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The Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project began in early 1999.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

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

Notes: Document review statistics current as of April 2009. ES&H = Environment, Safety, and Health; LANSCE = Los Alamos Neutron Science Center; WEM = Weapons Engineering and Manufacturing; WEP = Weapons Engineering and Physics; ERSS = Environment & Remediation Support Services; NEPA = National Environmental Policy Act; EA = Environmental Assessment; EIS = Environmental Impact Statement.

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 1×10^{-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 2×10^{-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 ES-2. Classes of airborne radionuclides with highest Priority Indices for each period of LANL operations

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

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

radioactivity while the maximum effluent concentration for ^{89}Sr was used for gross beta radioactivity. The waterborne radionuclide classes that yielded the highest Priority Indices for each period from 1945 through 1996 are identified in Table ES-3.

Table ES-3. Classes of waterborne radionuclides with highest PIs for periods of LANL operations

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

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}Pu in soil included global fallout from atmospheric testing of nuclear devices. The average concentration of ^{239}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[a]

Chemical	Slope Factor (SF) $(mg\ kg^{-1}\ d^{-1})^{-1}$	Reference Dose (RfD) $(mg\ kg^{-1}\ d^{-1})$	Peak annual use (kg)	Ranked based on cancer effects		Ranked based on non-cancer effects	
				Use × SF	Rank	Use × RfD^{-1}	Rank
Acetone	-	0.9	18,800	-	-	20,889	13
Benzene	0.055	0.004	181	10	7	45,250	9
Carbon tetrachloride	0.13	0.0007	558	73	5	797,143	5
Chlorodifluoromethane[b]	-	14.3	32,200	-	-	2,252	17
Chloroform[c]	0.0805	0.01	3,088	249	4	308,800	7
Dichlorodifluoromethane[b]	-	0.0571	32,200	-	-	563,923	6
Dioxane	0.011	-	32	0.35	8	-	-
Methanol	-	0.5	6,600	-	-	13,200	14
Methyl ethyl ketone	-	0.6	22,000	-	-	36,667	12
Methylene chloride	0.008	0.06	2,200	17	6	36,667	11
n-Hexane	-	0.06	304	-	-	5,067	16
Tetrachloroethylene	0.54	0.01	10,540	5,692	2	1,054,000	4
TNT (2,4,6-trinitrotoluene)	0.03	0.0005	37,950	1,139	3	75,900,909	3
Toluene	-	0.08	3,300	-	-	41,250	10
Trichloroethane (methyl chloroform)	-	0.2	39,300	-	-	16,500	8
Trichloroethylene	0.4	0.0003	27,719	11,088	1	92,396,667	1
Uranium (as a heavy metal)	-	0.0006	47,500	-	-	79,166,667	2
Xylene[b,d]	-	0.0286	290	-	-	10,140	15

[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 1.67×10^{-4} Sv y^{-1} based on 1 in 100,000 added risk of fatal or non-fatal cancer using a risk factor of 6.0×10^{-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

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

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

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

[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 1.67×10^{-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 1.67×10^{-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 1.7×10^{-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 1.67×10^{-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 2.11×10^{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 4.4×10^{-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 5.4×10^{-6} Sv (0.54 mrem). This is well below the screening criterion of 1.67×10^{-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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