclide collection values that will be attributed to a nuclide such as plutonium. Plutonium has the lowest value for maximum effluent concentration, so if a nuclide collection contained both plutonium and uranium, then the value was counted for plutonium. This method was used to prevent both “double counting” the release and to assign the larger value to plutonium. This practice may overstate the importance of plutonium, particularly after the late 1970s. When the “nuclide set” was created for uranium, only those entries that did not contain plutonium isotopes were included.

**Effluent Data for Plutonium:** Plutonium data were obtained for calendar years from 1948 through 1996. Release estimates are not available for D Building. D Building started operation in late 1943/early 1944,
and continued to be used until around 1953. It is important to note that no airborne effluent data were included in LANL compilations for the years 1944 through 1947. In addition, the releases from DP Site reported by LANL for 1948, 1949, and 1950 are apparently based on simple estimates first made by Jordan and Black using methods that are not well documented (Jordan and Black 1958).

Airborne plutonium releases were prioritized based on values compiled for the 1979 FEIS and also documented in a 1975 publication (Maraman et al. 1975). Values for 1948–1955 were adjusted upward by the LAHDRA team (by roughly a factor of 20) to agree with results of a study conducted by the LANL industrial hygiene group in 1955 and 1956 and reported by Edwin C. Hyatt in 1956 (Hyatt 1956). In that study, stack concentrations were measured with improved, isokinetic stack sampling systems that were operated alongside the original systems (Hyatt 1955). After six months of sampling, results were compared and correction factors were determined and applied to releases previously reported for 1948-1955. Past that point, the improved sampling system was used.

All values from 1948 through 1975 were adjusted upward further by the LAHDRA team using a sample line loss correction factor equal to 5 for 1945-1958 and 2 for 1959-1975 based on analyses performed by LANL staff (Fuehne 2008). The reduction of the line loss correction factor starting with 1959 is in consideration of the fact that a single stage of high efficiency particulate air (HEPA) filters was added to the combined process exhaust system at DP West in 1959 (Maraman et al. 1975), and the particle size distribution in that exhaust stream likely shifted toward smaller particles. A filter burial correction factor of 2.33 was also applied to plutonium release totals reported by LANL for 1948 through 1975 based on assessments performed by LANL staff (Fuehne 2008). These line loss and filter burial corrections might also be appropriate for years following 1975, but have not been applied in this calculation. No documentation has been found identifying when LANL first applied these correction factors, but routine application is evident by the 1980s.

The maximum effluent concentration used for calculation of priority indices for plutonium releases was 2.0×10⁻¹⁴ μCi mL⁻¹ from 10CFR20 Appendix B, Table 2. Table 17-1 presents the estimated annual release totals (μCi) and priority indices (dilution volume, L) for plutonium. The priority indices for plutonium over the years of LANL operations range in magnitude from 10¹¹ to 10¹⁸.

**Uranium Effluent Data:** The uranium data found range from 1949 to 1996. Some of these data are uranium inventory data from uses in experiments involving explosive testing and some data are from stack monitoring. In the case where a nuclide collection contained both plutonium and uranium, it was counted in the plutonium data. The uranium data are for nuclide collections that contain only uranium. For the explosion data, the mass was multiplied times a specific activity for the nuclide group (for
example, depleted uranium or natural uranium). Uranium data from stack sampling also had the sample line loss and filter burial correction factors applied to all data prior to 1976, in the same manner as described for plutonium releases (Fuehne 2008).

Atmospheric Release Fractions (ARF) and Respirable Factions (RF) (USDOE 1994) were multiplied to get a range of Overall Release Fractions (ORF). The ORF-corrected values represent the amount of the radionuclide that got into the air and contains respirable-size particles. The geometric mean of the ORF, estimated as the square root of the range of values, is 0.001. This value was applied to the entire uranium inventory documented as expended in explosive tests.

The maximum effluent concentration used for calculation of priority indices for uranium releases was \(6.0 \times 10^{-14} \text{ µCi mL}^{-1}\) for \(^{235}\text{U}\) from 10CFR20 Appendix B, Table 2. Table 17-2 presents estimates of annual release quantities and priority indices for uranium. The overall range for the priority indices was from approximately \(10^{11}\) to approximately \(10^{17}\). In general, in the post-1973 era, the uranium priority indices appear to indicate greater significance than plutonium. In the pre-1973 era, plutonium was of greater significance. It is noteworthy that the years 1967, 1968, and 1969 have very high uranium release values. These values are directly from the LANL documents (see Fig. 17-2 below). During the LAHDRA project it was not possible to confirm if these values were actually quantities released, or whether they might represent quantities expended in explosive testing. It is possible that quantities expended were documented without consideration of fractions that were aerosolized.

<table>
<thead>
<tr>
<th>TA-15 (R-Site)</th>
<th>1967</th>
<th>Normal Uranium</th>
<th>1.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA-15 (R-Site)</td>
<td>1967</td>
<td>Tritium</td>
<td>3.59 \times 10^3</td>
</tr>
<tr>
<td>TA-15 (R-Site)</td>
<td>1968</td>
<td>Normal Uranium</td>
<td>0.75</td>
</tr>
<tr>
<td>TA-15 (R-Site)</td>
<td>1968</td>
<td>Tritium</td>
<td>4.50 \times 10^3</td>
</tr>
<tr>
<td>TA-15 (R-Site)</td>
<td>1969</td>
<td>Normal Uranium</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Fig. 17-2. Unusually high uranium values (in curies) documented by LASL (Andrews ca. 1973)

Tritium: Effluent data obtained for tritium range from 1967 to 1996, even though tritium was used at Los Alamos as far back as 1945 or possibly 1944. No correction factors were applied to tritium data. The maximum effluent concentration used for calculation of priority indices for tritium releases was \(1.0 \times 10^{-7} \text{ µCi mL}^{-1}\) from 10CFR20 Appendix B, Table 2. Table 17-3 presents estimated annual release quantities and priority indices for tritium. The priority indices for tritium range from \(10^{12}\) to \(10^{14}\). In the post-1973 era, tritium appears to have been more significant than uranium or plutonium, but less significant than MAP.
Tritium has a relatively short half-life (approximately 12.3 y compared to plutonium and uranium at thousands of years) and it is readily incorporated into compounds. More data are required for pre-1967 tritium releases at LANL. LAHDRA staff have found and added to the project information database additional documents containing tritium release data associated with episodic releases before and after 1967, but these data are scattered across many documents and have not yet been compiled or used to bound releases before 1967.

**Radioactive Lanthanum (RaLa):** The RaLa testing program at Los Alamos was the subject of a dose reconstruction by LANL personnel, including a source term evaluation (Dummer et al. 1996). All of the RaLa release data obtained by the LAHDRA team are from explosive tests from 1944 to 1962, with no shots conducted during 1951. No correction factors were applied to the activity data by the LAHDRA team. Since it was desired to estimate the actual RaLa releases to air, the same ORF used for uranium (0.001) was applied to RaLa source strength data for each shot.

The maximum effluent concentration used for calculation of priority indices for RaLa releases was $2.0 \times 10^{-9}$ µCi mL$^{-1}$ for $^{140}$La from 10CFR20 Appendix B, Table 2. Table 17-4 presents annual estimates of quantities released and priority indices for the RaLa tests. The priority indices ranged from $10^{11}$ to $10^{13}$. While a detailed evaluation of LANL’s dose assessment for RaLa releases has not been performed, it appears from this preliminary assessment that RaLa does not warrant high priority in assessments of airborne radionuclide releases.

**Mixed Fission Products (MFP):** MFP data reported by LANL begin in 1961 and continue through 1996. Their variability is quite high. The reasons for this variability and the lack of data prior to 1961 have not yet been explored. It is believed that the main source of MFP radionuclides was the Omega reactor. For some years— for example 1969, 1972, 1973, and 1994— the reported MFP activity released was much higher than in other years. The reasons for these elevated values have not yet been explored.

The maximum effluent concentration used for MFP was $1.0 \times 10^{-7}$ from Footnote 2 to the radionuclide tables in Appendix B to 10CFR20. Table 17-5 presents estimated annual release quantities and priority indices for MFP releases. The priority indices for MFP are not high in relative terms; they range in magnitude from $10^6$ to $10^{12}$. If the correction for decay during environmental transport were applied, they would be even lower, since MFP radionuclides in general have short half-lives.

**Mixed Activation Products (MAP):** MAP make up the largest portion of the airborne radioactive releases after 1973. Reactors and large accelerators are the main producers of MAP radionuclides. At Los Alamos, this would mean the majority of the MAP would come from TA-53 and the Los Alamos Meson Physics Facility (LAMPF), now called the Los Alamos Neutron Science Center (LANSCE). Although
LAMPF started operations in 1971, no pre-1976 effluent data were found for MAP. Based on the conventions used by LANL to report activation product releases, the nuclides included in the MAP “nuclide set” were as follows:

- “MAP”,
- Gaseous Mixed Activation Products (“G/MAP”),
- Particulate Various Activation Products (“P/VAP”), and
- Air activation products C-11, N-13, O-15, and Ar-41.

These are all short-lived MAP radionuclides that accelerator Health Physicists traditionally consider to be “MAP.” However, this facility also releases activation products that are longer-lived particulates. These particulate releases are traditionally not considered “MAP”. Short-lived MAP is measured via an in-stack ion chamber, whereas the particulates are long-lived and measured by counting of in-stack filters in a laboratory.

The maximum effluent concentration used for prioritization of MAP releases was a value of $2.0 \times 10^{-7}$ µCi mL$^{-1}$ published by the International Atomic Energy Agency (IAEA 1979). Table 17-6 presents estimates of annual release quantities and priority indices for MAP releases. Priority indices varied in magnitude from $10^8$ to $10^{15}$. In 1990, the priority index was smaller than in other years. Examination of the available data indicated that for 1991 there are five records with data relevant to the MAP “nuclide set,” but for 1990, there are only two records. This paucity of reported data, with possibly some data missing, resulted in the lower priority index for 1990. No further investigation has yet been possible.

Fig. 17-3 presents a combined plot of annual priority index values for airborne radionuclide releases from LANL facilities, and Table 17-7 presents a summary of the classes of radionuclides with highest priority indices for each period of LANL operations.
<table>
<thead>
<tr>
<th>Year</th>
<th>Release, µCi</th>
<th>Priority Index, L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948</td>
<td>1.31E+07</td>
<td>6.57E+17</td>
</tr>
<tr>
<td>1949</td>
<td>6.36E+07</td>
<td>3.18E+18</td>
</tr>
<tr>
<td>1950</td>
<td>4.53E+07</td>
<td>2.27E+18</td>
</tr>
<tr>
<td>1951</td>
<td>7.66E+06</td>
<td>3.83E+17</td>
</tr>
<tr>
<td>1952</td>
<td>1.23E+07</td>
<td>6.13E+17</td>
</tr>
<tr>
<td>1953</td>
<td>6.17E+06</td>
<td>3.09E+17</td>
</tr>
<tr>
<td>1954</td>
<td>3.68E+06</td>
<td>1.84E+17</td>
</tr>
<tr>
<td>1955</td>
<td>1.45E+07</td>
<td>7.27E+17</td>
</tr>
<tr>
<td>1956</td>
<td>9.03E+05</td>
<td>4.51E+16</td>
</tr>
<tr>
<td>1957</td>
<td>8.74E+05</td>
<td>4.37E+16</td>
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<tr>
<td>1958</td>
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<td>4.84E+16</td>
</tr>
<tr>
<td>1959</td>
<td>2.18E+06</td>
<td>1.09E+17</td>
</tr>
<tr>
<td>1960</td>
<td>4.44E+05</td>
<td>2.22E+16</td>
</tr>
<tr>
<td>1961</td>
<td>9.50E+04</td>
<td>4.75E+15</td>
</tr>
<tr>
<td>1962</td>
<td>1.14E+05</td>
<td>5.70E+15</td>
</tr>
<tr>
<td>1963</td>
<td>8.12E+04</td>
<td>4.06E+15</td>
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<tr>
<td>1964</td>
<td>3.36E+04</td>
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<td>6.35E+15</td>
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</tr>
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<tr>
<td>1996</td>
<td>2.33E+01</td>
<td>1.17E+12</td>
</tr>
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*Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.
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*Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.*
Table 17-3: Airborne Tritium Release Estimates and Priority Indices

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\(^a\) Note regarding scientific notation: \(4.96E^{+05}\) equals \(4.96\times10^{05}\), which equals 4.96×100,000 or 496,000.
Table 17-4: Airborne RaLa Release Estimates and Priority Indices

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*a Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.
Table 17-5: Airborne MFP Release Estimates and Priority Indices

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<td>1996</td>
<td>4.07E+02</td>
<td>4.07E+06</td>
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Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.
<table>
<thead>
<tr>
<th>Year</th>
<th>Release, µCi</th>
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<td>1988</td>
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<tr>
<td>1996</td>
<td>1.12E+10</td>
<td>5.60E+13</td>
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</tbody>
</table>

*a Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.*
Figure 17-3. Priority Indices for Airborne Radionuclide Releases from LANL Operations
### Table 17-7. Classes of airborne radionuclides with highest priority indices for each period of LANL operations

<table>
<thead>
<tr>
<th>Years</th>
<th>Radionuclide Class with Highest Priority Indices</th>
<th>Range of Annual Priority Indices (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944-1947</td>
<td>Radioactive Lanthanum</td>
<td>6×10^{11} to 1×10^{13}</td>
</tr>
<tr>
<td>1948-1966</td>
<td>Plutonium</td>
<td>7×10^{14} to 1×10^{18}</td>
</tr>
<tr>
<td>1967-1969</td>
<td>Uranium</td>
<td>1×10^{17} to 1×10^{17}</td>
</tr>
<tr>
<td>1970-1974</td>
<td>Plutonium</td>
<td>2×10^{14} to 3×10^{15}</td>
</tr>
<tr>
<td>1975</td>
<td>Uranium</td>
<td>7×10^{13} to 7×10^{13}</td>
</tr>
<tr>
<td>1976-1977</td>
<td>Tritium</td>
<td>3×10^{13} to 4×10^{14}</td>
</tr>
<tr>
<td>1978-1989</td>
<td>Mixed Activation Products</td>
<td>6×10^{14} to 4×10^{15}</td>
</tr>
<tr>
<td>1990</td>
<td>Tritium</td>
<td>1×10^{14} to 1×10^{14}</td>
</tr>
<tr>
<td>1991</td>
<td>Uranium</td>
<td>1×10^{15} to 1×10^{15}</td>
</tr>
<tr>
<td>1992-1996</td>
<td>Mixed Activation Products</td>
<td>6×10^{13} to 7×10^{14}</td>
</tr>
</tbody>
</table>

### Conclusions regarding prioritization of airborne radionuclides

The LAHDRA prioritization of airborne radionuclide releases shows that, based on LANL compilations of releases, plutonium and uranium were of primary concern until the early 1980s. From then until the present, MAP radionuclides appear to have been of primary concern. However, in some cases, limited or no data were found in LANL compilations of releases for important nuclides such as plutonium (D Building data and pre-1948 data), polonium, tritium before 1967, all nuclides pre-1950, and non-point source emissions.

A calculation was completed in October 2006 that analyzed the reported releases from DP West for calendar year 1957, using the actual daily stack sampling and analysis reports. This was done to compare with the LANL compilation (Andrews ca. 1973) that has been the basis for asserted releases of plutonium from LANL. The analysis of the 1957 data by the LAHDRA team showed that 40% of all operating hours at DP West Site were not monitored, with the unmonitored periods mostly associated with weekends and holidays. Therefore, a method for estimating the hours where the stacks were not monitored is needed. The method used by LANL was likely conservative, in that it scaled from operating hours to estimate hours in which no stack measurement was made. The LAHDRA review of the 1957 data also showed that the simple assumptions made in the early 1970s, such as stack and sample stream flow rates, were used for all periods. These assumptions appear to have not always been appropriate.

The air concentration and fallout tray data for the 37-d operating period during 1957 over which the Jordan and Black work was performed (Jordan and Black 1958) could be used to benchmark air transport models for assessment of airborne releases from DP West Site. However, the LAHDRA project team has been unable to identify the 37-d period, and LANL staff have been unable to supply information about the Jordan and Black study beyond what is contained in the associated journal paper.
Comments and Issues

Data completeness - This prioritization effort was intended to present a “first look” at the scope and extent of radionuclides released at LANL over the years of its operation. Because the primary focus of LAHDRA was information gathering, limited effort was expended toward entering or evaluating raw data identified in historical documents at LANL. In general, the values used in the prioritization came from LANL compilations, with adjustments made as available data supported. Little effort was expended to analyze the data from logbooks or other more detailed data sources. A significant amount of original release information (that is, lab measurements of a filter from a stack) for the 1950s and 1960s is available, and could be captured and analyzed if further evaluation of airborne releases is undertaken.

Polonium - No effluent data have been found for polonium, other than gross alpha measurements of buildings and stacks at DP East Site, where polonium and other materials were handled and processed. It is known that significant quantities of polonium were used. Due to its shorter half-life, perhaps thousands of times more curies of polonium then plutonium were used. In the early years, plutonium was the most valuable substance on earth and was held in strict control. However, since polonium was more readily available, it was not inventoried as closely as plutonium. Large amounts were used in explosive or destructive tests for nuclear weapon initiators.

An annex to B Building was built by the end of March, 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun weapon components and gun initiators. Operational in April 1944, it had performed nearly 180 experiments by the end of September (about one per day) with unknown quantities of polonium and beryllium released (LASL 1944-1945). In August 1944, a “coffin” was authorized, that is a box operated at negative pressure with a gas mask filtered exhaust, to be used to limit contamination of the machine gun and room during experiments with plutonium. It was to be placed into operation in September, 1944. While the LAHDRA team has addressed releases of beryllium from the B-Building gun testing (See Chapter 20), polonium releases from that activity have not yet been addressed.

Pre-1967 tritium - There are no pre-1967 effluent data for tritium. The LAHDRA project has identified documents that refer to significant tritium releases before 1967, in most cases associated with accidental or episodic releases. This information is scattered across many historical documents, such as incident reports. The LAHDRA team has identified no location in which documents related to tritium releases before 1967 have been assembled. If time could be devoted to a directed search of records (some already captured by the LAHDRA team and some not) for episodic tritium release data, it is likely that a tritium source term for years before 1967 could be bounded.
Unmonitored releases - In the early years of Los Alamos operations, some plutonium processing facilities such as D Building and the facilities at the DP West Site, were designed and operated with positive building pressure (LASL 1947) (see Fig. 17-4 below). This could have resulted in significant unintentional release of building air out of doors and exit points other than the stacks. Similar release pathways could also be active for large facilities such as LANSCE.

fig. 17-4. Excerpt from a description of DP Site facilities and their ventilation systems (LASL 1947).

Small contributors - There are a number of nuclides like Mn-54, Au-194, or Ac-227, which do not fall into one of the six existing “nuclide sets”. Since there were few data records involving these radionuclides, and it is known that these nuclides were not primary radionuclides that LANL was working with, priority indices were not calculated. The overall contribution of these nuclides is thought to be very small and subsequently no priority indices are computed or assigned in this calculation.

Beryllium - In the site-wide FEIS (USDOE 1979), Table 4.1.2-8 contains information on explosive tests for uranium and beryllium (see Fig. 17-5 below). Using this information, the priority indices in Table 17-8 were computed based on required dilution volume in liters. Note that the priority index for beryllium is five times that of uranium. Furthermore, these data are only from explosive tests, and as discussed in Chapters 11 and 20, there were other sources of beryllium such as the beryllium shop and initiator testing.

ORF Corrections – In the site-wide FEIS (USDOE 1979), the percentages of various elements aerosolized from explosive tests are listed as 10%, or 0.1 (see Fig. 17-5). In this LAHDRA prioritization calculation, it was asserted that the Overall Release Fraction (ORF) was 0.001. This was based on a combination of Airborne Release Fraction and Respirable Fraction. If the LANL asserted figure of 0.1 were to be used, the uranium priority index would change significantly for the years in which uranium was used in explosive tests. For the LAHDRA prioritization, the ORF value of 0.001 was retained as it was judged to be more appropriate.
Table 17-8. Priority index calculations for depleted uranium and beryllium emissions in 1976 based on data from LANL’s 1979 FEIS

<table>
<thead>
<tr>
<th>Material</th>
<th>1976 Annual Usage (kg)</th>
<th>Percent Aerosolized</th>
<th>Aerosolized Quantity (kg)</th>
<th>Applicable Standard (ng/m³)</th>
<th>Priority Index (L)</th>
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<tbody>
<tr>
<td>Depleted Uranium</td>
<td>1023</td>
<td>10%</td>
<td>102.3</td>
<td>9,000</td>
<td>$1.14\times10^{13}$</td>
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<tr>
<td>Beryllium</td>
<td>25.5</td>
<td>2%</td>
<td>0.51</td>
<td>10</td>
<td>$5.10\times10^{13}$</td>
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</table>

Pre-1973 LANL plutonium releases – Figs. 19-6 and 19-7 are a table and text, respectively, from the site-wide FEIS that document the 1.2-curie cumulative historical release value for airborne plutonium through 1972. The assessment of airborne plutonium releases from LANL operations would benefit from further examination of airborne plutonium releases before 1948, as there were minimal control measures in place during this period.
**Table 4.1.2-3**

**Atmospheric Releases of Radioactivity**

Cumulative Radionuclides Released to the Atmosphere Prior to 1973

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Amount</th>
</tr>
</thead>
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<tr>
<td>$^3$H</td>
<td></td>
</tr>
<tr>
<td>Mixed Fission Products</td>
<td>0.006</td>
</tr>
<tr>
<td>$^{235}$U</td>
<td>0.086</td>
</tr>
<tr>
<td>$^{238}$U</td>
<td>0.005</td>
</tr>
<tr>
<td>$^{238}$Pu</td>
<td>0.056</td>
</tr>
<tr>
<td>$^{239}$Pu</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Fig. 17-6.** Cumulative airborne radionuclide releases through 1972 as reported in the LANL FEIS

The inventory of radioactive atmospheric releases before 1973 (see Table 4.1.2-3) was made on the basis of stack sampling through December 1972. The absence of stack sampling programs during the early years of the Laboratory and continuing uncounted tests with high explosives involving natural or depleted uranium prevented preparation of a complete inventory. In general, the inventory covers releases during the period from 1948 through 1972 for plutonium, 1961 through 1972 for mixed fission products, and 1967 through 1972 for other radionuclides such as tritium, $^{235}$U, and $^{238}$U. Inventories of short-lived nuclides such as $^{131}$I, $^{89}$Rb, $^{133}$Xe, $^{135}$Xe, $^{41}$Ar, $^{11}$C, $^{13}$N, and $^{15}$O (whose half-lives range from about 2 minutes to 8 days) were not included, since they decay rapidly and have little biological significance. The activity values for $^{239}$Pu include contributions from $^{241}$Am and other alpha emitters associated with the $^{239}$Pu. Data since 1973 is based on actual stack sampling.

Probable releases of radioactivity to the atmosphere during the next 25 years are likely to be less than releases to date. For example, if releases of plutonium were to continue at the 1976 rate for 25 years, the cumulative amount would be less than 1.5% of the total plutonium released before 1976. Construction and use of a new plutonium facility with extensive filtration equipment is expected to significantly reduce plutonium emissions. At the 1976 rate, tritium releases over 25 years would be about the same as the total before 1976. New treatment equipment and construction of new facilities for tritium research are expected to significantly reduce tritium releases from the 1976 level.

**Fig. 17-7.** Text regarding airborne releases before 1973 from the LANL FEIS

**ORF Corrections** – In the site-wide FEIS (USDOE 1979), the percentages of various elements aerosolized from explosive tests are listed as 10%, or 0.1 (see Fig. 17-5). In this LAHTRA prioritization calculation, it was asserted that the Overall Release Fraction (ORF) was 0.001. This was based on a combination of Airborne Release Fraction and Respirable Fraction. If the LANL asserted figure of 0.1 were to be used, the uranium priority index would change significantly for the years in which uranium was used in explosive tests. For the LAHTRA prioritization, the ORF value of 0.001 was retained as it was judged to be more appropriate.
Alternate Methods for Characterizing Airborne Releases—

Measurements of Plutonium in Soil as Indicators of Historical Releases

Until around 1978, releases of airborne plutonium from LANL were either not measured at all or were improperly measured or reported. Major release points that were not measured for plutonium include the historic D Building, the first plutonium component manufacturing facility in the world, and DP West Site releases before 1948. D Building operated until around 1953. Also never considered in LANL compilations of plutonium releases were non-point source emissions from major fires at plutonium disposal areas in the 1940s and radioactive disposal area operations that continue to this day. Until the around 1959, release points such as DP West at LANL were not provided with single stage HEPA filters (Maraman et al. 1975). A second stage of HEPA filters were finally installed around 1973. Until the mid-1950s, the DP West Site Stacks were not equipped with an appropriate sampling system, resulting in underreporting of releases by large factors. Thus, the LAHDRA project had a need to estimate potential releases from LANL operations using methods beyond those based on reported stack monitoring results. One method identified was to use amounts of plutonium measures in soil samples collected around Los Alamos to estimate the amount of airborne plutonium that was released.

Efforts by LANL

The staff at LANL attempted to measure the amount of plutonium in the soils around LANL in the 1957-1958 timeframe. Fig. 17-8 is taken from the 1958 publication “Evaluation of the Air Pollution Problem Resulting from Discharge of a Radioactive Effluent” by Harry Jordan and Ralph Black (Jordan and Black 1958). The darker areas in the figure indicate the canyons. The image shows circles of increasing distance from the main stacks at D. P. West along with soil sampling results and locations. The authors asserted that they were able to compare their values with the actual release data since releases were measured at D. P. West. Only the 6 results to the east (right) that are circled were used by Jordan and Black because they “show rather remarkable agreement” with the LANL stack effluent records showing 13.1 g or 0.82 Ci of plutonium (as stated in their own words). Results that were substantially higher were not used because they thought that they were higher because of failure of “attempts to avoid extraneous contamination.” Although they asserted agreement, they were apparently unaware of or ignored major changes in the stack sampling system in 1955 that were the subject of a study by Edwin Hyatt that resulted in significant modification of release estimates.
The LAHDRA team sees at least five major problems with the Jordan and Black paper:

1. LAHDRA is unable to find any supporting records or logbooks about the referenced work.
2. Jordan and Black excluded any high samples, for what appear to have been erroneous reasons.
3. Jordan and Black compared the soil to incorrect stack monitoring results and asserted that the soils and stack data agreed. The DP West stack measurements are now thought to be up to a factor of 100 or more in error (lower than the correct value), even without inclusion of pre-1948 releases at DP West or any other LANL source terms. Edwin Hyatt replaced the stack sampling system in 1955 and found that the old system under-sampled the releases by a factor of approximately 20 as compared to the 1955 sampler (Hyatt 1955, Hyatt 1956). In addition, corrections for sample line loss of up to 5 and filter burial of 2.33 were not generally made until the late 1970s (Fuehne 2008).
4. The lab at LANL analyzed too much soil at once, resulting in low and variable recovery of the plutonium from soil in the acid leaching process.
5. The radiochemist responsible for the soil analysis has stated his results were only intended to be qualitative (whether plutonium is present) and not meant to be quantitative (how much plutonium is present) (Flack et al. 2004).

In 1971, other Los Alamos scientists attempted to reproduce the work of Jordan and Black. W. Purtymun and W. Kennedy published “Plutonium and Strontium in Soil near Technical Area 21” (Kennedy and Purtymun 1971). Their measured soil concentrations were much higher than Jordan and Black’s. In order to explain the higher soil concentration, the 1971 report attempted to correct for the small amount of global fallout from nuclear weapons testing and also assumed four times more plutonium was deposited on the soil from the releases. By assuming four times more plutonium was deposed, Kennedy and Purtymun also asserted that their results agreed with invalid and significantly understated stack measurements. The LAHDRA team took steps in their evaluation to avoid the problems with the Jordan and Black analysis that are identified above.

Efforts by the LAHDRA Project Team

As a result of the lack of valid or accurate effluent measurements for early airborne releases of plutonium, the LAHDRA team has considered several nontraditional methods to gain information about the potential magnitude of historical plutonium releases. Measurements of plutonium in soil around LANL make up an “environmental record” that is a potentially useful indicator of past releases. Members of the project team have performed several iterations of analysis to estimate the total integrated airborne plutonium release that would be consistent with the environmental record of plutonium found in soil samples in the Los Alamos area.

Initial Assessment

The initial iteration of an assessment by LAHDRA to estimate airborne plutonium releases was based on 37 measurements of plutonium in soil samples collected near Los Alamos from 1975 to 1977 (Purtymun et al. 1980). These measured concentrations of $^{239}$Pu in soil included global fallout from atmospheric testing of nuclear devices. The average concentration of $^{239}$Pu of distant sample sites (approximately 50 miles from LANL) was $0.006 \pm 0.001$ pCi g$^{-1}$. This value was subtracted from the 37 values used in the analysis. The “corrected” soil concentrations reflected 0.003 to 0.045 pCi g$^{-1}$ net positive contributions of $^{239}$Pu from LANL operations. None of these measurements were near the release points.

The Radiological Safety Analysis Computer program was run with Los Alamos meteorological data to calculate $^{239}$Pu deposition at various distances in each direction from a unit release (1 Ci) of $^{239}$Pu over 50 y (Schrader 2003). Pasquill-Gifford Stability Class C and a deposition velocity of 0.001 m s$^{-1}$ were assumed. The calculated deposition at each distance was converted to a soil concentration based on the annular area involved and the soil density and sampling depth reported by LANL. The ratio of each
measured soil concentration to the concentration calculated for that same area from the RSAC modeling of a unit release yielded a factor that corrects the unit source in RSAC to give agreement between the soil data and the RSAC results. For example, a ratio of 15 would indicate that 15 curies of plutonium was released rather than 1 Ci.

The ratios over the 37 sampling locations were log-normally distributed. Based on the distances involved with releases from D Building (where plutonium was first processed), the geometric mean was 620 curies, with a factor of uncertainty (geometric standard deviation of the mean) of 1.2. For the distances associated with releases from the DP Site (where plutonium processing took place from late 1945 to 1978) the geometric mean was 670 curies, with a factor of uncertainty of 1.3. While these results have a high degree of mathematical uncertainty, they indicated that airborne plutonium releases from LANL operations could have been hundreds of times higher than the 1.2 Ci officially reported, and were much closer to the actual LANL releases.

**Second Iteration**

Following the initial analyses based on a small sample size, a search for additional soil sampling data was performed, and over 600 soil sample analyses were located (Fresquez et al. 1996). A new analysis was done using this expanded dataset. The ratio of plutonium and cesium was calculated using LANL data and plotted along with the dry pCi g⁻¹ of plutonium and cesium. Further examination of the resulting data plotted as a lognormal cumulative frequency distribution reveals that there are two datasets for plutonium:

- Those measurements that reflect contributions from LANL operations (“impacted” measurements), and
- Those measurements that reflect no significant contribution from LANL operations, only fallout from weapons testing (“fallout” measurements).

A mean value for fallout from LANL publications that was consistent with the dataset for fallout was subtracted from the plutonium to get net plutonium for the “impacted” samples. The values of these impacted samples were then plotted on a map at the associated sample collection location.

Two approaches were then used. First, 679 soil samples at 34 sample points were analyzed. Of these, 106 samples at 24 sample points were judged impacted based on analysis of the plot of plutonium-to-cesium ratios. These points were used for geospatial studies of the location and magnitude of elevated levels of plutonium soil concentration. This first approach was oriented towards analysis of the data, not towards estimation of LANL releases. The $^{239}$Pu to $^{137}$Cs ratio is the middle curve in Fig. 17-9. As can be seen, the ratio sharpens the differences observed in $^{239}$Pu, with a slightly worse fit to a lognormal distribution. This ratio helps establish the point at which samples impacted by LANL operations can be
detected. A ratio of about 0.065 marks the break (or “knee”) in the line, above which data shows evidence of LANL impact, and below which, the site added $^{239}\text{Pu}$ is so low that the variability of fallout $^{239}\text{Pu}$ and $^{137}\text{Cs}$ masks its presence. This shows that the population of a large number of soil measurements can be used to separate the LANL-impacted locations from those that exhibit fallout alone. The higher one restricts the data above the ratio of 0.065, the less influence fallout has on the $^{239}\text{Pu}$ concentration.

![Fig. 17-9. Cumulative Frequency Distributions of $^{137}\text{Cs}$, $^{239}\text{Pu}$, and Pu/Cs Ratio Data](image)

In the second approach, a total uncertainty for each soil sample was calculated, and only those measurements with uncertainty in the plutonium to cesium ratio less than 25% were analyzed. This resulted in a data set with 119 members. The plutonium-to-cesium ratio was studied, and the Pu/Cs ratio $<0.065$ criterion was used to select a 37-sample subset of the 119 samples previously selected for low uncertainty. These samples lie within 5.5 km of either DP West Site or D Building. The results from use of these 37 samples were less dependent on the assumed background from fallout, since the values for plutonium were higher and the background is a smaller percentage of the value.

For these 37 samples, the net plutonium and the range and bearing from the D Building and DP West Site were calculated. The RSAC program was used to calculate the soil concentration as a function of wind
direction and distance for a one-curie source term. When divided into the net sample data, an estimate of the integrated LANL source term was obtained for each of the 37 samples.

The cumulative frequency distribution plots for all 37 sample points for either DP West Site as source or D Building as source are shown in Fig. 17-10. The results were log-normally distributed. If the release was attributed to the DP Site, an average of 60 Ci and a median of 12 Ci were obtained with a geometric standard deviation (factor of uncertainty) of 9. If the site releases were attributed solely to D Building, an average of 101 Ci and a median of 46 Ci were obtained with a corresponding geometric standard deviation (factor of uncertainty) of 5. The smaller uncertainty for D Building suggests that large and previously undocumented releases from D Building could have occurred. However, these results rely on many parameters, which should be the subject of further study. The methods established with this analysis, when validated, could be extended to other contaminants of concern for which monitoring data are not available for key periods of time, such as beryllium.

![Source Term](image)

**Fig. 17-10.** D-Building and DP West Site Source Term Fits
Finally, an attempt was made to explore the relative contribution of D Building and DP West Site to estimated site-total releases. Many combinations of the possible release totals for the two sites were analyzed to find the breakdown that best satisfied the following criteria:

- Minimize the absolute value of the difference between concentrations calculated from LANL releases (D Building plus DP West Site) and measured soil concentrations, averaged over all measurement locations
- Minimize the standard deviation of that mean (i.e., minimize uncertainty).

If one sums a fraction of D Building results with that of DP West Site adjusted for 100% release, the curve would lie midway between those shown in Fig. 17-10. The slope progressively decreases from a factor of 9 (100% DP West Site) to a factor of 5 (100% D Building). A completely flat curve would show that all of the measured soil samples provide the same result, indicating no uncertainties in the answer. Thus, although DP Site happens to fit a lognormal distribution better than D Building, the results suggest most of the releases came from D Building.

Additional Refinements– Jordan and Black Revisited

A detailed review of the 1958 Jordan and Black journal paper was performed during 2006. The soil data used by Jordan and Black have orders of magnitude variability. When plotted as a function of downwind distance, no radial dependence is observed. The air concentration data and fallout tray data are not correlated. The issues with these data lead Jordan and Black to select only six data points as representative, rejecting 85% of their own data. Using the same six points selected as representative by Jordan and Black, the LAHDRA team was unable to reproduce the asserted release, indicating other undocumented assumptions may have been used. The asserted release is consistent with the 1973 “Joe Graf binders” compilation assembled by LANL for the first site-wide environmental impact statement. The deficiencies in that estimate include a lack of pre-1948 data, an estimate for DP West alone for 1948-1950, absence of sample line loss and burial correction factors, no releases from non-point sources such as dumps and dump fires, and no releases from D Building. In summary, the Jordan and Black data lack a basis and any supporting information that would permit its use for back-calculation of the plutonium source term in air.

Material Disposal Area G Calculation

A calculation was completed by the LAHDRA team in November 2006 for non-point source emissions from Material Disposal Area (MDA) G. A LANL staff member had objected to use of soil data from that area for estimating DP West emissions (Shonka and Mejias 2006). This assessment addresses whether soil samples were impacted by MDA G operations, resulting in a falsely high assertion of source term from either DP West Site or D Building. The LAHDRA calculation demonstrated that the LANL
assertion was correct, and that soil samples in that area are significantly impacted by operations at MDA G. However, this calculation also indicated that the release of plutonium from MDA G may be the most important source of plutonium released by LANL since 1981. This non-point source emission has not previously been considered or reported by LANL. The data from one particular location show a gradual reduction of soil concentrations over time, which has been reported by LANL elsewhere. This reduction implies that back-calculation of source terms from the 1940s could be low for data collected in the late 1970s and late 1980s if weathering is not considered.

Identification of Another Potential Dataset for Sampling of Soils Near D Building

While reviewing the ERSS Domino database in March 2007, a LAHDRA document analyst noticed an urgent request in 1993 by LANL staff for soil sampling from the hillside of Los Alamos Canyon, near the location of the former Original Technical Area, to support an EPA audit. In response to a request by the LAHDRA team, Dave Sarracino from the LANL sample office searched his database and provided a printout of sample results associated with that documented request from that ERID (LANL 1993b).

An e-mail authored by LANL staff member M. McNaughton was added that explained that the sample area, depth, and volume were not available because those data were considered not relevant. McNaughton went on to opine that the data should not be used for source term calculations since he felt the locations were impacted by water runoff from TA-1.

The data provided by LANL fit a single log-normal distribution (97%) with a median value of 11 pCi g⁻¹ and a geometric standard deviation of 3.3. This indicates that 95% of the data lie within a factor of ten of the median of 11 pCi g⁻¹. The previous environmental monitoring data LAHDRA used for source term calculations had plutonium levels greater than background (background samples were not averaged in) and had a geometric mean that is significantly less (by more than two orders of magnitude) than these hillside samples. Because of the closer distance, these results support median release estimates of between 1 and 100 Ci, with no correction for weathering.

Arguments for and against the use of these samples can be summarized as follows. Some LANL staff members’ opinions as to why the 1993 hillside/bench top samples should not be used were summarized in a 23 October 2007 e-mail from McNaughton that asserts that sampling locations in the 1993 campaign were selected to correspond to locations of the effluent pipes known as outfalls numbered 137; 138, and 140 along with locations down-gradient from these pipes. It goes on to assert that almost all plutonium at these locations was therefore carried by water and thus the data were unsuitable for use in characterizing airborne releases from D Building. LAHDRA team members believe that the 1993 hillside/bench top samples are worthy of evaluation because, aside from McNaughton’s assertions, there is no evidence that
the statements in his e-mail reflect the actual case. The referenced McNaughton e-mail was provided without references.

The planned sampling sites appear to follow straight lines and show no meander of a typical gravity flow path on irregular terrain. The TA-1 area was documented to have been covered with many feet of clean fill following the removal of D Building. This removed the washout source term for up to 40 y (1953 – 1993). Any water flow over the hillside over the last 40 years would have tended to remove plutonium previously deposited along water flow pathways, not add to it. If there is a new or continuing source term from TA-1 as McNaughton suggests, LANL would need to remediate or mitigate it.

The bench top is not a manmade structure, such as a weir, that would have uniform flow over the entire area. Surface water under gravity flows along low lying channels. In rocky terrain such as the bench top, the flow channels do not change over time as much as in alluvial plains, where episodic floods can change the path of a stream. The flow behavior has been observed in that area during rainfall by LAHDRA team members. The materials deposited in those channels tend to be variable over the years with gradual buildups of sedimentary deposits followed by scouring during episodic high flow periods. Thus, waterborne material deposited during the first ten years of TA-1 operations would likely no longer be present in 1993 in the water pathways. If the samples along water flow paths simply integrated, as McNaughton’s argument implies, then the streams in the bottom of the canyons would be highly hazardous locations.

Thirty nine of the sampling locations (43%) in the 1993 sampling were assigned (one of eight) identical values, likely because there was insufficient material at each location to make a sample, and collected soil was composited and analysis yielded a single value. Several of the sampling locations (3) were sampled to depths of over a foot. The soil concentrations at those sites are similar to others in the data set. These locations were likely not along water flow paths.

The data are well correlated (97%) with a single log-normal distribution, with a median of 11 pCi g⁻¹ and a geometric standard deviation of 3.3. If there were two processes at work (areas with or without water pathway transport mechanisms), there would likely have been more than one distribution evident.

The data should be examined for potential utility in characterizing historical releases because of the paucity of data regarding D Building releases, which were not measured by LANL. The data could provide another “piece of the puzzle” for estimating D-Building releases.
Suggestions for Improvement of the Current Analysis

The quantity of plutonium released by LANL appears to have been potentially one hundred times or more higher than LANL has asserted. However, the historical LANL soil measurements data that are available and have been used to date for back calculation of the LANL plutonium source term are not ideally suited for this task. Attempts by the LAHDRA team to use existing soil analyses have been critiqued by a LANL staff member citing several issues– some acknowledged by the LAHDRA team and some disputed. Unless LANL has additional documentation that could clarify this issue, a new program of soil sampling, oriented towards resolving the magnitude of releases from significant operations, would be desirable.

The areas around D Building and DP West have been heavily disturbed and suitable soil sampling locations would be problematic. A LANL Technician observed that the hillside of South Mesa across Los Alamos Canyon from the TA-1 has remained relatively undisturbed. This area should be considered for a new program of soil sampling. The samples should continue along the canyon rim from the bridge at Diamond Drive to the area across from D.P. West. If possible, the samples should be analyzed with a new method of measurement called Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This method can distinguish between weapons-grade plutonium samples that have not been used in a nuclear weapon and fallout samples with plutonium left over after a nuclear detonation. The United States Transuranium and Uranium Registries (USTUR) have performed an initial study of the method with promising results. This method and new analysis of the samples might permit accurately estimating how much of the plutonium found in any individual living in Los Alamos was due to global fallout and how much was due to releases of plutonium from LANL.

Without any new soil samples, the material found by LAHDRA in various LANL document repositories could be used for source term estimation, with a more rigorous effort to quantify uncertainties associated with various parameters.
Analysis of Measurements of Plutonium in Body Tissues of Los Alamos Area Residents

Before the late 1970s, plutonium releases from Los Alamos operations were either not measured or were inaccurately measured and reported by LANL. Consequently, alternate methods are needed for determining airborne releases from the early operations at LANL that could have affected off-site populations. The LAHDRA project team investigated the use of data concerning the plutonium levels in tissues obtained from autopsies of LANL residents to estimate plutonium releases.

The LANL Human Tissue Sampling Program

The Human Tissue Analysis Program was a 35-year effort by LANL to study the levels of plutonium in workers and in the general population of the United States. The general population was exposed to plutonium from atmospheric testing of nuclear weapons. Populations located near plutonium facilities, such as the D Building and DP West Site in Los Alamos, were also exposed to plutonium released during operations. Fig. 17-11 is an autoradiograph of a lymph node taken from the lung of a deceased worker from Los Alamos (McInroy 1995). It shows several groups of alpha tracks (radiating in a typical star pattern) from tiny particles of plutonium inhaled while working at the laboratory.

Compilations of the LANL human tissue analysis data have been published periodically, and the Los Alamos Science magazine summarized the program in the November 23, 1995 issue that was devoted to a discussion of the Human Radiation Experiments (McInroy 1995). Researchers at LANL first began obtaining samples of tissues from autopsies performed in Los Alamos at the medical center following a nuclear criticality accident that resulted in the death of Cecil Kelley in 1959. He had worked at LANL for many years and had plutonium in his body before the accident. The collection and analysis of tissues was intended to answer questions about the behavior of plutonium in the human body. In later years, the program was expanded to other areas of the country in order to estimate the amount of nuclear fallout people were subjected to from the atmospheric testing of nuclear weapons. The non-worker tissue program ended in 1980. Nearly 1,000 decedents had tissues removed during their autopsies and sent to LANL by coroners.

Fig. 17-11. Alpha tracks from plutonium in former worker’s lung tissue
The LAHTRA project team considers the human tissue sample data associated with residents of the Los Alamos area important because they can support the characterization of public exposures that resulted from LANL releases of plutonium during the initial decades of the facility’s operations. In the past, when LANL reported results from the human tissue program, comparisons were made between various areas of the country. Samples from New York City were taken in the 1967-1968 time frame while samples from all other areas of the country (other than near Los Alamos) were taken only over the 1974 -1975 time frame. By that time, plutonium releases from LANL had been greatly reduced by the installation of HEPA filters on the various exhaust points. Consequently, worldwide fallout from weapons testing became an increasingly important source of plutonium exposure for Los Alamos residents. Individuals who arrived in Los Alamos after the 1960s might be expected to have mostly experienced intakes of nuclear fallout from weapons testing while people who arrived earlier could have inhaled or ingested greater amounts of plutonium from LANL releases.

The comparisons LANL staff have published have considered only the Los Alamos data for individuals who died in those limited years (1974-75 or 1967-68), to support comparison with the datasets collected from other parts of the country, since cases from New Mexico for earlier years would have been exposed to different levels of nuclear weapons testing fallout. Since there are only a few cases for those years, data from early and late arrivals; men and women; old and young; etc. were combined. When the combined cases data from these few years are compared to other areas of the country, the variability is so great that one cannot see if there was a difference between Los Alamos and other areas or not. From this result, LANL has asserted that there are no measurable differences between Los Alamos and other areas of the country. While this statement is correct, the LAHTRA team believes that it is misleading.

The data have been analyzed by Los Alamos to demonstrate that the differences in median values of plutonium concentration in tissues between states in the U.S. were small. However, the autopsy results from deaths at the Los Alamos Medical Center (designated as either Los Alamos residents or residents of Northern New Mexico) were generally the highest median values for nearly all organs compared to other states. Although other tissues were sampled, the LAHTRA project team is primarily interested in the results from the liver, skeleton, and lungs. The lungs provide information about plutonium inhaled in the last few years prior to death, while plutonium accumulates in liver and skeleton and provides an estimate of the total plutonium inhaled over a person’s life. Because of relatively slight differences in the time (decades) that plutonium remains in either the liver or skeleton, it is possible to observe differences between people who were exposed to plutonium long ago and people who had more recent exposures.

The LAHTRA Project located and copied the death certificates from workers and residents of the Los Alamos area who contributed samples to the program (LANL 1978). The addresses of many of these individuals were obtained from cross referencing with the yearly listings in the telephone directories.
maintained by the Los Alamos Historical Society and from other LANL documents and public records. The logbooks from the human tissue sample program and solutions of many of the sampled tissues were transferred by LANL to the United States Transuranium and Uranium Registries (USTUR) after the program ended. USTUR maintains them still today.

The exposure to fallout plutonium in an area would be broadly similar for most individuals who share similar lifestyles. However, the exposure to releases from plutonium facilities would not be similar, since individuals residing closer to the facility would generally have experienced greatest exposure to releases. These individuals might be a small subset of the total population. This subset, individuals residing close to a nuclear facility, might not significantly alter the median value of a dataset, especially when small numbers of samples are all the data that are available.

Analysis of the Autopsy Program Results by the LAHDRA Project

The LAHDRA staff attempted an independent analysis of the autopsy program results (Shonka 2004). This effort demonstrated that excess plutonium is present in non-worker residents of Los Alamos over what would be expected from global fallout from nuclear weapons testing. It also established and tests a method for uncovering the history of residence locations for autopsy cases. This history establishes the range and bearing from LANL release points along with the years of occupancy at each residence. This method could be used to reduce the uncertainty in retrospective dose reconstructions and possibly permit use of the autopsy data for bounding LANL releases.

The data from the residents who were present in Los Alamos can be used to estimate exposures for any resident of Los Alamos and also be used to provide upper and lower bounds on the plutonium source term from LANL operations. A full analysis of the data would require that the range and bearing from significant release points at Los Alamos, along with the time dependent source term, be incorporated into a model. Additionally, the date of death should be used in correcting the autopsy results for fallout.

From the results of this calculation, the median estimated exposure is a factor of 5 times higher in the long-term residents, while the geometric standard deviation is reduced by 20% from that of all Los Alamos residents taken as an aggregate population. This implies that stratifying the population results can significantly improve (that is, reduce the uncertainty) of the estimate of the potential exposures that an individual in Los Alamos received from past operations. The current model does not remove the range and bearing impact on the results, and further improvements are suggested.

Another use of this analysis would be the application of this method to estimate worker exposure for LANL workers who were not considered plutonium workers, and did not receive routine internal dosimetry.
Methods

The method used in this calculation was as follows:

1. Enter the data from the 1979 Health Physics journal paper (McInroy et al. 1979).
2. Conduct a public records search for information on Los Alamos residents in that journal article.
3. Calculate the ratio of deposited plutonium in the liver vs. vertebrae.
4. Plot the standard deviation of Pu Ratio for the populations of Los Alamos and Denver.
5. Draw conclusions about the individual cases in Los Alamos and possibilities of exposure.

Dose Estimates from Exposure of Organs to Plutonium

The autopsy data are provided for various organs in units of disintegrations per minute (dpm) per kg of organ. The following material is presented to assist in understanding what these units (dpm kg\(^{-1}\) organ) mean in terms of dose or risk. A fraction of the plutonium present in inhaled air is retained in the lung. The lung retains the plutonium for about a year or a year and one-half. Thus, the autopsy data for lung tissue largely reflects the plutonium air concentration for the last few years prior to death. Since most of the autopsies are from the 1960s and 1970s, the lung data largely reflect atmospheric fallout from the testing of nuclear weapons. The largest plutonium releases from Los Alamos appear to have occurred in the 1940s and 1950s. This plutonium, if measurable, would no longer be present in lung tissue.

The International Commission of Radiological Protection (ICRP) Report No. 30 model of plutonium behavior in the human body (ICRP 1979) distributes plutonium present in systemic circulation, with 45% going to the liver, 45% to bone, and the remainder going largely to excretion. Small fractions are assigned to other organs. The liver and skeleton retain the plutonium for decades. Reference Man (ICRP 1975) notes that Thoracic Vertebrae are 75% trabecular, the spongy bone in which marrow resides. Thus, the vertebrae and liver are appropriate tissues to sample to measure plutonium deposited in an individual over a long period. The program at LANL sampled these two tissues, along with other tissues such as lung.

The autopsy data are provided in dpm kg\(^{-1}\) organ. It may be of some use to understand the potential doses that are involved with the measured data. The dose, in rem per dpm kg\(^{-1}\) skeleton, can be derived as follows: a systemic uptake of 1 dpm ultimately results in 0.45 dpm in the skeleton or liver. The liver has a mass of 1.8 kg in Reference Man, resulting in 0.25 dpm kg\(^{-1}\) in liver tissue for each dpm that is incorporated into the body.

A conversion for the skeleton depends on the type of tissue sampled. The entire skeleton ranges from 10% to 20% trabecular bone by weight. If the tissue sample had the same proportions, one could divide by about 2 kg (or 20% of the 10 kg total mass of skeleton) to yield a value of 0.225 dpm kg\(^{-1}\) skeleton.
This value is close to that for liver. It has also been noted that the plutonium concentration in bone (from humans) is inversely proportional to the percent bone ash (McInroy et al. 1979). Plutonium is concentrated in the trabecular bone rather than hard, compact cortical bone. Each person is, of course, unique and their weights are not the same as the average that is expressed in Reference Man. The LANL compilations provide the actual dpm kg\(^{-1}\) organ, and express the data as if the individual had the same weight organ as reference man.

The dose resulting from a 1 dpm systemic uptake depends on the chemical form of the intake (and of course the isotope, particle size, etc.). For inhalation of \(^{239}\text{Pu}\) oxide, Federal Guidance Report No. 11 asserts a dose factor of \(8.21 \times 10^{-04}\) Sv Bq\(^{-1}\) for bone surfaces, which converts to 1.37 mrem dpm\(^{-1}\) (intake) (USEPA 1988). Dividing 1.37 mrem by 0.225-dpm kg\(^{-1}\) skeleton then gives 6 millirem committed bone dose per dpm kg\(^{-1}\) skeleton.

The committed effective dose equivalent (CEDE) is a measure of radiation exposure that estimates risk by adding the dose from all of the organs (weighted for their risk for cancer) for as long as the radioactive material will be present in the body. On the basis of CEDE, the value for \(^{239}\text{Pu}\) oxide is 0.6 mrem CEDE per dpm kg\(^{-1}\) skeleton, or 0.6 mrem CEDE per dpm kg\(^{-1}\) liver. For more soluble forms (inhalation Class W), the values for \(^{239}\text{Pu}\) are 16 and 0.9 mrem per dpm kg\(^{-1}\) skeleton for bone surfaces and CEDE, respectively. Values for \(^{238}\text{Pu}\) are similar to those for \(^{239}\text{Pu}\). A simplification that expresses the results in the right “ballpark” would be that 1 dpm kg\(^{-1}\) results in approximately one mrem CEDE for either liver or vertebrae results from the autopsy program.

 Fallout Levels of Plutonium

The plutonium deposition from worldwide fallout in the Los Alamos area has been reported by LANL (Purtymun et al. 1990). Soil and river sediment samples were taken. The data were reported in units of concentration, fCi g\(^{-1}\). One can convert the concentration measured in soil samples to areal deposition by multiplying the concentration by the mass of soil sampled and dividing by the total area of the samples. This conversion is needed to be able to compare the LANL data with that taken by the Environmental Measurements Laboratory (EML) as reported by Krey for the Denver area (Krey et al. 1976). Krey reported fallout for the Denver area as \(1.7 \pm 0.5\) mCi km\(^{-2}\). Krey’s data did not include the contribution to fallout from Chinese testing in the late 1970s that may be present in the LANL data from the early 1980s. Krey’s data also would not have included any weathering that might have occurred between the time of the Denver samples and those taken around Los Alamos. Both of these minor influences would likely offset one another, since weathering would tend to decrease the values and the Chinese testing would tend to increase the values.
Each site sampled by LANL consisted of a square area 9 m on each side, with soil collected from each corner and the center. Each sample was 7.5 cm in diameter and 5 cm deep. The samples were combined to form a composite sample. The total volume of soil collected was 1100 cm$^3$, which would weigh nearly 2 kg at an estimated average soil density of 1.8 g cm$^{-3}$. This is believed to be a conservative (high) soil density, which will overstate the fallout levels compared to values if a lower soil density value were assumed. The area collected by the LANL sampling method was 221 cm$^2$.

Plutonium release estimates put forward by LANL staff have been found in LANL documentation for 1948 – 1973. This total value is approximately 1.2 Ci (Andrews ca. 1973). This activity could contaminate an area of 1200 km$^2$ (assuming an unrealistic completely and uniform fallout distribution) to a level of 1 mCi km$^{-2}$. Thus, the sampling for background levels of plutonium in Los Alamos would have to be outside of a radius of 20 km to avoid including the impact of site operations in the results (a radius of 20 km includes approximately 1200 km$^2$).

As described by Purtymun, six sites within a 50-mi radius of Los Alamos were sampled in 1981 and 1983, and additional locations along the continental divide were sampled in 1986. In fact, the sampling locations were located at approximately a radius of 50 mi, or 80 km. Thus, the sampling locations were far enough removed from the site to avoid significant impact from LANL releases if the releases were on the order of curies.

In the Purtymun study, the average of the $^{239}$Pu results for the six sites within the 50-mi radius near Los Alamos over two years was 8.75 ± 5 fCi g$^{-1}$. The data appear to fit a normal distribution with a better correlation than a lognormal distribution. In areal deposition, this value corresponds to approximately 0.8 ± 0.5 mCi km$^{-2}$. The integrated level of fallout plutonium for Los Alamos (Purtymun et al. 1990) appears to be about one-half of that for Denver (Krey et al. 1976). If the soil density is lower, then the fallout plutonium levels found by Purtymun are even smaller than one-half of those found by Krey near Denver.

Further Interpretation of the Autopsy Data

The autopsy data reported by McInroy et al. in 1979 in *Health Physics* shows that the cumulative frequency distributions of liver concentrations (dpm kg$^{-1}$ liver) are nearly identical between Los Alamos and Denver. However, the vertebrae autopsy samples from Los Alamos are higher than Denver, and their different slope indicates the plutonium has been in the body longer. These data are shown in Fig. 17-12 and Fig. 17-13. To facilitate comparison, the figures from McInroy et al. were superimposed on one another in those figures.
Fig. 17-12. Liver Autopsy Results

Fig. 17-13. Vertebrae Autopsy Results
If Los Alamos indeed had one half (or less) of the fallout as Denver, the liver results should show this. However, this is not the case. The liver data would seem to indicate the plutonium present at Los Alamos is roughly equal that of Denver. If one accepts the earlier fallout data from Purdyman and Krey, then this implies that the “extra” or “added” plutonium (that which makes the plutonium liver concentrations equal) is due to LANL emissions. The liver results show that autopsy samples from residents of Los Alamos appear to have “added” plutonium. If there were two distinct populations, one might expect to see a bend in the curve indicating added plutonium in the fraction of the population living nearest the release points. However, no bend is seen. This is probably due to the fact that if the added plutonium was due to facility operations, one might expect that the impact would be sporadic, with only a few individuals impacted based on the winds and other factors. It is likely that releases from the site were not sufficient to cause this “bend” in the CFD plot or that the inherent variability of various factors dominates the distribution and masks the presence of two populations.

Conclusions

The vertebrae results show differences between Los Alamos and Denver, with the differences occurring in the population with higher bone concentrations. This result also appears to be consistent with a hypothesis that releases at Los Alamos impacted the population.

The data also show significant divergence in the ratio of concentrations in the skeleton to that of the liver. Fig. 17-14 shows a cumulative frequency distribution graph for the ratio of vertebrae results to those of liver for all autopsy cases that had data for both organs. Four sets of data are shown, with two sets also fit to an exponential distribution. The two data sets with fitted exponentials are for Denver and Los Alamos. The other data sets are discussed in the next section.

The curves and data regarding vertebrae to liver ratios were not reported by McInroy et al. The information in Fig. 17-14 was computed as an element of this calculation. In general, the cases with positive results for both liver and skeleton would be the cases with highest reported data. The results from Denver appear to be log-normally distributed about a median ratio of 1.73. One individual (out of 38) had nearly 25-times as much plutonium in their vertebrae as in their liver.

The Los Alamos data (with a median ratio of 2.72) has three of the 17 results greater than 25, with one result approaching a ratio of 200 (off scale and not shown in Fig.17-14). The value of 2.72 indicates plutonium exposures that happened longer ago than those associated with the lower ratios. This is due to the difference in clearance time of plutonium from liver vs. vertebrae.
The ICRP model for plutonium behavior in the human body assumes that the skeleton retains plutonium with a biological half-life of 50 years, and the liver retains plutonium for 20 years (McInroy et al. 1979). When coupled to the results shown above, there appears to be an indication that not only is there added plutonium from site releases present in the autopsy samples obtained from Los Alamos, but also that the plutonium in Los Alamos residents appears to be due to exposures to plutonium that were earlier (longer ago) than atmospheric weapons testing exposures in the Denver population. It is important to note that the Denver population was not significantly exposed to plant releases from Rocky Flats. The downwind direction from Rocky Flats is predominately toward the east, and although there are persons living in this area, the population density is very low, and the likelihood that those persons were included in the Denver study is very low.

A vertebrae-to-liver ratio of one would be indicative of recent exposure. Larger ratio values would indicate that the exposure occurred at some point in the past, or that the exposures were higher in the past than more recent ones. An exponential function provides a good fit to the data shown in Fig. 17-14, which implies that the data are log-normally distributed. The median value, read from the chart at zero for the “X-Axis”, shows a value of 1.73 for Denver, corresponding to less-aged exposures. Los Alamos shows a median value for the vertebrae-to-liver ratio of nearly 2.72. The geometric standard deviation is 2.3 times larger for Los Alamos compared to Denver. If the air concentration had been constant over
time, this would be a ratio indicative of exposure that began about 10 y prior to autopsy. Given the large values of the ratio for Los Alamos, these data indicate that exposures in the early years were higher than the later years.

Reduction of the Uncertainty in Autopsy Results

The publicly released autopsy results were published as blind samples, with no information concerning identity or residential history for each case. In a small city such as Los Alamos, relatively few deaths occurred each year. The LANL autopsy data had five attributes that could be used to establish the identity of the donor without obtaining the data from official or private records: (1) year of death; (2) resident of the City of Los Alamos; (3) sex; (4) age; and (5) cause of death. These five attributes were used to match a number of the autopsy cases to Los Alamos area residents.

Death certificates and an index key for participants in the autopsy program were found in the LANL Archives during 2006 (LANL 1978). The death certificates facilitated development of residence histories for each autopsy case. The documents included information regarding the “usual residence” of the decedent, as well as the “length of stay” in the place of death. In instances where the individual died in Los Alamos and was also a resident of Los Alamos, this value was considered to be the length of time that the person lived in Los Alamos.

For each participant who reportedly lived in Los Alamos, historical telephone directories were consulted for the years that the decedent was expected to have lived there. Directories were available for the years 1943-1944 and 1946-1969. None were available for 1945. Addresses were listed as street addresses beginning in 1948. In the 1943, 1944, 1946, and 1947 directories, addresses were listed as “T-numbers.” Each house in the town was assigned a unique T-number. Historical maps of the original Technical Area were used to identify the exact location (latitude/longitude) of the T-number addresses. Several other sources were also consulted, including a September 1956 Atomic Energy Commission Albuquerque Operations Office directory, USAEC Los Alamos directories 1966-1972; a 1968-1969 Los Alamos school directory, and a 1964 Albuquerque Operations phone book.

For each name listed in the human tissue program information database, the “year of arrival in Los Alamos” and “length of time in Los Alamos” variables were used to determine in which directories each participant would likely be listed as a resident. In instances where the database contained two estimates of the “length of time in Los Alamos,” the estimate corresponding with the greatest number of years was used in this search. For each year that it was believed the participant lived in Los Alamos, the corresponding phone directory was consulted to find their address for that year. In many cases, participants lived at a given address for more than one year and the variables “begin year” and “end year”
were associated with each address. The 2-3 years preceding and following the time period during which it was believed that the participant lived in Los Alamos were also checked in the telephone directories.

For participants that could not be located using the historical telephone directories, several other approaches were available. Obituaries printed in the Los Alamos Monitor, which was published several times per week, often provided detailed information regarding how long an individual lived in Los Alamos and, in some cases, where they lived. If address information was not directly provided, residential histories could also be determined by searching under family members’ names during the relevant time periods. Ninety names were searched using this method and 36 matches were found. Marriage licenses often contained an address at the time of the marriage, but were also used to confirm familial relationships between some of the participants (such as father/daughter versus spouse). In some instances (particularly for women), the residential history could easily be tracked in the phone directories using the spouse’s name. One hundred and two marriage licenses were searched for using this method and nine matches were found. Lastly, online genealogy services were used as an additional source of information.

In total, there were 236 autopsy cases for which tissue activity data were available, with 60 of those participants having been LANL employees. Associated with these participants were 809 residential locations, of which 677 were identified as addresses and 542 could be geocoded using an Internet-based service so that distance to D Building and DP West could be calculated. For some addresses, a global positioning satellite (GPS) unit was used to determine coordinates. In some cases, the historical address is no longer a residence. To support spatial analysis, geological coordinates were obtained for the addresses of the participants using Tele Atlas®. For each address, range from D Building and DP West were calculated.

Fig. 17-14 on Page 17-39 also shows two sets of data plotted as cumulative frequency distributions: pre-1950 data and post-1950 data. The plot of post-1950 data is uncertain due to there being only three cases with data for vertebrae and liver, one of which is the outlier. The pre-1950 data has a larger median and slightly smaller geometric standard deviation than that shown for all data from Los Alamos.

Additional Avenues for Investigation

Solutions of the original samples taken under the LANL human tissue analysis program, as well as logbooks associated with the program, have been maintained by USTUR for many of the autopsy cases. Because of that, it may be possible to determine how much of any autopsied individual’s exposure was due to fallout or releases from LANL. A new method of measurement called Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can distinguish between weapons-grade plutonium that has not been used in a nuclear weapon and plutonium from fallout that resulted from a nuclear detonation. USTUR has
performed an initial study of the method with promising results. This method and new analysis of the samples might permit accurate estimation of how much of the plutonium found in the tissues of any former Los Alamos resident was due to global fallout and how much was due to releases of plutonium from LANL.

LAHDRA project team members have discussed the case of a clerical worker who worked near D Building and whose tissues were obtained for the autopsy program. It was suggested that the case might be a limiting case for exposure to plutonium for residents, since that individual was closer to the D Building than nearby residences. LANL staff analyzed that case in detail in a recent publication entitled “Los Alamos Study of Early Los Alamos Internal Exposures to Plutonium” (Miller et al. 2008). The clerical worker case was summarized in Table 3, “Bioassay Data for Clerical Worker.” LANL staff went on to conclude the following:

“Also of interest is the possible inhalation dose to members of the public in these days resulting from releases from the Los Alamos facilities. The dose was calculated for a clerical worker who was part of the Los Alamos plutonium autopsy study and had tissue burdens higher than those for others in the group of Los Alamos workers having low potential for exposure. A dose of this magnitude probably represents an upper limit for dose to workers who were not plutonium workers or who were merely town residents.”

The data for the identified worker are summarized in Table 3 of that article. LAHDRA team members take issue with at least aspects of this analysis. First, the method used for assessing her exposure was a Bayesian method pioneered by LANL but not generally used for internal exposure elsewhere. In particular, the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) project administered by the National Institute for Occupational Safety and Health (NIOSH) has declined to use this method for LANL cases. The use of Bayesian methods requires a priori assumptions that affect the final result. While these assumptions are not sufficiently detailed in the Miller et al. article to reproduce their results, careful reading of the article appears to indicate that the variability of the LANL resident data set was not considered or included in the assessment. The assessment was purported to be for the clerical worker, but as can be seen with the data from Los Alamos residents, human variability is large and failure to consider it is a major issue with the analysis. Thus, while the result may apply to that individual, the study failed to address all of the uncertainties that would permit LANL to assert their conclusion that it also applies to the resident population.

After LAHDRA team members examined Table 3 of the Miller et al. paper, they were unable to find the stated clerical worker’s bioassay data in any of the human tissue sample program publications or supporting materials obtained from Los Alamos. This issue was raised with LANL, and a response was provided that stated that LANL was unable to determine which case was represented, and also was unable
to find any matching data in the autopsy cases (Eisele 2008). They LANL staff went on to offer that the data came from a phone call to J. McInroy, the retired manager of the program. Table 3 of that publication might be in error, as the information presented does not agree with previous LANL publications of the data. LAHDRA project staff have been unable to determine if any of the other tables in that publication were also affected. The LAHDRA project team believes that this case is one of many that could be used to assess the impact of D Building releases on Los Alamos residents, but are not convinced that the data for the referenced clerical worker, if they can be located, will serve as a meaningful bounding case for any evaluation. If properly analyzed, the results and the results of other town residents would be useful for assessing the potential impacts of historical releases of plutonium from Los Alamos facilities.

LAHDRA team members and USTUR personnel have shared information concerning the autopsy results. A complete computer printout from the program dated 1991 has been obtained that can be reviewed against the publications that document the autopsy results. This printout has information in it that is protected under the Privacy Act, and cannot be released to the public. Attempts are underway to “clean up” the old computer output so that it can be scanned and optical-character-recognition processed to support entry into a spreadsheet to facilitate analysis. If that task is successful, the data from previous publications that LAHDRA currently uses (from the 1980 time frame) will hopefully be reconciled with the LANL data.

A review of other autopsy cases from New Mexico was made in an effort to review the possible plutonium exposure from the 16 July 1945 Trinity test. That review showed that there are no cases in the highest exposure contours of the downwind plume area as delineated by Quinn (Quinn 1990). The highest recorded plutonium levels were a woman from Truchas, New Mexico who was old enough to have been alive at the time of the Trinity test. Her liver concentration was 60 times higher than the average New Mexico resident. Truchas is next to the 1 mR h⁻¹ contour line (at H+12 hours), which is does not reflect doses from inhalation or ingestion of radioactive material (Quinn 1990).
Prioritization of Waterborne Radionuclide Releases

Since 1944, operations undertaken at LANL have produced liquid wastes containing radioactive materials. Waterborne radioactive waste was released without treatment to Acid Canyon from 1944 to 1951 (see Fig. 17-15), when a treatment plant became operational. The LAHDRA team calculated Priority Indices for waterborne radionuclides in the following categories: total plutonium, \(^{238}\text{Pu}\), \(^{239}\text{Pu}\), \(^{89}\text{Sr}\), \(^{90}\text{Sr}\), tritium, gross alpha, and gross beta radioactivity. LANL also reported the following radionuclides at various times over the years; effluent data were tabulated but priority indices are not presented herein for \(^{140}\text{Ba}/^{140}\text{La}\) (radioactive lanthanum), \(^{227}\text{Ac}\), \(^{241}\text{Am}\), \(^{7}\text{Be}\), \(^{134}\text{Cs}\), \(^{137}\text{Cs}\), \(^{57}\text{Co}\), \(^{60}\text{Co}\), \(^{54}\text{Mn}\), \(^{22}\text{Na}\), \(^{83}\text{Rb}\), \(^{84}\text{Rb}\), \(^{75}\text{Se}\), \(^{85}\text{Sr}\), and \(^{88}\text{Y}\). It is important to note that data were not available for all radionuclides for all years. For example, from 1962 through 1971, \(^{239}\text{Pu}\) measurements were not reported, but total plutonium measurements were. The reasons for the changes in nuclides analyzed and/or reported over time are not known. In some later years, uranium measurements were made, but associated results were stated in terms of milligrams of uranium of unstated \(^{235}\text{U}\) enrichment. As a result, since information that has been reviewed indicates that overall waterborne releases of uranium were relatively low, uranium was not evaluated in this assessment. The radionuclides named above are the only radionuclides for which historical compilations of liquid releases prepared by LANL were found.

Data Sources

Three main data sources for waterborne radioactive effluents from LANL operations were found by the LAHDRA team:

![Fig. 17-15. During early Los Alamos operations, untreated liquid radioactive wastes were discharged to Acid Canyon through this pipe.](image)
• (Andrews ca. 1973) – “Joe Graf Binders” 1 and 2– Two binders of documents assembled by LANL Environment, Safety, and Health (ES&H) staff for group leader Joe Graf in the early 1970s that document releases from LANL before 1973. This was done to support development of a draft site-wide Final Environmental Impact Statement (FEIS). The FEIS was finally published in 1979. The documents assembled in these binders include records of room air concentrations, stack monitoring data, ES&H reports, and miscellaneous memos.


Priority index (PI) values were calculated by computing the volume of liquid that would be required to dilute the annual activity released to be equal to the worst-case maximum effluent concentration documented in Title 10 of the Code of Federal Regulations, Part 20 (USNRC 2003). The priority indices are intended to be guidelines for determining if a nuclide set requires further iterations of calculation and refinement, or if it warrants lower priority relative to other radionuclides (O’Brien and Burmeister 2004). For example, a PI of $10^6$ indicates that 1 million L of liquid (water) would be required to dilute the released material to a concentration equal to the maximum effluent concentration. The priority index approach does not consider dilution and dispersion that can occur between the release point and points of potential public exposure. Although the lowest available (most conservative) effluent concentration limits are used, the priority indices do not otherwise address uptake factors. They do not consider decay in transport, which means as calculated, the priority index approach would tend to overstate the importance of short-lived materials. Within these limitations, PIs provide a simple tool for establishing the relative importance of various liquid-borne releases.

Priority Index was calculated as follows:

$$Priority\ Index\ (PI, L) = \frac{Total\ Nuclide\ Activity\ Released\ in\ \mu Ci\ \gamma^{-1}}{Maximum\ Effluent\ Concentration\ in\ \mu Ci\ mL^{-1}} \times 1,000\ \text{mL}\ L^{-1}$$
The maximum effluent concentration values shown in Table 17-9 were used (USNRC 2003). The concentration limit used for gross alpha radioactivity was the value for $^{239}$Pu, which has the same value as $^{238}$Pu, and the value for $^{89}$Sr was used for prioritizing releases of gross beta radioactivity.

Table 17-9. Maximum Effluent Concentrations Used for Waterborne Radionuclide Prioritization

<table>
<thead>
<tr>
<th>Nuclide Category</th>
<th>Maximum Effluent Concentration ($\mu$Ci mL$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Alpha Radioactivity</td>
<td>$2.00 \times 10^{-8}$</td>
</tr>
<tr>
<td>Gross Beta Radioactivity</td>
<td>$8.00 \times 10^{-6}$</td>
</tr>
<tr>
<td>$^3$H</td>
<td>$1.00 \times 10^{-4}$</td>
</tr>
<tr>
<td>Plutonium</td>
<td>$2.00 \times 10^{-8}$</td>
</tr>
<tr>
<td>$^{238}$Pu</td>
<td>$2.00 \times 10^{-8}$</td>
</tr>
<tr>
<td>$^{239}$Pu</td>
<td>$2.00 \times 10^{-8}$</td>
</tr>
<tr>
<td>$^{89}$Sr</td>
<td>$8.00 \times 10^{-6}$</td>
</tr>
</tbody>
</table>

For the years 1948 to 1996, LANL liquid waste and effluent data were collected and analyzed by the LAHDRA project team. No summary data were found for the years 1974, 1975, or 1976. Given the releases in years preceding and just after that period, and considering the operational history documents that were reviewed, it is considered unlikely that releases during these missing years would significantly change any of the conclusions of this prioritization if they were found. A Microsoft Access® database was created to tabulate the effluent data that were captured and to link them to specific LANL documents that were assembled by the LAHDRA project team. In most cases, these documents are available as scanned document images as Adobe Acrobat® Portable Document Format (PDF) files. The database records in turn link to associated document image files to allow viewing of the actual LANL references for the data of interest. That database is called the Off-Site Releases (OSR) database and contains information for both airborne and waterborne effluent data.

Summary of Results for Prioritization of Waterborne Releases

Table 17-10, Table 17-11, and Table 17-12 comprise the summary data for the prioritization of waterborne radionuclide releases from LANL. The first two tables present annual releases of the various radionuclides, in curies. The third table presents priority indices for each radionuclide on an annual basis, calculated as the dilution volume required for dilution of the reported release quantity to the MPC. It was determined that the radionuclides in Table 17-12 were relatively insignificant due to the very low activity reported; therefore in Fig. 17-16, the plotted nuclides of interest are Pu, $^{238}$Pu, $^{239}$Pu, $^{89}$Sr, $^{90}$Sr, $^3$H, gross alpha, and gross beta radioactivity. In this calculation, a data cutoff of 1996 was used since it was
deemed that this was far enough into the modern era, and prioritization was primarily focused on earlier eras before treatment and monitoring capabilities had developed.

**Plutonium**: Waterborne plutonium effluent data throughout the years have been reported as Pu, $^{238}$Pu, or $^{239}$Pu. During the very early years of LANL operations, the constant value reported for plutonium would suggest that there was one number that was “spread” among those years as an estimate. In later years, for which plutonium measurements were specified for several nuclides including $^{239}$Pu, the LAHDRA project team entered the values into the database as $^{239}$Pu. For instance, for 1993, plutonium was reported as Pu-$^{238,239,240}$ and was entered into database as $^{239}$Pu. Then again in 1994, plutonium releases were reported as Pu-$^{238,239,240}$, but as $^{238}$Pu and $^{239}$Pu for both 1994 and 1995. In this case, the plutonium was entered as $^{238}$Pu and $^{239}$Pu. Separate radionuclide reporting was used whenever possible. The priority indices for plutonium range from approximately $10^7$ to around $10^{11}$. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

**Strontium**: The priority index values for strontium range from $10^5$ to $10^9$. It is important to note that LANL changed reporting conventions for strontium several times. Sometimes $^{89}$Sr and $^{90}$Sr were reported separately, and sometimes they were not. In the later years, when $^{89}$Sr is not reported separately, the strontium values were recorded as $^{90}$Sr in the database by the LAHDRA project team. This may result in increased PI values for $^{90}$Sr, but since the MPC for $^{90}$Sr is lower than that for $^{89}$Sr, this is a conservative assumption. Note that from 1989 to 1995, $^{89}$Sr was either not in the compilations or was reported as Sr-$^{82,85,89,90}$ all in one. These data were entered into the database as $^{90}$Sr. That is why $^{89}$Sr does not show data points in Fig. 17-16 for those years. Subsequently, it appears that $^{90}$Sr has increased in priority relative to $^{89}$Sr for these years. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

**Tritium**: The PI values for tritium range from $10^6$ to $10^8$. Based on the currently available information, it would appear that tritium warrants lower priority than the other radionuclides. See Table 17-10 for annual release totals in curies (Ci) and Table 17-12 for priority indices (dilution volume, L).

**Other Radionuclides**: In Table 17-11 there are reported effluent values for other reported radionuclides. PI values calculated for these radionuclides ranged from $10^4$ to $10^8$, except for one $^{227}$Ac value at $10^{11}$ and several $^{241}$Am values of $10^9$. There were a number of these radionuclides present, but none in concentrations that would yield greater priority indices than the primary nuclide set. The information for these “other” radionuclides is included for completeness.
Conclusions regarding prioritization of waterborne radionuclides

It is important to note that the information compiled here is for waterborne effluents. The current results indicate that, based on the assembled information as evaluated to date, plutonium would warrant the highest concern for waterborne radionuclide releases. It is not yet possible to definitively address the relative importance of waterborne effluents versus airborne effluents. It can be noted that, in general, pathways for public exposure from liquid releases appear to have not been as complete as those for airborne releases, due to the ephemeral nature of surface water flow in many cases, with a large part of off-site transport possibly occurring during heavy rains or runoff from periods of snow melting.

Comments and Issues

In the later years, when plutonium or strontium radionuclides were not listed by nuclide separately, values were entered into the database as $^{239}$Pu and $^{90}$Sr, respectively. This may have result in increased PI values for $^{239}$Pu or $^{90}$Sr. Since the maximum effluent concentration values for these radionuclides are lower than for their sister radionuclides $^{240}$Pu and $^{89}$Sr, this was a conservative assumption. There were two years (1970 and 1971) for which gross gamma radioactivity was reported (LAHDRA 2000); however, because LASL’s Annual Environmental Surveillance report for 1971 did not include gross gamma measurements, the data on gross gamma for 1970 and 1971 were not included in this work.
Table 17-10. Waterborne Radionuclide Releases from LANL (Ci) Based on LANL Compilations a
Year

Pu

Pu-239

Sr-89

Sr-90

1945

1.02E+ 00

Pu-238

3.50E-03

6.05E-02

1.88E-01

Sr-89, Sr-90

3.00E+ 00

H-3

1946

1.02E+ 00

3.50E-03

6.05E-02

1.88E-01

3.00E+ 00

1947

1.22E+ 00

3.50E-03

6.05E-02

1.88E-01

3.00E+ 00

1948

1.22E+ 00

3.50E-03

6.05E-02

1.88E-01

3.00E+ 00

1949

1.22E+ 00

3.50E-03

6.05E-02

1.88E-01

3.00E+ 00

1950

2.02E+ 00

3.50E-03

6.05E-02

1.88E-01

3.00E+ 00

1951

2.41E+ 00

3.50E-03

3.05E-02

1.77E-01

3.25E+ 00

2.45E-03

1952

8.01E-01

3.50E-03

2.05E-02

1.73E-01

5.00E+ 00

4.11E-03

1953

2.24E-03

3.50E-03

2.05E-02

1.73E-01

5.00E+ 00

4.97E-03

1954

3.21E-03

3.50E-03

2.05E-02

1.73E-01

5.00E+ 00

5.42E-03

1955

3.14E-03

3.50E-03

2.05E-02

1.73E-01

5.00E+ 00

1.06E-01

1956

1.81E-03

3.50E-03

1.89E+00

5.03E-01

5.00E+ 00

1.07E-01

2.30E-01

1957

1.94E-03

3.50E-03

4.47E-01

2.47E-01

5.00E+ 00

1.68E-02

2.33E-01

1958

9.16E-02

3.50E-03

2.25E-01

2.01E-01

5.00E+ 00

9.46E-03

1.65E+00

1959

2.06E-03

3.50E-03

7.25E-02

1.81E-01

5.00E+ 00

9.84E-03

4.40E+00

1960
1961

4.36E-03
1.07E-02

3.50E-03
3.50E-03

8.85E-02
3.85E-02

1.85E-01
1.75E-01

5.00E+ 00
5.00E+ 00

1.34E-01
7.55E-01

1.35E+00
6.05E-01

1962

6.84E-03

1.80E-02

1.00E-03

5.00E+ 00

1.15E-02

1.22E+00

1963

6.81E-03

1.49E-01

3.98E-02

5.00E+ 00

2.84E-02

1.28E+00

1964

3.11E-03

6.07E-02

8.87E-02

3.20E+ 00

5.67E-03

2.67E+00

1965

4.48E-03

4.23E-02

6.18E-02

2.00E+ 00

7.30E-03

8.13E-01

1966

2.50E-03

2.44E-02

3.56E-02

2.00E+ 00

4.73E-03

3.98E-01

1967

6.58E-03

5.35E-02

1.34E-02

2.00E+ 00

1.51E-02

6.86E-01

1968

4.20E-03

3.26E-02

8.20E-04

4.89E-02

5.16E-03

3.26E-01

1969

8.36E-03

5.46E-02

1.31E-02

1.54E-03

1970

6.47E-03

1.54E-02

2.24E-02

1971

4.24E-03

2.80E-02

Gr oss Alpha

Gross Beta

4.33E-03

4.19E-01

8.28E-03

6.38E-01

2.70E-03

6.50E-04

4.68E-03

1.21E-02

1.16E-02

1.09E+00

1972

7.86E-03

1.10E-03

4.15E-03

6.51E-03

9.60E+ 00

1.49E-02

3.96E-01

1973

8.60E-03

8.00E-04

4.90E-03

7.50E-03

1.90E+ 01

1.55E-02

9.99E-01

1977

2.63E-03

1.55E-03

2.29E-03

3.10E-02

3.97E+ 01

1978

4.36E-03

2.05E-03

2.67E-03

1.05E-02

1.41E+ 01

1979

1.76E-03

6.37E-04

6.10E-03

1.42E-02

3.31E+ 01

1980

8.23E-03

1.31E-03

4.10E-02

1.81E-02

4.50E+ 01

1981

3.35E-03

5.54E-02

4.16E-02

2.37E-02

1.74E+ 01

1982

3.10E-03

1.68E-02

1.18E-02

1.34E-02

1.53E+ 01

1983
1984

1.10E-02
6.19E-03

4.23E-02
8.23E-03

5.68E-02
2.62E-01

2.54E-03
7.03E-03

1.04E+ 01
1.32E+ 01

1985

3.92E-03

5.83E-03

9.01E-03

1.26E-03

7.02E+ 01

1986

1.50E-03

3.60E-03

9.20E-03

6.90E-04

2.45E+ 01

1987

1.40E-03

3.20E-03

6.40E-02

1.00E-03

1.11E+ 02

1988

1.10E-03

3.20E-03

8.10E-02

2.00E-04

2.62E+ 01

1989

6.00E-04

2.00E-03

1.80E-02

1.10E-03

4.10E+ 01

1990

2.00E-04

6.00E-04

2.53E-01

1.20E+ 01

1991

3.00E-04

1.00E-03

1.24E-01

1.06E+ 01

1992

3.20E-04

3.90E-04

1.70E-02

1.06E+ 01

1.08E-03

3.40E-03

2.66E+ 00
2.23E+ 00

1974
1975
1976

1993
1994

2.80E-03

4.00E-04

3.70E-02

1995

3.40E-03

6.00E-04

6.00E-04

7.31E-01

1996

2.25E-03

3.90E-04

6.00E-04

1.02E+ 00

a

6.60E-04

Note regarding scientific notation: 4.96E+05 equals 4.96×10+5, which equals 4.96×100,000 or 496,000.

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### Table 17-11. Other Waterborne Radionuclide Releases from LANL (Ci) Based on LANL Compilations

<table>
<thead>
<tr>
<th>Year</th>
<th>Ba-La-140</th>
<th>Ac-227</th>
<th>Cs-137</th>
<th>Am-241</th>
<th>Be-7</th>
<th>Co-57</th>
<th>Co-60</th>
<th>Mn-54</th>
<th>Na-22</th>
<th>Rb-83</th>
<th>Rb-84</th>
<th>Sr-75</th>
<th>Sr-85</th>
<th>Y-88</th>
<th>Cs-134</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>2.00E-03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1946</td>
<td>2.00E-03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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*Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.*
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a Note regarding scientific notation: 4.96E+05 equals 4.96×10^5, which equals 4.96×100,000 or 496,000.
Fig. 17-16. Priority Indices for Waterborne Radionuclide Releases from LANL.
References


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Chapter 18: Screening-Level Evaluation of Airborne Plutonium Releases from DP West Site

Because airborne plutonium releases from DP West Site were documented to have been significantly higher than has been officially reported and residential areas were located quite close to the site, a screening assessment using the methodology of National Council on Radiation Protection and Measurements (NCRP) Report No. 123 (NCRP 1996) was performed for releases from DP West Site Building 12 stacks during 1949, the apparent year of peak emissions. The NCRP methodology uses three levels of screening calculations for atmospheric transport pathways. Level I screening uses the simplest approach and incorporates a high degree of conservatism to avoid underestimating doses to people. Level II screening accounts for dispersion in the atmosphere and combines all significant pathways into a single screening factor. Level III screening includes more definitive pathways analysis for inhalation, external exposure, and ingestion of terrestrial food products in the form of vegetables and/or animal food products.

The documented release of 86.6 g of $^{239}$Pu from the DP West Building 12 stacks during calendar year 1949 [see Fig. 18-1; (Hyatt 1956)] was converted to a $^{239}$Pu release rate using a specific activity value of 0.063 Ci g$^{-1}$ (ANL/EVS 2005). This is the approximate value that the LASL investigators used in 1956 to convert from measured total alpha activity to the total activity released values, in grams, that were reported in the 1956 memorandum. Multiplicative sample line loss and filter burial correction factors of 5 and 2.33, respectively, were applied based on evaluations conducted by LANL staff (Fuehne 2008). The average $^{239}$Pu release rate for 1949 was calculated as follows:

$$86.6 \text{ g} \times 5.0 \times 2.33 \times 0.063 \text{ Ci g}^{-1} \times 3.7 \times 10^{10} \text{ Bq Ci}^{-1} \div 3.2 \times 10^7 \text{ s y}^{-1} = 7.35 \times 10^4 \text{ Bq s}^{-1} 239\text{Pu}$$

The annual exhaust volume of 1.88x$10^9$ m$^3$ y$^{-1}$ for the Building 12 stack [see Fig. 18-2; (Andrews ca. 1973)] was converted to 58.8 m$^3$ s$^{-1}$ to support calculation of the average concentration of plutonium in the stacks.

For the screening-level evaluation of releases from the DP West Building 12 stacks in 1949, the closest potentially exposed members of the public were residents at the trailer park located 1 km west of the stacks (see Fig. 18-3). Based on the Level I screening method’s assumption that the wind blew toward the closest potentially exposed individual 25% of the time, concentrations at that point were estimated as one-quarter of the average stack concentration. The exposure point concentration (Bq m$^{-3}$) was multiplied by the all-pathways screening factor (Sv per Bq m$^{-3}$) from Table 1.1 of NCRP Report No. 123 to yield a screening value that was compared to a limiting value.
### DP WEST, BLDG. 12 STACK SAMPLING.

Total activity released from all Stacks in Grams/Month.

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<td>0.98</td>
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<td>10.43</td>
<td>16.72</td>
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**Fig. 18-1.** Table of corrected annual releases from DP West Building 12 stacks for 1948 through 1955 per Hyatt (1956)
Fig. 18-2. Sheet showing exhaust flow volume and (uncorrected) annual releases from DP West Building 12 Stacks for 1948-1972 (Andrews ca 1973). This handwritten sheet is the most basic documentation found of the 1.2-Ci release total that LASL reported in 1979 for operations before 1973.
Fig. 18-3. Annotated modern aerial photograph showing former locations of DP West Site Building 12 stacks and nearby residential areas. Trailer park drawing is excerpted from USAEC Drawing LA FM 125 (Sheets L7-SW-1 and L6-SE-1).
For this screening assessment, the limiting value selected was $1.67 \times 10^{-4} \text{ Sv y}^{-1}$, which is based on 1 in 100,000 added risk of fatal or non-fatal cancer using a risk factor of $6.0 \times 10^{-2} \text{ Sv}^{-1}$ (ICRP 1990).

**It is important to emphasize that the results of the screening calculations are strictly for comparison with an environmental standard (limiting value), to determine if compliance with that standard is assured or further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals.**

For Level II screening, the release height was determined to be 58.6 ft above ground level based on LASL Drawing 12T35397A2 (See Fig. 18-4). The dimensions of the portion of Building 12 that housed the filters and precipitators and faced west was estimated to have been 14.3 m high by 27.9 m wide (see Fig. 18-5) based on analysis of Photograph 2284 and a report documenting demolition of the building (Christensen et al. 1975).

The atmospheric concentration at the exposure point was estimated using Equation 1 with $f = 0.25$, $Q = 7.35 \times 10^4 \text{ Bq s}^{-1}$, and $u$ equal to the suggested default value of 2 m s$^{-1}$.

$$C = \frac{f \cdot Q \cdot B}{u}$$

(1)

Where:

- $C =$ average atmospheric concentration at exposure point, $\mu\text{Ci m}^{-3}$
- $f =$ fraction of time that the wind blew toward the receptor of interest
- $Q =$ release rate ($\mu\text{Ci s}^{-1}$)
- $B =$ the Gaussian plume model diffusion factor modified for building wake effects (from Fig. 1.5 of NCRP Report No. 123)
- $u =$ mean wind speed, m s$^{-1}$

The resulting concentration was multiplied by the atmospheric screening factor from Table 1.1 of NCRP Report No. 123 to obtain the Level II screening value. In accordance with NCRP recommendations, that screening value was compared to 10% of the limiting value in recognition of uncertainties inherent within the calculations and associated assumptions.
Fig. 18-4. Drawing of DP West Site Building 12 filter house and stacks

Fig. 18-5. Annotated section of Photograph 2284 showing Building 12 from the east
Historical documents and interviews with residents of Los Alamos indicate that residents were allowed to maintain vegetable gardens after World War II, including at the trailer park west of DP Site, but no evidence has been found of production of animal food products within the townsite. The two screening values were summed and compared to the screening limit (i.e., the limiting value divided by ten as in Level II) to determine whether further evaluation of historical exposures is warranted. In Level III screening, the exposure point air concentration from Level II screening was multiplied by a screening factor for inhalation and external sources/submersion from Table 1.1 of NCRP Report No. 123 and by a second screening factor for vegetable consumption from the same table to obtain screening values for inhalation and external exposure as well as for consumption of home grown vegetables.

**Screening Worksheets**

The final 18 pages of this chapter present copies of the applicable worksheet pages by which the NCRP Report No. 123 screening method was applied to the DP West Building 12 stack releases.

**Results of the Screening**

The results of preliminary screening of airborne $^{239}$Pu releases from DP West site Building 12 stacks during 1949 are presented in Table 18-1. In Level I and Level II screening, the screening value exceeded the limiting value by at least four orders of magnitude, prompting application of the screening methodology at the next highest level.

The results of the screening calculations are strictly for comparison with an environmental standard (limiting value), to determine if compliance with that standard is assured or further investigation is warranted. The screening values are not intended to represent estimates of actual doses to individuals.

The results of Level III screening, which again exceeded the limiting value by over four orders of magnitude, indicate that airborne $^{239}$Pu releases from Building 12 stacks— as represented by estimated releases during 1949— warrant further evaluation by experts in environmental radiological assessment.
Table 18-1. Summary of the preliminary screening of airborne $^{239}\text{Pu}$ releases from DP West Site Building 12 stacks during 1949 using the methodology of NCRP Report No. 123

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<th>Features of Screening Methodology</th>
<th>Screening Value ($\text{Sv y}^{-1}$)</th>
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<th>NCRP Guidance</th>
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<td>Vent air, specific pathways (inhalation, external exposure, consumption of vegetables), same dispersion assumptions as Level II.</td>
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<td>&quot;Seek assistance from experts in environmental radiological assessment&quot;</td>
</tr>
</tbody>
</table>
References


1.1 Atmosphere Screening Level I: Vent Air

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

I-A-1: Specify the radionuclide released by chemical symbol and atomic mass number (for example, $^{131}$I).

I-A-2: Specify the release rate, $Q$, of the radionuclide entered in I-A-1. This release rate is obtained by estimating the amount released continuously or intermittently in 1 y (Bq y$^{-1}$) and dividing by the number of seconds in a year ($3.2 \times 10^7$ s y$^{-1}$).

I-A-3: Enter the volumetric flow rate of the exhaust vent, $V$. If the volumetric flow rate of the exhaust vent is unknown, assume a value of 0.3 m$^3$ s$^{-1}$.

I-A-4: Calculate the air concentration in the exhaust vent, $C_e$, for the radionuclide by dividing the release rate (I-A-2) by the volumetric flow rate (I-A-3).

I-A-5: Assume that the wind blows only 25 percent of the time toward the potentially exposed individual. Multiply the values in I-A-4 by 0.25 to calculate the atmospheric concentration, $C$.

I-A-6: Select from Table 1.1 the all paths screening factor, $SF$, for the radionuclide entered in I-A-1. The value of $SF$ includes the combined effects of all significant potential pathways of exposure.

I-A-7: Calculate the screening value, $SV$, by multiplying the atmospheric concentration (calculated in I-A-5) by the $SF$ (I-A-6).

I-A-8: Sum the results in I-A-7 for all radionuclides for all sheets.

I-A-9: Enter the appropriate limiting value. This limiting value may be equivalent to a regulatory dose limit.

I-A-10: If the screening value of the dose estimate in I-A-8 is less than the limiting value entered in I-A-9, compliance with the limiting value is assured. If the value in I-A-8 is greater than the limiting value, proceed to the next level of screening (Section 1.2).
I-A-1: Radionuclide

Pu-239

I-A-2: Release rate, $Q$

$7.4 \times 10^4$ Bq s$^{-1}$

I-A-3: Volumetric flow rate, $V$

$58.8$ m$^3$ s$^{-1}$

I-A-4: Exhaust concentration: $C_e = \frac{Q V}{V}$

$1,300$ Bq m$^{-3}$

I-A-5: Atmospheric concentration: $C = 0.25 C_e$

$310$ Bq m$^{-3}$

I-A-6: Enter Table 1.1 $SF$ values for the radionuclide

$1.0 \times 10^0$ Sv per Bq m$^{-3}$

I-A-7: Screening value: $SV = C \times SF$

$310$ Sv y$^{-1}$

I-A-8: Sum results for all radionuclides in I-A-7

$310$ Sv y$^{-1}$

I-A-9: Limiting value

$1.67 \times 10^{-4}$ Sv y$^{-1}$


No

Yes– STOP
No– Proceed to Section 1.2
1.2 Atmosphere Screening Level II: All Pathways

II-bi: Basic Information, bi, Required for Completing
Screening Levels II and III
(for description of parameters see Figure 1.3)

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

II-bi-1: Enter radionuclide from I-A-1 by chemical symbol and
atomic mass number.

II-bi-2: Enter for the radionuclide the air concentration in the
exhaust vent, \( C_e \), as calculated in I-A-4.

II-bi-3: Determine the height above ground, \( H \), at which the release
will occur. This determination should exclude the effect of
plume rise. If the release occurs in a narrow valley, use
\( H = 0 \).

II-bi-4: Determine the height, \( h_b \), and width, \( h_w \), of the building
most influencing the dispersion process. This should be the
building on which the release point is located unless there
is a much larger building in the immediate vicinity, in
which case the latter building should be used for this pur-
pose.

II-bi-5: For the building most influencing flow, determine the sur-
face area, \( A_0 \), of the side of the building nearest the location
of potential human exposure. Multiply the height of the
building, \( h_b \), by the width of the building side nearest the
potential receptor, \( h_w \).

II-bi-6: Determine the diameter of the stack or vent from which
the radionuclide is being released. If the vent is other than
circular, determine its equivalent circular diameter, \( d \), by
multiplying the area of the vent by 1.3 and taking the
square root of the product.

II-bi-7: Determine the wind speed, \( u \), at the release point. If data
are not readily available, assume a value of 2 m s\(^{-1}\).

II-bi-8: Determine the distance, \( x \), between the release point and
the nearest point routinely occupied by humans. Proceed
to II-A-1.
II-bi-1: Radionuclide from I-A-1 Pu-239

II-bi-2: Enter from I-A-4 the calculated concentration in the exhaust vent, $C_e$ 1,300 Bq m$^{-3}$

II-bi-3: Release height, $H$ 17.9 m

II-bi-4: Building height, $h_b$ 14.3 m

and building width, $h_w$ 27.9 m

II-bi-5: Building surface area: $A_G = h_b h_w$ 399 m$^2$

II-bi-6: Diameter of stack or vent, $d$ 1.3 m

II-bi-7: Wind speed, $u$ 2 m s$^{-1}$

II-bi-8: Distance from release point to point of exposure, $x$ 1047 m

Proceed to II-A-1
II-A: Initial Decisions

II-A-1: If the release point and the exposure point are both located (a) on the roof, or (b) on the same side of the building, or (c) in the same building, or confinement of the plume is important, proceed to Section II-B. If none of these conditions apply, proceed to II-A-2.

II-A-2: Multiply the building height, $h_b$, in II-bi-4 by 2.5. The result will be used to determine the effect of the building on the atmospheric dispersion of the released radionuclide(s). Enter the release height, $H$. Compare the result of the multiplication with $H$. If $H$ in II-bi-3 is greater than 2.5 times $h_b$, proceed to Section II-C. This condition represents the case where the building will not affect atmospheric dispersion. In this case proceed to II-C. If $H$ is less than or equal to 2.5 times $h_b$, proceed to II-A-3. This condition represents the case where the building will affect atmospheric dispersion.

II-A-3: To determine which type of atmospheric dispersion model should be used for situations in which building wakes are formed, take the square root of the building surface area, $A_c$, (II-bi-5) and multiply the result by 2.5. If the distance, $x$, between the point of release and the nearest point of exposure (II-bi-8) is equal to or less than 2.5 times the square root of $A_c$, or is equal to or less than 100 m proceed to Section II-D. This condition represents the case where the receptor is in the near-wake region of the building. If the distance, $x$, between the point of release and the nearest point of exposure (II-bi-8) is greater than 2.5 times the square root of $A_c$, and greater than 100 m proceed to Section II-E. This condition represents the case where the receptor is outside the near-wake region of the building.
II-A-1: Are the point of release and the potentially exposed individual located as described on the preceding page? 

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yes</strong>– Proceed to Section II-B</td>
<td><strong>No</strong>– Proceed to Section II-A-2</td>
</tr>
</tbody>
</table>

II-A-2

hₜ (II-bi-4) 
2.5 hₜ = 
H (II-bi-3) 

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>14.3 m</td>
<td>36 m</td>
</tr>
<tr>
<td>17.9 m</td>
<td></td>
</tr>
</tbody>
</table>

Is H greater than 2.5 hₜ?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No</strong></td>
<td></td>
</tr>
</tbody>
</table>

Yes– Proceed to Section II-C

(no building wakes)

No– Proceed to Section II-A-3

(building wakes)

II-A-3

Aₜ (II-bi-5) 
2.5 Aₜ^½ = 
x (II-bi-8) 

<p>| | |</p>
<table>
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<tr>
<td>399 m²</td>
<td>50 m</td>
</tr>
<tr>
<td>1047 m</td>
<td></td>
</tr>
</tbody>
</table>

Is x equal to or less than 2.5 Aₜ^½ or equal to or less than 100 m?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No</strong></td>
<td></td>
</tr>
</tbody>
</table>

Yes– Proceed to Section II-D

(near wake region)

No– Proceed to Section II-E

(outside near-wake region)
II-E: Receptor Outside the Near-Wake Region of Building

Condition: Distance to exposure point is greater than 2.5 times the square root of the building surface area, \( A_o \), and greater than 100 m.

II-E-1: If the downwind distance to the nearest point of potential human exposure, \( x \), is less than 2 km from the point of release, use Figure 1.5 to determine the value of the building wake dispersion factor, \( B \), corresponding to the building surface area, \( A_o \), given in II-bi-5 and \( x \) in II-bi-8.

If the downwind distance, \( x \), to the nearest point of potential human exposure is greater than 2 km from the point of release, use Figure 1.4, assuming a release height at ground level, or 0 m. Substitute the value \( P \) from Figure 1.4 for the building wake dispersion factor.

II-E-2: Enter radionuclide, release rate, \( Q \), and wind speed, \( u \). To calculate the downwind atmospheric concentration for each radionuclide for the potentially exposed individual, assume that the wind blows 25 percent of the time toward the potentially exposed individual. Multiply the release rate from I-A-2 by the dispersion factor, \( B \) or \( P \), in II-E-1 and by 0.25; then divide by the wind speed, \( u \), given in II-bi-7. However, if \( u > 5 \text{ ms}^{-1} \), use \( u = 5 \text{ ms}^{-1} \) in this calculation.

Enter the calculated atmospheric concentration, and proceed to Section II-F.
II-E-1: Dispersion factor $B$ from Fig. 1.5 or $P$ from Fig. 1.4 [see Exhibits G and H] $4 \times 10^{-5}$ m$^{-2}$

II-E-2: Radionuclide Pu-239

Release rate, $Q$: $7.35 \times 10^4$ Bq s$^{-1}$

Wind speed, $u$: 2 m s$^{-1}$

Atmospheric concentration: $0.37$ Bq m$^{-3}$

$C = 0.25 \frac{Q}{u} (B \text{ or } P)$

[0.25 (I-A-2) (II-E-1)] (II-bi-7)$^{-1}$

Proceed to Section II-F
II-F: Comparison of Screening Value Using Screening Limiting Dose

II-F-1: Enter the radionuclide from II-bi-1. Enter the atmospheric concentration calculated for the radionuclide from Section II-B-1, II-B-2, II-C-2, II-D-1, or II-E-2, depending on atmospheric concentration model used.

II-F-2: Enter from Table 1.1 the all paths screening factor, $SF$, for the radionuclide.

II-F-3: Multiply the atmospheric concentration entered in II-F-1 by the atmospheric screening factor entered in II-F-2 to obtain the screening value, $SV$.

II-F-4: Sum the results in II-F-3 for all sheets and all radionuclides.

II-F-5: Take the limiting value from I-A-9, divide by 10, and enter. (Note: There are uncertainties inherent within the calculations and assumptions made in this Section. Dividing this limiting value by a factor of 10 reduces the possibility of exceeding the limiting value because of these uncertainties.)

II-F-6: If II-F-5 is greater than II-F-4, compliance with the limiting value is assured. If the value in II-F-5 is equal to or less than II-F-4, proceed to Screening Level III.
II-F-1: Radionuclide from II-bi-1
   Pu-239

   Atmospheric concentration, \( C \), from
   II-B-1, II-B-2, II-C-2, or II-E-2
   \( 0.37 \text{ Bq m}^{-3} \)

II-F-2: Atmospheric screening factor, \( SF \),
   from Table 1.1 for each radionuclide
   \( 1 \times 10^6 \text{ Sv per Bq m}^{-3} \)

II-F-3: Calculate screening value:
   \[ SV = C \times SF \]
   (II-F-1) (II-F-2)
   \( 0.37 \text{ Sv y}^{-1} \)

II-F-4: Sum the results in II-F-3 for all sheets and radionuclides
   \( 0.37 \text{ Sv y}^{-1} \)

II-F-5: (I-A-9) \( \times 0.1 \)
   \( 1.67 \times 10^{-5} \text{ Sv y}^{-1} \)

II-F-6: Is II-F-5 greater than II-F-4?
   No

Yes– STOP
No– Proceed to Screening Level III
1.3 Atmosphere Screening Level III: Specific Pathways

III-A: Calculation of Inhalation and External Exposure

*Condition:* It is assumed that inhalation and external exposure pathways always exist at the location corresponding to distance, \( x \), given in II-bi-8.

*Note:* Use a separate sheet for each radionuclide until all radionuclides are summed.

III-A-1: Enter the radionuclide and the calculated atmospheric concentration from Section II-F-1 for the downwind distance, \( x \).

III-A-2: For each radionuclide, enter the screening factor given in Table 1.1. These factors include the combined effects of internal exposure through inhalation and external exposure to the contaminated plume and ground surface.


Sum the results for the screening dose.
### III-A-1: Radionuclide from II-F-1

- **Pu-239**
- Atmospheric concentration, $C$, from II-F-1: 0.37 Bq m$^{-3}$

### III-A-2: Screening factor, $SF$, from Table 1.1

- 0.55 Sv per Bq m$^{-3}$

### III-A-3: Screening value for inhalation and external exposure for each radionuclide: $SV = C \times SF$

- (II-A-1) (II-A-2): 0.20 Sv y$^{-1}$
- Sum of results for all radionuclides and for all sheets: 0.20 Sv y$^{-1}$
III-B: Exposure via the Ingestion of Terrestrial Food Products

Note: Use a separate sheet for each radionuclide until all radionuclides are summed.

III-B-1: Enter radionuclide from III-A-1.

III-B-2: For conditions where pasture and/or vegetable gardens exist at the receptor location (distance x) given in II-bi-8, enter the atmospheric concentration from III-A-1 for the food categories that may be produced at this location. Enter zero for the food categories that are not likely to be produced at this location. If all the values entered are greater than zero, skip III-B-3 and proceed to III-B-4. If some of the values entered are zero, go to next step.

III-B-3: For food categories that are not produced at the location (distance x) given in II-bi-8: (a) Determine the straight-line distance between the nearest potential production location of each food category and the point of release. (b) Return to the beginning of Section II. (c) Specify new values of x in II-bi-8 for the nearest potential production locations of each food category. (d) Recalculate the atmospheric concentration in either II-C, II-D or II-E for each food category. (e) Enter the recalculated atmospheric concentration for each food category. (Note: The atmospheric concentration will be used to calculate the concentration of radionuclide in terrestrial food products at the nearest specified sites of potential food production.)
III-B-1: Radionuclide from II-A-1

Pu-239

III-B-2: Can vegetable gardens and/or pastures occur at location \( x \) (II-A-1)?

Yes– For each food category potentially produced at location \( x \), enter the atmospheric concentration from III-A-1 in blanks below.

No– Enter zero in blanks below for the atmospheric concentration for the food categories not produced at location \( x \) and go to next step.

Vegetables

0.37 Bq m\(^{-3}\)

Animal food products

0 Bq m\(^{-3}\)

If all the above values are greater than zero– Proceed to III-B-4

III-B-3: (a) Determine distance to the point of nearest production for each food category
(b) Return to Section II.
(c) Specify \( x \) in II-bi-8 for each food category.
(d) Recalculate atmospheric concentrations for each food category.
(e) Enter recalculated atmospheric concentration from either II-C, II-D, or II-E for each radionuclide and food category in the blanks below.

Vegetables

Bq m\(^{-3}\)

Animal food products

Bq m\(^{-3}\)
III-B-4: Calculate the concentration of the radionuclide in terrestrial food products.
Enter value for the concentration of the radionuclide in the atmosphere at the nearest potential sites of vegetable production, and milk and meat production. These values should be obtained from either III-B-2 or III-B-3.

III-B-5: Estimate the screening value from the ingestion of terrestrial foods.
(a) For each radionuclide and food product, enter appropriate screening factor from Table 1.1.
(b) Multiply the atmospheric concentration of the radionuclide (estimated in III-B-4) by the radionuclide-specific screening factors.
(c) Sum the results to obtain the total ingestion screening value. Proceed to III-C.
III-B-4: Enter radionuclide from III-B-1

Pu-239

Enter atmospheric concentration, $C$, from either III-B-2 or III-B-3

Vegetables

0.37 Bq m$^{-3}$

Animal food products

0 Bq m$^{-3}$

III-B-5: (a) Enter appropriate screening factor, $SF$, from Table 1.1

Vegetables

0.45 Sv per Bq m$^{-3}$

Animal food products

0 Sv per Bq m$^{-3}$

(b) Screening value: $SV = C \times SF$

(II-B-4) (III-B-5)

Vegetables

0.17 Sv

Animal food products

0 Sv

(c) Sum the results to obtain the total screening value from ingestion of radionuclide

0.17 Sv

Proceed to III-C
III-C: Receptor Exposed to Pathways from Multiple Locations

Condition: The hypothetical individual residing at the location (distance $x$) in III-A-1 is assumed to have access to contaminated foods at the potential sites of production nearest the point of release.

III-C-1: Calculate the screening value from all pathways.
   (a) Enter from III-A-3 the total screening value calculated for inhalation and external sources of exposure.
   (b) Enter the total screening value calculated in III-B-5 for ingestion of contaminated food.
   (c) Add the inhalation and external screening values entered in III-C-1(a) to the ingestion doses in III-C-1(b) to calculate the total screening value from all pathways of exposure.

III-C-2: Enter the screening limiting value from II-F-5.

III-C-3: If the total screening value from all pathways in III-C-1(c) is less than the screening limit in III-C-2, compliance with the limiting value is assured. If III-C-1(c) is equal to or greater than III-C-2, seek assistance from experts in environmental radiological assessment.
III-C-1: (a) Enter III-A-3: external and inhalation screening value \[0.20\] Sv

(b) Enter III-B-5: screening value from ingestion \[0.17\] Sv

(c) Sum external, inhalation, ingestion screening values:

\[\text{[III-C-1(a)] + [III-C-1(b)]} = 0.37\] Sv

III-C-2: Enter II-F-5: screening limit \[1.67 \times 10^{-5}\] Sv

III-C-3: Is III-C-1(c) less than III-C-2?

\[\text{No}\]

Yes– STOP

No– Seek expert assistance
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Chapter 19: Prioritization of Chemical Releases from LANL

Operations at LANL have involved many non-radioactive materials, including metals, inorganic chemicals, and organic chemicals including solvents. For the sake of simplicity in this report, we will refer to these materials as “chemicals”. Prior to the 1970s, uses of chemicals and their ultimate fate were poorly tracked and documented compared to radionuclides. One particularly challenging portion of the LAHDRA project, for this reason, has been the collection of information concerning historical uses of chemicals, identification of those that were most likely released off site, and determination of which chemicals have been most important in terms of potential off-site health hazards.

Sources of Information Regarding Historical Chemical Usage

The sources of information about chemical usage at LANL that have been most useful to the LAHDRA team include a modern-day chemical inventory, historical chemical inventories, and various types of LANL site documents.

Current Chemical Inventory

LANL maintains an inventory of chemicals present on-site to comply with annual environmental reporting requirements for hazardous chemical emissions. Information on the quantities and types of chemicals used at LANL was collected starting in 1991 and a Microsoft Access® database was completed in 1993 (ESH 1999). The initial tracking system called the Automated Chemical Inventory System (ACIS) had been updated annually since 1994. Recently, the inventory system was changed to the Injury Illness and Chemical Management Online Application by E3. Although the project team was granted access and training for the new system, the initial analysis of chemical inventory data conducted in 2000 was not repeated due to the limited usefulness of recent chemical inventory data for evaluating historical emissions of chemicals from LANL.

Fig. 19-1. Personnel involved in early explosives testing at Los Alamos.
The ACIS database includes the following fields:

- Chemical name, CAS number, and bar code
- Location of chemical (technical area, building)
- Quantity, units of measure, and physical state (solid, liquid, gas)

ACIS is available on the internal LANL Web site using a SecureID card. Access to the database allows the data to be compiled in different ways, and provides details such as the specific locations of chemicals through database search capabilities. A paper copy of the ACIS Microsoft Access® database file was provided to the project team by the ESH-5 group on January 26, 1999. At that time, the database contained approximately 120,000 records. Subsequently, access through a Web interface was granted to allow limited searches to be performed. A request for an official-use-only copy of the database for performing more complex searches was granted. However, the database does not include radionuclides, explosives, beryllium, depleted uranium, or other bulk metals. It contains many trade name products with no information on whether they include any hazardous materials. The database also does not include any information regarding how the chemicals are used or their potential for release to the environment.

Preliminary review of the ACIS database indicates that 37 chemicals were each present onsite at 250 or more individual locations and therefore represented the largest onsite quantities. Twelve of the thirteen chemicals present onsite in the highest quantities do not have USEPA recommended toxicity values for potential cancer and non-cancer systemic health effects, although some can be irritants or corrosives at high concentrations. The 37 high quantity chemicals selected from ACIS are shown in Table 19-1 in order of decreasing estimated on-site quantities.

Of the 37 high quantity chemicals, the 13 with USEPA recommended toxicity values are shown in Table 19-1 ranked in order of generic toxicity, “1” being more toxic than “13”. Generic toxicity includes both cancer and non-cancer chronic health effects with no bias toward any route of potential exposure (e.g., inhalation, ingestion, and dermal contact) or to any potential environmental exposure medium (e.g., air, soil, water, food products) since little is known about how the chemicals were used and the potential for off-site release.

LANL personnel suggested that site files of Material Safety Data Sheets could be reviewed for the trade name products to determine if the trade name products contain any hazardous materials. An analysis of the remaining inventory chemicals not included in Table 19-1 for quantity and location of use information could be conducted in future phases of the dose reconstruction to further prioritize recent chemical use at LANL. For chemicals that could be released to the off-site environment as a result of their use, air
Table 19-1. Selected Data from a Current LANL Chemical Inventory

<table>
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<tr>
<th>Chemical</th>
<th>Onsite Quantity</th>
<th>Toxicity Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>4.2 x 10^7 L</td>
<td>--</td>
</tr>
<tr>
<td>Argon</td>
<td>3.8 x 10^7 L</td>
<td>--</td>
</tr>
<tr>
<td>Helium</td>
<td>3.7 x 10^7 L</td>
<td>--</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>1.6 x 10^8 L</td>
<td>--</td>
</tr>
<tr>
<td>Oxygen</td>
<td>1.6 x 10^8 L</td>
<td>--</td>
</tr>
<tr>
<td>Propane</td>
<td>1.3 x 10^7 L</td>
<td>--</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>2.2 x 10^4 L</td>
<td>--</td>
</tr>
<tr>
<td>Toluene</td>
<td>2.1 x 10^4 L</td>
<td>8</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>1.5 x 10^4 kg</td>
<td>--</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>8.6 x 10^3 kg</td>
<td>--</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>7.1 x 10^3 L</td>
<td>--</td>
</tr>
<tr>
<td>Sodium carbonate</td>
<td>6.8 x 10^3 kg</td>
<td>--</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>6.6 x 10^3 L</td>
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</tr>
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<td>Acetone</td>
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<td>Ethylene glycol</td>
<td>5.1 x 10^3 L</td>
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<td>Chlorodifluoromethane</td>
<td>4.8 x 10^3 L</td>
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<td>Methyl alcohol</td>
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<tr>
<td>Nitric acid</td>
<td>2.6 x 10^3 L</td>
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<td>Isopropanol</td>
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</tr>
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<td>Hydrogen peroxide</td>
<td>7.8 x 10^2 L</td>
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<tr>
<td>Buffer solutions</td>
<td>6.3 x 10^2 L</td>
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<td>Acetic acid</td>
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<td>Hexane</td>
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<td>Methylene chloride</td>
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<td>Miscellaneous chlorofluorcarbon</td>
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<tr>
<td>1,1,1,2-Tetrafluoroethane</td>
<td>4.4 x 10^2 L</td>
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</tr>
<tr>
<td>Photographic developer products</td>
<td>3.9 x 10^2 L</td>
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</tr>
<tr>
<td>Dimethyl sulfoxide</td>
<td>3.8 x 10^2 L</td>
<td>--</td>
</tr>
<tr>
<td>Chloroform</td>
<td>3.4 x 10^2 L</td>
<td>1</td>
</tr>
<tr>
<td>Benzene</td>
<td>2.1 x 10^2 L</td>
<td>2</td>
</tr>
<tr>
<td>Ether</td>
<td>2.0 x 10^2 L</td>
<td>9</td>
</tr>
<tr>
<td>Dichlorodifluoromethane</td>
<td>1.5 x 10^2 L</td>
<td>6</td>
</tr>
<tr>
<td>Photographic fixer products</td>
<td>1.2 x 10^2 L</td>
<td>--</td>
</tr>
<tr>
<td>Tetrahydrofuran</td>
<td>6.0 x 10^1 L</td>
<td>3</td>
</tr>
<tr>
<td>Ethylenediamine tetraacetic acid</td>
<td>3.8 x 10^1 kg</td>
<td>--</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>2.1 x 10^1 L</td>
<td>11</td>
</tr>
<tr>
<td>1,1-Difluoroethane</td>
<td>8.5 x 10^0 L</td>
<td>13</td>
</tr>
</tbody>
</table>
dispersion and other transport models and exposure models can be used to estimate an onsite threshold quantity that would not result in adverse health impacts to off-site populations using site-specific assumptions regarding dispersion, transport and exposure. The threshold quantity approach could be used to focus data gathering efforts on those chemicals for which the on-site inventory quantity exceeds the threshold quantity. However, the chemical inventory database only contains information on selected chemicals present at LANL since 1991.

**Historical Chemical Inventories**

Harry Schulte, a former Industrial Hygiene group leader, is reported to have conducted a chemical inventory in the early 1970s (ESH 1999). A draft report was prepared, but was never finalized. It was suggested that the draft report and supporting data might be located in the Industrial Hygiene group files in the Central Records Center. Surviving members of Mr. Schulte’s group reportedly do not have any copies in their possession. This 1970s chemical inventory information has not been located by the project team.

For years prior to the initiation of the current chemical inventory program, the project team identified several lists of chemicals used at LANL in years prior to 1980s environmental reporting requirements. The lists represent the years 1947-50 (Repos. No. 296), 1971 (Repos. Nos. 756, 883, 997), and 1970s (Repos. Nos. 279, 284, 1380, 2015). Quantities and locations of use are typically not provided in these lists. The project team identified considerable documentation related to chemical use in specific areas for the 1980s and 1990s as LANL began collecting these data in response to regulatory requirements.

Table 19-2 is a list of chemicals documented as having been used at LANL at some point in time. This list was compiled from the LANL documents that have been reviewed to date, entered into the project database, and released to the public. Copies of many of the reviewed documents have not yet been obtained by the project team from LANL as of the preparation of this report. Classification, privacy act, and legal privilege reviews are required prior to public release. Documents used to identify the chemicals in Table 19-2 are included in the reference section and are described below.
Table 19-2. Chemicals Historically Used at LANL

<table>
<thead>
<tr>
<th>Elements</th>
<th>Inorganics</th>
</tr>
</thead>
<tbody>
<tr>
<td>aluminum</td>
<td>asbestos (magnesium silicate)</td>
</tr>
<tr>
<td>antimony</td>
<td>bromide</td>
</tr>
<tr>
<td>arsenic</td>
<td>cyanide</td>
</tr>
<tr>
<td>barium</td>
<td>hydrochloric acid</td>
</tr>
<tr>
<td>beryllium</td>
<td>hydrofluoric acid</td>
</tr>
<tr>
<td>bromine</td>
<td>nitric acid</td>
</tr>
<tr>
<td>cadmium</td>
<td>oxalic acid/ oxalate</td>
</tr>
<tr>
<td>chromium</td>
<td>perchloric acid/ perchlorate</td>
</tr>
<tr>
<td>copper</td>
<td>phosphoric acid</td>
</tr>
<tr>
<td>dioxane</td>
<td>sodium hydroxide</td>
</tr>
<tr>
<td>fluoride</td>
<td>sodium thiosulfate</td>
</tr>
<tr>
<td>gallium</td>
<td>sulfuric acid</td>
</tr>
<tr>
<td>iron</td>
<td></td>
</tr>
<tr>
<td>lanthanum</td>
<td></td>
</tr>
<tr>
<td>lead</td>
<td></td>
</tr>
<tr>
<td>lithium</td>
<td></td>
</tr>
<tr>
<td>manganese</td>
<td></td>
</tr>
<tr>
<td>mercury</td>
<td></td>
</tr>
<tr>
<td>molybdenum</td>
<td></td>
</tr>
<tr>
<td>nickel</td>
<td></td>
</tr>
<tr>
<td>niobium</td>
<td></td>
</tr>
<tr>
<td>platinum</td>
<td></td>
</tr>
<tr>
<td>samarium</td>
<td></td>
</tr>
<tr>
<td>silver</td>
<td></td>
</tr>
<tr>
<td>tantalum</td>
<td></td>
</tr>
<tr>
<td>thallium</td>
<td></td>
</tr>
<tr>
<td>uranium (normal and depleted)</td>
<td></td>
</tr>
<tr>
<td>vanadium</td>
<td></td>
</tr>
<tr>
<td>zinc</td>
<td></td>
</tr>
<tr>
<td>zirconium</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volatile Organic Compounds</th>
<th>Semi-Volatile Organics</th>
<th>Explosives</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetone</td>
<td></td>
<td>Baratol (mixture of barium nitrate and TNT)</td>
</tr>
<tr>
<td>benzene</td>
<td></td>
<td>Comp. B (mixture of 60% RDX and 40% TNT)</td>
</tr>
<tr>
<td>carbon tetrachloride</td>
<td></td>
<td>Cyclotol (mixture of 70-75% RDX and 25-30% TNT)</td>
</tr>
<tr>
<td>chloroform</td>
<td></td>
<td>Explosive D (ammonium picrate; ammonium-1,3,5-trinitrophenol)</td>
</tr>
<tr>
<td>chlorodifluoromethane</td>
<td></td>
<td>HMX</td>
</tr>
<tr>
<td>dichlorodifluoromethane</td>
<td></td>
<td>(octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)</td>
</tr>
<tr>
<td>difluoroethane</td>
<td></td>
<td>nitrobenzene</td>
</tr>
<tr>
<td>ethanol</td>
<td></td>
<td>nitrocellulose</td>
</tr>
<tr>
<td>ether</td>
<td></td>
<td>nitromethane</td>
</tr>
<tr>
<td>isopropanol</td>
<td></td>
<td>NQ (nitroguanidine; Picrite)</td>
</tr>
<tr>
<td>kerosene</td>
<td></td>
<td>Octol (mixture of 70-75% HMX and 25-30% TNT)</td>
</tr>
<tr>
<td>methanol</td>
<td></td>
<td>PBX</td>
</tr>
<tr>
<td>methyl chloride (chloromethane)</td>
<td></td>
<td>Pentalite</td>
</tr>
<tr>
<td>methyl ethyl ketone (2-butanone)</td>
<td></td>
<td>PETN (pentaerythritol tetranitrate)</td>
</tr>
<tr>
<td>methylene chloride (dichloromethane)</td>
<td></td>
<td>picric acid</td>
</tr>
<tr>
<td>tetrachloroethylene</td>
<td></td>
<td>PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)</td>
</tr>
<tr>
<td>tetrabromoethane</td>
<td></td>
<td>RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)</td>
</tr>
<tr>
<td>tetrahydrofuran</td>
<td></td>
<td>Saltex</td>
</tr>
<tr>
<td>toluene (toluol)</td>
<td></td>
<td>TATB (1,3,5-triamino-2,4,6-trinitrobenzene)</td>
</tr>
<tr>
<td>trichloroethylene</td>
<td></td>
<td>Tetryl (1,3,5-trinitrophenyl-methylnitramine)</td>
</tr>
<tr>
<td>trichloroethylene</td>
<td></td>
<td>TNT (2,4,6-trinitrotoluene)</td>
</tr>
<tr>
<td>xylene</td>
<td></td>
<td>Torpex</td>
</tr>
</tbody>
</table>
Table 19-3 is a compilation of data located by the project team regarding quantities of chemicals used or released historically from LANL. Five documents report quantities of primarily volatile organic solvents that were used at LANL from 1971 until 1985. Three documents identify chemical quantities as “released or lost to the atmosphere”. One of the three documents, Repos. No. 1197, is a third source of the same numbers provided in Repos. Nos. 610 and 1324. It states that the amount of airborne solvents is taken from LASL stock issue records. However, it is often reasoned that all of the volatile solvents will in time become airborne no matter what the disposal method. Therefore, it appears that 100% volatilization was assumed. The chemicals listed in Table 19-3 are in the order of quantity used or released. Selection of the chemicals addressed in these documents was based on State and Federal air pollution requirements at the time of reporting. From Table 19-3, it can be concluded that trichloroethane and trichloroethylene were the most used volatile organic chemicals at LANL in the early 1970s. However, trichlorethylene appears to have been replaced by Freons in the early 1980s. Methyl ethyl ketone was also used in high quantities until 1982.

Site Documents

In the late 1980s, the Senate Committee on Armed Services asked the Office of Technology Assessment to evaluate what was known about the contamination and public health problems at the Nuclear Weapons Complex (U.S. Congress 1991). Contaminated sites and initial cleanup activities at LANL were described in this report. A summary of hazardous substances released to the environment at LANL formed the basis for our initial list.

For each of the over 600 solid waste management units (SWMUs) identified in the 1990 Solid Waste Management Units Report (LANL 1990), the unit, waste and releases information sections were reviewed by the project team to identify additional chemicals that may have been released from LANL.

An additional 480 SWMUs were added by the EPA in 1994, and another 1,000 Potential Release Sites (PRSs) were included in the investigation by the Department of Energy, for a total of 2,120 areas of concern. The 1996 Baseline Environmental Management Report (USDOE 1996) describes historical activities at the potential release sites involving: asbestos, barium, lead, depleted uranium, beryllium, and PCBs. High explosives, organic solvents, and ordnance are also cited but specific chemical names are not provided.
### Table 19-3: Reported Quantities of Chemicals Historically Used or Released at LANL

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</thead>
<tbody>
<tr>
<td></td>
<td>(kg released)</td>
<td>(kg issued)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg losses)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td>(kg used)</td>
<td></td>
</tr>
<tr>
<td><strong>ORGANICS</strong></td>
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<td></td>
</tr>
<tr>
<td>Methyl chloroform (trichloroethane)</td>
<td>26,571</td>
<td>19,138</td>
<td>25,600</td>
<td>18,300</td>
<td>22,900</td>
<td>34,000</td>
<td>28,300</td>
<td>24,100</td>
<td>13,741</td>
<td>23,800</td>
<td>28,200</td>
<td>39,300</td>
<td>25,600</td>
<td>31,100</td>
<td>27,674</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>27,719</td>
<td>17,007</td>
<td>20,400</td>
<td>15,500</td>
<td>16,200</td>
<td>9,400</td>
<td>13,200</td>
<td>10,200</td>
<td>7,400</td>
<td>2,041</td>
<td>6,900</td>
<td>3,400</td>
<td>3,200</td>
<td>400</td>
<td>2,204</td>
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<td>Acetone</td>
<td>16,625</td>
<td>6,531</td>
<td>10,800</td>
<td>13,300</td>
<td>15,000</td>
<td>16,200</td>
<td>12,400</td>
<td>13,800</td>
<td>8,200</td>
<td>3,265</td>
<td>9,200</td>
<td>12,800</td>
<td>12,500</td>
<td>32,200</td>
<td>28,400</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>10,540</td>
<td>680</td>
<td>3,400</td>
<td>1,000</td>
<td>820</td>
<td>880</td>
<td>1,000</td>
<td>1,400</td>
<td>–</td>
<td>340</td>
<td>1,400</td>
<td>9,100</td>
<td>340</td>
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<tr>
<td>Kerosene</td>
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<td>8,100</td>
<td>5,000</td>
<td>5,900</td>
<td>4,800</td>
<td>4,600</td>
<td>4,400</td>
<td>3,800</td>
<td>–</td>
<td>4,100</td>
<td>5,800</td>
<td>5,300</td>
<td>5,500</td>
<td>2,800</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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</tr>
<tr>
<td>Ethanol</td>
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<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
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</tr>
<tr>
<td>Toluene</td>
<td>2,063</td>
<td>–</td>
<td>2,300</td>
<td>2,100</td>
<td>1,200</td>
<td>2,700</td>
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<td>–</td>
<td>2,100</td>
<td>650</td>
<td>60</td>
<td>60</td>
<td>190</td>
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<tr>
<td>n-Butyl acetate</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>3,311</td>
<td>5,170</td>
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<td>10</td>
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<tr>
<td>Ethyl acetate</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<td>–</td>
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<td>–</td>
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<td>104</td>
<td>2,404</td>
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<tr>
<td>Methanol</td>
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<td>590</td>
<td>540</td>
<td>1,500</td>
<td>1,700</td>
<td>6,600</td>
<td>4,300</td>
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<td>–</td>
<td>3,300</td>
<td>2,400</td>
<td>3,400</td>
<td>3,100</td>
<td>730</td>
</tr>
<tr>
<td>C Methylene chloride</td>
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<td>–</td>
<td>820</td>
<td>820</td>
<td>310</td>
<td>1,000</td>
<td>820</td>
<td>2,200</td>
<td>290</td>
<td>771</td>
<td>170</td>
<td>180</td>
<td>230</td>
<td>430</td>
<td>100</td>
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<td>Isopropanol</td>
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<td>–</td>
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<td>218</td>
<td>952</td>
<td>950</td>
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</tr>
<tr>
<td>n-Heptane</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>209</td>
<td>304</td>
<td>290</td>
<td>210</td>
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<td>–</td>
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</tr>
<tr>
<td>C Chloroform</td>
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<td>250</td>
<td>500</td>
<td>380</td>
<td>370</td>
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<td>–</td>
<td>200</td>
<td>310</td>
<td>250</td>
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</tr>
<tr>
<td>Carbon tetrachloride</td>
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<td>260</td>
<td>250</td>
<td>100</td>
<td>250</td>
<td>230</td>
<td>200</td>
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<td>280</td>
<td>100</td>
<td>180</td>
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<td>60</td>
</tr>
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<td>Xylene</td>
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<td>–</td>
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</tr>
<tr>
<td>Benzene</td>
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<td>181</td>
<td>127</td>
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<td>141</td>
<td>32</td>
<td>40</td>
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<td>–</td>
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<td>–</td>
<td>–</td>
<td>70</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
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<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Dioxane</td>
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<td>–</td>
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<td>14</td>
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</tr>
<tr>
<td>Cadmium</td>
<td>1.E-02</td>
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<tr>
<td>Nitric acid</td>
<td>20,200</td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>80,000</td>
<td>–</td>
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<td><strong>GASES</strong></td>
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<tr>
<td>Helium</td>
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<td>–</td>
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</tr>
<tr>
<td>Sulfur hexafluoride</td>
<td>6,612</td>
<td>–</td>
<td>17,400</td>
<td>6,700</td>
<td>10,300</td>
<td>11,400</td>
<td>12,200</td>
<td>13,700</td>
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<td>11,400</td>
<td>6,900</td>
<td>10,600</td>
<td>8,800</td>
<td>14,200</td>
</tr>
</tbody>
</table>

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3. Attachment II to Air Quality Regulation Review #: NAAQS, Chemical and gas usage. June 9, 1980. (Rep. No. 610);
The project team has been following Environmental Restoration (ER) activities at LANL since the project began in early 1999. Numerous press releases and fact sheets regarding environmental investigations and surveillance activities have been provided by the ER Project and have supplied some relevant information. For example, oxalic acid was used to purify uranium and plutonium in early operations at TA-1 and TA-21. Oxalate has been detected in a groundwater monitoring well in Lower Los Alamos Canyon (LANL 1998). Recently, perchlorate was detected in a groundwater monitoring well in Mortandad Canyon, in a water supply well in lower Pueblo Canyon, and in the CMR Building ductwork (LANL 2000). Perchloric acid is used in high-explosive (HE) formulation (Dobratz 1995) and in nuclear chemistry analyses conducted in CMR Building.

Explosives including HMX, RDX, and TNT that have been detected in a groundwater monitoring well at TA-16 (S Site) and at Material Disposal Area-P reflect machining and subsequent disposal activities that occurred at TA-16, the center for research in high explosives since the 1940s. Prior to the construction of the High-Explosives Wastewater Treatment Facility at TA-16 in the 1990s, over 12 million gallons of water per year were used to keep the surface of high explosives cool and wet while machining. Following settling of the solids and heavier materials, the remaining water was discharged to the environment via outfalls. The wet solids were trucked to a burning ground, separated from liquids with a sand filter, then dried and ignited. The filtrate was treated before being discharged. Solvents such as acetone, methanol and ethanol were released to the atmosphere by volatilization from the water discharged at the outfalls (LANL 1998, 1999).

Detonable quantities of explosives have been removed from MDA-P during RCRA clean-closure excavation activities (Santa Fe New Mexican 1999). A document located on microfiche in the Central Records Center at LANL (author and date unknown; Repos. No. 672) states that quantities of explosives burned at TAs-14, 15, 16, 36, and 40 range from 100-300 lb/yr at TAs-14 and 33, to 96,300 lb/yr at TA-16. Normal uranium, HE-contaminated solvents (unidentified) and other combustibles are also disposed of by burning at these locations.

Project team review of X-Division Progress Reports from 1944 through 1945 has yielded reported estimates of quantities of high explosives used during that time period. These data are presented in Table 19-4.
Table 19-4: Reported Quantities of High Explosives Used per Month (lbs)

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Barium Nitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,250</td>
<td>3,170</td>
<td>19,850</td>
<td>42,750</td>
<td>35,000</td>
<td>57,500</td>
<td>60,000</td>
<td>-</td>
<td>-</td>
<td>18,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composition B</td>
<td></td>
<td>6,800</td>
<td>5,366</td>
<td>7,510</td>
<td></td>
<td></td>
<td>23,523</td>
<td>27,600</td>
<td>47,150</td>
<td>80,850</td>
<td>20,600</td>
<td>87,500</td>
<td>90,250</td>
<td>66,850</td>
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<tr>
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<td>5,366</td>
<td>7,510</td>
<td></td>
<td></td>
<td>3,900</td>
<td>4,200</td>
<td>7,510</td>
<td>12,800</td>
<td>20,400</td>
<td>20,150</td>
<td>-</td>
<td></td>
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</tr>
<tr>
<td>Composition B-2</td>
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<td>5,366</td>
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<td></td>
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<td>4,200</td>
<td>7,510</td>
<td>12,800</td>
<td>20,400</td>
<td>20,150</td>
<td>-</td>
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<tr>
<td>TNT</td>
<td></td>
<td>650</td>
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<tr>
<td>Aluminum-TNT 60/40</td>
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<td>650</td>
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<td>4,750</td>
<td>9,200</td>
<td>12,800</td>
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<td>20,150</td>
<td>-</td>
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<td>-</td>
<td>6,000</td>
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<tr>
<td>Torpex ¹</td>
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<td>1,100</td>
<td>1,250</td>
<td>6,953</td>
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<td></td>
<td>937</td>
<td>1,008</td>
<td>1,390</td>
<td>1,750</td>
<td>200</td>
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<td>Saltex</td>
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<td>1,100</td>
<td>1,250</td>
<td>6,953</td>
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<td>937</td>
<td>1,008</td>
<td>1,390</td>
<td>1,750</td>
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<td>Pentolite</td>
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<td>500</td>
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<td></td>
<td></td>
<td>500</td>
<td>0</td>
<td>1,390</td>
<td>1,750</td>
<td>200</td>
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<td>463</td>
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<td>1,390</td>
<td>1,750</td>
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<tr>
<td>PTX</td>
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<td></td>
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<td></td>
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<td>41,000</td>
</tr>
<tr>
<td>Reported TOTAL</td>
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<td>18,494</td>
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<td>54,435</td>
<td>109,950</td>
<td>135,450</td>
<td>168,250</td>
<td>147,150</td>
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<td>41,000</td>
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<tr>
<td>Rejected Castings</td>
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</tr>
</tbody>
</table>


¹ Torpex is 5:1 Comp B:TNT

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Quantities of explosives used are not reported in the monthly X-Division Progress Report for November 1944.
A 1981 memorandum from R. W. Ferenbaugh to H. S. Jordan dated January 27, 1981 states that 20,000 – 30,000 kg (91,000 – 136,000 lbs) per year of waste explosives were disposed of at TA-16 by open burning. Explosive burning experiments conducted at LASL several years prior to 1981 estimated annual emissions of 600-800 kg of NOx, 100-200 kg of carbon monoxide, and 300-500 kg of unidentified particulates from this open burning process (Ferenbaugh 1981; Repos. No. 611).

An effluent material summary for group GMX-7 (Drake 1971; Repos. No. 2114) includes several explosives dispersed at TA-40 as gaseous detonation products during the period July – September 1971 (Table 19-5). Toxic material reports for December 1979 through September 1980 (Dinegar 1980; Repos. No. 2112) report the approximate amounts of HE exploded per month in WX-7 shots at TA-40 and TA-22.

![Fig. 19-2. LANL workers watch an explosive test in the distance](image)

### Table 19-5. Reported Quantities of Explosives Dispersed

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitromethane</td>
<td>450 kg (990 lb)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td>Comp B</td>
<td>34 kg (75 lb)</td>
<td>0.1</td>
<td>3.1</td>
<td>10.8</td>
<td>22.4</td>
<td>13.2</td>
<td>6.7</td>
<td>19.6</td>
<td>--</td>
<td>52.8</td>
<td>9.6</td>
</tr>
<tr>
<td>Baratol</td>
<td>--</td>
<td>0.1</td>
<td>2.9</td>
<td>17.1</td>
<td>63.7</td>
<td>21.1</td>
<td>16.4</td>
<td>25</td>
<td>--</td>
<td>89</td>
<td>3.4</td>
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<tr>
<td>TATB</td>
<td>--</td>
<td>0.4</td>
<td>0.7</td>
<td>0.25</td>
<td>0.1</td>
<td>0.4</td>
<td>0.4</td>
<td>0.03</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>TNT</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>2.7</td>
<td>5.4</td>
<td>13.5</td>
<td>2.7</td>
<td>5.4</td>
<td>--</td>
<td>25</td>
<td>2.7</td>
</tr>
<tr>
<td>Octol</td>
<td>--</td>
<td>--</td>
<td>12</td>
<td>6</td>
<td>3</td>
<td>--</td>
<td>6</td>
<td>3</td>
<td>--</td>
<td>6</td>
<td>--</td>
</tr>
<tr>
<td>PETN</td>
<td>7 kg (15 lb)</td>
<td>0.02</td>
<td>0.09</td>
<td>0.06</td>
<td>0.05</td>
<td>0.1</td>
<td>0.01</td>
<td>0.13</td>
<td>0.03</td>
<td>0.05</td>
<td>1.2</td>
</tr>
<tr>
<td>PBX</td>
<td>0.9 kg</td>
<td>0.1</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
<td>0.3</td>
<td>0.05</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Tetryl</td>
<td>0.05 kg</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td>TOTAL</td>
<td>492 kg</td>
<td>1 kg</td>
<td>19 kg</td>
<td>37 kg</td>
<td>44 kg</td>
<td>49 kg</td>
<td>32 kg</td>
<td>54 kg</td>
<td>1 kg</td>
<td>174 kg</td>
<td>18 kg</td>
</tr>
</tbody>
</table>

-- not reported
Research, development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; Repos. No. 658). Many new formulations of the conventional explosives HMX, RDX and TNT were synthesized and tested at LANL since the 1940s (Dobratz 1995). Other high explosives such as Baratol, Comp B, Pentolite, Torpex, and Tetryl were tested at the firing site at TA-14 (IT Corporation 1989; Repos. No. 2192).

Uranium and other metals such as lead, beryllium, aluminum and cadmium (HAI 1993; Johnson and Dahl 1977; Repos. No. 2249) were released to the environment as a result of test shots conducted at LANL since the 1940s. Drake and Eyster (1971; Repos. No. 1412) estimate that between 75,000 and 95,000 kg of uranium has been expended in experimental shots at LANL from 1949-1970. Normal uranium was used until 1954, then depleted uranium was used exclusively. The estimate does not address where the uranium went, only that they don’t have it any longer. A 1952 AEC report states that test shots at LASL routinely dispersed 300 lbs of uranium per month and 200 lbs of barium per month (English 1952). Two 1971 memoranda (Drake 1971; Repos. No. 2114) report toxic materials dispersed by GMX Division shots for April and May 1971 as shown in Table 19-6.

<table>
<thead>
<tr>
<th>Toxic Material</th>
<th>April 1971</th>
<th>May 1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium-238</td>
<td>171 kg (376 lb)</td>
<td>142 kg (312 lb)</td>
</tr>
<tr>
<td>Beryllium</td>
<td>0.7 kg</td>
<td>3 kg</td>
</tr>
<tr>
<td>Tritium</td>
<td>125 cm³ STP</td>
<td>208 cm³ STP</td>
</tr>
<tr>
<td>Lead</td>
<td>0.042 kg</td>
<td>0.8 kg</td>
</tr>
<tr>
<td>Bromine</td>
<td>0.165 kg</td>
<td>--</td>
</tr>
</tbody>
</table>

-- not reported

Most of the documents describing PCBs at LANL that have been identified by the project team to date are logbooks of analytical results with unidentified sampling locations. Several documents describe storage and disposal of PCB wastes at TAs-21 and 54 (Santa Fe Engineering 1995; Repos. No. 1262). PCB cleanups were conducted at TAs-3, 53, and near groundwater production wells in the mid 1980s and 1990s as a result of leaking transformers and capacitors (Unknown 1997 [Repos. No. 1094]; LANL 1993 [Repos. No. 1269]). Aroclor-1242 was used as a coolant in CMB-11 division in 1961 (Enders 1969; Repos No. 1409).

A 1973 document, “Summary of wastes and effluents for Omega Site TA-2”, estimates that 1.4 lb d⁻¹ of hexavalent chromium were released to the air in cooling tower effluent. The Omega West Reactor (OWR) primary water was cooled via a 5 MW evaporative cooling tower. Trichloro-s-triazinetrione
(C₃N₃O₃Cl₃), a common microbicide, was added to the secondary-side water in the tower to control algae growth. A second product containing polyacrylate polymer, polyoxylated aliphatic diamine, and tolyltriazole was added to control scale and corrosion. Cooling tower water was discharged to the environment via entrainment in the exhaust air stream and through discharges of blowdown water to Los Alamos Canyon Creek. These blowdown discharges were another measure used to control scale and corrosion in the secondary (sump) water by eliminating solids. Repos. No. 645 reports that these discharges totaled approximately 60,000 gallons per week in 1973. Another 300 gallons per week of blowdown water came from the heat exchanger for the primary water in the OWR’s demineralizer loop. Like the main OWR exchanger, the cooling water for this heat exchanger came from the municipal water supply.

Repos. No. 645 also reports the exhaust air stream from the OWR cooling tower included entrained secondary water that was discharged to the environment at a rate of 3.9 gal min⁻¹. The document states this resulted in the discharge of 20 lb of sulfuric acid and 1.4 lb of hexavalent chromium to the atmosphere per 24 h period.

Draft Comprehensive Environmental Assessment and Response Program (CEARP) documents from 1986 (Repos. No. 525) report a staff member recalling the use of potassium dichromate in the cooling tower water prior to a time when the heat exchanger components were changed from aluminum to steel. CEARP was the Department of Energy’s Superfund program for Federal Facilities in the 1980s. The employee stated that mist from the tower would drift about the site and turn things green. This “greening” effect went away with the switch to steel components (and the subsequent reduction in use of potassium dichromate). The use of potassium dichromate as a corrosion inhibitor is confirmed in Repos. No. 645, which states that the blowdown discharges from the cooling tower (~60,000 gal per week) included approximately 14.5 pounds of hexavalent chromium. This same document reports that the blowdown also included 3 lb of chlorophenol biocide and 200 lb of sulfuric acid in the form of sulfate salts (used for pH control). The blowdown from the demineralizer loop heat exchanger contributed another 20 lb of sulfuric acid and 0.5 lb of chlorophenol biocide. Repos. No. 645 also says it was planned to make the switch from aluminum to stainless steel components in fiscal year 1974 to reduce the amount of corrosion inhibitor required and thus reduce the amount of hexavalent chromium in the blowdown water.

An inventory of pollutant releases to the environment for 1971 (Repos. No. 883) states that use of chromates will be discontinued once the aluminum heat exchanger is replaced with a stainless steel unit. This same document reports the average concentration of hexavalent chromium in the TA-2 blowdown to be 25 mg L⁻¹, which was 2,500 times the quality standard of 0.01 mg L⁻¹ for that era. The same effluent
stream is reported to contain total dissolved solids at an average concentration of 800 mg/l, which also exceeded the applicable quality standard of 500 mg L⁻¹.

The Water Boiler’s cooling tower used potassium dichromate by the hundreds of pounds; waterborne effluent ran down the nearby creek, and sometimes chromium “rained from the sky,” and windshields on people’s cars had to be replaced (G. Neely, 1999 personal communication). Condensate poured on the ground; there was a tree in the area with Cs-137 in its leaves as a result. There was reportedly also asbestos in some TA-2 buildings.

Repos. No. 2211 reports that a “very serious” mercury spill took place at the Clementine site on December 31, 1948 that required a “prolonged period” of cleanup. This report also mentions that routine monitoring for mercury vapor had been going on at the Clementine site prior to this incident.

Repos. No. 2201 reports that a mercury spill occurred at the Clementine site between January 20, 1951 and February 20, 1951. Air samples were collected and analyzed for mercury vapor and urine samples were collected from three exposed workers. The report states that “the results obtained showed all exposures below hazardous levels.”

In late 1952, it was reported that members of H Division had been participating in conferences relative to the large quantity of contaminated mercury to be pumped from the fast reactor at Omega Site. Since the material was contaminated with plutonium, it appeared to the participants that the plutonium hazard was more serious than that of the mercury vapor [Repos. No. 124].

Perchlorate was identified in shallow groundwater in Mortandad Canyon at concentrations ranging from 80 to 220 ppb. Perchlorate was also found in groundwater characterization wells at 12 ppb and in drinking water supply wells at 2 to 3 ppb, just above analytical detection limits. It is assumed that the perchlorate contamination was discharged in effluent from the TA-50 Radioactive Liquid Waste Treatment Facility, and also from legacy waste that was discharged into Acid Canyon from the TA-45 treatment plant which operated from 1943 to 1964.

In August 2002, benzene was identified in soil at TA-48 from historical solvent use.

Accident/ incident files from the Health Divisions were identified for 1944-1991 (Repos. Nos. 3461-3496). However, the files primarily document chemical spills and indoor exposures to workers. Operations related to the presence of the chemical are not described. The documentation of a few incidents that could have resulted in releases to the off-site environment was extracted and entered into the project database. A document titled “Chronological Record of Accidents at LASL” lists a fatality due
to asphyxiation by methyl chloroform at “New” Sigma Building on February 14, 1961 (Unknown 1979; Repos. No. 514). Details of the accident are not provided.

Many of the Health/Industrial Hygiene Division reports and correspondence files include memoranda regarding the presence of numerous solvents, metals, and acids in various LANL divisions. However, details regarding building locations, quantities used, or the operations involved are rarely provided. The chemicals mentioned are included in Table 13-1.

**Preliminary Prioritization for Chemicals**

USEPA Region 9 Preliminary Remediation Goals (PRGs) are target cleanup levels based on conservative assumptions regarding direct exposure to soil through ingestion, dermal contact and inhalation, and direct inhalation of vapors and particulates (USEPA 2002). PRGs are based on cancer as an endpoint if available cancer potency factors (“slope factors”) result in a more conservative (lower) PRG than would result based solely on evaluation of non-cancer health effects.

As a first step towards prioritization of potential chemical releases, PRGs for chemicals used and possibly released historically from LANL were used by the LAHDRA team to rank the potential of various chemicals to result in adverse health effects to off-site populations. The lower a PRG, the higher the potential for off-site health effects if the compound were released beyond the site boundary—this preliminary ranking does not address actual quantities released or whether real exposures occurred; however, these factors will be considered as the prioritization process advances.

PRGs for soil were used to rank chemicals usually present in the environment as particulates, and PRGs for air were used to rank volatile chemicals. Both soil and air PRGs were considered for explosives. Toxicity factors are not available for some chemicals used at LANL, and estimates of quantities used have been identified through systematic document review for only a subset of those chemicals with published toxicity factors. Estimates of quantities of a material used on an annual basis are in some cases available. “Annual use” is typically the highest known annual usage of a compound from available data, and in some cases may be based on a single year for which data are available. Reported values are often presented as quantities used, issued, lost, or released, and it is not always clear how the quantities were determined.
Table 19-7 shows a ranking of Los Alamos chemicals based on PRGs for soil, while Table 19-8 presents a ranking based on PRGs for air. Table 19-9 presents a ranking method that takes into account estimates of annual usage and U.S. EPA toxicity values such as slope factors and RfDs. Oral slope factors are used to indicate the strength of the chemical’s ability to cause cancer. A cancer slope factor is an upper bound probability estimate of cancer incidence per unit intake of a carcinogen over a lifetime. Therefore, the higher the slope factor, the more carcinogenic a chemical is according to the U.S. EPA. RfDs are used to rank a chemical’s ability to cause an adverse health effect other than cancer. According to the U.S. EPA, an RfD is an estimated daily intake that if taken over a lifetime, is not expected to cause an appreciable risk of adverse health effects. Hence, according to the U.S. EPA, the smaller the RfD, the more toxic the chemical. Chemicals were ranked based on slope factors and RfDs independently to distinguish between the most important chemicals in terms of cancer risk and adverse health effects. Chemicals that are considered carcinogens by the U.S. EPA were ranked based on annual usage multiplied by the cancer slope factor. Oral slope factors were used in all but one case because they were more conservative than the inhalation slope factor. All chemicals for which the U.S. EPA has published RfDs were ranked by multiplying the annual usage by the inverse of the RfD. Some chemicals have both ingestion and inhalation RfDs, and in these cases, the more conservative value was used in order to consider the most sensitive health endpoint.

References


Table 19-7: Ranking of LANL Chemicals Based on PRGs for Soil

<table>
<thead>
<tr>
<th>Chemical</th>
<th>PRG for soil [mg/kg]</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>3.90E-01</td>
<td>1</td>
</tr>
<tr>
<td>RDX (hexahydro)</td>
<td>4.40E+00</td>
<td>2</td>
</tr>
<tr>
<td>Thallium</td>
<td>5.20E+00</td>
<td>3</td>
</tr>
<tr>
<td>Perchlorate</td>
<td>7.80E+00</td>
<td>4</td>
</tr>
<tr>
<td>TNT (2,4,6-trinitrotoluene)</td>
<td>1.60E+01</td>
<td>5</td>
</tr>
<tr>
<td>Uranium</td>
<td>1.60E+01</td>
<td>6</td>
</tr>
<tr>
<td>Nitrobenzene</td>
<td>2.00E+01</td>
<td>7</td>
</tr>
<tr>
<td>Mercury</td>
<td>2.30E+01</td>
<td>8</td>
</tr>
<tr>
<td>Antimony</td>
<td>3.10E+01</td>
<td>9</td>
</tr>
<tr>
<td>Vanadium</td>
<td>7.80E+01</td>
<td>10</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>3.90E+02</td>
<td>11</td>
</tr>
<tr>
<td>Silver</td>
<td>3.90E+02</td>
<td>12</td>
</tr>
<tr>
<td>Lead</td>
<td>4.00E+02</td>
<td>13</td>
</tr>
<tr>
<td>Lithium</td>
<td>1.60E+03</td>
<td>16</td>
</tr>
<tr>
<td>Nickel (soluble salts)</td>
<td>1.60E+03</td>
<td>14</td>
</tr>
<tr>
<td>Manganese</td>
<td>1.80E+03</td>
<td>15</td>
</tr>
<tr>
<td>HMX (octahydro)</td>
<td>3.10E+03</td>
<td>17</td>
</tr>
<tr>
<td>Copper</td>
<td>3.10E+03</td>
<td>18</td>
</tr>
<tr>
<td>Fluoride</td>
<td>3.70E+03</td>
<td>19</td>
</tr>
<tr>
<td>Barium nitrate</td>
<td>5.40E+03</td>
<td>20</td>
</tr>
<tr>
<td>NQ (nitroguanidine; Picrite)</td>
<td>6.10E+03</td>
<td>21</td>
</tr>
<tr>
<td>Acetone</td>
<td>1.40E+04</td>
<td>22</td>
</tr>
<tr>
<td>Iron</td>
<td>2.30E+04</td>
<td>23</td>
</tr>
<tr>
<td>Zinc</td>
<td>2.30E+04</td>
<td>24</td>
</tr>
<tr>
<td>Aluminum</td>
<td>7.60E+04</td>
<td>25</td>
</tr>
<tr>
<td>Bromine</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Gallium</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Lanthanum</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Niobium</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Platinum</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Samarium</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Tantalum</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Zirconium</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
Table 19-8: Ranking of LANL Chemicals Based on PRGs for Air

<table>
<thead>
<tr>
<th>Chemical</th>
<th>PRG for air [microgram/m³]</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromium (total)</td>
<td>1.60E-04</td>
<td>1</td>
</tr>
<tr>
<td>Beryllium</td>
<td>8.00E-04</td>
<td>2</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.10E-03</td>
<td>3</td>
</tr>
<tr>
<td>Polychlorinated biphenyls- Aroclor 1242 (1254)</td>
<td>3.43E-03</td>
<td>4</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>1.70E-02</td>
<td>5</td>
</tr>
<tr>
<td>Chloroform</td>
<td>8.30E-02</td>
<td>6</td>
</tr>
<tr>
<td>Hexachlorobutadiene</td>
<td>8.60E-02</td>
<td>7</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>1.30E-01</td>
<td>8</td>
</tr>
<tr>
<td>Benzene</td>
<td>2.50E-01</td>
<td>9</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>3.20E-01</td>
<td>10</td>
</tr>
<tr>
<td>1,4-Dioxane</td>
<td>6.10E-01</td>
<td>11</td>
</tr>
<tr>
<td>Tetrahydrofuran</td>
<td>9.90E-01</td>
<td>12</td>
</tr>
<tr>
<td>Hydrogen Cyanide</td>
<td>3.10E+00</td>
<td>13</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>4.10E+00</td>
<td>14</td>
</tr>
<tr>
<td>Phosphoric acid</td>
<td>1.00E+01</td>
<td>15</td>
</tr>
<tr>
<td>Chloromethane</td>
<td>9.50E+01</td>
<td>16</td>
</tr>
<tr>
<td>Xylene</td>
<td>1.10E+02</td>
<td>17</td>
</tr>
<tr>
<td>Dichlorodifluoromethane</td>
<td>2.10E+02</td>
<td>18</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>2.10E+02</td>
<td>20</td>
</tr>
<tr>
<td>Toluene</td>
<td>4.00E+02</td>
<td>19</td>
</tr>
<tr>
<td>Ethyl Ether</td>
<td>7.30E+02</td>
<td>21</td>
</tr>
<tr>
<td>Methanol</td>
<td>1.80E+03</td>
<td>22</td>
</tr>
<tr>
<td>Trichloroethane (methyl chloroform)</td>
<td>2.30E+03</td>
<td>23</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>3.30E+03</td>
<td>24</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>5.10E+03</td>
<td>25</td>
</tr>
<tr>
<td>Ethylene glycol</td>
<td>7.30E+03</td>
<td>26</td>
</tr>
<tr>
<td>1,1-Difluoroethane</td>
<td>4.20E+04</td>
<td>27</td>
</tr>
<tr>
<td>Chlorodifluoromethane</td>
<td>5.10E+04</td>
<td>28</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Ethanol</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Isopropanol</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Kerosene</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Tetrabromoethane</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>n-Butyl acetate</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Asbestos (magnesium silicate)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Bromide</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Hydrofluoric acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Nitric acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Sodium thiosulfate</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Sulfur hexafluoride</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Baratol (barium nitrate+TNT)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Comp B (60% RDX; 40% TNT)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Cyclotol (70-75% RDX; 25-30% TNT)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Explosive D (NH3 picrate; NH3-1,3,5-trinitrophenol)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Nitrocellulose</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Nitromethane</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Octol (70-75% HMX; 25-30% TNT)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>PBX</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Pentolite</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>PETN (pentaerythritol tetranitrate)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Picric acid</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>PTX-2 (2,6-bis-picrylamino-3,5-dinitropyridine)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Saltex</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>TATB (1,3,5-triamino-2,4,6-trinitrobenzene)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Tetryl (1,3,5-trinitrophenyl-methylnitramine)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Torpex (83%Comp B; 17% TNT)</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>Slope Factor (SF) [mg/kg-d]</td>
<td>Reference Dose (RfD) [mg/kg-d]</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Acetone</td>
<td>-</td>
<td>0.9</td>
</tr>
<tr>
<td>Barium nitrate</td>
<td>not in RAIS</td>
<td>not in RAIS</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.055</td>
<td>0.004</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>0.13</td>
<td>0.0007</td>
</tr>
<tr>
<td>Chlorodifluoromethane</td>
<td>-</td>
<td>0.0571</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.0805</td>
<td>0.01</td>
</tr>
<tr>
<td>Dichlorodifluoromethane</td>
<td>-</td>
<td>0.0571</td>
</tr>
<tr>
<td>Dioxane</td>
<td>0.011</td>
<td>-</td>
</tr>
<tr>
<td>Methanol</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>-</td>
<td>0.6</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>0.008</td>
<td>0.06</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>-</td>
<td>0.06</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.54</td>
<td>0.01</td>
</tr>
<tr>
<td>Tetrahydrofuran</td>
<td>not in RAIS</td>
<td>not in RAIS</td>
</tr>
<tr>
<td>TNT (2,4,6-trinitrotoluene)</td>
<td>0.03</td>
<td>0.0005</td>
</tr>
<tr>
<td>Toluene</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>chloroform)</td>
<td>-</td>
<td>0.2</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>0.4</td>
<td>0.0003</td>
</tr>
<tr>
<td>Uranium</td>
<td>-</td>
<td>0.0006</td>
</tr>
<tr>
<td>Xylene</td>
<td>-</td>
<td>0.0286</td>
</tr>
</tbody>
</table>

1 All values were obtained from the Risk Assessment Information System (RAIS) available at: http://rais.ornl.gov
2 Inhalation RfD was used because it was more conservative than the oral RfD. In all other cases, oral RfDs were used because they were most conservative
3 Inhalation cancer slope factor was used because it was more conservative than the oral slope factor. In all other cases, oral slope factors were used because they were most conservative
4 Combined congener values were used (combined, p-, m-, o-).

ESH.  Interview with members of the LANL Environmental, Safety and Health Division (ESH-5) Jonathan Tapia and Bill Hargraves on January 6, 1999 by Susan Flack of the project team.


Chapter 20: A Screening-Level Evaluation of Airborne Beryllium Releases from LANL Operations

Introduction

Historical records indicate that beryllium was used at Los Alamos for some time before its health hazards were fully recognized (Shipman 1951, Hempelmann and Henrickson 1986). While beryllium became recognized as a worker health hazard, potential exposures to members of the public who lived in Los Alamos have not been as well characterized. Because residents lived closer to production and testing areas at Los Alamos than at any other nuclear weapons complex site, this screening-level assessment of potential public exposures was undertaken.

Identification of Sources of Beryllium Releases at LANL

Based upon the review of information collected under the LAHDRA project, screening level assessments were completed for the following historical operations at Los Alamos that involved processing or use of significant quantities of beryllium:

- Early machining operations at a shop in the Original Technical Area, TA-1, known as V Shop
- Machining in shops at TA-3, Building SM-39, that started late in 1953
- The testing of atomic bomb components by firing them from a 20-mm anti-aircraft autocannon in an annex to B Building at TA-1
- The hot pressing of beryllium oxide powder in Q Building at TA-1 to make reactor components
- The expenditure of beryllium in explosive tests conducted at the PHERMEX facility at TA-15

Estimation of Release Rates over Averaging Periods Shorter Than a Year

Limits on occupational and public exposures to beryllium are stated as concentrations that vary with averaging time, including those specified for instantaneous concentrations as well as 8-h and 30-d average concentrations. Generally, the shorter the exposure (or stack sampling) time is, the higher the allowed concentration. However, reported LANL air concentrations of beryllium are often reported or can only be estimated in terms of annual averages or totals released over a year. During any year, concentrations over short periods will be greater than (and at other times also less than) the annual average. Because there is evidence to suggest that the occurrence of chronic beryllium disease is not related to duration of exposure (ATSDR 2002), indicating that exposures over short periods can be of health significance, the LAHDRA
team recognized the need for a method to predict the upper bounds of airborne beryllium concentrations over time intervals from less than an hour to 30 d based on data that represent concentrations or releases over a full year.

In order to estimate the magnitude of the variations of airborne concentrations that one would expect within a year, a study was made of another material released in particulate form by LANL, plutonium. Like beryllium, facilities that exhaust plutonium to the air have been subject to increasingly stringent controls, resulting in the use of filters on the exhausts in the 1950s and high efficiency particulate air (HEPA) filters by the mid-1960 for both contaminants. Like beryllium, samples of the exhaust air from plutonium facilities at LANL have been collected on filters to assess effluent air concentrations. Further discussion of similarities between particles of plutonium and beryllium, how they behave, and how they have been assessed by others is provided elsewhere (Shonka 2009). Unlike beryllium, however, plutonium samples have been routinely reported for time intervals as short as a work day.

In order to estimate how high beryllium release rates from chronic release sources could have been over averaging periods shorter than a year, the detailed monitoring data that are available for airborne plutonium releases from DP West Site stacks for 1956 and 1957 were analyzed. The relationships between work-day averaged concentrations and weekly, monthly, and annual average concentrations were characterized, and a table of multipliers was generated that can be applied to annual data to estimate peak releases over a series of shorter durations. To support this preliminary screening, airborne beryllium releases were assumed to vary over time like the measured airborne plutonium releases (that is, having similar ratios of annual averages to averages over shorter periods), and estimated annual beryllium releases were converted to release rates over shorter durations so that airborne concentrations over appropriate averaging periods could be compared to occupational and ambient exposure limits. If further evaluation of historical beryllium operations and releases is undertaken, a more detailed analysis of operational and air sampling data for beryllium activities might support a more direct characterization of the temporal variations of beryllium concentrations in exhaust streams.

Nine-hour averaged air concentrations of plutonium (corresponding to weekday working hours) for the four main stacks on Building 12 at DP West Site for calendar years 1956 and 1957 were entered into a spreadsheet. Raw daily data have not been located for earlier years. HEPA filters were added to the process exhaust system at DP West in 1959, and because the bulk of the releases from the facility appear to have come from exhausts that were not HEPA filtered, the earlier data was chosen as most representative of the conditions of greatest interest.
Averages were computed for 9 h (the raw data) as well as for weekly (45 h), monthly (196 h) and annual (2,349 h) averages. The data were maintained as 9-h working days in order to match the recorded data. In addition, the actual days for each week and month within 1956 and 1957 were maintained. Except for the annual average data, which had only one data point for each series (1956 and 1957), the data for each averaging period were fit to lognormal distributions with excellent residuals.

One can fit a lognormal distribution to an equation of the form \( y = a \times e^{bx} \), where \( y \) is the natural log of the observed concentration and \( x \) is the standard deviation. The exponential constant \( (e^b \text{ in the equation } y = a \times e^{bx}) \) provides the geometric standard deviation of the lognormal distribution. Both 1956 and 1957 had similar exponential factors, and the data were averaged for a best estimate. Examination of the data showed no general time dependence in concentration over the course of a year (such as slow falloff with time), even though LANL emissions did trend lower over the decades of DP West operations. The “\( b \)” value was plotted as a function of the log of the integration time and fit to a linear equation. With this equation, the geometric standard deviations \( (e^b) \) for treated particulate releases were predicted for various integration times ranging from 6 min to one month.

The analyses of the releases from DP West are summarized in Table 20-1 below. The 95th percentile for monthly data would correspond (roughly) to a concentration reached on one day of each month. As one goes to shorter time intervals, the 95th percentile is reached more and more often, and is not a useful factor to use for a conservative analysis. For example, using the 95th percentile, the 1-h data would be expected to either be larger or smaller than the annual average by a factor of 8.2 for 1 h out of every 20. Thus, hourly data would expect to be exceeded every 1 or 3 d, and 6 min (0.1 h) data would be seen as often as twice a day. As a result, the table also lists the multiplicative factor that would be found for a concentration that would be attained once per 1600-h work year. Using the “once per year” values, one can see from Table 20-1 that the 1-h data would exceed the annual average values by a factor of 30 for the estimated highest hour of the 1600 hour work year. Although the regulatory requirements dictate an instantaneous limit, this analysis has limited the averaging period to a minimum of 0.1 h. The data indicate that at 30 min of sampling or exposure time (0.5 h) the concentration would exceed annual averages by a factor of 47 once per year. No “once per year” multipliers are provided for weekly or monthly time periods. The 95th percentile should be used for screening for those time periods. The duration factors are not used in the estimation of episodic releases, for which releases for each event were estimated and converted to average concentrations over longer periods based on assumed numbers of events of stated material content within each period.
Table 20-1. Geometric standard deviation data based on analysis of detailed DP West plutonium stack sampling data, with factors to estimate release rates over periods shorter than 1 y

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Equivalent Hours</th>
<th>“b” Value a</th>
<th>95th Percentile</th>
<th>Once per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 min</td>
<td>0.1</td>
<td>1.3</td>
<td>13.6</td>
<td>149</td>
</tr>
<tr>
<td>30 min</td>
<td>0.5</td>
<td>1.1</td>
<td>9.5</td>
<td>47</td>
</tr>
<tr>
<td>Hour</td>
<td>1</td>
<td>1.1</td>
<td>8.2</td>
<td>30</td>
</tr>
<tr>
<td>Work Day</td>
<td>8</td>
<td>0.8</td>
<td>5.2</td>
<td>8.3</td>
</tr>
<tr>
<td>Day</td>
<td>24</td>
<td>0.7</td>
<td>4.1</td>
<td>4.6</td>
</tr>
<tr>
<td>Work Week</td>
<td>40</td>
<td>0.6</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Week</td>
<td>168</td>
<td>0.5</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Month</td>
<td>730</td>
<td>0.3</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>Work Year</td>
<td>1,600</td>
<td>0.2</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>8,760</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

a The term $e^b$ represents the geometric standard deviation of the lognormal distribution fitted to DP West stack sample analysis results.

Estimation of Beryllium Release Rates for Identified Emission Sources

Fabrication of components from beryllium metal and oxide (TA-1 and TA-3)


South Mesa Building 39, “SM-39,” Beryllium Shop 4 was outfitted with a HEPA filter on the exhaust in 1964. Release measurements after this time period were found for 6 y in the 1960s and reported in a manner that permits annual average releases to be computed. The study of DP West stack particulate releases of plutonium, discussed earlier, provide a means to estimate the concentrations for shorter time periods. The exhaust system apparently ran only during normal working hours. LAHDRA does not know if the stack sampler pump was only operated when the stack exhaust fan was operating. This assessment assumes that the sampler pump also only ran during the hours of operation. If it did not, then the “sampler hours of operation” correction would provide an additional factor of 5.5 increase for the total beryllium released, ($\approx 8760 \text{ h} / 1600 \text{ h}$) since the concentration in the stack would be expected to be much lower when the machining operations ceased during non-working hours. The documentation of the data for 1964 through 1966 did not identify fan hours of operation, so the average of the operating hours (1600) for the 1968 through 1970 period was chosen.

Table 20-2 and Table 20-3 below summarize the release data found (LASL 1969, 1970). Table 20-3 has the duration factors from Table 20-1 for each time interval applied to the data from 1970 to
permit comparison with applicable limits. The screening calculations utilize 1970, the highest year that has been found to date.

The annual release rate for 1600 h (0.0245 µg s\(^{-1}\) for 1970) must be adjusted by 1600 h / 8760 h to correctly express the average release rate in a year. In Table 20-2, the “Working Hours” column refers to the fan operating time, which is also the operational release period. The Mass Released column is the release for the specified year. The stack flow rate was 2,000 ft\(^3\) min\(^{-1}\) (LASL 1970).

In Table 20-3, the time periods of one day or longer have been corrected for the fact that the release occurs over a shorter time than the integration period. For example, the year release rate is 0.0245 µg s\(^{-1}\) times 1602.6 h of operation divided by 8760 h y\(^{-1}\). For time periods less than the operating period (i.e., 1 h or less), this factor is no longer applied, since the 6 to 9 h workday was longer than those time periods, so correcting for the time the stack exhaust was not operating is not needed.

The work day time period corresponds to an 8 h day, the work week to a 40 h period, the month to a 730 h period, and the year to 8760 h. These were chosen in order to permit comparison to occupational and ambient exposure limits.

### Table 20-2. Measured beryllium releases from SM-39 shop at TA-3 after 1963

<table>
<thead>
<tr>
<th>Year</th>
<th>Working Hours</th>
<th>Mass Released, g</th>
<th>Working Hours Release Rate, µg s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>1600</td>
<td>0.0105</td>
<td>0.0018</td>
</tr>
<tr>
<td>1965</td>
<td>1600</td>
<td>0.0106</td>
<td>0.0018</td>
</tr>
<tr>
<td>1966</td>
<td>1600</td>
<td>0.0188</td>
<td>0.0033</td>
</tr>
<tr>
<td>1967</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>1545.7</td>
<td>0.0089</td>
<td>0.0016</td>
</tr>
<tr>
<td>1969</td>
<td>1687.7</td>
<td>0.0378</td>
<td>0.0062</td>
</tr>
<tr>
<td>1970</td>
<td>1602.6</td>
<td>0.1416</td>
<td>0.0245</td>
</tr>
</tbody>
</table>

### Table 20-3. Estimated SM-39 beryllium shop release rates after 1963 based on measurements made in 1970 and application of duration factors

<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1970</td>
<td>3.65</td>
</tr>
</tbody>
</table>
b) TA-3, SM-39 Beryllium Shop Operations 1953 - 1963

The beryllium shop at SM-39 was put into operation in 1953 to replace the inadequate facilities in the main shop at V Building in the Original Technical Area. At the start of operations, no provisions were made for HEPA filtration of exhausts. Release measurements were not found for the SM-39 shop in this era. In order to estimate a lower bound for air concentrations and releases from the SM-39 beryllium shop from 1953 to 1963, measurements from the late 1960s were adjusted to account for the fact that no HEPA filters were in place. In general, HEPA filters are considered to attain a filtering efficiency of 99.97% (USDOE 2003). This corresponds to a reduction of the effluent by a factor of 3,333 (=1/ (1-0.9997)). This efficiency is obtained at a particle size diameter of 0.3 µm in diameter, with better efficiencies realized for smaller and larger particles. Data indicate that the filter systems used during this era attained efficiencies in the 90% range. An assumed 95% efficiency would attain reduction by a factor of 20. The ratio of the pre- and post-1964 filter reduction factors is 167 (=3,333/20). For this assessment, SM-39 exhaust monitoring data from 1970 were multiplied by 167 to estimate release rates for 1953 through 1963 (see Table 20-4). Use of this factor likely understates the releases by a considerable amount, given that the airborne particles larger or smaller than 0.3 micron diameter would have been filtered more efficiently. A partially offsetting factor for this conservatism may come from the fact that an improperly installed HEPA filter may not have attained 99.97% efficiency. Because the values represent long term averages, they were multiplied by the factors in Table 20-1 for the desired sampling or exposure time to provide the data in Table 20-5. For comparison purposes, the 1970 data that were the basis for 1953-1964 is repeated in Table 20-5. The 1,600 h y⁻¹ exhaust operating period was also assumed. The impact of the lack of HEPA filters before 1964 is readily seen in Table 20-5 by comparing the 1953–1963 data with the 1970 values.

Table 20-4. Estimated airborne releases from the SM-39 beryllium shop from 1953 to 1963

<table>
<thead>
<tr>
<th>Year</th>
<th>Working Hours</th>
<th>Annual Average Concentration, µg m⁻³</th>
<th>Mass Released, g</th>
<th>Working Hours Release Rate, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1953–1963</td>
<td>1600</td>
<td>4</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>1970</td>
<td>1602.6</td>
<td>0.0260</td>
<td>0.1416</td>
<td>0.0245</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1953-1963</td>
<td>610</td>
</tr>
<tr>
<td>1970</td>
<td>3.65</td>
</tr>
</tbody>
</table>
c) V-Building Shop Operations at TA-1 between 1949 and 1953

The main shops in V Building at the Original Technical Area, TA-1, were used for machining beryllium prior to the startup of the SM-39 shop at TA-3 in 1953. Around late 1948, when LANL was informed of the hazardous nature of beryllium, the high speed machining operations were relocated into an annex to V Building and an exhaust system was added with filters. For the purposes of this analysis, it was assumed that the non-HEPA filters that were used had comparable filtering efficiencies to the filtering system used at the SM-39 shop at TA-3 before HEPA filtration was added. Because the operations in the V Building shop appear to have been grossly similar to those at the SM-39 shop, the estimated release rate for the SM-39 shop for 1953-1963 was used for V Building shop from 1949 to 1953. The main difference between the two emission sources in terms of prioritization will be the shorter separation of V Building from nearby residences. Estimated beryllium releases are summarized in Table 20-6 and applied to various averaging periods in Table 20-7.

Table 20-6. Estimated airborne releases from the V-Building shop at TA-1 from 1949 to 1953

<table>
<thead>
<tr>
<th>Year</th>
<th>Working Hours</th>
<th>Annual Average Concentration, µg m⁻³</th>
<th>Mass Released, g</th>
<th>Working Hours Release Rate, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949 – 1953</td>
<td>1600</td>
<td>4</td>
<td>24</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 20-7. Estimated V-Building beryllium shop release rates for 1949 through 1953 with duration factors applied

<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1953-1963</td>
<td>610</td>
</tr>
</tbody>
</table>

d) V-Building Shop Operations at TA-1 between 1943 and 1948

At the start of LANL, the main shops in V Building at TA-1 were used for machining beryllium. Prior to around 1948, when LANL was informed of the hazardous nature of beryllium, the operations occurred in the shop itself with no specialized exhaust ventilation. Because the nature of the operations at the V-Building shop appear to have been grossly similar to the SM-39 shops at TA-3, use of that release rate estimate is appropriate. However, the releases were not collected by a process exhaust system and were not released through a stack. We assume that the releases occurred from the normal ventilation of the shop area, perhaps a ventilation fan. In contrast to the case of the post-1949 V-shop operations, the main change in prioritization will be the diffuse release through building.
ventilation as opposed to a stack. As in the case of the V-Building shops 1949 - 1953, because the nature of the operations was grossly similar to the TA-3 shops, use of the release rate estimate for the SM-39 shop 1953-1963 is appropriate. As for all sources of chronic releases, the Table 20-1 factors were applied to correct the annual average to the sampling or exposure time of interest. Estimated beryllium releases are summarized in Table 20-8 and applied to various averaging periods in Table 20-9.

Table 20-8. Estimated airborne releases from the V-Building shop at TA-1 from 1943 to 1948

<table>
<thead>
<tr>
<th>Year</th>
<th>Working Hours</th>
<th>Annual Average Concentration, µg m⁻³</th>
<th>Mass Released, g</th>
<th>Working Hours Release Rate, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1943 – 1948</td>
<td>1600</td>
<td>87</td>
<td>472</td>
<td>82</td>
</tr>
</tbody>
</table>

Table 20-9. Estimated V-Building beryllium shop release rates for 1943 through 1948 with duration factors applied

<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1943-1948</td>
<td>12,156</td>
</tr>
</tbody>
</table>

Gun Testing of Atomic bomb Initiators Containing Beryllium– B Building Annex at TA-1

If one approximates an atomic bomb initiator as a sphere of beryllium of a radius given by the 20-mm barrel diameter of the gun at B Building, each of the daily initiator tests used 566 g (the mass of a metal sphere of beryllium of 10 mm radius), and an estimated 10% was aerosolized and exhausted from the room, or 57 g per test. Documents that describe initiator testing have a data block that lists typical values of 90 to 120 “Gr” projectile weights. This mass is close to the mass of a normal projectile the auto-cannon would fire, and would be consistent with grams rather than grains. If the projectile weight was in grains, only 8 g would be used for the entire projectile, which seems too low in mass to be realistic. Using the stated mass of the projectile would mean that the beryllium released would be five times less that stated earlier (solid sphere of beryllium of 20 mm diameter) for each shot. For this initial assessment, 120 g is assumed expended, of which 10% was released. During the first 180 d of the program, 180 initiator tests were conducted. That being the case, it appears that the B- Building Annex alone released more than 2160 g (10% of 120 g for 180 tests) over the one half year in 1944 for which data were found. This would amount to 4,320 g y⁻¹.
After each test was fired, the 10% fraction assumed to be aerosolized was dispersed into the room and removed by the ventilation system. It was assumed that a flow rate sufficient to produce 12 air changes per hour was used. If the beryllium was uniformly mixed into the room volume, the concentration would drop exponentially with a time period equal to the inverse of the ventilation rate. A time sufficient to produce two air changes (0.1 h or 6 min) would remove most of the beryllium and was assumed to be the release period. Thus, the release would correspond to 12 g of beryllium over 360 s, or 0.033 g s\(^{-1}\). The data sheets reviewed indicate test frequency of roughly once per day. Thus, a test was assumed to occur 365 days per year. Because the release rate considers the release time, the duration factors of Table 20-1 are not applied for these episodic releases. With a release each day (365 d y\(^{-1}\)) and duration of 0.1 h, the release is assumed to occur over a 36.5-h operating period. However, the release rate when averaged over longer periods of time drops with the ratio of the averaging period to that of the considered duration of release. No annual average concentration is provided. The hours of operation of what is believed to have been a nominal 600 ft\(^3\) min\(^{-1}\) ventilation fan are not known. Estimated beryllium releases are summarized in Table 20-10 and applied to various averaging periods in Table 20-11.

**Table 20-10.** Estimated airborne beryllium releases from B-Building gun testing at TA-1, 1944-1948

<table>
<thead>
<tr>
<th>Years</th>
<th>Operating Period, h</th>
<th>Mass Released, g</th>
<th>Release Rate, µg s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1943 – 1948</td>
<td>36.5</td>
<td>4,320</td>
<td>33,333</td>
</tr>
</tbody>
</table>

**Table 20-11.** Estimated beryllium release rates from B-Building gun testing (duration factors not applied)

<table>
<thead>
<tr>
<th>Years</th>
<th>6 min</th>
<th>30 min</th>
<th>Hour</th>
<th>Work Day</th>
<th>Work Week</th>
<th>Month</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1943-1948</td>
<td>33,333</td>
<td>6,667</td>
<td>3,333</td>
<td>417</td>
<td>417</td>
<td>139</td>
<td>139</td>
</tr>
</tbody>
</table>

Explosive testing of bomb components containing beryllium

During the peak year of dynamic testing, 1964, a total of 106 kg of beryllium was used at TA-15, a fraction of which was aerosolized into fine particulate form that would distribute downwind. While LANL has traditionally assumed 2% of the mass is aerosolized, this assumption (along with others) fails to account for the mass of beryllium expended at the firing sites and found in nearby soils. Lawrence Livermore National Laboratory (LLNL) has used assumptions that 8% of the mass is aerosolized. Both of those values (either 2% or 8%) were the result of experiments conducted by the laboratories. Finally, the Dual-Axis Radiographic Hydrodynamics Test (DARHT) facility EIS, which was published more
recently, assumed a value of 10%. For this analysis, it was assumed that 10% of the 106 kg expended in 1964 was aerosolized.

The amount of beryllium used in a specific experiment is classified. In order to estimate a release rate, it was assumed that between 50 and 150 experiments were performed at the three firing sites during the year (less than once per week), with a total of 100 experiments performed. It was assumed that 80% of the experiments did not use beryllium at all, and of the 20 experiments that did, 16 used small amounts of beryllium (together accounting for 50% of the total mass) and 4 of them used larger amounts (together accounting for 50% of the total mass). Each of the larger experiments might have used 13.25 kg.

The duration of the exposure from the explosive test was taken to be 0.25 h as the puff drifted off-site with the prevailing wind. This heuristic estimate is based partially on the estimated size of the puff a short time after detonation and subsequent dispersion of that puff as it drifts approximately 5,000 m off site with an average wind speed.

Because the release rate considers the release time, the factors of Table 20-1 are not needed. Table 20-12 provides the annual average values (10% of 106 kg dispersed in 0.25 h × 100 tests = 25 h) as well as the peak (one of 4 tests in the year that dispersed 10% of 13.25 kg in 0.25 h). Table 20-13 applies the peak rate to time intervals of a week or less, and assumes the annual release rate for the year and the month. If one had assumed that one of the shots that month was one in which 13.25 kg was used (and the rest averaged the 1.06 kg), then the month would be a factor of 2.3 times larger. This was not used in order to maintain a simpler set of assumptions. Using this method provides an average rate for the month equal to the annual rate. In fact, it is likely that the month in which a larger than average quantity of beryllium was used in shots had higher release rates than 336 µg s⁻¹ over the 730 h period. This can be accounted for if assessment of beryllium releases continues and detailed (classified) shot records are retrieved and summarized in a manner that would be publicly releasable.

### Table 20-12. Estimated airborne beryllium releases from TA-15 explosive testing

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration of Exposure, h</th>
<th>Mass Released, g</th>
<th>Release Rate, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964 (year)</td>
<td>25</td>
<td>10,600</td>
<td>117,778</td>
</tr>
<tr>
<td>1965 (month)</td>
<td>2.08</td>
<td>1,766</td>
<td>235,467</td>
</tr>
<tr>
<td>1964 (maximum shot)</td>
<td>0.25</td>
<td>1,325</td>
<td>1,472,222</td>
</tr>
</tbody>
</table>
Table 20-13. Estimated beryllium release rates from TA-15 explosive testing (duration factors not applied)

<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1964</td>
<td>1,472,222</td>
</tr>
</tbody>
</table>

Hot Pressing of Beryllium Oxide Powder in Q Building at TA-1

LANL ordered 6,100 lbs of beryllium oxide (BeO) for use in reactors by January 15, 1944 (LASL 1944). For this assessment, it was assumed that the 6,100 lbs of BeO powder that was ordered was actually used in 1944. This is a metric ton of the element beryllium alone.

In order to estimate the amount of BeO (and Be) that would be released; the methods of the USDOE Handbook of Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities were used (USDOE 1994). For this application, it was necessary to estimate an Overall Release Fraction (ORF). The Atmospheric Release Fractions (ARF) and Respirable Fractions (RF) were then multiplied to get a range of Overall Release Fractions (ORF). The geometric mean of the ORF, computed as 0.0025 (the square root of the product of the upper and lower bounds), was then applied to the total BeO ordered for 1944.

The ARF was estimated as between 5% of the mass on the high end, and 0.5% of the mass on the low end. The RF was estimated as the mass fraction below 5 µm diameter. The upper bound was estimated from the known upper size limit (-325 mesh or 44 µm) and an assumed geometric standard deviation of 3 for the particle size. Two standard deviations (3×3 = 9) were used to estimate the geometric mean of 5 µm, which means one half of the mass of BeO was below 5 µm and was respirable. A value for respirable fraction (RF) that was ten times smaller was used as an estimate for the lower bound. These values are summarized in Table 20-14.

Table 20-14. Release fraction parameter values for BeO powder processing

<table>
<thead>
<tr>
<th></th>
<th>Upper Bound</th>
<th>Lower Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne Release Fraction (ARF)</td>
<td>0.05</td>
<td>0.005</td>
</tr>
<tr>
<td>Respirable Fraction (RF)</td>
<td>0.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Overall Release Fraction (ORF)</td>
<td>0.025</td>
<td>0.00025</td>
</tr>
<tr>
<td>Geometric Mean of ORF</td>
<td>0.0025</td>
<td></td>
</tr>
</tbody>
</table>
Applying the geometric mean of the overall release fraction (0.25%) to the 6,100 pounds of BeO used in 1944 results in a release of 6,932 g of respirable BeO from Q Building during the year, which would have contained 2,495 g of beryllium. Table 20-15 and Table 20-16 provide the total releases and the release rates with duration factors applied for Q-Building BeO powder pressing during 1944. It can be assumed that these releases likely continued to occur until the late 1940s, when LANL began to impose more stringent controls on beryllium operations.

**Table 20-15.** Estimated airborne beryllium releases from BeO powder pressing in Q Building at TA-1

<table>
<thead>
<tr>
<th>Year</th>
<th>Duration of Exposure, h</th>
<th>Mass Released, g</th>
<th>Release Rate, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>1600</td>
<td>2,495</td>
<td>433</td>
</tr>
</tbody>
</table>

**Table 20-16.** Estimated beryllium release rates from BeO pressing in Q Building at TA-1 with duration factors applied

<table>
<thead>
<tr>
<th>Year</th>
<th>Release Rate for Stated Averaging Period, µg s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 min</td>
</tr>
<tr>
<td>1944</td>
<td>64,475</td>
</tr>
</tbody>
</table>

**Estimation of Atmospheric Dilution Factors**

Beryllium Machining at V Shop in the Original Technical Area

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on V Building that met or exceeded the 2.5-times building height criterion for avoidance of building wake effects. Because of this, building wakes will be a consideration. Based on review of drawings and photographs of the Original Technical Area, the surface area of V Building, $A_G$, was approximately $39 \times 15 = 585 \text{ m}^2$, the square root of which is 24.2 m; 2.5 times that value is 60.5 m. The distance from V Building to the nearest residence, the southernmost Sundt apartment on 24th Street, was approximately 165 m (see Fig. 20-1). As this value exceeds both 2.5-times the square root of $A_G$ and 100 m, this is a case of exposure outside the near-wake region.
Fig. 20-1. Approximate distances from Original Technical Area beryllium facilities to nearest residences
The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

\[
C = \frac{f \cdot Q \cdot B}{u}
\]

Where:
- \(C\) = average atmospheric concentration at receptor, µg m\(^{-3}\)
- \(f\) = fraction of time that the wind blows toward the receptor of interest
- \(Q\) = effluent release rate (µg s\(^{-1}\) in this application)
- \(B\) = the Gaussian plume model diffusion factor modified for building wake effects
- \(u\) = mean wind speed, m s\(^{-1}\)

Because the distance, \(x\), to the nearest potentially exposed individual is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine \(B\). That figure indicates that a value of \(9 \times 10^{-4}\) m\(^{-2}\) should be used for \(B\) when \(x = 165\) m and \(A_C\) falls between 300 and 1,000 m\(^2\). The NCRP Report 123 method incorporates a value of 0.25 for \(f\), and recommends a default of 2 m s\(^{-1}\) for \(u\) when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), \(C/Q\), as follows:

\[
C/Q = (0.25) (9 \times 10^{-4}\) m\(^{-2}\)) (2 m s\(^{-1}\))\(^{-1}\) = 1.13 \times 10^{-4}\) s m\(^{-3}\)
\]

This value can be multiplied by the estimated release rate of beryllium from V Building (µg s\(^{-1}\)) to estimate the airborne beryllium concentration (µg m\(^{-3}\)) at the southernmost Sundt apartment on 24th street in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, \(f\) will be set to 1, and relative concentrations will be four times the \(C/Q\) value shown above.

**Beryllium Oxide Pressing at Q Building in the Original Technical Area**

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on Q Building that met or exceeded the 2.5-times building height criterion. Because of this, building wakes will be a consideration. Based on review of drawings and photographs of the Original Technical Area, the surface area of the Q Building, \(A_C\), was approximately 10 m \(\times\) 5 m = 50 m\(^2\), the square root of which is 7.1 m; 2.5 times that value is 17.7 m. The distance from Q Building to the nearest residence, the southernmost Sundt apartment on 25th Street, was approximately 136 m (see Fig. 20-1). As this value
exceeds both 2.5-times the square root of $A_G$ and 100 m, this is a case of exposure outside the near-wake region.

The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

$$C = \frac{f Q B}{u}$$

Where:

- $C =$ average atmospheric concentration at receptor, $\mu g m^{-3}$
- $f =$ fraction of time that the wind blows toward the receptor of interest
- $Q =$ effluent release rate ($\mu g s^{-1}$ in this application)
- $B =$ the Gaussian plume model diffusion factor modified for building wake effects
- $u =$ mean wind speed, m s$^{-1}$

Because the distance, $x$, to the nearest residence is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine $B$. That figure indicates that a value of $2 \times 10^{-3}$ m$^{-2}$ should be used for $B$ when $x = 136$ m and $A_G$ falls between 0 and 100 m$^2$. The NCRP Report 123 method incorporates a value of 0.25 for $f$, and recommends a default of 2 m s$^{-1}$ for $u$ when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), $C/Q$, as follows:

$$C/Q = (0.25) (2 \times 10^{-3} m^{-2}) (2 m s^{-1})^{-1} = 2.5 \times 10^{-4} s m^{-3}$$

This value can be multiplied by the estimated release rate of beryllium from Q Building ($\mu g s^{-1}$) to estimate the airborne beryllium concentration ($\mu g m^{-3}$) at the southernmost Sundt apartment on 25th street in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, $f$ will be set to 1, and relative concentrations will be four times the $C/Q$ value shown above.

**Beryllium Processing in the SM-39 Shops at TA-3**

The photographs and documents that have been reviewed indicate that associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of this, building wake will be a consideration. The distance from Building SM-39 to the closest residential area, Western Area housing, is approximately 960 meters (Fig. 20-2). Based on review of aerial photographs of SM-39, the width of the north end of the building is approximately 76 m. Based on review of historical photographs, the height of that building is approximately that of a two story
building, or roughly 7 m. The cross-sectional area of the north end of the building is therefore 532 m², the square root of that value is 23, and 2.5-times the square root is 58. As the distance to the nearest public exposure point exceeds 2.5-times the square root of \( A_G \), this is a case of exposure outside the near-wake region. The concentration at the exposure point can be estimated as follows (NCRP 1996):

\[
C = \frac{f Q B}{u}
\]

Where:
- \( C \) = average atmospheric concentration at receptor, \( \mu g \ m^{-3} \)
- \( f \) = fraction of time that the wind blows toward the receptor of interest
- \( Q \) = effluent release rate (\( \mu g \ s^{-1} \) in this application)
- \( B \) = the Gaussian plume model diffusion factor modified for building wake effects
- \( u \) = mean wind speed, \( m \ s^{-1} \)

Because the distance to the nearest residence, \( x \), is less than 2 km, Figure 1.5 of NCRP Report 123 was used to determine \( B \). That figure indicates that a value of \( 5.5 \times 10^{-5} \ m^{-2} \) should be used for \( B \) when \( x = 960 \) m and \( A_G \) falls between 300 and 1,000 m². The NCRP Report 123 method incorporates a value of 0.25 for \( f \), and recommends a default of 2 m s⁻¹ for \( u \) when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), \( C/Q \), as follows:

\[
C/Q = (0.25) (5.5 \times 10^{-5} \ m^{-2}) (2 \ m \ s^{-1})^{-1} = 6.88 \times 10^{-6} \ s \ m^{-3}
\]

This value can be multiplied by the estimated release rate of beryllium from the SM-39 shops to estimate the airborne beryllium concentration (\( \mu g \ m^{-3} \)) at the southernmost residences of the Western Area in Los Alamos. For evaluation of episodic releases, when it is appropriate to assess concentrations when the wind is blowing toward the identified nearest exposure point, \( f \) will be set to 1, and relative concentrations will be four times the \( C/Q \) value shown above.

**Gun Testing of Weapon Components in the Annex to B Building in the Original Technical Area**

Based on review of drawings and 1940s photographs of the Original Technical Area, there was no stack on B Building that met or exceeded the 2.5-times building height criterion. Because of this, building wakes will be a consideration. The surface area of the building, \( A_G \), is approximately 62 m × 15 m = 930 m², the square root of which is 30.5 m; 2.5 times that value is 76.2 m. The distance from the center of the rear (southern facing) side of B Building to the southernmost Sundt apartment on 25th Street in Los Alamos was 49 m (Fig. 20-1). As this is less than both 2.5-times the square root of \( A_G \) and 100 m, this is...
Fig. 20-2. Approximate distance from Building SM-39 at TA-3 to the southernmost residences of the Western Area in Los Alamos

SM-39 to Western Area housing = approximately 960 m
a case of exposure in the near-wake region. The concentration at the exposure point can therefore be estimated as follows (NCRP 1996):

\[ C = \frac{f Q}{\pi u h K} \]

Where:
- \( k \) = a constant of value 1 m, and
- \( h \) = the smaller of the building height or building width, m.

In this case, building height, \( h_b \) (~15 m) is less than its width, \( h_w \) (~62 m).

The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), \( C/Q \), as follows. Because the B-Building gun tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting \( f \) to 1.

\[ C/Q = (1)[(3.14) \times (2 \text{ m s}^{-1}) \times (15 \text{ m})]^{-1} = 1.06 \times 10^{-2} \text{ s m}^{-3} \]

This value can be multiplied by the estimated release rate (\( \mu \text{g s}^{-1} \)) of beryllium from the back center of B Building to estimate the airborne beryllium concentration (\( \mu \text{g m}^{-3} \)) at the southernmost Sundt apartment on 25th Street in Los Alamos.

**Beryllium Expended in Explosive Testing at TA-15 (PHERMEX facility)**

Based on review of drawings, photographs, and descriptions of the TA-15 facilities, associated releases were not exhausted through a stack that met or exceeded the 2.5-times building height criterion for nearby structures. Because of this, building wakes (or wakes from nearby structures) will be a consideration. The distance from the main PHERMEX building to the nearest residential area, the Royal Crest Trailer Park on East Jemez Road, is approximately 4,500 m (see Fig. 20-3). There were no large buildings in the immediate area of PHERMEX. As the distance to the nearest public exposure point exceeded 2.5-times the square root of \( A_G \) for all buildings in the area of the testing, this is a case of exposure outside the near-wake region. Because the distance to the nearest public exposure point exceeds 2 km, the concentration at the exposure point can be estimated as follows (NCRP 1996):

\[ C = \frac{f Q B}{u} \]

Where:
- \( C \) = average atmospheric concentration at receptor, \( \mu \text{g m}^{-3} \)
- \( f \) = fraction of time that the wind blows toward the receptor of interest
\[ Q = \text{effluent release rate (µg s}^{-1}\text{ in this application)} \]
\[ P = \text{the Gaussian plume model diffusion factor as a function of downwind distance assuming a release height (}H\text{) at ground level, 0 m.} \]
\[ u = \text{mean wind speed, m s}^{-1}\]

Because \(x\) is greater than 2 km, Figure 1.4 of NCRP Report 123 is used to determine \(P\). That figure indicates that a value of \(5 \times 10^{-6}\) m\(^{-2}\) should be used for \(P\) when \(x = 4500\) m and \(H = 0\) m. The NCRP Report 123 method incorporates a value of 0.25 for \(f\), and recommends a default of 2 m s\(^{-1}\) for \(u\) when site specific data are not available. The above equation can be rearranged to yield a relative concentration (concentration for a unit release rate), \(C/Q\), as follows. Because the PHERMEX explosive tests were episodic releases, concentrations will be estimated for the conditions when the wind was blowing toward the identified nearest exposure point by setting \(f\) to 1.

\[
C/Q = (1) \left(5 \times 10^{-6}\ \text{m}^{-2}\right) \left(2 \text{ m s}^{-1}\right)^{-1} = 2.5 \times 10^{-6}\ \text{s m}^{-3}
\]

This value can be multiplied by the estimated release rate of beryllium from explosive testing at TA-15 (µg s\(^{-1}\)) to estimate the airborne beryllium concentration (µg m\(^{-3}\)) at the Royal Crest Trailer Park on East Jemez Road in Los Alamos.

**Estimation of Concentrations at Points of Interest**

Concentrations of airborne beryllium at the nearest residence (µg m\(^{-3}\)) from each identified beryllium operation were estimated by multiplying the estimated release rate (µg s\(^{-1}\)) by the applicable relative concentration value (s m\(^{-3}\)). Results are shown in Table 20-17. The estimated release rate and concentration values for BeO powder pressing, V Shop, and SM-39 Shop releases are presented as 6-min, 30-min, and 8-h average values that would be expected to be reached or exceeded once per year and monthly average concentrations that would be expected to be reached or exceeded 5% of the time. For the explosive tests at TA-15, the results in Table 20-17 for periods longer than a week are values averaged over the periods shown based on 100 shots in a year, each with 0.25-h duration of exposure, that together released 10% of the total beryllium reported expended in 1964. For periods shorter than a month, the results are values averaged over the periods shown based on one shot, with 0.25-h duration of exposure, occurring during the period and releasing 1.25% of the total beryllium reported expended in 1964.
Fig. 20-3. Approximate distance from TA-15, PHERMEX area, to the Royal Crest Trailer Park on East Jemez Road in Los Alamos
Table 20-17. Results of screening-level assessment of potential airborne beryllium concentrations in residential areas of Los Alamos

<table>
<thead>
<tr>
<th>Distance to exposure point (m)</th>
<th>B-Building Gun Tests&lt;sup&gt;a&lt;/sup&gt;</th>
<th>BeO Powder Pressing</th>
<th>V-Shop Machining 1943-48</th>
<th>V-Shop Machining 1949-53</th>
<th>SM-39 Shop 1953 to 1963</th>
<th>SM-39 Shop after 1963</th>
<th>PHERMEX Explosive Tests&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative concentration (s m&lt;sup&gt;-3&lt;/sup&gt;)</td>
<td>1.1×10&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>2.5×10&lt;sup&gt;-4&lt;/sup&gt;</td>
<td>1.1×10&lt;sup&gt;-4&lt;/sup&gt;</td>
<td>1.1×10&lt;sup&gt;-4&lt;/sup&gt;</td>
<td>6.9×10&lt;sup&gt;-6&lt;/sup&gt;</td>
<td>6.9×10&lt;sup&gt;-6&lt;/sup&gt;</td>
<td>2.5×10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>Release rates (µg s&lt;sup&gt;-1&lt;/sup&gt;) for stated averaging periods:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 h:</td>
<td>33,000</td>
<td>64,000</td>
<td>12,000</td>
<td>610</td>
<td>610</td>
<td>3.7</td>
<td>1,500,000</td>
</tr>
<tr>
<td>0.5 h:</td>
<td>6,700</td>
<td>20,000</td>
<td>3,900</td>
<td>190</td>
<td>190</td>
<td>1.2</td>
<td>740,000</td>
</tr>
<tr>
<td>8 h:</td>
<td>420</td>
<td>3,600</td>
<td>680</td>
<td>34</td>
<td>34</td>
<td>0.20</td>
<td>46,000</td>
</tr>
<tr>
<td>730 h (1 month):</td>
<td>140</td>
<td>150</td>
<td>29</td>
<td>1.4</td>
<td>1.4</td>
<td>0.0086</td>
<td>670</td>
</tr>
<tr>
<td>Exposure point concentrations (µg m&lt;sup&gt;-3&lt;/sup&gt;) for stated averaging periods:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1 h:</td>
<td>350&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>16&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.4&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.069&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.0042</td>
<td>0.000025</td>
<td>3.7&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.5 h:</td>
<td>71&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>5.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.44&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.022&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.0013</td>
<td>0.0000080</td>
<td>1.8&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>8 h:</td>
<td>4.4&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>0.90&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.077&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.0038</td>
<td>0.00023</td>
<td>0.000014</td>
<td>0.12&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>730 h (1 month):</td>
<td>1.5&lt;sup&gt;d,e&lt;/sup&gt;</td>
<td>0.038&lt;sup&gt;d,e&lt;/sup&gt;</td>
<td>0.0033</td>
<td>0.00016</td>
<td>0.000010</td>
<td>0.00000059</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

<sup>a</sup> Episodic releases
<sup>b</sup> Possible exceedance of OSHA/AEC 8-h time weighted average limit = 2 µg m<sup>-3</sup>
<sup>c</sup> Possible exceedance of OSHA/AEC ceiling limit = 25 µg m<sup>-3</sup>
<sup>d</sup> Possible exceedance of USEPA Reference Concentration = 0.02 µg m<sup>-3</sup>
<sup>e</sup> Possible exceedance of National Emission Standard for ambient air averaged over a 30-d period = 0.01 µg m<sup>-3</sup>
Identification of Relevant Toxicologic or Regulatory Benchmarks

The current OSHA permissible exposure limit (PEL) for occupational exposure to beryllium is 2 µg m\(^{-3}\) (8-h time weighted average). A ceiling limit of 5 µg m\(^{-3}\) must not be exceeded during the work shift, except that a 30-minute excursion over the ceiling limit is allowed as long as the air concentration never exceeds 25 µg m\(^{-3}\) during the 30-minute period (NIOSH 2003).

The U.S. Atomic Energy Commission issued “Recommendations for Control of Beryllium Hazards” in August 1951 that included three standards: a 2 µg m\(^{-3}\) in plant 8-h average beryllium concentration; a 25 µg m\(^{-3}\) beryllium air concentration which can never be exceeded; and, a 0.01 µg m\(^{-3}\) monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt 1957).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 µg m\(^{-3}\) (USEPA 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1996 (Kreiss et al. 1996) and 1949 (Eisenbud et al. 1949).

The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 µg m\(^{-3}\) (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed and included area samples, process breathing-zone samples, and personal lapel samples (the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 µg m\(^{-3}\) in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

According to the Agency for Toxic Substances and Disease Registry (ATSDR 2002), there is evidence to suggest that the occurrence of chronic beryllium disease is not related to duration of exposure and can have a long latency period. Very few studies assessing the occurrence of chronic beryllium disease also measured airborne beryllium levels. Eisenbud et al. (1949) found no cases of chronic beryllium disease in
residents living at least 0.75 miles away from a beryllium manufacturing facility. The airborne beryllium concentration at this distance was estimated to range from 0.01 to 0.1 µg m\(^{-3}\).

It is the opinion of the ATSDR that the available database does not support the derivation of acute, intermediate, or chronic duration inhalation MRLs (minimal risk levels). Eisenbud et al. (1949) found no cases of chronic beryllium disease among community residents chronically exposed to 0.01-0.1 µg m\(^{-3}\) of beryllium. The study used relatively insensitive methods to detect chronic beryllium disease, therefore it’s not known if the residents exposed to 0.01 µg m\(^{-3}\) of beryllium would test positive for sensitization or subclinical chronic disease. No human acute or intermediate duration studies that identify a NOAEL or LOAEL for respiratory effects were identified. Animal studies have not identified a reliable NOAEL, and the LOAELs are several orders of magnitude higher than the LOAEL from the Kreiss et al. (1996) occupational exposure study. Although the critical target of beryllium toxicity has been identified as the respiratory tract, an animal model that mimics all aspects of chronic beryllium disease has not been identified. Therefore, it is inappropriate to derive inhalation MRLs from the animal data (ATSDR 2002).

Several studies attempted to associate beryllium sensitization and/or chronic beryllium disease with mean, cumulative, and peak exposure levels and duration of employment, but no consistent associations were found. Although the data are insufficient for establishment of concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 µg m\(^{-3}\). Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels (0.00003–0.0002 µg m\(^{-3}\)) are very low (ATSDR 2002).

**Comparison of Estimated Concentrations with Relevant Benchmarks**

The results of the preliminary screening of airborne beryllium concentrations in residential areas of Los Alamos, in terms of estimated airborne concentrations over four different averaging periods, are represented in Fig. 20-4 along with representations of the regulatory limits that can be applied to beryllium concentrations in occupational or public settings. The estimated airborne beryllium concentrations that exceeded one or more of those limits are also identified with footnotes in Table 20-17. While occupational exposure limits are not directly applicable to exposures of members of the public, they are presented as benchmarks to which the calculated concentrations can be compared. Limits imposed on exposures to members of the public are generally lower than those imposed on worker exposures, so concentrations in residential areas must be maintained lower than those accepted in workplace environments.
**Fig. 20-4.** Screening-level estimates of airborne beryllium concentrations in public areas near LANL for six historical operations
Conclusions

The screening results indicate that the 8-h time weighted average permissible exposure limit of 2 µg m⁻³ for beryllium adopted for workers by OSHA and the AEC could have been exceeded in residential areas by releases from the B-Building gun tests. The OSHA/AEC ceiling limit of 25 µg m⁻³ for workers could also have been exceeded for releases from those tests based on concentrations estimated for 0.5-h and 0.1-h averaging periods. The USEPA reference concentration of 0.02 µg m⁻³ could have been exceeded in residential areas by releases from B-Building gun testing, BeO powder pressing, V-Shop machining, and tests at PHERMEX. The National Emission Standard of 0.01 µg m⁻³ for beryllium in ambient air averaged over a 30-d period could have been exceeded in residential areas from the B-Building gun tests and BeO powder pressing.

References


LASL. Beryllium memos from LANL Archives Collection A-1984-019, Box 36, Folder 1 Los Alamos Scientific Laboratory. 1944. Repos. No. 4975.

LASL. H-5 Air Sample Data Sheet - Beryllium Shops and Exhaust Los Alamos Scientific Laboratory. 1969. Repos. No. 7816


Chapter 21: Public Involvement within the LAHDRA Project

Unlike some dose reconstruction projects that have been conducted, the LAHDRA project team was not advised by a committee formed in accordance with the Federal Advisory Committee Act. Public meetings were held once or twice each year at various locations in the Los Alamos-Española-Taos-Pojoaque-Santa Fe region. The meetings included presentations and discussions concerning progress in information gathering, knowledge gained about historical activities of relevance to off-site releases, problems that were being encountered in accessing and obtaining relevant documents, plans for completion of information gathering, and progress toward prioritizing historical releases. Updates on noteworthy aspects of project activities were also presented at annual conferences of relevant professional societies.

Postings on the LAHDRA Web site included summaries of all public meeting presentations and associated public comments and discussion, summaries of workshops that were conducted to offer more detailed overviews of project-related topics for interested parties from LANL and the public, downloadable copies of Interim Reports of the project, video clips of excerpts of public meeting presentations, and information concerning contacting LAHDRA team members and accessing the project document collection and the DocSleuth database at local libraries. CDC and contractor team members also met with and offered briefings to representatives of the Eight Northern Pueblo Council and many of the individual pueblos in Northern New Mexico.

Through 2008, there were 15 public meetings and two workshops hosted by CDC and the LAHDRA project team. These meetings were held in Pojoaque (6 occasions), Los Alamos (5), Española (3), Santa Fe (2), and Taos (1). Eight interim versions of the report of the LAHDRA project were issued as information gathering progressed.

Fig. 21-1. A view of the LAHDRA public meeting in July 2008
Dates and major topics of the meetings are listed below, in order of most recent to earliest.

Summaries of all public meetings and workshops, including copies of the presentations and paraphrasing of public comments and questions, are available on the project Web site at http://www.lahdra.org/meetings/meetings.htm

- Wednesday, July 23, 2008 - Project update, status of document review
- Wednesday, July 18, 2007 - Progress in document reviews, study of plutonium releases in the 1940s and 1950s, public exposures from the Trinity test, report updated
- Wednesday, July 26, 2006 - Project update, status of document review, new database
- Thursday, June 23, 2005 - Project update, discuss new contract
- Tuesday, July 27, 2004 - CDC announces completion of work under first LAHDRA contract
- Wednesday, July 9, 2003 - Project update, outlook for continued work
- Wednesday, July 10, 2002 - Project update, impact of access restrictions
- Tuesday, November 27, 2001 - Project update, access to records
- Tuesday, April 24 and Thursday, April 26, 2001 - Project update, access restored, document availability
- Wednesday, September 13, 2000 - Project update, draft report, access issues
- March 8, 2000 - Project update
- October 5, 1999 - Interviews with current and retired workers
- July 27, 1999 - Project update and sample documents
- February 23, 1999 - Project introduction

Fig. 21-2. A photographic display presented at the July 2008 public meeting
Chapter 22: Findings of the LAHDRA Project

The LAHDRA project has significantly expanded the quantity of original documentation that is publicly available relevant to past operations at Los Alamos, activities by LANL personnel within New Mexico, and the potential for public health effects from past environmental releases.

The body of information that has been gathered by LAHDRA document analysts is not perfect or complete, and the project team was only able to scratch the surface toward careful analysis of its contents. Some documents that were generated at LANL will never be found due to their loss or destruction, others are difficult or impossible to read because of their age and repeated photocopying, and many of the authors and participants from the periods of highest releases have passed away. In spite of these factors, the members of the LAHDRA study team believe that enough information exists to reconstruct public exposures from the most significant of LANL’s releases to a degree of certainty sufficient to allow health professionals to judge if significant elevations of health effects should be expected or measurable.

For the latter part of the project, some documents containing certain categories of sensitive information were withheld from review by LAHDRA analysts. Because documents in these categories included nuclear weapon design details, foreign intelligence, and other types of information that are truly not relevant to studies of off-site releases or health effects, it does not appear that any information needed for dose reconstruction was withheld. The existence of an appeal process by which a federal employee from CDC could review withheld documents to verify that they contained no needed information was a key consideration in the adoption of that conclusion. And while text was redacted from many selected documents prior to public release, LAHDRA analysts had access to original and redacted copies and could verify that the redacted text did not contain information that would be needed for dose reconstruction.

The LAHDRA project has been conducted with a high level of transparency, so that interested parties could review documents as the team members have selected, perform their own assessments if they so choose, and see if they come to the same conclusions. Significant effort was directed to making DocSleuth and the LAHDRA collection of over 8,000 documents available to all interested parties in the most readily usable fashion. From the beginning of the project, search plans were shared at public meetings, and progress reports highlighted significant milestones, accomplishments, and challenges. Preliminary prioritization assessments were openly shared, even though there was the possibility that information obtained later might prompt revisions of approaches, assumptions, or conclusions. Members of the public, activist groups, and LANL personnel were encouraged to comment on the search plans and draft work products and make recommendations for refinement or follow-up work. The quality and
utility of the products of the LAHDRA project has been enhanced by this interaction with scientists and members of the public.

The information gathered by the LAHDRA team indicates that airborne releases to the environment from Los Alamos operations were significantly greater than has been officially reported or published to the scientific community. The preliminary prioritization steps that have been performed within the LAHDRA project, while they have been quite simple, have provided information regarding the relative importance of past releases of airborne radionuclides, waterborne radionuclides, and chemicals. In general, it has been shown that early releases were most important (1940s-1960s) than those that followed, and that plutonium was the most important radionuclide in those early years. Airborne activation products from accelerator operations were most important after the mid-1970s, and gross alpha-emitting radioactivity was important for waterborne releases from the mid-1950s to the mid-1970s. Among chemicals, organic solvents as a class were likely most important, followed by TNT and uranium as a heavy metal.

While prioritization analyses have provided relative rankings of contaminants within categories, the preliminary analyses described herein provided no estimates of concentrations to which members of the public were exposed, resulting intakes, or doses to members of the public that could be converted to estimated health risks or compared to toxicologic benchmarks or decision criteria. Priority Indices based on dilution volumes required to be in compliance with maximum allowable effluent concentrations do not reflect how uptake factors vary between radionuclides or the decay that occurs between release point and the location of potential public exposure. And because of the paucity of details regarding uses and releases of chemicals before the 1970s, the preliminary ranking process used for toxic chemicals did not incorporate estimates of the fractions of quantities of chemicals that were on-hand or used were available for release to the environment or were likely released.

Within the effort to prioritize past releases from LANL activities, it was possible for the project team to advance to screening-level analyses of potential public exposures from airborne releases of plutonium, beryllium, tritium, and uranium. While those analyses have yielded information that is relevant to evaluation of the potential health significance of the four evaluated materials, it is important to keep in mind that screening results are not meant to represent actual doses that were received by members of the public or concentrations to which residents could have been exposed. They are meant to support decisions concerning whether further investigation of identified releases should be pursued.

LAHDRA has been almost exclusively an information gathering effort. If estimates of historical exposures to members of the public are desired for the releases that have been identified and prioritized by the LAHDRA team, it will be necessary to delineate pathways of human exposure that were complete, to characterize environmental fate and transport, and to calculate doses and the subsequent health risks to
groups who were exposed. Methods to perform these steps have been developed and applied for numerous other atomic weapons complex sites, but would have added dimensions to properly reflect the effects of the complex terrain in which LANL is set and to represent the transport of waterborne releases that often soak into dry stream beds before they travel very far, to be transported to a large part by occasional high flow events that wash contaminants toward the Rio Grande.

A number of historical operations have been identified by LAHDRA analysts as areas that might have been particularly important in terms of off-site exposures. In addition, critical information gaps have been identified in several areas.

- **Early airborne releases of plutonium.** Plutonium was processed in crude facilities in D Building during World War II, and many roof-top vents were unfiltered and unmonitored. After DP West Site took over production late in 1945, there was some filtering of releases, but poor monitoring practices caused releases to be underestimated. Documents indicate that DP West releases for 1948-1955 alone were over 100-times the total reported by the Lab for operations before 1973. A screening-level assessment of public exposures from releases of plutonium in 1949 showed that airborne plutonium releases warrant further evaluation.

- **Airborne beryllium releases.** Los Alamos used significant quantities of beryllium before the health hazards of the material were fully appreciated, and it was processed very close to residential areas. Preliminary screening indicated that early beryllium processing could have resulted in concentrations in residential areas that exceeded worker exposure limits, the USEPA reference concentration, and the National Emission Standard for beryllium.

- **Public exposures from the Trinity test.** Residents of New Mexico were not warned before the 1945 Trinity blast or informed of health hazards afterward, and no residents were evacuated. Exposure rates in public areas from the world’s first nuclear explosion were measured at levels 10,000-times higher than currently allowed. Residents reported that fallout “snowed down” for days after the blast, most had dairy cows, and most collected rain water off their roofs for drinking. All assessments of doses from the Trinity test issued to date have been incomplete in that they have not addressed internal doses received after intakes of radioactivity through inhalation or consumption of contaminated water or food products.

- **Airborne uranium releases.** LANL has used uranium since its beginnings in enrichments ranging from depleted to highly enriched. It has been machined and fabricated into weapon and reactor components and large quantities have been expended in explosive testing. Preliminary screening assessments indicate that enriched uranium releases do not warrant high priority in terms of potential
health risk, but show that releases of depleted uranium warrant further investigation. None of these evaluations, however, consider releases from LANL’s early operations. Early releases could have been much larger than those from the 1970s forward, for which effluent data have been summarized. Further investigation is needed before a conclusive assessment can be made of potential health risks from LANL’s airborne uranium releases.

- **Tritium releases before 1967.** Los Alamos used tritium as early as 1944, and received it in increasing quantities in the decades that followed for use at ten or more areas of the Lab. In spite of this, LANL compilations of effluent data include no tritium releases before 1967. LAHDRA team members located scattered documents that describe numerous episodic releases within the 22-year period of tritium usage for which official reports of LANL releases include no data for the radionuclide. These documents call into question the release estimates reported by LANL for 1967 forward and indicate that releases before 1967 constitute a data gap that must be addressed if the health significance of LANL tritium releases is to be evaluated.

Based upon the and the information that has been gathered and the findings of the LAHDRA project, CDC and other interested parties will judge if the available information indicates that past releases of any materials could have been sufficiently high that detailed investigation of past releases and public exposures is warranted, and if it appears that sufficient information exists to support detailed investigation if the requisite funding could be made available. Potential further investigations that could be undertaken for one or more contaminants of highest priority could range from screening level assessments of potential public exposures to more rigorous exposure assessments like those that have been conducted for other MED/AEC/DOE sites and have become known as dose reconstructions. Unlike the prioritization analyses performed to date, these assessments would likely incorporate modeling of environmental transport, exposure pathway analysis, and reflection of the uncertainties and variability associated with input data, assumptions, and models so that the ranges of exposures received by likely members of the public can be specified at a stated level of confidence. Assessments of that type are often performed in an iterative fashion, with uncertainty analyses focusing research on components of the assessment that are contributing most to the overall uncertainty of results. Further refinement can be directed to those elements, and the process repeated until the uncertainty of results is acceptable or cannot be further reduced.