Beryllium has been used at Los Alamos since 1943 in various operations related to nuclear reactors and weapons production, including machining, fabrication and testing of components. The discovery of beryllium in 1798 was credited to the French chemist Louis Nicolas Vauquelin upon formulation of beryllium hydroxide. Elemental beryllium, however, was not isolated prior to two independent experiments in 1828. Beryllium occurs naturally only as the $^9\text{Be}$ isotope, although five additional isotopes are produced artificially, $^6\text{Be}$ to $^{11}\text{Be}$ (IPCS 1990).

Beryllium is the lightest of all solid and chemically-stable substances and has an unusually high melting point of 1287°C (HSDB 2005). The metal has a number of chemical properties in common with aluminum, including a very high affinity for oxygen. On exposure with air, a thin film of beryllium oxide forms on the surface of bare metal, providing the metal with high resistance to corrosion. This film also renders beryllium resistant to water and cold oxidizing acids (IPCS 1990).

Neutron emission upon alpha-bombardment is the most important of the nuclear physical properties associated with beryllium. Its low neutron absorption properties and its high-scattering cross-section distinguish beryllium as a suitable moderator and reflector of structural material in nuclear facilities. While most other metals absorb neutrons from the fission of nuclear fuel, beryllium atoms only reduce the energy of such neutrons and reflect them back into the fission zone (IPCS 1990).

**Industrial Uses of Beryllium**

Interest in and application of beryllium grew after the discovery in the 1920s that addition of only two percent beryllium to copper resulted in an alloy that was six times stronger than copper alone (IPCS 1990, Becker and Vigil 1999). Metallic beryllium was examined as a possible tamper material as early as 1943 in the U.S. nuclear weapons program. Enough beryllium had been accumulated at Los Alamos by May 1946 to allow for critical mass experiments (Hanson 1995). However, use of large quantities in the nuclear weapons program in the 1940s would have exhausted the entire U.S. supply of the metal. Beryllium was used as a substitute for gold or natural uranium reflectors in early atomic weapons, thereby saving much weight and money (Hanson 1995).

Beryllium metal did not become readily available to American industry until 1957. Since that time, beryllium use has been widespread as an additive to glass, ceramics and plastics; in camera shutters, submarine cable housings, and dental prostheses; and in beryllium-copper alloys in products such as golf
clubs, springs, pivots, and pinions. Beryllium is additionally used in the semiconductor, precision electronics, spacecraft, and missile manufacturing industries (IPCS 1990).

A timeline depicting events of importance regarding uses of beryllium in general and at AEC/DOE facilities, uses at Los Alamos, states of knowledge regarding health effects, and promulgation of guidelines and regulatory limits is presented in Table 11-1.

**Records Searches for Beryllium Information**

The project team has identified few reports written during the period of historical beryllium operations at LANL other than H-Division Progress Reports. Most of the early H-Division reports mention beryllium air sampling in specific LANL buildings, but no details regarding the associated beryllium operations are provided. Several documents were located in the LANL Records Center and Report Collection that provide summaries of historical monitoring activities associated with beryllium metal machining and firing site operations (Mitchell and Hyatt 1957, Becker and Vigil 1999). A Johns Hopkins report (JHSPH 1999) was recommended to the project team by a former LANL worker, and a copy was provided by M. Cadorette, Project Coordinator, after initial contact with the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) office in Española, NM.

Very little historical stack monitoring data for beryllium have been located by the project team. If stack releases of beryllium were not routinely monitored, indoor air monitoring data might be useful for estimating source terms for beryllium releases to the environment.

**Operations Involving Beryllium Release to the Environment**

Two types of operations at LANL, machining and firing tests, have resulted in releases of beryllium to the environment. The machining, grinding, sanding and general handling of beryllium components typically occurred in machine shops or experimental laboratory settings. Dynamic testing has involved use of beryllium and other materials in explosive tests in the open air or with various forms of containment or confinement. Industrial Hygiene records indicate that activities involving beryllium have been performed at 20 different Technical Areas between 1943 and 1980. The main facilities that housed beryllium operations within the Original Technical Area are shown in Fig. 11-1. Beryllium metal was processed in the shops and metallurgical labs, and soluble beryllium salts were handled in the chemical labs (JHSPH 1999).
### Table 11-1. Beryllium timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>First description of acute beryllium disease (Weber and Engelhardt 1993)</td>
</tr>
<tr>
<td>1943</td>
<td>Chemical pneumonia reported in workers extracting beryllium from beryl ore (Van Ordstrand et al. 1943)</td>
</tr>
<tr>
<td>1943</td>
<td>U.S. Public Health Service publishes NIH Bulletin 181 stating that beryllium metal is not toxic (Hyslop et al. 1943)</td>
</tr>
<tr>
<td>~1944</td>
<td>Beryllium machining began in V Shop at LASL’s Original Technical Area</td>
</tr>
<tr>
<td>1946</td>
<td>First cases of chronic beryllium disease (CBD) in fluorescent light bulb workers (Hardy and Tabershaw 1946)</td>
</tr>
<tr>
<td>1947</td>
<td>United States Atomic Energy Commission (USAEC) is formed</td>
</tr>
<tr>
<td>1949</td>
<td>USAEC establishes a 2 µg m⁻³ occupational exposure limit at their facilities (Eisenbud et al. 1949)</td>
</tr>
<tr>
<td>1949</td>
<td>Beryllium machined in V Shop Annex (also known as the “Old Beryllium Shop”) at LASL</td>
</tr>
<tr>
<td>1952</td>
<td>Exhaust system enlarged in Old Beryllium Shop at LASL</td>
</tr>
<tr>
<td>1953</td>
<td>Beryllium is machined in the new beryllium shop at LASL and the old beryllium shop is closed</td>
</tr>
<tr>
<td>1957</td>
<td>ACGIH proposes a 2 µg m⁻³ Threshold Limit Value exposure limit (ACGIH 2006)</td>
</tr>
<tr>
<td>1958</td>
<td>USAEC contracts with Brush Wellman for 200,000 lbs of beryllium per year (Stange 2005)</td>
</tr>
<tr>
<td>1959</td>
<td>Health protection in beryllium facilities; summary of 10 y of experience (Breslin and Harris 1958, Breslin and Harris 1959)</td>
</tr>
<tr>
<td>1971</td>
<td>OSHA adopts the 2 µg m⁻³ permissible exposure limit (PEL) 8-hr TWA (time-weighted average) (OSHA 2008)</td>
</tr>
<tr>
<td>1973</td>
<td>National Emission Standard for beryllium in ambient air 0.01 µg m⁻³ averaged over a 30-d period (USEPA 2004)</td>
</tr>
<tr>
<td>1977</td>
<td>NIOSH recommends a 0.5 µg m⁻³ limit to OSHA, classifies beryllium as a potential occupational carcinogen (USDOE 1999) based on an increased risk for lung cancer associated with exposure to high levels of beryllium in the workplace before the 1950s (ACGIH 2006)</td>
</tr>
<tr>
<td>1984</td>
<td>First case of CBD at the USDOE Rocky Flats Plant (Stange 2005)</td>
</tr>
<tr>
<td>1998</td>
<td>ACGIH proposes a 0.2 µg m⁻³ TLV®-TWA to minimize CBD and sensitization</td>
</tr>
<tr>
<td>1998</td>
<td>USEPA establishes a reference concentration of 0.02 µg m⁻³ based on sensitization and progression to CBD (USEPA 2009)</td>
</tr>
<tr>
<td>1999</td>
<td>USDOE establishes a 0.2 µg m⁻³ action level that triggers workplace precautions and control measures (USDOE 1999)</td>
</tr>
<tr>
<td>2000</td>
<td>Energy Employees Occupational Illness Compensation Program Act (EEOICPA) passed by Congress</td>
</tr>
<tr>
<td>2001</td>
<td>EEOICPA makes first CBD claim award (Stange 2005)</td>
</tr>
<tr>
<td>2007</td>
<td>ACGIH proposes a 0.05 TLV®-TWA and a 0.2 TLV®-STEL (short term exposure limit) (NRC 2008)</td>
</tr>
</tbody>
</table>
Fig. 11-1. December 1946 view, looking south, of the Original Technical Area with buildings that had significant beryllium involvement identified; Buildings Gamma, V, and M on the left, B and Q in the center, and Sigma, I, and Delta toward the right. Based on photo LAHM-P1990-40-1 courtesy of the Los Alamos Historical Society.
Machining and Component Production Operations

The first production job assigned to the metallurgy groups at Los Alamos involved the manufacture of specially-shaped high-density beryllium oxide bricks required for the Water Boiler reactor. Production of these bricks was accomplished by hot-pressing beryllium oxide powder into a graphite die or mold of suitable shape. The die and contents were heated to approximately 1,700 °C using an induction coil connected to a high-frequency converter under a pressure of 1,000 psi. This process consolidated the semi-plastic beryllium oxide powder into a dense coherent mass in the shape of the die. Occasionally, grinding of the bricks to a precise size was required when critical dimensions had to be met (Smith 1945).

Until 1948, beryllium was machined in the center of a large machine shop located in V Building at the Original Technical Area, TA-1, known as V Shop (JHSPH 1999). Flexible exhaust ducts were placed near the cutting tool and the captured dust was exhausted into the shop’s atmosphere. Due to the use of coarse fiberglass filter media, the Industrial Hygiene Group recommended that the filtered air be exhausted outside the shop.

In 1949, an addition was built onto the main shop where only beryllium would be machined. All machines were equipped with local exhaust hoods. Each machine hood was exhausted by a blower-filter unit equipped with a wool-felt filter. The air was exhausted outside the building through a common stack. The quantity of air exhausted by each unit was approximately 200 ft³ min⁻¹. In 1951, the concentrations of beryllium in stack effluent ranged from 0.1 to 2.0 µg m⁻³ (JHSPH 1999).

In 1952, the local exhaust system was enlarged to provide a larger quantity of air for each machine and to add an additional lathe and mill to the shop. The blower was capable of exhausting 2,000 ft³ min⁻¹ through the five local exhaust hoods in the shop, thus providing approximately 400 ft³ min⁻¹ for each hood. A cloth tube filter was installed outside the old beryllium machine shop to maximize collection efficiency for air cleaning prior to release to the environment. The unit consisted of two steel chambers each containing 32 cloth tubes (cotton bags containing asbestos floc as a filter aid) operating continuously with a total capacity of 2,000 ft³ min⁻¹. The collection efficiency determined by isokinetic sampling during normal machining operations was 98.8%. The mass median diameter particle size in samples collected with a cascade impactor in the duct before the filter was 4 microns (µm) (Mitchell and Hyatt 1957).

In August 1953, the shop was closed down and all machines and equipment were cleaned to prepare for the move to a new shops building at TA-3, SM-39 (JHSPH 1999). Operations in the new beryllium shop were started in October 1953 and included two lathes, a mill, a surface grinder, and an index mill used as...
a drill press, all in hood enclosures. The cloth tube filter was moved to the filter room above the machine shop in the new building. A dynamic separator was installed before the cloth tube filter and dampers were installed on all machine hoods. Orlon bags with no filter aid were used instead of cotton bags with asbestos floc. The theoretical collection efficiency increased to 99.9% but the Orlon bags were not as effective (Mitchell and Hyatt 1957).

Continuous stack samples were collected downstream of the dust tube filter in both the old and new beryllium shops. Of the 309 samples collected between 1952 and 1956 (44 from the V Shop and 265 from the SM-39 Shop), 53% were below 0.05 µg m⁻³ (the method detection limit), 67% were below 0.10, 77% were below 0.2, 94% were below 1.0, 99% were below 2.0, and 100% were below 25 µg m⁻³.

Although no tolerance for beryllium stack discharge had been recommended, it was the opinion of the Industrial Hygiene Group at that time that the neighborhood tolerance of 0.01 µg m⁻³ was never exceeded based on the results from the exhaust stacks and atmospheric dilution (Mitchell and Hyatt 1957).

Beryllium work was also initially performed at the Delta, Gamma, I, M, and [old] Sigma buildings at TA-1. Work activities at old Sigma included extrusion, welding, heating beryllium in a furnace, and flame plating beryllium onto substrates. Beryllium metal was welded and machined at Delta building, and beryllium oxide materials were used at M Building. V Shop was a foundry and machine shop where a variety of metals, including beryllium were processed (JHSPH 1999).

As summarized in Table 11-2 and Table 11-3, industrial hygiene records indicate that sampling for beryllium has been conducted at numerous buildings at TA-3 and at 19 other Technical Areas. The Sigma Complex at TA-3 is made up of three large buildings and several smaller buildings totaling over 200,000 ft². These facilities, built in the 1950s and 1960s, house laboratory areas for materials synthesis, and processing, characterization, and fabrication of materials such as beryllium, uranium, thallium, and aluminum alloys. The Sigma Complex is home to two groups of the Materials Science and Technology Division– Ceramics (MST-4) and Metallurgy (MST-6).

The three main buildings of the Sigma Complex are:

- Sigma Building (SM-66)– built in 1959 and 170,000 ft² in size;
- Rolling Mill Building (SM-141)– built in the early 1960s and covering 20,000 ft²; and
- Press Building (SM-35)– built in 1953 and 10,000 ft² in size.
Table 11-2. Beryllium operations at TA-3 buildings

<table>
<thead>
<tr>
<th>Bldg No.</th>
<th>Building Name</th>
<th>Beryllium Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM-16</td>
<td>Van de Graaff Lab</td>
<td>Sanding</td>
</tr>
<tr>
<td>SM-29</td>
<td>New CMR Bldg</td>
<td>chemical synthesis, vaporization, purification</td>
</tr>
<tr>
<td>SM-30</td>
<td>Warehouse</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-39</td>
<td>Shops Bldg</td>
<td>machining, milling, brazing, heat treating, cutting</td>
</tr>
<tr>
<td>SM-32</td>
<td>Center for Material Science</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-43</td>
<td>Admin Bldg</td>
<td>foils, mirrors, BeO rods</td>
</tr>
<tr>
<td>SM-49</td>
<td>Physics Bldg</td>
<td>thin foils</td>
</tr>
<tr>
<td>SM-66</td>
<td>New Sigma Bldg</td>
<td>Casting, etching, brazing</td>
</tr>
<tr>
<td>SM-141</td>
<td>Rolling Mill Bldg</td>
<td>Coating</td>
</tr>
<tr>
<td>SM-184</td>
<td>Old Occupational Health Lab</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-218</td>
<td>Magnetic Energy and Storage</td>
<td>Unknown</td>
</tr>
<tr>
<td>SM-287</td>
<td>Scyllac Bldg</td>
<td>Unknown</td>
</tr>
</tbody>
</table>


BeF = beryllium fluoride; BeO = beryllium oxide; Be-U = beryllium uranium alloy

Table 11-3. Beryllium operations at Technical Areas other than TA-1 and TA-3

<table>
<thead>
<tr>
<th>TA No.</th>
<th>Technical Area Name</th>
<th>Beryllium Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA-6</td>
<td>Two-Mile Mesa</td>
<td>Foils</td>
</tr>
<tr>
<td>TA-8</td>
<td>Anchor Site West</td>
<td>storage of BeF and BeO</td>
</tr>
<tr>
<td>TA-9</td>
<td>Anchor Site East</td>
<td>BeF fusion furnace</td>
</tr>
<tr>
<td>TA-14</td>
<td>Q Site</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-15</td>
<td>R-Site</td>
<td>test firing with kg quantities of Be</td>
</tr>
<tr>
<td>TA-16</td>
<td>S-Site</td>
<td>laundry, burn pit</td>
</tr>
<tr>
<td>TA-18</td>
<td>Pajarito Site</td>
<td>Processing Be-U blocks and BeO rods, ultrasonic cleaning</td>
</tr>
<tr>
<td>TA-21</td>
<td>DP Site</td>
<td>Machining, milling, arc melting, palletizing</td>
</tr>
<tr>
<td>TA-33</td>
<td>HP Site</td>
<td>Machining using a method X machine</td>
</tr>
<tr>
<td>TA-35</td>
<td>Ten Site</td>
<td>high temperature Be salts</td>
</tr>
<tr>
<td>TA-39</td>
<td>Ancho Canyon</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-40</td>
<td>DF Site</td>
<td>milling, test firing</td>
</tr>
<tr>
<td>TA-41</td>
<td>Icehouse</td>
<td>test firing</td>
</tr>
<tr>
<td>TA-46</td>
<td>WA Site</td>
<td>Heating</td>
</tr>
<tr>
<td>TA-53</td>
<td>LANSCE</td>
<td>targets and beam stops</td>
</tr>
<tr>
<td>TA-11</td>
<td>K Site</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-43</td>
<td>Health Research Lab</td>
<td>Unknown</td>
</tr>
<tr>
<td>TA-48</td>
<td>Radiochemistry</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

One-third of Sigma Building space contains the mechanical and ventilation equipment necessary to protect the health and safety of personnel. The remaining area includes laboratories, offices, and administrative areas. The Rolling Mill Building contains laboratories for beryllium processing, powder metallurgy, ceramics research and rapid solidification research. The Press Building houses a 5,000-ton capacity hydraulic press with a 12-foot maximum opening and laboratories for hazardous materials research (LANL 1995).

Two 1992 files regarding permits for beryllium operations mention historical beryllium cutting operations at DP West Site’s Building 5 in the 1960s and possibly 1950s, and existing beryllium operations in Sigma building (TA-3-66), TA-16-450, and TA-55-4. The operations at Sigma Building and TA-16-450 had existed since the 1950s (Gutierrez 1992, Tiedman 1992). An H-1 Division notebook discusses procedures for monitoring beryllium in stack effluent from the CMR Building Wing 5 Filter Tower in February 1954 (Enders 1954).

**Dynamic Testing Operations**

Air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, although beryllium was involved in relatively few tests until 1954 (Voelz and Jordan 1974). Becker and Vigil (1999) reviewed the historical beryllium expenditure in dynamic tests conducted by the DX Division at LANL, present data on known beryllium concentrations in soil at firing sites, beryllium air concentrations measure onsite and beyond LANL boundaries, and beryllium concentrations in swipe samples. Records for beryllium use in dynamic testing activities at Los Alamos date back to 1955 and include shot records in the form of internal LANL memoranda, DX Division office records and published annual beryllium expenditures in LANL Environmental Surveillance reports. It is presumed that beryllium was expended in dynamic testing activities before 1955, although there has been no compilation of these data. They assumed that 160 kg of beryllium was used prior to 1955, but no explanation for this estimate is provided.

Table 11-4. Beryllium expenditure at LANL firing sites 1955-1997

<table>
<thead>
<tr>
<th>Site</th>
<th>Status as of 1999</th>
<th>Beryllium Expended (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-44 (TA-15)</td>
<td>Closed</td>
<td>346</td>
</tr>
<tr>
<td>PHERMEX (TA-15)</td>
<td>Active</td>
<td>332</td>
</tr>
<tr>
<td>E-F Site (TA-15)</td>
<td>Closed</td>
<td>321</td>
</tr>
<tr>
<td>R-306 (TA-15)</td>
<td>Active</td>
<td>43.6</td>
</tr>
<tr>
<td>All other firing sites at TA-15, -36, -39</td>
<td>--</td>
<td>21.4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>1,064</strong></td>
</tr>
</tbody>
</table>


Using a mass balance approach and the following assumptions, Becker and Vigil (1999) estimated soil concentrations of beryllium for three firing sites.

- 160 kg of beryllium expended prior to 1955
- more shots at E-F Site during years prior to 1955
- 2% of beryllium becomes aerosolized
- uniform soil concentration to a depth of 6 inches

The authors of the study found less beryllium in soil than they predicted, so they give possible explanations for the discrepancy, such as erosion and non-representative sampling. They postulated that the soil sampling might not have been representative of actual onsite contamination, or that other processes such as mass movement and erosion removed contamination from the firing sites.

LANL has conducted open-air dynamic experiments in which weapons components are either detonated or impacted against a target, which results in soil contamination with beryllium (Sauer et al. 2001). Monthly reports written by the LANL Dynamic Testing Division from December 1975 through December 1987 document fugitive emissions from explosive test shots, including quantities of beryllium released. During this 13-y period, 178 kg of beryllium were released as a result of test shots conducted at TA-15, TA-36 and TA-40. According to the monthly reports, 98% of the total beryllium emissions occurred between 1977 and 1982, and in 1984. However, about one-third of the monthly reports for the 13-y period are missing from the collection identified by the project team, and 75% of the missing reports are from the years 1983, 1985, 1986, and 1987. In the reports that are available, 55% of the monthly values are reported as 0 kg. The average monthly release is 1.65 kg with a standard deviation of 2.42 kg. The median monthly release is 0.02 kg, the 95% upper confidence limit on the mean is 2.04 kg, and the maximum monthly release is 10.6 kg (for November 1976).
**B Building Annex**

LANL Director’s Office Files for 1944 describe a request for four alpha detectors from Chicago for “0.05 d/cc/s” (disintegrations per cubic centimeter per second) in air in a 14” × 25” duct flowing 800 ft³ min⁻¹ and in other ducts (Bainbridge 1944). The detector was apparently for B Building annex, which was used for testing initiators and was an unmonitored release point for beryllium and polonium.

Information regarding the former B Building Annex at TA-1 was located in source material for the book *Critical Assembly* (LASL 1944-1945, Hoddeson et al. 2004). A folder in the LANL Archives contains draft chapters and LANL memos that were referenced in each chapter and describe the gun device and initiator testing. The B-Building annex, called the “wart on B Building,” was authorized by J. Robert Oppenheimer and constructed by the end of March 1944. It held a 20-mm, remotely fired, anti-aircraft autocannon used for testing scaled-down versions of gun-assembled atomic weapon components such as initiators. By mid-April of 1944, the annex was in operation. In August 1944, a “coffin” was authorized that was a box that was operated at negative pressure and equipped with a gas mask filter on its exhaust. By the end of September, the gun had been used in nearly 180 experiments at a frequency of one per day. Chapter 7 in Critical Assembly does not mention beryllium, nor did the assembled memos, as beryllium was not viewed as a hazardous material in the early 1940s. About 50 lbs per month of beryllium was used in the fabrication of initiators (LASL 1944-1945).

**Quantities of Beryllium Used at Los Alamos**

It has been estimated that 1,064 kg of beryllium was used between 1955 and 1997 and another 160 kg was used prior to 1955 at Los Alamos (Becker and Vigil 1999). Ninety-four percent of the beryllium was expended at PHERMEX, E-F, and R-44 firing sites and another 4% was expended at firing site R-306. Detailed information is not available on the remaining 2%, but it is presumed that it can be divided among the other firing sites.

According to Becker and Vigil (1999), the greatest annual expenditure of beryllium, in excess of 100 kg, occurred in 1964 and significant beryllium use occurred between about 1957 and 1971 (see Fig. 11-2). Beryllium use since 1985 has been relatively low, with annual expenditures remaining less than 5 kg.
In a 1977 report, LASL scientists estimated that 2% of the beryllium present in test devices becomes aerosolized during dynamic experimentation (Dahl and Johnson 1977). Based on this estimate, it has been calculated that approximately 1,200 kg of beryllium remains in the soil at Los Alamos and approximately 94% or 1,128 kg remains at the E-F, R-44, and PHREMEX firing sites per LANL records.

Monthly reports written by the LANL M-DO Division document fugitive emissions from explosive test shots conducted during from December 1975 to December 1987 (LANL 1975-1987). The emissions data are shown in Table 11-5. The release locations are the explosive test areas at TA-15, TA-36 and TA-40.

**Workplace and Environmental Monitoring for Beryllium**

Air concentrations of beryllium have been monitored at LANL for both indoor machining and outdoor firing tests operations since 1948 (Voelz 1970). Measures to control beryllium exposure were in place at Los Alamos beginning in 1948 based on recommendations from occupational medicine pioneer Dr. Harriet Hardy of the Massachusetts Institute of Technology (MIT), who collaborated with the AEC in Los Alamos. The Industrial Hygiene Program was introduced at LASL that same year (Mitchell and Hyatt 1957).
Table 11-5. Beryllium released to the environment by shots at TA-15, TA-36, TA-40

<table>
<thead>
<tr>
<th>Year</th>
<th>Beryllium (kg)</th>
<th>Beryllium Oxide (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>1976</td>
<td>25.54</td>
<td>0</td>
</tr>
<tr>
<td>1977</td>
<td>34.7</td>
<td>3</td>
</tr>
<tr>
<td>1978</td>
<td>29.2</td>
<td>0</td>
</tr>
<tr>
<td>1979</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>1980</td>
<td>9.8</td>
<td>0</td>
</tr>
<tr>
<td>1981</td>
<td>10.6</td>
<td>0</td>
</tr>
<tr>
<td>1982</td>
<td>26</td>
<td>0</td>
</tr>
<tr>
<td>1983</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>1984</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>1985</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1986</td>
<td>2.1</td>
<td>0</td>
</tr>
<tr>
<td>1987</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>175</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: LANL 1975-1987

Beryllium Metal Machining

The Industrial Hygiene Group at LASL made periodic surveys of beryllium machining operations from early 1948 through August 17, 1951. After September 1951, daily air samples were collected whenever beryllium was being machined. From September 1951 through 1955, a sampling rate of 20 L min\(^{-1}\) and a filtering velocity of 130 ft min\(^{-1}\) with Whatman #41 filter paper resulted in a collection efficiency of 70%. In 1956, a sampling rate of 10 L min\(^{-1}\) and a filtering velocity of 65 ft min\(^{-1}\) with Whatman #44 filter paper resulted in a theoretical collection efficiency of 99.8%.

A continuous air sampler with a sampling rate of 20 L min\(^{-1}\) and a filtering velocity of 130 ft min\(^{-1}\) using Whatman #4 filter paper was used to monitor beryllium air concentrations for short periods of exposure. The sampler was set to collect hourly general air samples in the vicinity of the machining operations. The reported collection efficiency was 80%. Starting in 1954, the hourly samples were only analyzed when an 8-h breathing zone sample approached the tolerance level of 25 µg m\(^{-3}\).

Air samples collected to assess beryllium concentrations through June 1950 were collected with an electrostatic precipitator and sent to the University of Rochester for analysis (Mitchell and Hyatt 1957). Although air samples were analyzed by the Industrial Hygiene Group beginning in June 1950, samples continued to be collected by the electrostatic precipitator through August 1951. Starting in September 1951, samples were collected using a portable pump connected to a sampling head equipped with filter paper. Samples collected after June 1951 were analyzed using a method based on the fluorescence of
morin with beryllium in an alkaline solution (Sax and Kramlich ca 1952). Beryllium concentrations ranging from 0.05 to 300 µg were adequately detected with this method. It is reported that air samples were analyzed by atomic adsorption in the early to mid 1990s, while samples collected in the late 1990s were analyzed by inductively coupled plasma atomic emission spectroscopy (Becker and Vigil 1999).

From 1950 to 1953, filter type respirators were occasionally used on special jobs. In some cases the filters from these respirators were analyzed for beryllium content. Analyses of respirator filters used during filter unit cleaning, and used during drilling operations without local exhaust ventilation, showed beryllium concentrations ranging from 300-400 µg m⁻³.

An experiment performed by the Industrial Hygiene Group in 1951 to determine the greatest sources of exposure during beryllium operations revealed that rough cutting created the heaviest source of dust. One air sample collected in the hood 8 inches from the cutting tool while rough cuts were being made on a piece of bar stock yielded a beryllium concentration of 725 µg m⁻³ (Mitchell and Hyatt 1957).

Routine air samples collected between September 1957 and June 1958 at the machine shop were well below permissible levels (LASL 1957, 1958). A distinct rise in the average beryllium concentration at the beryllium shop in 1957 was tracked to full time work on a crash program to make special beryllium pieces. The number of air samples collected at CMB-6 was also increased greatly during this time frame in association with a research project to determine the best method of joining two pieces of beryllium.

The beryllium machine shop at Los Alamos was washed down weekly and surface swipe tests were performed to ensure that loose beryllium dust levels were maintained below 15 µg ft⁻² (Mitchell and Hyatt 1957)

Firing Sites

A 1970 letter report from the LANL Health Division Leader to the Deputy Director of Military Application, USAEC, describes the historical air sampling of beryllium near explosive tests at LASL from 1948 to 1959 (Voelz 1970). While air samples and fallout trays were used to monitor beryllium during explosive tests starting in 1948, beryllium was involved in relatively few tests until 1954. In 1954 there was beryllium exposure during test firing of beryllium pieces in conjunction with explosives at TA-39, the Ancho Canyon Site. Most of the samples were collected between 1956 and 1959 when all tests occurred at R Site and were conducted by the GMX-4 group. In 1955, Group W-3 conducted an experiment at TA-33 in which a device exploded and large pieces of beryllium were thrown all over the firing area. Tests involving beryllium after 1959 were conducted at Ancho Canyon by GMX-6 and at
PHERMEX by GMX-11. Table 11-6 summarizes the data described in the 1970 Voelz letter report. The letter report also states that a few of the fallout trays “showed beryllium in the collected material” but no elaboration is provided. The report concludes, “Because of our experience with these results, shots containing beryllium are not monitored regularly but only when some special conditions of testing are planned.”

<table>
<thead>
<tr>
<th>Site</th>
<th>No. of Shots</th>
<th>No. of Samples (N)</th>
<th>No. of Samples &gt;MDC of 0.05</th>
<th>Maximum Onsite</th>
<th>Maximum Offsite</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-Site</td>
<td>39</td>
<td>156</td>
<td>11</td>
<td>0.66 (0.34)</td>
<td>0.05</td>
</tr>
<tr>
<td>Ancho Canyon</td>
<td>8</td>
<td>24</td>
<td>1</td>
<td>0.004</td>
<td>NR</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>2</td>
<td>NR</td>
<td>0</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

MDC = minimum detectable concentration; NR = Not reported.
1 Measured 800 y directly downwind from the shot.
2 Measured at Ten Site (TA-35).
3 Measured 150 y from the shot.

Air sampling for beryllium was performed by the LANL Environmental Surveillance program in the early 1970s and resumed in the 1990s. Samples collected on the roof of TA-59-1 during 1971 and 1972 yielded beryllium air concentrations between 0.06 and 0.4 ng m$^{-3}$ (0.00006 and 0.0004 µg m$^{-3}$). Quarterly samples of airborne beryllium collected onsite, at the Lab perimeter, and regionally in northern New Mexico in 1990, 1992, 1993 and 1994 as part of the AIRNET program ranged from 0.002 to 0.061 ng m$^{-3}$. When quarterly sampling was resumed in 1998, quarterly Airnet beryllium values ranged from 0 to 0.1 ng m$^{-3}$. Area air samples collected in 1998 at two firing sites during dynamic shots ranged from 0.013 to 0.381 µg m$^{-3}$ of beryllium (Becker and Vigil 1999).

Beryllium concentrations in surface water samples collected from the E-F Firing Site (TA-15) in March 1985 ranged from <1 – 2 parts per billion (ppb) in the dissolved fraction, and from 1.2 – 11.5 ppb in the suspended fraction.

The environmental fate of beryllium released from disposal of neutron sources containing beryllium metal that cannot be recycled or reused is a research interest of the Off-Site Source Recovery Program at LANL. A 2000 progress report describes the experimental use of beryllium-contaminated soils obtained from LANL Dynamic Experimentation Division firing sites. Two samples (locations not specified) contained 74 and 29 mg kg$^{-1}$ of beryllium (Sauer et al. 2000). Table 11-7 summarizes the soil data from six firing sites (Cokal and Rodgers 1985, Vigil and Becker 1999)
Table 11-7. Beryllium concentrations in soil at firing sites, µg g⁻¹

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>Samples (n)</th>
<th>Range</th>
<th>Mean</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHERMEX</td>
<td>1987</td>
<td>59</td>
<td>1 – 470</td>
<td>31.5</td>
<td>1 – 2.4</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>1993</td>
<td>21</td>
<td>&lt;1 – 218</td>
<td>13.4</td>
<td>NR</td>
</tr>
<tr>
<td>PHERMEX</td>
<td>1998</td>
<td>18</td>
<td>0.14 – 74</td>
<td>7.1</td>
<td>NR</td>
</tr>
<tr>
<td>E-F</td>
<td>1985</td>
<td>9</td>
<td>2.3 – 14.4</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>E-F</td>
<td>1999</td>
<td>60</td>
<td>NR</td>
<td>1.3</td>
<td>NR</td>
</tr>
<tr>
<td>R-44, R-45</td>
<td>1994</td>
<td>44</td>
<td>NR</td>
<td>7.2</td>
<td>NR</td>
</tr>
<tr>
<td>TA-39</td>
<td>1995</td>
<td>22</td>
<td>&lt;1.3 – 9.1</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>TA-40</td>
<td>1995</td>
<td>39</td>
<td>&lt;1.3</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

NR = Not Reported

Aerosolization of beryllium from open-air shots has been studied by groups at LANL (Dahl and Johnson 1977) and at Lawrence Livermore National laboratory (LLNL) (Shinn et al. 1989). Dahl and Johnson (1977) determined that 2% of the beryllium mass became respirable (<10 µm) due to aerosolization. For a shot containing 600 g of beryllium, the concentration of beryllium 4,376 y downwind of the shot would be 0.2 µg m⁻³ 15-30 min after detonation for 1-3 min. Shinn et al. (1989) found that 8% of the beryllium mass became aerosolized, and that the beryllium was largely in the form of insoluble, high-fired beryllium oxide. For a shot containing 900 g of beryllium, the concentration of respirable beryllium 55 y from the shot was 3.2 µg m⁻³ for 10 min. However, measured soil concentrations at three LANL firing sites were less than predicted assuming 2% or 8% aerosolization (Becker and Vigil 1999), suggesting that aerosolization could be greater than 8% (Sauer et al. 2001).

Beryllium resuspension has been evaluated in three studies, two at LANL and one at Sandia National Laboratories. Sandia researchers estimated a resuspension factor of 1×10⁻⁷ m⁻¹ for wind blown soil (1 g Be per m² of soil = 0.1 µg m⁻³ Be in air) (Luna et al. 1983). A LANL researcher predicted that resuspension of beryllium from a firing site could result in worker exposures to 0.6 µg/m³ of beryllium (Maez 1997). However, measured beryllium concentrations during drilling activities at a LANL firing site were four orders of magnitude lower (Mroz 1995).

Episodic Releases

In a joint effort with the U.S. Air Force, an experiment was performed at Beta Site (TA-5) to evaluate the potential air or ground contamination that might result from the burning of a plane containing significant amounts of beryllium (LASL 1957). A piece of beryllium was placed above a large quantity of jet fuel and ignited. Air and soil monitoring results failed to reveal detectable quantities of beryllium at a range of distances downwind of the fire.
Waste Disposal

Small quantities of beryllium residues were among the chemical waste disposed of in Areas G and L at LANL. Waste was disposed of in Areas G and L by emplacement in shafts, trenches and pits excavated in the Bandelier Tuff at depths up to 65 ft. In late 1985, 18 boreholes to 100- to 135-ft depths were drilled in Bandelier Tuff from the top of Mesita del Buey. Core samples were collected from seven of the boreholes at about 10-ft intervals. Only two of 70 samples collected contained concentrations of metals, not otherwise specified, were above their detection limits. Both were acquired at shallow depths (20 ft or less) at Area L (LANL 1987). All rags and waste from housekeeping activities in the old and new beryllium shops were disposed of in the burial pit (Mitchell and Hyatt 1957).

Off-Site Area Monitoring

Air samples were collected quarterly between 1990 and 1994 in northern New Mexico, around the Laboratory perimeter in Los Alamos, White Rock and Bandelier National Monument, and within the Laboratory primarily at TA-52, TA-16 and TA-3 (Becker and Vigil 1999). The mean beryllium concentration recorded at the off-site locations during this timeframe was 0.014 ng m\(^{-3}\), while the mean concentration reported at the on-site locations was 0.009 ng m\(^{-3}\). Additional sampling was performed at off-site and on-site locations in 1998 and the mean air concentration recorded at all sampling locations during this year was 0.021 ng m\(^{-3}\).

Exposure Guidelines for Beryllium

The U.S. Atomic Energy Commission issued “Recommendations for Control of Beryllium Hazards” in August 1951 that included three standards: a 2 µg m\(^{-3}\) in-plant, 8-hr average beryllium concentration; a 25 µg m\(^{-3}\) beryllium air concentration that can never be exceeded; and a 0.1 µg m\(^{-3}\) monthly average concentration at the breathing zone in the neighborhood of a plant handling beryllium (Mitchell and Hyatt 1957).

The current OSHA permissable exposure limit (PEL) for occupational exposure to beryllium is 2 µg m\(^{-3}\) (8-h time weighted average). A ceiling limit of 5 µg m\(^{-3}\) must not be exceeded during the work shift, except that a 30-min excursion over the ceiling limit is allowed as long as the air concentration never exceeds 25 µg m\(^{-3}\) during the 30-min period (NIOSH 2003).

The current USEPA Reference Concentration (RfC) for beryllium is 0.02 µg/m\(^{3}\) (USEPA 2009). The RfC is an estimate (with uncertainty spanning an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of
deleterious effects during a lifetime. The RfC is based on beryllium sensitization and progression to chronic beryllium disease (CBD) identified in studies published in 1949 and 1996 (Eisenbud et al. 1949, Kreiss et al. 1996). The Kreiss et al. (1996) occupational exposure study identified a LOAEL (Lowest Observed Adverse Effect Level) for beryllium sensitization in workers exposed to 0.55 µg m\(^{-3}\) (median of average concentrations). A cross-sectional study was conducted of 136/139 of the then-current beryllium workers in a plant that made beryllia ceramics from beryllium oxide powder. Measurements from 1981 and later were reviewed and included area samples, process breathing-zone samples, and personal lapel samples (the last year only). The Eisenbud et al. (1949) study, using relatively insensitive screening methods, suggests a NOAEL (No Observed Adverse Effect Level) of 0.01-0.1 µg m\(^{-3}\) in community residents living near a beryllium plant. The LOAEL from the Kreiss et al. study was used for the operational derivation of the RfC because the screening method used in the Eisenbud et al. (1949) study was less sensitive than the method used in the Kreiss et al. (1996) study.

**Beryllium Releases and Exposures at Los Alamos**

It has been reported that largest number of men at Los Alamos were exposed during machining of beryllium, although the most difficult processes to control involved the use of powdered beryllium and soluble beryllium compounds (Hyatt and Milligan 1953). Worker exposure to beryllium from dynamic testing was substantially less than that encountered in the machine shop or laboratory settings primarily because beryllium was present during detonations conducted outside under atmospheric conditions, and because during detonation and afterwards, workers were confined to a closed control bunker or detained at road blocks set up ¼ mile or more from the firing site (Becker and Vigil 1999). Post-shot dispersion of beryllium particles caused by wind was expected to occur rapidly and to significantly dilute beryllium concentrations present in air at the firing sites. If exposures to beryllium did occur at firing sites, it is indicated that exposures would have occurred during dust resuspension from soil and vegetation during brush removal.

Secondary occupational exposure of workers’ families significantly increased beryllium intake through dust when clothing of occupationally exposed individuals were not kept at the workplace, as was usually the case in the 1940s (IPCS 1990). Eisenbud et al. (1949) reported that short-term beryllium levels of 125 to 2,000 µg m\(^{-3}\) were measured in the indoor air after clothing from employees at a beryllium-producing plant were shaken. The authors estimated that approximately 17 µg d\(^{-1}\) could be inhaled by a person during the laundering of the same clothing. However, it is documented that Los Alamos provided their workers in the machine shop with a provision of complete protective clothing with adequate showering facilities (Mitchell and Hyatt 1957). This clothing consisted of coveralls, underwear, socks and safety
shoes. Canvas booties were worn over the safety shoes before leaving the machine shop to go to the tool crib. Likewise, it has been noted that employees working at firing sites wore dedicated work shoes that were removed and remained onsite each evening (Becker and Vigil 1999).

**Medical Surveillance of LANL Workers**

Medical surveillance of workers at LANL began in the 1940s (Stefaniak et al. 2003). A memo from Dr. Cleve Beller of LANL dated January 24, 1947 announced that all Sigma Building personnel that handled beryllium were examined or had made arrangements to be examined by the Health Group (LASL 1944-1950). As of completion of a report detailing beryllium use at DX Division Firing Sites (Becker and Vigil 1999), it was noted that nine workers in the DX Division were in the beryllium medical surveillance program. It was reported that none of these individuals had been identified with chronic beryllium disease or beryllium-associated illness.

An internal memo from Dr. Thomas Shipman of LASL in May 1951 suggests that the health effects associated with beryllium were unknown to Los Alamos until November 1947 when Dr. Harriet Hardy of MIT held a meeting to discuss beryllium-related health concerns (LASL 1944-1950). The result of this meeting was a stoppage of certain beryllium operations (not described) and the use of beryllium at LANL was subjected to careful scrutiny from that point forward.

In a series of memos between Dr. Hardy and Dr. Thomas Shipman, a case of apparent chronic beryllium poisoning was discussed (LASL 1944-1950). It was noted that the individual in question worked at Los Alamos from 1946 until 1949 for P Division in Building U, which was documented as being in the vicinity of the beryllium machining shop. However, this individual’s exposure potential was not limited to that alleged at Los Alamos, as he was also employed at other facilities, including Oak Ridge, where beryllium was also used. A memo from Dr. Hardy to Dr. Guy Fortney at Oak Ridge in September 1964 reported that the beryllium content in this individual’s lungs at his time of death was 0.021 µg g⁻¹. Two additional cases of apparent berylliosis among LANL personnel were reported in a memo from Dr. Shipman in February 1953.

As of June 1998, 110 workers have been diagnosed with chronic beryllium disease; the majority of these workers are associated with the Rocky Flats and Y-12 (Oak Ridge) plants (Becker and Vigil 1999). A Former Worker Medical Surveillance Program that included screening for chronic beryllium disease (CBD) was started in 1999 (Stefaniak et al. 2003).
Beryllium Toxicology and Epidemiology

Acute beryllium disease is usually observed at relatively high beryllium exposure levels, has a short period of induction, and is usually resolved within a couple of months of exposure termination. It is believed to be an inflammatory response to beryllium and most regions of the respiratory tract are affected; some reported symptoms include nasopharyngitis, shortness of breath, labored breathing, and chemical pneumonitis (ATSDR 2002).

Chronic beryllium disease is a systemic granulomatous disorder that predominantly affects the lungs. In general, the occurrence of this disease has been confined to workers exposed to beryllium metal and to less soluble beryllium compounds, such as beryllium oxide. However, there have been cases among residents living near beryllium manufacturing facilities and in families of workers who wore contaminated clothing at home. Chronic beryllium disease is caused by an immune reaction to the inhaled beryllium that is deposited in lung airspaces and retained for a prolonged period. In certain individuals who become sensitized to beryllium, the beryllium in the lungs binds to protein/peptides in the lungs and inflammatory cells accumulate in the lungs. This results in the formation of granuloma and the development of fibrosis. Susceptibility to chronic beryllium disease is believed to have a genetic component (ATSDR 2002).

A number of large-scale screening studies have examined beryllium workers and found beryllium sensitization rates of 1–15% in workers involved in the production of beryllia ceramics and nuclear weapons. More than half of the beryllium sensitized workers were diagnosed with chronic beryllium disease. Several studies attempted to establish associations between beryllium sensitization and/or chronic beryllium disease and mean, cumulative, and peak exposure levels and duration of employment. In general, no consistent associations were found. Although the data are insufficient for establishment of concentration-response relationships, the available occupation exposure studies do provide exposure levels that may result in beryllium sensitization. Beryllium sensitization and/or chronic beryllium disease have been detected at exposure levels of 0.5 µg m⁻³. Respiratory disease is not likely to occur from exposure to beryllium levels in the general environment because ambient air levels of beryllium (0.03–0.2 ng m⁻³) are very low (ATSDR 2002).
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Chapter 12: Processing and Testing of High Explosives at Los Alamos

Research, development, and testing of high explosives were conducted at more than 25 different Technical Areas of LANL (Goldie 1984; LANL 1990). Many new formulations of the conventional explosives HMX, RDX and TNT were synthesized and tested at LANL since the 1940s (Dobratz 1995). Other high explosives such as Baratol, Comp B, Pentolite, Torpex, and Tetryl were tested at firing sites such as those at TA-14 (IT Corporation 1989). The initial plan for the first atomic weapon was for a gun type weapon that would use “slow-burning” propellants. When it became clear in July 1944 that the weapon would have to be an implosion design due to the presence of the $^{240}$Pu isotope in the active material, high explosives became a key component of the plan.

X-Division

The implosion program began in April 1943 with a proposal by S. H. Neddermeyer on an elementary theory of high-explosives assembly, but there was no established art to follow. Implosion research started as the concern of one small group and grew into the Laboratory’s major problem in the early 1940s. The first implosion tests at Los Alamos were made in an arroyo on the mesa just south of the laboratory on July 4, 1943. The test device consisted of tamped TNT surrounding steel spheres. In April 1944, G. B. Kistiakowsky became the leader for the implosion program.

Data from photographing the interiors of imploding devices indicated the need for controlled quality of high-explosive (HE) castings. Special photographic techniques were developed at LANL to study the implosion process, such as rotating pyramid and rotating mirror photography, high-explosive flash photography, and flash x-ray photography. The Anchor Ranch range (TA-9) had been designed for implosion research, but a large casting plant and several widely spaced test sites were needed. Construction of the casting plant was begun in the winter of 1943 at S (Sawmill) Site (TA-16). S-Site was staffed almost entirely by men from the Army’s Special Engineering Detachment (SED), because finding men with experience in handling explosives was nearly impossible (Hawkins et al. 1961). At the end of the war, there were over 1,000 SED men assigned to the X-Division (Kistiakowsky 1975).

In July 1944, a new development in the implosion program involved the use of explosive lenses that would convert a multiple-point detonation into a converging spherical detonation wave thus eliminating troublesome interaction. The design of lens molds was a difficult first step and took several months. In the August 1944 reorganization, Division X was formed under G. Kistiakowsky to experiment with
explosives and their fabrication and to set up a production system. Three groups from the old Ordnance Division (E-Division) in U Building—Implosion Experimentation, HE Development, and S-Site Group, were transferred to the new Explosives (X) Division. Investigation of implosion dynamics and design of the active core were given to the Weapon Physics (G) Division (Hawkins et al. 1961).

**Explosives Production and Testing**

X-Division records indicate that about 20,000 experimental quality castings were produced in an 18-month period, and a much larger number rejected for quality control reasons. The principal types of HE used were Composition B, Torpex, Pentolite, Baranol and Baratol. The use of risers and overcasting to concentrate imperfections and minimize the very dangerous task of machining HE resulted in over 50,000 machining operations without a detonation (Hawkins et al. 1961). According to Kistiakowsky (1975), tens of thousands of castings were made, primarily of Comp B and Baratol. Baratols, with a higher percentage of barium nitrate (76%) than TNT was used for the slow component of the lens system, and cyclotolts such as Comp B (60% RDX: 40% TNT) were used for the fast component (Kistiakowsky 1975; Gibbs and Popolato 1980).

As described in Wilder (1973), operations at S-Site consisted of melting HE and pouring it into molds whose shape was determined by theoretical calculations. The initial facilities at S-Site were inadequate especially for machining. As a result, there was continuous planning and construction of new buildings until just before the Trinity test in July 1945. Casting operations in Building 42 used stainless steel candy kettles, jacketed and steam heated. The molten explosive was poured from the kettle into a rubber bucket and then into steel molds. The mold was finished with Cerrotu, a low-melting casting alloy around a master shape supported in the steel weldment. In Wilder’s opinion, development of the explosive component of the bomb was greatly facilitated by the use of self-adhesive tape just about everywhere. Building 27, built in 1945, had larger kettles and the temperature of cooling water could be varied.

After casting, the HE was taken by hand truck to Building 43 to be machined. The equipment in Building 43 consisted of one K&T milling machine and several Delta drill presses. Comp B was machined under water, and Baratol was initially machined dry but later water was used. Building 55 housed the one small high-speed hammer mill used for grinding barium nitrate. Buildings 31, 32 and 33, built in 1945, were machining bays for Fosdick radial-arm drills. As S-Site activities expanded, they moved into V-Site (TA-25). Three methods were used to protect the cast HE from chipping. Castings were sprayed with the best “Bar Top” varnish available, felt was glued to one of two mating surfaces, and blotting paper was glued to the sides, in Buildings 519 and 520. Practice assemblies were made in Gamma Building in the main
Technical Area. The floors were padded with wrestling mats. The Trinity bomb was assembled in Building 516. All explosive operations produced great quantities of scrap that was collected daily and burned in the area where Building 260 was located (Wilder 1973).

According to Hawkins et al. (1961), S-Site at its peak used over 100,000 lbs of high explosives per month. G. Kistiakowsky’s recollection was that about 25 tons (50,000 lbs) were trucked up the hill per month during the most active HE casting period. X-Division Progress Reports indicate that between 140,000 and 170,000 lbs per month of high explosives, primarily Comp B, TNT and barium nitrate (BN), were used during the months of May, June, July and August 1945 (see Table 12-4). Precision molds and machining were required, and according to Kistiakowsky (1975), there were over 500 machinists and toolmakers available during the peak period. A full-size casting weighed about 100 lbs, and 1 g of HE will reportedly blow off a hand. Kistiakowsky expressed his concerns about using S-Site since five tons of HE had to be trucked past Oppenheimer’s office and T-Division every day on its way to S-Site. He requested that a new site be established in Pajarito Canyon but his request was denied by Captain Parsons (Kistiakowsky 1975).

L-Site (TA-12, akaTA-67) was constructed in the spring of 1945 and used for one year as an explosives test facility, then abandoned in the mid 1950s. Soil tests in 1993 identified RDX, TNT and picric acid at the open firing pit and firing pad 1. Q-Site (TA-14) has been used for development and testing of explosives since 1944. HMX and metals were identified in Q-site soils [Harris 1993; RCRA Facility Investigation plans for OU-1082 (S-Site) and OU-1086 (R-Site)].

Sites in the vicinity of TA-16 (S-Site) formerly used in the 1940s for x-ray studies (P and T-Sites) and assembly operations (V-Site), and several storage magazines (TA-28, 29, and 37) were decommissioned and absorbed into the S-Site complex or are still active. S-Site, K-Site and two of the three magazines were still active as of 1994. TA-11 (K-Site) was originally built to study implosion symmetry and was more recently used for drop tests to study impact initiation of explosives. The resulting debris in the immediate vicinity of the drop tower is picked up and removed for disposal at the TA-16 burning ground. These eight sites are the focus of the Remedial Field Investigation for Operable Unit 1082 (LANL 1994).

Between 1944 and 1948, eight firing sites (A-H) were established at TA-15 (R-Site). Experiments using from 50 lbs up to 2 tons of HE were conducted at these firing points. Firing points E and F were the most active. Up to 65,000 kg of uranium and 350 kg of beryllium have been expended at these two firing sites. Hazardous materials, including uranium, beryllium and lead, have largely been left in place at these sites where the materials were deposited by the explosion. Other materials that may have been deposited
include steel, aluminum, mercury, boron, cadmium, gold, and tritium reportedly in small amounts. TA-15 is the focus of the Remedial Field Investigation for Operable Unit 1086 (LANL 1993).

Other Uses of Explosives at LANL

During the VJ Day celebration at the Laboratory, Kistiakowsky reportedly borrowed a military jeep with a driver and gave the LANL scientists a “21-gun salute” by detonating 21 boxes of Comp B explosive, although someone attending the party said there were actually 22 explosions. It was also reported that the Pajarito ski hill was cleared of trees using plastic explosives (Kistiakowsky 1975).

Key Facilities for High Explosives at Los Alamos

S Site (TA-16) was initially called Sawmill Site, after a portable sawmill that had been erected on the site, and left huge piles of sawdust behind. Its name was shortened to S Site. [Martin 1998]. Investigations at S Site have included development, engineering design, prototype manufacture, and environmental testing of nuclear weapons warhead systems. TA-16 is the site of the Weapons Engineering Tritium Facility for tritium handled in glove boxes. Development and testing of high explosives, plastics, and adhesives, and research on process development for manufacture of items using these and other materials are accomplished in extensive facilities.

Facilities include a slurry plant with a capacity of 300 lbs of explosive per batch (Cochran et al. 1987). The material being cast was a two-phased slurry consisting of a dense solid phase dispersed in molten TNT. [Hoddeson et al. 1993] At first Torpex was used, then PTX-2 (Picatinny ternary explosive 2), Comp B, Pentolite, Baranol, and Baratol. Earlier operations centered on using high explosives (HE), and developing HE lenses to bring about implosion. LANL workers melted HE and poured it into molds whose shape was determined by theoretical calculations. Early castings were worked with hand tools, saws, rasps, and planes, to a template. HE compounds used included Comp. B, TNT, and Baratol.

Early explosives processing facilities included:

- S-24 (possibly a.k.a. TA-16-24) A casting building
- TA-16-42 Casting (stainless steel candy kettles, jacketed and steam heated, with agitator; HE was poured into a rubber bucket, then to molds)
- TA-16-43 Machining (K&T milling machine, drill presses, fly cutters. Comp. B was machined under a stream of water. Baratol was initially machined dry because thought water would dissolve the barium nitrate; later machined wet.
- TA-16-44 Physical inspection (dimensional inspection)
• TA-16-48  “gamma-graph” facility (gamma radiography of large or dense objects).
• TA-16-55  Barium nitrate grinding machinery.
• TA-16-81  Used to dry nitrocellulose (spread out on trays).
• TA-16-260  Near the east end of this building was area for daily burning of scrap. Sometimes the material exploded instead of burning.
• TA-16-27  Built in 1945 to make full-scale castings.
• 30 thru 34  Built at same time to machine Baratol and Comp. B castings from Building 27.
• 94 thru 98  Built when it became desirable to machine all surfaces of the HE material.
• 16-515 thru 520  (called V Site) were under a group other than GMX-3; they had a large mechanical shaker that was used to test the first bomb. The Trinity bomb was assembled in 516. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.” “Mechanical Testing” done here per Repository No. 225 (c. 1981)

Some of the early work being done was considered too dangerous to be performed at TA-1, so these operations were placed at remote locations. Alpha Site at TA-4 was used as a firing site for high explosives (HE). It was originally used to fire several charges per day of up to 1000 lbs and was then converted to accommodate studies of small equation-of-state tests that used only a few pounds of HE per shot. Beta Site at TA-5 was used extensively in 1945 as a firing site for the pin or electric method for studying implosions. Larger charges could be safely used at TA-5, and shots of several hundred pounds were used. S-Site at TA-16 was developed for production of HE to be used in the various tests. [LA-UR-97-4765]

In 1944, a small control building and two firing sites were established at TA-15; one for quantities of HE up to 50 lbs and the second for larger amounts. These probably became Firing Sites A and B. Firing Site A was probably in use by the end of 1944 and Firing Site B shortly thereafter. In 1946, TA-15 was made into a permanent location for explosives experiments related to nuclear weapons design, involving experiments with up to 3/4 tons of HE. By 1947, Firing Sites C,D,E, and F were in use. In 1948, E and F were designated as one firing site, E-F, and Firing Sites G and H were added. Today, Firing Sites A through H are not used, and most structures associated with these firing sites have been decommissioned and dismantled. The hazardous materials used in these explosives tests, e.g. U, Be, and Pb, have largely been left in place at the firing sites where the materials were deposited by the explosion or pushed aside to clean the area. Other materials that may have been deposited in very small amounts include steel, Al, Hg, boron, cadmium, gold, and ³H. Many types of HE were used. While they may have left some residues, no unexploded high explosives have been found in the analyses of site soils. Site E-F was most heavily used and reportedly contains the largest quantities of hazardous materials. Up to 72 tons of uranium and approximately 800 lb of beryllium may have been expended in tests at Firing Site E-F. In the 1950s,
Firing Sites R-44 and R-45 were completed. These sites have been used for various explosives tests, R-45 for smaller tests and R-44 for larger ones [1086 RFI Report; 10/30/95].

TA-15, “R-Site,” is currently the home of PHERMEX (the pulsed high-energy radiographic machine emitting x-rays) a multiple-cavity electron accelerator capable of producing a very large flux of x-rays for weapons development testing. It is also the site where DARHT (the dual-axis radiographic hydrotest facility) was constructed. This site is also used for the investigation of weapons functioning and systems behavior in non-nuclear tests, principally through electronic recordings.

TA-9, Anchor Site East, housed exploration of fabrication feasibility and physical properties of explosives. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied. Name refers to Anchor Ranch, a small cattle operation that was in the area when the MED took it over in 1943. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.”

TA-14, Q Site, is a dynamic testing site used for running various tests on relatively small explosive charges for fragment impact tests, explosives sensitivities, and thermal responses. “Active” per 10/2/84 memo from R. Goldie to D. Pinyan; subject was “Areas Containing or Contaminated by Explosives.”

References


Kistiakowsky 1975. Audio tapes of interviews borrowed from LANL Library.


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Chapter 13: The LANL Health Division

Although the Health Division at LANL (“H Division”) was responsible for monitoring worker health, operations or activities that were associated with potential worker exposures were often also associated with potential off-site releases and public health consequences. The LAHDRA project team examined a large number of health-related progress reports published by the Health Group, Health Division, and successor organizations that carried on programs related to worker and environmental health. This chapter provides an overview of the organizational structure of the Health Division and its subgroups (such as health physics and industrial hygiene) and describes the various health and safety activities that those groups conducted over the years at LANL. A complete listing of the documents issued by the H Division and its successor groups that the LAHDRA team has located and selected as relevant to off-site releases or health effects is presented as an appendix at the end of this chapter.

The project team located and reviewed approximately 430 documents that consisted of Health Division Progress Reports or reports that are known successors to the Health Division. An example of a successor report might be one named under a different title such as Quarterly Progress Report – Group H-1 Health Physics. Many division or group reports were published monthly, although quarterly and annual reports are available for select years and were also reviewed. The oldest reports available are Health Group and Health and Safety reports for 1943 to 1945. In early 1946, Louis H. Hempelmann, MD, then acting director of the Health Division, wrote a report titled History of the Health Group (A-6) (March 1943 – November 1945). That report discusses issues related to the safe handling of plutonium and polonium and monitoring and prevention of worker exposures to these materials. Discussions of hazards associated with the RaLa and Omega Site operations as well as other health and safety issues, including injuries, are also presented in the report (Hempelmann 1946b). Another early Health Group report titled, Health Hazards of LANL Groups by Division, is a compilation of letter reports that provide summaries of early operational hazards and health and safety measures used by LANL to control worker exposures (Hempelmann 1946a). Many of the groups such as occupational medicine, industrial hygiene, health and safety, and health physics remained part of the Health Division up through the 1970s.

In 1975, the Health Division expanded its name to “Operational Environmental Health and Safety” then in 1981 changed it to “Health, Safety, and Environment.” The division has had other name changes since that time. Divisional activities continued to be published in progress reports under these and other health and safety related division or division group names.
**History of H Division**

According to the report titled “History of the Health Group,” a directive from the laboratory Director J. Robert Oppenheimer, dated 13 November 1943, stated that the medical supervision of technical personnel was to be directed primarily at protection of persons from the hazards of the project (Hempelmann 1946b). The primary function of the Health Group (A-6) at that time was to establish safe tolerance levels, develop monitoring methods, and to ensure that tolerance levels were not exceeded for worker exposures to hazardous materials. The primary concern was the monitoring and control of workers’ exposures to radioactive materials. Preparation of routine monitoring procedures for workers was primarily the function of each operational unit or lead individual during this early period. Effluent or environmental monitoring that would be of interest for a dose reconstruction study are not mentioned in this report.

The original policy of the Health Group was to depend entirely on information gained from health research and development groups elsewhere, such as the “Met. Lab” in Chicago. Because that policy and support from outside organizations did not always provide the needed information in time to establish safe operating procedures for use at Site Y, research sections were set up within the Health Group, such as for development of instrumentation and biological methods for testing for overexposure (Hempelmann 1946b). For example, approximately half of the 25- to 30-page monthly reports of the era describe various areas of research and papers published on the health effects of radiation by H-4, the radiobiology group, and instrument development and testing work conducted by the electronic and biophysics sections of Radiologic Safety, H-1. Accidents were reported in the Occupational Safety group (H-3) section of the division reports.

On 1 June 1947, the Health Group was renamed the Health Division and Louis H. Hempelmann, MD was the Division leader from 1943 until the end of 1948. Thomas L. Shipman, MD, assumed responsibilities from Hempelmann in 1948. In 1943, the Health Group consisted of 10 staff and expanded to 97 by 1949; by 1951, the group had grown to 158 staff (Hempelmann 1946b, LASL 1950b, 1951)

**Documentation of H-Division Activities**

The reports of the Health Group were typically called Health Reports, and the Division reports were called H-Division Progress Reports. The Health Reports are organized in three sections: radiation problems, chemical hazards, and general safety. By 1951, the Health Division was divided into six groups. Monthly progress reports generally consist of four to seven sections corresponding to the operating groups in the division. The six primary groups that operated under the Health Division included:
• H-1, Administrative and Medical Records later became Radiologic Safety (later renamed H-1 Health Physics); H-Division administrative activities were reported separately but not given an H number; Radiologic Safety included monitoring, electronics, and biophysics sections;

• H-2, Occupational Health included health physics, industrial hygiene, and occupational biochemistry sections; later when Radiologic Safety became a separate group called H-1 Health Physics, Occupational Medical was created to maintain responsibility for general clinical functions such as physicals and first aid;

• H-3, Training of Military personnel and Medical staff (LANL employee care) later became Occupational Safety and the training function was merged into H-Division Administration;

• H-4, Radiobiology conducted research on clinical aspects of exposure to chemicals and radionuclides including monitoring programs and instrumentation;

• H-5, Industrial Hygiene and Occupational Biochemistry sections were split off from H-2 and formed this group in June 1949; and

• H-6, Monitoring (CMR-12) was merged into H-1 and then became Radiologic Physics, including the old Biophysics group (Special Problems) and the Meteorology section.

Many of the activities performed by these groups are still being performed today under different divisional and/or group names.

Constructed during 1952-54, the Health Research Laboratory at TA-43 is adjacent to the Los Alamos Medical Center in the Los Alamos town site. Research performed at this site has included structural, molecular, and cellular radiobiology, biophysics, mammalian radiobiology, mammalian metabolism, biochemistry, and genetics. The Department of Energy Los Alamos Area Office is also located within TA-43.

The reference list located at the end of this chapter presents the most up to date list of Health Division progress or related group reports that were located and reviewed by the project team. The references are grouped by year and title. These reports document and offer insights into LANL’s health and safety program and describe health protection philosophies used to monitor personnel, work areas, and loss of material to the off-site environment. The list indicates which reports are thought to have been generated but for which copies have not been located by the project team as of the writing of this report. Some of the missing reports might be missing because a report was not issued for that period, or copies might have been lost or filed differently than other reports of the same type.
Groups within the Health Division or from other divisions with health and safety responsibilities also published monthly or quarterly progress reports. Relevant information pertaining to off-site emissions discovered during document reviews was noted, summarized, and included as appropriate in other sections of this report. Below is a list of H (Health) Division and group reports and the years for which reports were located and reviewed during the LAHDRA project. This list does not necessarily list reports by their exact titles, but rather is intended to provide an overview of the types of health-related reports for various periods. The reference list at the end of this chapter does identify relevant reports by their actual titles.

- Health Reports of the LASL Health Division (1943 – 1945)
- Health Division monthly and quarterly progress reports (1946 – 1972)
- Summary of Research, Development, and Health Activities in the CMR Division (1944 – 1951)
- H-1 General Monitoring Section (1956 – 1964)
- CMR-12 Monthly Reports (1945 – 1950)
- Air Monitoring Results – DP West (1946 – 1952)
- Weekly Reports of Stack Release Data for DP West (1950 – 1956)
- Monthly and Annual Reports, DP East (1951 – 1955)
- Health, Safety, and Environment quarterly and annual reports (1975 through 1990)
- Environment, Safety, and Health (1990 – 2005)
- Environment, Health, Safety, and Quality (2005 – present)

Health Division Perceptions of Hazards at Los Alamos National Laboratory

In 1943, the hazards of the project were reported to be limited to external radiation from the cyclotron, the Van de Graaff, the D-D source, and the radium sources. There were also hazards attributed to uranium and the usual chemical laboratory hazards, but these were not serious according to Louis H. Hempelmann. Only one accident was noted that occurred during the first year of Site Y operations. It involved overexposure to radiation from the cyclotron. The main concern of the Health Group at this time was the interpretation of blood counts on exposed personnel to radiation. Normal variation in blood counts was not well known at the time (Hempelmann 1946b).

In February 1944, plutonium arrived at LANL in significant quantities. The members of Chemistry and Metallurgy (CM) Division and the Health Group became concerned about the dangers of working with
this material. Control of alpha-emitting radioactive materials was described as rather uneventful for the first year. After an accident in August 1944 in which a milligram of plutonium blew up in a worker’s face, a research program to develop tests for detecting overexposure of personnel with plutonium began. A urine test was developed in January 1945 that required a new (free of alpha contamination) laboratory (ML Building) to conduct the bioassay tests. Following the first human tracer experiment in April 1945, results of the urine tests were evaluated with increased certainty. Until the urine test was perfected, nose counts were the only index used to monitor personnel exposures. Due to the difficult and time consuming nature of the urine test, the most heavily exposed persons as indicated by nose counts underwent frequent urinalyses. Available alpha monitoring equipment lacked both sensitivity and portability, so swipe samples were used to detect contamination of hands, nostrils, and workplaces. A proportional counter using a methane-filled, thin windowed tube was developed by D. Froman and R. Watts at LANL and installed in the D-Building washroom as a hand counter in June 1944 (Hempelmann 1946b).

In September 1944, the CM-1 group was reorganized and many members of the monitoring and decontamination section were transferred to A-6, the Health Group. The new structure did not lead to cooperation between the two groups, and in January 1945, H-1 (CM-12), was given full responsibility for the entire alpha contamination problem in the CM Division. At that time it was necessary to redesign the existing facilities in D Building in order to safely handle the increased amounts of plutonium being handled there. In July 1945, CM-5 handled amounts of plutonium that exceeded the capacity of its safety equipment, and four persons exceeded the safe amount of one microgram of plutonium in their bodies according to urine tests.

According to Louis Hempelmann, polonium was never the hazard that plutonium was. Because it was less radioactive, easier to test in the urine, and relatively simple technical operations were most often used, minimal polonium contamination and exposure hazard was recognized. Only two workers exceeded the tolerance limit for polonium (1500 counts per minute, “cpm,” in a 24-h urine sample) by 1946 (Hempelmann 1946b).

The perceived external radiation hazard at LANL did not change until September 1944, when the Water Boiler reactor at Omega Site went into operation. Later, when a higher powered version went into operation (January 1945), there were several instances of overexposure when the exhaust line developed leaks. There was also an accident that resulted in serious exposure to several chemists during decontamination of the active material. By the time of Hempelmann’s 1946 early history summary, there had been two serious accidents in critical assembly work at Omega Site, one that overexposed four individuals to gamma and neutron radiation, and one fatality. The report does discuss concerns for off-site emissions, monitoring, or control measures (Hempelmann 1946b).
During the radioactive lanthanum (RaLa) implosion tests that started in September 1944, members of the chemistry group CM-4 received periodic overexposures to beta radiation. The toxicity and accepted methods for prevention of toxicity from exposure to high explosives were more familiar. In certain cases, safe operational procedures were delayed by inadequacies in construction of exhaust systems, washrooms, etc., but no serious trouble was encountered between March 1943 and October 1945 according to some H Division reports (Hempelmann 1946b).

Although monthly H-Division reports from 1947 forward repeatedly mention the hazards of beryllium, there is no mention of beryllium in Hempelmann (1946b). Table 13-1 presents a summary of materials of concern in terms of potential health hazard, based on review of H-Division reports.

### Table 13-1. Materials of Concern from H-Division Reports

<table>
<thead>
<tr>
<th>Material of Concern (Location of Concern)</th>
<th>Examples of H-Division Reports (LAHDRA Project Repos. Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsine</td>
<td>2275, 2392</td>
</tr>
<tr>
<td>Benzol (DP West)</td>
<td>2259, 2266, 2267</td>
</tr>
<tr>
<td>Beryllium (V Shop, Sigma, R-Site, CMR)</td>
<td>2202, 2433, 2434, 2258, 2259, 2262, 2300, 2224, 2392</td>
</tr>
<tr>
<td>Fluorides (D Building)</td>
<td>2266</td>
</tr>
<tr>
<td>Lithium (Sigma, K)</td>
<td>2270, 2275, 2300, 2301, 2298</td>
</tr>
<tr>
<td>Mercury spills (Omega Site, U-14, K bldg)</td>
<td>2433, 2434, 2211, 2259, 2298</td>
</tr>
<tr>
<td>Polynuclear Aromatic Hydocarbons (scintillation fluids)</td>
<td>2209, 2270, 2275, 2216</td>
</tr>
<tr>
<td>Impurities in RaLa source (Bayo)</td>
<td>2207, 2261, 2262, 2263, 2267, 2268, 2301</td>
</tr>
<tr>
<td>Trichloroethylene (TU, Sandia, Omega, S-Site)</td>
<td>2259, 2260, 2265, 2267, 2201</td>
</tr>
<tr>
<td>TNT (S-Site)</td>
<td>2257, 2433, 2434, 2258, 2260, 2260, 2264, 2201</td>
</tr>
<tr>
<td>Thorium</td>
<td>2287, 2383</td>
</tr>
<tr>
<td>Uranium (TU, Sigma, HT)</td>
<td>2257, 2211, 2263, 2216, 2224</td>
</tr>
<tr>
<td>Plutonium</td>
<td>2330, 2375, 7188</td>
</tr>
<tr>
<td>Polonium</td>
<td>124, 3049, 7188</td>
</tr>
</tbody>
</table>

### Incidents Documented in H-Division Reports

Following are examples of the type of information contained in the monthly H-Division reports. These examples come from reports covering a time period of approximately the mid-1950s to the mid-1960s and highlight operational conditions at LANL and effluent monitoring activities that are relevant to the LAHDRA project.

Examples of chronic issues or problems cited include:
• Liquid waste management problems at Ten Site (TA-35) for the liquid waste streams generated by the RaLa program. Problems with plant capacity and equipment lead to several unplanned discharges of large volumes of radiostrontium-bearing wastes to Mortandad Canyon.

• Leakage around improperly installed filtration units site-wide. For example, a report issued on the release of alpha activity from DP West stacks in 1955 states “definitely that the CWS-6 filters are poorly installed and consistently leak contaminated air around the edges of the filters” (Shipman 1955). In 1964, in-place DOP-testing of the filters on top of DP West Building 4 showed their efficiency to be “approximately 15%” (LASL 1964).

• Glove box explosions and fires at DP West Site are reported in numerous reports.

• Emissions of TNT dust from facilities at S Site (TA-16) are reported in numerous reports.

• Beryllium contamination of soil at R-site (TA-15). The magnitude of the contamination and the potential for resuspension prompted remediation activities on several occasions.

• Unsatisfactory media and methods for sampling airborne effluent streams for radioactive iodine due to low and unpredictable collection efficiencies. This was a particular problem for quantifying radiiodine releases from Wing 9 of the CMR Building, but it was also an issue at Omega Site and DP West Site.

• Lack of suitable instrumentation and methods for monitoring airborne effluents from the Omega Stack, and corresponding uncertainty in assessments of exposure to residents of the old trailer court area (most likely the trailer park on DP Road and overlooking Omega Site; see Chapter 15).

• Lack of appropriate monitoring instrumentation was also a chronic issue at Ten Site, where stack effluents during RaLa source preparation activities often could not be assayed due to excessive radioactivity.

• Failures of containment mechanisms for samples being irradiated in the Omega West Reactor. For example, such a failure on 7 August 1961 resulted in contamination being found on cars in the parking lot and in other areas around the building (LASL 1961b). On 23 December 1963, a rather large “sample” was irradiated in the reactor’s vertical port and had to be removed through the roof of the building. The sample was then dragged down the road to its storage location. Afterward, the roof of the building and the road read 50 mR h⁻¹ and 20 mR h⁻¹, respectively, from contamination by ₁₂₂Sb and ₁₂₄Sb (Shipman 1964).

• Soil and groundwater contamination downstream from the TA-35, TA-45, and (in later years) TA-50 liquid waste outfalls were reported during the 1950s and 1960s in various reports.
Specific examples of contamination being spread to private property include:

- A contamination incident at the Water Boiler on 16 August 1950 resulted in contamination being spread to a private home (LASL 1950a).
- In 1961, a $^{137}\text{Cs}$ contamination incident at TA-48 resulted in contamination being tracked off site by workers; 28 homes and 47 vehicles were surveyed for contamination (LASL 1961a).
- $^{90}\text{Sr}$ contamination was spread to a worker’s vehicle on 2 June 1961 from a spill at the H-7 waste treatment laboratory (LASL 1961c).

Specific examples of episodic events and sources of fugitive and unmonitored emissions include:

- On 8 January 1953, LASL discovered that a polonium-beryllium source had ruptured at the Pajarito Site and found that contamination had spread to Los Alamos residential areas. Follow-up monitoring was performed to assess the extent of the unmonitored release (Shipman 1953).
- Dust from the demolition of contaminated buildings in the Original Technical Area (TA-1). Demolition activities included Buildings CM, D, HT, J-2, M, ML, and N. Debris from these demolition projects was often burned at the contaminated dump site.
- In 1956, glass vials containing tritium gas were disposed of at Beta Site (TA-5) by placing ten at a time in a barrel and dropping a weight on them. At one point, a tritium concentration of 15,000 $\mu\text{Ci m}^{-3}$ was measured at a distance of 100 ft from the barrel.
- Unintentional releases of tritium from Building TA-33-86 required the site to be evacuated and access restricted by road blocks on multiple occasions (Shipman 1958, 1959b).
- A nuclear criticality accident at DP West (Building 2) on December 30, 1958 killed one worker and exposed numerous others (Shipman 1959a).
- A fire in a plutonium-contaminated CWS filter at DP West Room 501 on 15 July 1959. Highly-contaminated ash was found both inside and outside the building (Shipman 1959b). Another fire occurred in the incinerator drybox exhaust system in DP West Room 313 on 8 December 1959. Buildup of residues allowed the fire to spread throughout the exhaust system. It is reported that the exhaust stack was red hot up to 5 ft above the roof (LASL 1959).
- In 1960, hydrogen sulfide emissions from Building TA-46-1 led to complaints from workers about fumes being drawn back into the building through the intake air system (Shipman 1960).
References


Appendix 13A: Listing of Reports Issued by the Los Alamos Health Group, Health Division, and Successor Groups

The following compilation of reference documents related to LANL’s Health Division highlights those sources of information that contain information relevant to operational activities and effluent monitoring practices, particularly for those early operational years when reporting of source term information (i.e., basic monitoring data, sampling methods) varied in content both in quantity and quality and are presented in a variety of division and group report formats. The reference list is organized chronologically and grouped by report titles.

1943 – 1946 Health Group Reports

Hempelmann, L. H. 1943a – Health Report, LAMS-6, August 9, 1943 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7184


Hempelmann, L. H. 1944c – Health Report, LAMS-81, April 14, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7188


Hempelmann, L. H. 1944e – Health Report, LAMS-126, August 30, 1944 Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 3953


Hempelmann, L. H., 1946b, Health Hazards of LANL Groups by Division, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 136
1944 – 1945 Health and Safety Reports

LASL (Los Alamos Scientific Laboratory), 1944a, Health and Safety Report – CM Division LAMS-87, April, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7189


LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-129, August, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7193

LASL (Los Alamos Scientific Laboratory), 1944b, Health and Safety Report – CM Division LAMS-143, September, 1944, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 7194


1947 Health Division Reports


1948 Health Division Reports


Note: H Division Monthly Progress Reports for May 20 – June 20, 1948 and June 20 – July 20, 1948 have not been located at LANL.


Note: An H Division Annual Progress Report for 1948 has not been located at LANL.

1949 Health Division Reports


LASL (Los Alamos Scientific Laboratory), 1949g, H Division Monthly Progress Report, LAMS 929, June 20, 1949 - July 20, 1949, HSPT-REL-94-266, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2301


Note: An H Division Monthly Progress Report for September 20 – October 20, 1949 was not located at LANL.


Note: An H Division Monthly Progress Report for November 20, 1949 - December 20, 1949 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1950a, H Division Annual Report 1949, LA-1072, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2270

**1950 Health Division Reports**

Note: An H Division Monthly Progress Report for December 20, 1949 - January 20, 1950 was not located during project research activities.


Note: An H Division Monthly progress report for November 20 - December 20, 1950 was not located during project research activities.


1951 Health Division Reports

Note: An H Division Monthly Progress Report for December 20, 1950 - January 20, 1951 was not located during project research activities.


LASL (Los Alamos Scientific Laboratory), 1951f, H Division Monthly Progress Report, May 20, 1951 - June 20, 1951, HSPT-REL-94-357, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2226

LASL (Los Alamos Scientific Laboratory), 1951g, H Division Monthly Progress Report, June 20, 1951 - July 20, 1951, HSPT-REL-94-360, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 2227


1952 Health Division Reports


1953 Health Division Reports


1954 Health Division Reports


1955 Health Division Reports


Note: An H Division Annual Progress Report for 1955 was not located during project research activities.

1956 Health Division Reports


Note: An H Division Monthly Progress Report for July 20 – August 20, 1956 was not located during project research activities.


Note: An H Division Annual Progress Report for 1956 was not located during project research activities.

1957 Health Division Reports


Note: An H Division Monthly Progress Report for March 20 - April 20, 1957 was not located during project research activities.


1958 Health Division Reports


Note: An H Division Annual Progress Report for 1958 was not located during project research activities.

1959 Health Division Reports


Note: An H Division Annual Progress Report for 1959 was not located during project research activities.

**1960 Health Division Reports**


Note: An H Division Annual Progress Report for 1960 was not located during project research activities.

**1961 Health Division Reports**


Note: An H Division Annual Progress Report for 1961 was not located during project research activities.

**1962 Health Division Reports**


Note: An H Division Monthly Progress Report for June 21 - July 20, 1962 was not located during project research activities.


Note: An H Division Monthly Progress Report for October 21 - November 20, 1962 was not located during project research activities.


Note: An H Division Annual Progress Report for 1962 was not located during project research activities.

**1963 Health Division Reports**


Note: An H-Division Progress Report for September 21 - October 20, 1963 was not located during project research activities.


Note: An H Division Annual Progress Report for 1963 was not located during project research activities.

1964 Health Division Reports


Note: An H Division Monthly Progress Report for January 21 – February 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for March 21 - April 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for May 21 - June 20, 1964 was not located during project research activities.


Note: An H Division Monthly Progress Report for September 21 - October 20, 1964 was not located during project research activities.


Note: H Division Monthly Progress Reports for October 21 - November 20, 1964 and November 21, 1964 – December 20, 1964 were not located during project research activities.

Note: An H Division Annual Progress Report for 1964 was not located during project research activities.

**1965 Health Division Reports**


**1966 Health Division Reports**


**1967 Health Division Reports**


1968 Health Division Reports


1969 Health Division Reports


1970 Health Division Reports


Note: Monthly or quarterly H Division Progress reports for the period October - December, 1970 were not located during project research activities.

1971 Health Division Reports


1972 Health Division Reports


Note: Quarterly Progress Reports for July – September 1972 and October – December 1972 was not located during project research activities.

1973 and 1974 Health Division Reports

Note: H-Division Quarterly Progress Reports from third quarter of 1972 through 1980 were not located during the project. Quarterly reports were located for 1981 and second quarter 1982. Additional H-Division reports for this time period and later were not located during project research activities.

1981 Health Division Reports


LASL (Los Alamos Scientific Laboratory), 1981c, Health Division Quarterly Report, April - June 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 936


LASL (Los Alamos Scientific Laboratory), 1981e, Health Division Quarterly Report, October - December 1981, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 935

1982 Health Division Reports


Note: Quarterly Progress Reports for January – March, 1981 and July – December, 1981 were not located during project research activities.

Note: Starting the third quarter of 1972, LASL began to publish quarterly and monthly Health Physics reports.

1972 Health Physics Reports


1973 Health Physics Reports


1975 Health Physics Reports

Dummer, J.E., 1975a, Quarterly Progress Report – Group H-1 Health Physics, July – September 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392a

Dummer, J.E., 1975b, Quarterly Progress Report – Group H-1 Health Physics, October - December 1975, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 448

1976 Health Physics Reports


Dummer, J.E., 1976b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1976, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392c

Dummer, J.E., 1976c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1976, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392d


1977 Health Physics Reports


Dummer, J.E., 1977b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392c

Dummer, J.E., 1977c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1977, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392d


Note: Starting in the third quarter of 1978, Area Heath Physics (Group H-1) began reporting activities in separate monthly and quarterly reports. The last report with these titles that were located during the project is for January 1981 activities.

1978 Health Physics Reports


Dummer, J.E., 1978b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392g

Dummer, J.E., 1978c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1978, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392h

Note: Starting in the third quarter of 1978, Area Health Physics began reporting activities in separate monthly and quarterly reports.


1979 Health Physics Reports

Dummer, J.E., 1979a, Quarterly Progress Report – Group H-1 Health Physics, January - March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392j

Dummer, J.E., 1979b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392k

Dummer, J.E., 1979c, Quarterly Progress Report – Group H-1 Health Physics, July - September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392l

Dummer, J.E., 1979d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392m.

Dummer, J.E., 1979e, Area Health Physics Monthly Report, January 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5473

Dummer, J.E., 1979f, Area Health Physics Monthly Report, February 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. 5474

Dummer, J.E., 1979g, Area Health Physics Monthly Report, March 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5475

Dummer, J.E., 1979h, Area Health Physics Monthly Report, April 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5476


Dummer, J.E., 1979l, Area Health Physics Monthly Report, August 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5480

Dummer, J.E., 1979m, Area Health Physics Monthly Report, September 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5481


Dummer, J.E., 1979o, Area Health Physics Monthly Report, November 1979, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 5568


**1980 Health Physics Reports**


Dummer, J.E., 1980b, Quarterly Progress Report – Group H-1 Health Physics, April - June 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392o


Dummer, J.E., 1980d, Quarterly Progress Report – Group H-1 Health Physics, October - December 1980, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 392q

Note: Starting in the third quarter of 1978, Area Health Physics began reporting activities in separate monthly reports.


**1981 Health Physics Reports**


Note: Starting in the third quarter of 1978, Area Health Physics began reporting activities in separate monthly reports.


1982 Health Physics Reports


1983 Health Physics Reports


Note: Quarterly Progress Reports – Group H-1 Health Physics for April – June 1983, July – September 1983, and October – December 1983 were not located during project research activities.


Note: September 1983 Health Physics Monthly Activity Reports were not located during project research activities.


1989 Health Physics Reports


1990 Health Physics Reports


1991 Health Physics Reports


1975 EHS Reports


Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for July - September 1975 was not located during project research activities.

Note: A Quarterly Progress Report, Operational Environmental, Health, and Safety Activities for October – December 1975 was not located during project research activities.

LASL (Los Alamos Scientific Laboratory), 1975c, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, January - March 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4993
LASL (Los Alamos Scientific Laboratory), 1975d, Quarterly Progress Report, Health Research Division – Indirect Laboratory Support Activities, April - June 1975. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 4994

**1976 EHS Reports**


Note: A Quarterly Progress Report for July - September 1976 was not located during project research activities


**1977 EHS Reports**


**1978 ESH Reports**


**1979 ESH Reports**

Voelz, George L., 1979a, Quarterly Progress Report, January - March 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. No. 941
Voelz, George L., 1979b, Quarterly Progress Report, April-June 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. number pending

Voelz, George L., 1979c, Quarterly Progress Report, July - September 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 941

Voelz, George L., 1979d, Quarterly Progress Report, October - December 1979, Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 941

1980 ESH Reports

Voelz, George L., 1980a, Quarterly Progress Report, January - March 1980 Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 937

Note: A Quarterly Progress Report for April – June 1980 was not located during project research activities.

Voelz, George L., 1980b, Quarterly Progress Report, July - September 1980 Operational Environmental Safety and Health Activities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico. Repos. No. 938


1987 HSE Reports


1988 HSE Reports


1989 HSE Reports


1990 HSE Reports

LANL (Los Alamos National Laboratory), 1990, Health Safety Environment Update, Summary of 1990 Quarterly Reports, Los Alamos National Laboratory, Los Alamos, New Mexico. Repos. No. 878
Chapter 14: Environmental Monitoring at LANL

This chapter presents a summary of environmental monitoring and research data that may be useful for evaluation of historical releases from Los Alamos National Laboratory. The reports and monitoring data reviewed by the LAHDRA project team represent samples or measurements collected in both on-site and off-site areas potentially affected by past contaminant releases from Los Alamos National Laboratory operations. The information presented here is organized chronologically to highlight changes and improvements that have occurred during the evolution of LANL’s environmental monitoring programs since the start of Laboratory operations in 1943. Details on monitoring practices presented in this chapter are more heavily weighted toward pre-1970 monitoring since it was during this time period that the largest releases occurred.

Overall information availability is summarized in the following sections. Brief descriptions are included of several example environmental studies that are tied to past LANL activities. It is important to note that, while this chapter summarizes a number of environmental monitoring studies, it is not a complete historical record of every study conducted to date. Many more environmental studies are described and referred to in documents that were selected by the LAHDRA project team and added to the project information database.

Areas of Investigation

Environmental monitoring and research data reviewed by the LAHDRA project team primarily address sampling and measurement of environmental media such as air, water, soils, sediments, biota, and foodstuffs that were potentially impacted by radioactive and chemical contaminants released from LANL. Monitoring data of interest to this project represent measured concentrations of contaminants at on-site and off-site locations, including areas along the site boundary and residential communities that are nearby, regional, or useful for characterization of background concentrations. Historically, these data have typically been used by LANL to monitor trends in contaminant releases and/or to study the presence, migration, and fate of releases that have occurred or are occurring through transport mechanisms such as air dispersion, leaching, or surface flow to important water resources. Environmental monitoring data are of interest for potentially filling data gaps that exists in historical effluent monitoring data for various discharge points at LANL.

The following section describes the primary geographical areas of interest during the investigation. These areas were selected for investigation based on:
• The LAHDRA project team’s knowledge of the key release sources at the Laboratory,
• Previous environmental studies of on-site and off-site areas,
• Surface waters that have received past LANL emissions,
• Reported areas of contaminant accumulation in surface water, sediments, and surface and subsurface soils,
• Annual airborne releases and indications of how they have been affected by local and regional wind patterns as well as local and regional topography, and
• Historical environmental surveillance and monitoring and a review of environmental data availability.

Some environmental monitoring within the laboratory boundary and surrounding areas began within the first few years after the start of Laboratory operations in 1943. Monitoring was first conducted by members of the Health Group of Project Y, the United States Atomic Energy Agency, and the U.S. Geological Survey (USGS). In more recent years, other LANL divisions and the State of New Mexico have also conducted environmental monitoring and/or environmental studies. Most of the early monitoring involved collection of non-routine air, water, soil, and sediment samples that were analyzed for radioactive and occasionally elemental or chemical contaminants. The early environmental monitoring program was used to identify and characterize the spread of radioactive contamination to surrounding land areas and to estimate potential radiation exposures to workers as a result of laboratory activities and emissions.

Increased monitoring over the years meant the collection of a larger number of routine samples for all types of media and for a growing list of contaminants. The frequencies with which samples were collected also increased over the years. With the advent of new environmental protection and emission standards of the early 1970s, LASL saw the need to further increase their monitoring of the environment both on site and off site and enhance the formats with which they reported measurement results. The need to do more monitoring was also brought to the LASL’s attention by independent reviewers and experts (Parker 1974).

Based on reports reviewed to date, most of the emphasis for environmental monitoring during the early years was placed on measuring radioactive constituents; however, beginning in the late 1950s, some limited sampling was performed for lead, mercury, chromium, beryllium, and other elements and chemicals of interest. Early environmental documents pointed out the need to increase sampling for all media and to perform radiochemical analyses for isotopic plutonium and specific fission products.
associated with fall-out from atmospheric weapon tests to better differentiate between global fallout and impacts from LASL (Parker 1974).

The areas of concern for the investigation of environmental data include:

- Los Alamos community
- Española community
- White Rock community
- Surrounding Native American lands
- Los Alamos Canyon
- DP Canyon
- Pueblo Canyon
- Acid Canyon
- Rio Grande River
- Mortandad Canyon
- Bayo Canyon
- Pajarito Canyon
- Sandia Canyon
- Guaje Canyon
- Area reservoirs

**Conditions at LANL and Surrounding Areas**

The laboratory site and adjacent communities are situated on the Pajarito Plateau, which consists of a series of mesas separated by deep canyons. These canyons were cut by intermittent streams that trend south-eastward from an altitude of about 2,400 meters at the Jemez Mountains to about 1,800 meters at the eastern margin, where they terminate above the Rio Grande Valley. The canyons and mesas areas are underlain by the Bandelier Tuff composed of ashfall and ashflow pumice and rhyolite tuff that form the surface of Pajarito Plateau. The volcanic ash was deposited following an eruption that occurred about 1.2 million years ago (LASL 1980).

Surface waters are primarily intermittent streams that begin on the sides of the Jemez Mountains and supply base flow to the upper reaches of some canyons. The amount of flow in these streams is typically insufficient to maintain flow across the laboratory area before it is depleted by evaporation, transpiration, and infiltration. However, runoff from heavy thunderstorms and significant snowmelt reaches the Rio Grande several times a year. Over portions of LANL’s operational history, effluents from the Laboratory have provided sufficient volume to maintain surface flow in the canyons for distances up to 1.5 km (LASL 1980). Several photographs of LANL discharges to area canyons are shown in Fig. 14-1.
Groundwater occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in the canyons, (2) perched water in basalt, and (3) the main aquifer of the Los Alamos area. Deposited alluvium in the canyons ranges in thickness from 1 to 30 m and is quick permeable in contrast to the underlying volcanic tuff and sediments. This results in a shallow alluvial groundwater that moves down gradient in the alluvium and becomes depleted as it moves into the underlying volcanic deposits. In lower Los Alamos and Pueblo Canyons, a small local body of perched water is formed in the basalts by water filtration. This water discharges in the Los Alamos Canyon west of the Rio Grande. The main aquifer capable of municipal water supply rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the plateau. Depth to the aquifer decreases from 360 m along the western margin of the Plateau to about 180 m at the eastern margin. The water is under water table conditions in the western and central part of the plateau and under artesian conditions in the eastern part and along the Rio Grande (LASL 1980).
Availability of Environmental Data

Much of the environmental monitoring results reported for years prior to 1970 and reviewed by the project team are published in letter-type reports that vary widely in content and detail. In some cases, only a portion of a report was available for review or a report may only contain limited amounts of monitoring data or lack a description of the methods and purpose for a monitoring activity. Information presented in these earlier documents indicates that environmental monitoring was sporadic and generated a smaller amount of data when compared to results for later years, when monitoring activities were much more formalized and comprehensive.

By the late 1950s, attempts were made by the laboratory to formally consolidate environmental monitoring results into one report. One of the first such reports is titled *Los Alamos Environmental Monitoring Program* for the years 1959 and 1960. This report includes results for direct gamma measurements, air particulate sampling for analysis of alpha and beta air concentrations, and water sampling of potable water supplies, surface body waters, and test monitoring wells (Kennedy 1960). However, it was not until 1970, when LANL began to publish their annual environmental surveillance reports, that results of monitoring activities were routinely reported in a unified and comprehensive manner. Monitoring grew substantially over the next 35 years, with results published and documented in the annual environmental monitoring reports. Many of these annual reports are now available to the public on the laboratory’s Web site at [www.lanl.gov](http://www.lanl.gov).

Chronology of Early Environmental Monitoring at LANL (1943 – 1970)

Documents indicate that LANL began their first environmental monitoring activities sometime in 1944 or 1945. Monitoring was designed to measure radioactive and chemical concentrations in water, sediments, and soils with the intent of defining the impacts to the environment from laboratory liquid waste discharges to nearby canyons or burial grounds. The monitoring program evolved in the 1950s and expanded to include additional sampling and radiation surveys. Along with increases in water and soil sampling locations and sample collection frequencies, LANL began routine gamma radiation measurements and air sampling for gaseous and particulate radionuclides or non-radioactive contaminants. LASL periodically reported results for these early sampling and radiation survey activities in brief letter reports. Reports often present combined results for water and soil samples, ambient gamma measurements, and air samples (Tribby 1945; Tribby 1947, Kinsley 1947; LASL 1954a; Kennedy 1965). Occasionally, LASL reported results for radioactive fallout particulates from LANL operations using “Sticky trays” with gummed-paper to collect the radioactive contamination (Kennedy 1958). These early
sampling activities were sporadic and often involved non-routine monitoring to study changes in contaminant concentrations over time and movement of contaminants in the environment.

An independent safety appraisal of the LASL health and safety program conducted in 1947 by the Safety and Industrial Health Advisory Board of the National Safety Council was highly critical of the laboratory’s ability to control and monitor releases of hazardous materials to the environment (Williams 1948). In addition, LASL documents indicate that environmental monitoring lacked continuity and consistency in terms of sampling methods and data analysis and reporting. The use of staff from various groups operating somewhat independently from one another made it difficult to compile routine data into unified and consistent formats with the level of data and reporting quality that was desired (Kennedy 1958). Effluent and environmental monitoring programs were not as well developed as the methods and practices used for monitoring personnel radiation exposures during this time period and it is evident that the health and safety program was primarily directed towards reducing radiation exposures to workers. Documents available to the project team indicate that routine environmental air sampling was almost nonexistent until the mid to late 1950s.

Monitoring of Liquid Waste Releases

During early operations in the 1940s, liquid waste from the DP site (TA-21) and the Original Technical Area (TA-1) were released into Los Alamos Canyon and Pueblo Canyon. Periodic water and sediment samples were collected in the canyon creeks and drainage areas and in off-site areas such as the Rio Grande and analyzed for radioactive and chemical contaminant concentrations. Samples of liquid effluents were also collected at discharge points to determine if the amounts of waste released were within the legal or recommended concentration limits for the time and also used at the Hanford site (Tribby 1948). Many of the samples during this time were analyzed for plutonium, polonium, uranium, beta and gamma, and occasionally for heavy metals and other elements such as lead, bismuth, mercury, chromium, and fluorine (Tribby 1945; Kingsley 1947; Kingsley et al. 1947; Schnap et al. 1948; Shipman 1958).

Area supply wells and other potable water supplies were also sampled and tested (Kennedy 1948). The liquid effluent limits at that time were $6.3 \times 10^4 \mu\text{Ci L}^{-1}$ for plutonium and polonium and $5.0 \times 10^1 \mu\text{Ci L}^{-1}$ for mixed fission products such as $^{140}\text{La}$ and $^{140}\text{Ba}$. The earliest LANL documents that describe initial monitoring activities and results are for 1945 to 1950 (Tribby 1945; Tribby 1947; Schnap et al. 1948; Schnap 1950). Treatment of the liquid waste was initially minimal, but did increase as production and liquid waste volumes increased (Tribby 1948). The following excerpt from a LANL document depicts the sources of contamination and environmental areas targeted for sampling (Tribby 1945).
Water sampling was usually conducted after heavy rains since creek beds were often dry during seasonal periods of low precipitation. Many of the samples were collected in “pools” which is where liquid waste discharges and rainwater collected in lower-lying or down gradient drainage areas (Kingsley 1947). Concentrations for radioactive contaminants in water and soil samples were typically elevated at locations near effluent discharge points in the canyons and decreased to undetectable levels within short distances from points of discharge. Elevated levels were often identified during periods of liquid discharge but concentrations would decrease over time due to the decay of short-lived radionuclides such as polonium or from dilution and movement of longer-lived radioactive contaminants dispersed within surface waters during periods of moderate to heavy precipitation (Kingsley 1947; Schnap et al. 1948). Records indicate that LASL began to scale back on their liquid waste discharges to Los Alamos and Pueblo Canyons as additional waste treatment facilities at the laboratory became operational to reduce contaminants levels release to the canyons or burial grounds.

LASL found it necessary to expand their waste treatment capacity as growing production and research demands generated larger and larger volumes of liquid and solid radioactive and chemical waste. H-7 group became part of the H Division in June 1955 and assumed responsibility for liquid waste treatment
and management. The H-7 Group also oversaw a growing environmental monitoring program in those areas potentially impacted by liquid and airborne discharges. Two liquid waste treatment plants used coprecipitation for removal of plutonium and one plant was equipped with an ion exchange unit to remove barium-140 and radioactive strontium isotopes (Shipman 1958).

The Waste Treatment Plant at TA-45 received wastes from TA-1 and TA-3 and discharged treated liquid waste to Acid canyon. For example, 11.5 million gallons of waste was received in 1957. Treatment of the waste removed roughly 94% of the radioactivity and 99% of the plutonium, which allowed them to meet 10% of the NBS 52 Handbook tolerance for plutonium discharge (Shipman 1958). More treatment capacity was added as necessary and releases of contaminants decreased over time.

The Ten Site Waste Treatment plant at TA-35 handled liquid waste for the RaLa program with four 50,000 gallon tanks. Wastes contained mixtures of $^{140}$Ba, $^{140}$La, $^{89}$Sr, $^{90}$Sr, $^{90}$Y and trace amounts of other radionuclides. Waste treatment removed 93% of radioactivity and discharged roughly 92% of liquid waste volume to Mortandad Canyon after treatment (Shipman 1958).

In coordination with LANL, the United States Geological Survey (USGS) also collected routine water samples from local surface streams, the Rio Grande, supply wells, and monitoring wells and submitted the samples to LANL for radiochemical and water quality analyses. Monthly samples were analyzed for gross alpha, gross beta, plutonium, and uranium. Samples were also analyzed for pH, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO$_3$, and conductivity. Volumetric flow rates for streams located in Pueblo and Los Alamos canyons are also presented in study results. These additional sampling were also used to assess the potential impacts from LANL operations on water resources and to better understand the rate and direction of groundwater flow in the local and regional area (LASL 1959; Shipman 1956).

By the 1970s, LANL was conducting water sampling at various locations at distances of 40 to 50 kilometers away from the main laboratory area (LASL 1971a). Additional examples of early environmental monitoring studies of waterborne contamination are presented in a later section of this chapter.

**Soil Monitoring**

LANL also conducted soil sampling at on-site and off-site locations to further assess impacts from liquid waste discharges from TA-1 and TA-21. Soil samples were collected in areas along canyon creeks or in dry creek beds and drainage areas. Samples were often analyzed for plutonium, polonium, uranium, beta
and gamma heavy metals and other elements such lead mercury, chromium, and fluorine (Tribby 1945). Soil sampling results were reported along with results of their water monitoring activities. Concentrations results at on-site locations close to discharge points are often reported above detection limits or background levels. Results for sampling locations at greater from discharge points are often reported as “negative” meaning either concentration levels were below the method detection limits for analytical measurement techniques used at the time or were below an administrative or regulatory control limit (Kennedy 1952).

Results for soil samples collected in Acid Canyon (discharge from TA-45 plant), Mortandad Canyon (discharge from TA-35 plant), Los Alamos Canyon (discharge from TA-21), and at the laundry site were periodically reported in Health Division of reports or memoranda (Shipman 1958). Samples during this time period were analyzed according to location—gross alpha and plutonium at Acid and Los Alamos Canyons and $^{90}$Sr and yttrium at Mortandad Canyon.

In 1955, soil sample results showed strontium contamination in upper reaches of Mortandad Canyon that exceeded NBS Handbook tolerance levels (Shipman 1958). Study of plutonium, strontium, and cesium movement in tuff materials was begun during 1957 and reported that very little movement of radioactive material had occurred based upon comparison to sampling results for the previous years. Soil sampling continued throughout the 1950s and beyond. Results consistently showed strontium contamination in the canyon from Ten Site liquid waste discharges (Shipman 1956).

Grab and composite surface water samples were collected at various locations along the Rio Grande River and the Chama River. The rivers had a reported natural uranium background concentration of approximately $10^{-9} \mu \text{Ci cm}^{-3}$. Water samples are also collected at 7 perennial streams, 13 water supply wells, and 8 test monitoring wells located in various canyons within and surrounding the laboratory (Shipman 1956). In 1957, LANL began a study to evaluate the movement of $^{90}$Sr, $^{137}$Cs, and $^{239}$Pu released form LANL through the local soils, including tuff material (Shipman 1958).

By the 1970s, LANL was conducting soil and sediment sampling at various locations 40 to 50 km away from the site (LASL 1971a). Additional examples of early monitoring of soil contaminants and sampling studies are presented in a later section of this chapter.

**Air Monitoring**

A variety of air monitoring activities and measurements conducted by LANL were also used as another means of assessing impacts from routine or accidental air effluents from laboratory operations or from re-suspension of radioactively-contaminated soils or dry sediments. The primary focus of their early air
monitoring program from 1944 to around 1970 was to detect larger, accidental releases and as such this meant that routine sampling results at or below detection limits were not reported on a regular basis. These early monitoring stations were equipped with thin-walled GM tubes and a scaler/rate meter to record results. By the late 1950s and 1960s, air particulate filters and charcoal canisters were being used at most of these stations to measure gross alpha and beta and radioactive iodine concentrations in air. Routine reporting of these early measurements also appear to be sporadic and limited in the amount of data presented in LANL documents. It appears that only a limited amount of air monitoring results for 1940s and 1950s and, to some extent the 1960s, was published by LANL. It is also possible that results were published in reports that are now missing or were destroyed or simply were not located by the project team. Routine reporting of monitoring results, however, does not appear to have begun in earnest until 1970 based on available documents reviewed by the project team.

LASL did not have a well established network of air monitoring stations until the late 1950s and documents indicate that 25 to 36 monitoring stations were used from 1958 to 1992. Most of these stations were located on-site within the various Technical Areas at LANL or within the Los Alamos town site or the town’s immediate surrounding areas. The two on-site monitoring stations furthest away from the Main Technical area or Los Alamos town site were located in White Rock, New Mexico (approximately 6 miles to the southeast) and at the eastern site boundary. The report entitled *Los Alamos Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, January through June, 1971* (the predecessor report to LANL’s Annual Environmental Surveillance reports) indicates that LANL began to use two remote “off-site” air monitoring stations starting sometime in 1971. One station was placed in Española, New Mexico approximately 14 mi northeast of Los Alamos and the other station was located in Santa Fe, New Mexico, approximately 24 mi southeast of Los Alamos (LASL 1972a). In 1992 and 1993, LANL expanded the number of on-site monitoring stations to 52 including the addition of regional or remote stations at various locations up to approximately 45 mi northeast of LANL. The collective array of air monitoring stations became known as AIRNET monitoring program. During this expansion of air monitoring stations, LANL also increased the network to six off-site or remote monitoring stations. The remote stations since that time are located in Española, San Ildefonso Pueblo, El Rancho, and Jemez Pueblo New Mexico and still being used by LANL. An additional monitoring station was added within the city limits of Santa Fe. In 2003, LANL added a seventh remote monitoring station at Picuris Pueblo, New Mexico, making it the station furthest away from LANL at roughly 45 mi to the northeast. Most of these AIRNET stations or predecessor monitoring stations are still in operation today although routine or periodic reporting of monitoring results did not begin until the 1970s with the advent of LANL’s Annual Environmental Surveillance reports (LANL 1994; LANL 2008). Starting around the
early to mid-1960s, air filters were measured for gross alpha and beta activities and then made into composite samples once a month for isotopic analyses of long-lived alpha-emitting radionuclides such as plutonium. Charcoal canisters also continued to be analyzed for $^{131}$I by way of gamma measurements and water vapor was measured for tritium concentrations via liquid scintillation counting.

A comparison of environmental air monitoring programs at other DOE sites shows that LANL used similar measurement techniques throughout the years although they did not establish remote, off-site monitoring as early as some DOE sites. For example, the Oak Ridge Reservation (ORR) sites (X-10, Y-12, and K-25) used a formal network of local and perimeter (“on-site”) samplers and monitors during the 1940s and 1950s, but also began using remote (“off-site”) gamma and air monitoring stations in the early 1960s. Eventually, the networks of monitoring stations were officially referred to as the local air monitors (LAMs), perimeter air monitors (PAMs), and remote air monitors (RAMs). ORR’s LAM and PAM monitoring stations used during this early period were equipped with ion-chamber type instruments to measure outdoor ambient gamma radiation levels. These instruments were later modified to measure beta radiation, although laboratory staff discovered the instruments were highly susceptible to weathering and proven to be unreliable for routine measurements. ORR eventually adopted the used of GM tubes with scaler/rate meters to measure both gamma and beta radiation. Charcoal canisters were used at selected stations for iodine measurements and tritium measurements were performed on rain water samples. Similar to the practices used by LANL, ORR also used film badges and TLDs in later years to measure gamma and beta radiation and air samplers to measure particulate and gaseous airborne concentrations of radioactive materials for determining impacts from site effluents and/or global nuclear fallout.

ORR used three remote air monitoring (RAM) stations as far back as 1956. These stations were also equipped with GM Tubes and scalers along with gummed-paper trays and rain collectors for measuring air particulate radioactive contaminants/fallout along with charcoal canisters for measuring radioactive iodine. The first three RAMs used were located in Corryton and Kingston, Tennessee and Berea Kentucky. The Corryton and Kinston stations were only used in 1956 and data for the Berea station is only available for 1957 and 1958. The Berea station was discontinued in 1962. Prior to 1959, seven additional remote air monitoring stations were added at various Tennessee Valley Authority (TVA) dam locations ranging in distance approximately 12 to 75 miles from the ORR (NIOSH 2004). In comparison, LANL’s primary focus during early air monitoring was not on remote locations as much as it was on monitoring impacts to local residential areas and nearby canyons. It wasn’t until around 1970 that LANL began to expand their air monitoring network beyond its site boundary.
Bayo Canyon (TA-10) and TA-35 – RaLa Test Shots

LANL documents from the 1940s and early 1950s indicate that initial air monitoring conducted by LANL was focused on monitoring radioactive fallout from the RaLa test shots conducted in Bayo Canyon. Radioactive and chemical debris from test shots containing $^{140}$Ba and $^{140}$La was released to the atmosphere at dispersion rates and directional patterns based on weather conditions at the time of each shot. Airborne contaminants would typically migrate beyond Bayo Canyon to surroundings areas. As discussed in a 1945 LANL document, the three primary hazards associated with RaLa shots included external radiation, explosive materials, and airborne contamination. Airborne contamination was monitored at the firing location and at other points in the canyon and on the Los Alamos mesa initially by members of Group A-6 (Steinhardt 1945). Measurements were made with film badges mounted 3 feet above the ground surface on wooden or metal stakes. Direct gamma measurements were also collected with a GM tube and a scaler/rate meter. Later on, fallout trays with gummed-paper were used to collect radioactive debris.

Radioactive fallout from most test shots was monitored to the extent practical as LANL acknowledged that some downwind areas surrounding Bayo Canyon were inaccessible due to the rugged terrain in part of New Mexico. Following test shots, the road from the Main Tech area (TA-1) to the East Gate was often closed to vehicle traffic to allow time for removal and/or decay of radioactive contamination to levels deemed acceptable to allow resumption of public access on the roads. For example, the radioactive plume from a RaLa shot conducted on April 20, 1949 passed over and contaminated the area from the East Main Gate to Los Alamos town site. The incident required decontamination of the main road (Highway 285) before the road was reopened to the public or other workers. Because of these incidences, LANL sought to improve their weather and fallout predictions by requesting the assistance from meteorologists from the Kirkland Air Force Base in Albuquerque (LASL 1949a).

Debris from another shot on May 20 of the same year drifted out of the canyon and contaminated the main road to Los Alamos at the Frijoles junction and resulted in maximum gamma-beta readings of 10 mR h$^{-1}$ (LASL 1949b). Throughout this time period, staff from the Biophysics section focused their efforts on further defining and predicting fallout from the RaLa shots to minimize exposures to workers and members of the public. In 1949, the fallout problem became more acute when LANL discovered a new mining operation in Guaje Canyon operated by the Santa Fe Pumice Company located about 3 mi away from Bayo Canyon. To minimize the spread of contamination and better characterize potential environmental and public health impacts from RaLa test shots, LANL increased their efforts to measure wind rose patterns including prevailing wind directions and maximum and average wind velocities of
prevailing winds (LASL 1949c). As reported in a 1949 monthly H Division progress report, the plume from an implosion test shot rose and spread contamination easterly as far away as 10 mi at a location known as “Camp May” (LASL 1949d).

Descriptions in the 1952 H Division annual report indicate that LANL continued to monitor dispersion and fallout of radioactive material from Bayo Canyon test shots. These surveys focused on tracking contamination in areas north and east of Bayo Canyon, White Rock, Totavi, Puje, and Espanola and to address growing concerns about releases from RaLa shots and from other facilities such as DP Site as production increased significantly during this period. In the report it was noted that additional sampling was conducted along East Road to assess impacts and hazards from DP Site as well as from Bayo Canyon releases. Health Division members from the H-1 and H-6 monitoring groups also expanded the on-site and off-site monitoring program to further address the growing concerns about impacts to the environment (Shipman 1953).

Laboratory safety personnel also expressed concerns about personnel and public exposures associated with RaLa test shots as well as airborne effluents from RaLa hot cell operations and operations at TA-2 (Omega), TA-3 (CMR Building), and TA-21 (DP Sites). The TA-35 hot cell facility was used to handle, store, and prepare the RaLa sources for test shots conducted in Bayo Canyon. The excerpt from a 1952 LANL document shown in Fig. 14-3 represents another example of LANL activities used during this time to assess the impacts from the TA-35 radioactive airborne effluents (Buckland, 1952).

The excerpt from a 1952 LANL document shown in Fig. 14-4 further indicates that LASL staff was aware of the importance of predicting weather conditions to minimize the spread of radioactive contamination and conducted periodic surveys to determine impacts of air effluents (Buckland, 1952). Other means of tracking cloud dispersions from the RaLa shots was through the use of air conductivity measurement. This technique proved to have advantages over the use of GM tube instruments, particularly when radiation fields approach saturation levels (LASL 1951). Based on review of project documents, it is not clear to what extent LANL used conductivity measurements in tracking radioactive, explosive cloud dispersions.
In a series of reports and memoranda from 1956 to 1959, monitoring of outdoor air concentrations and radiation levels within and surrounding TA-35 continued to be used to assess impacts from airborne effluents associated with $^{140}$Ba/$^{140}$La source production, LAPRE operations, and irradiated reactor fuel analyses (including fission products) and plutonium experiments in hot cells (LASL 1959). Availability of these environmental monitoring data are limited based on document searches conducted by the project team. These types of data could be useful as a tool for evaluating the accuracy of effluent estimates.
reported by the lab or release estimates derived from basic effluent measurement data. Further research including document searches for these early environmental data is recommended to be part of any future dose reconstruction study of LANL operations.

Main Technical Area and Greater Los Alamos and Surrounding Areas

In 1951, LANL continued to discuss the need to expand their air sampling program to improve the ability to measure contamination in areas outside of the Main Technical Area and DP Site resulting from laboratory activities. Health Division staff were recommending continuous operation of sampling stations at numerous locations adjacent to Los Alamos (LASL 1952).

In 1954, LANL used ten air particulate monitoring stations within the Los Alamos community to measure airborne alpha concentrations during the demolition of D Building (Johnson 1954). Additional on-site stations were also used to study impacts from LANL operations with a focus on detecting and/or measuring radioactive releases from TA-1 (Main Technical Area), TA-2 (Omega reactor), TA-3 (CMR Building), TA-21 (DP Sites), TA-35 (RaLa hot cells, LAPRE, etc), and TA-10 (Bayo Canyon). During that same year, 14 air samplers were used at locations in the Main Technical Area (TA-1), Los Alamos town site including residential areas, and along the site perimeter (LASL 1954a). The locations for the 14 air monitoring stations included:

<table>
<thead>
<tr>
<th>Location</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1636 34th Street</td>
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</tr>
<tr>
<td>194 Abbey Street</td>
<td>Adjacent to Foundry Building at TA-1</td>
</tr>
<tr>
<td>861 43rd Street</td>
<td>Roof of O Building at TA-1</td>
</tr>
<tr>
<td>2135 35th Street</td>
<td>Roof of V-Shop at TA-1</td>
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<tr>
<td>2500B 36th</td>
<td>Roof of HRL Building at TA-1</td>
</tr>
<tr>
<td>2379B Ivy Street</td>
<td>Roof of Gamma Building at TA-1</td>
</tr>
<tr>
<td>331A Manhattan Loop</td>
<td>Warehouse 18 at TA-1</td>
</tr>
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</table>

Measurement results for 1954 are presented in two data sets (LASL 1954a, LASL 1954b). Monitoring results for previous years were not identified by the project team but further research to locate relevant records would likely be warranted during any future LANL dose reconstruction investigation. A thorough evaluation of the quality of these data is warranted if used in the future for evaluating the accuracy of effluent release estimates.

In 1959, LANL proposed increasing air sampling for particulates to assess impacts from LANL operations on the surrounding communities by placing additional air samples on the rooftops of schools within the Los Alamos community (Kennedy 1959). By 1960, LANL’s air environmental monitoring
program had grown to 15 sampling locations to monitor airborne alpha contamination (including plutonium and polonium) and to assess any environmental impacts from laboratory operations (LASL 1961b). During 1965 the number of sampling locations expanded to 25 air stations positioned within the Los Alamos residential areas and population centers (such as schools) and along perimeter roads throughout the various technical areas at the laboratory. As was the case during previous environmental air sampling activities, these samplers were used to measure airborne particulates and short-lived radioactive gases routinely released from LANL or for detecting large amounts of radioactive material released during accidents (Kennedy 1965).

The air samplers used during this period contained two separate filter media to test for beta and gamma radioactivity. *Mine Safety Appliance (MSA) 4-inch diameter CR-17651* respirator particulate filters were analyzed for beta (fallout) activity using a gas proportional counter calibrated with a $^{90}\text{Sr}/^{90}\text{Y}$ standard. Samples were collected on a daily basis and also periodically merged into composite samples for analysis of $^{90}\text{Sr}$, $^{137}\text{Cs}$, and $^{144}\text{Ce}$. *MSA BM 2306* charcoal canister was mounted behind the particulate filter and used for measuring gamma (radioiodine) activity. The charcoal canisters were measured for iodine activity on a gamma spectrometer calibrated with a $^{131}\text{I}$ standard (Kennedy 1965).

A second air particulate sampler was used for measuring long-lived alpha activity such as plutonium. Samples were collected on a Gelman AM-3, 2 inch diameter filters and analyzed on a gas proportional counter calibrated to a $^{239}\text{Pu}$ standard. Samples were held for one week prior to counting to allow for the decay of natural radon and thoron. The lower limit of detection for these air samples was $4 \times 10^{-15}$ µCi cm$^{-3}$, or one-tenth the regulatory limit ($4 \times 10^{-14}$ µCi cm$^{-3}$) used at that time. If results exceeded the regulatory limit, then samples were analyzed for radionuclide concentrations using alpha spectroscopy. A maximum value of $2 \times 10^{-14}$ µCi cm$^{-3}$ was reported for 1959 and 1960 with the average result below the method detection limit. A charcoal canister was also used on a percentage of these air samplers, but documents with a full or partial set of sampling results were not identified during documents performed during the project (Kennedy 1965).

In 1993, LANL expanded the number of monitoring stations to 52 including regional locations as far away as Picuris Pueblo, New Mexico, located roughly 45 mi northeast of LANL (LANL 1994; LANL 2008).
Global Nuclear Fallout Measurements

Around 1958, LANL began specific collection of air particulate and rain water samples for analysis of beta radioactivity concentrations and performed gamma radiation measurements as part of the U.S. Public Health Service (PHS) program for reporting nuclear fallout data. LANL was one of eleven U.S Atomic Energy Commission sites that participated in the monitoring program and used one monitoring station located on the roof of laboratory’s Administration Building, SM-43 at TA-3 to serve this purpose (Kennedy 1960). The PHS program had a total of 44 monitoring stations located throughout the United States. Results were reported for airborne beta activity (pCi m⁻³), rain water radioactivity (pCi m⁻²), and gamma radiation (mR h⁻¹).

Results for the LANL nuclear fallout monitoring station are reported in a series of annual laboratory reports for the years 1958 to 1970 titled Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico or Beta Radioactivity in Environmental Air at Los Alamos, New Mexico (see Table 14-1). Reports that contain pre-1958 sampling results were not located during this project although it is believed LANL may have conducted these types of measurements prior to these publications. Reported monitoring results for measured concentrations or radiation levels were typically consistent with background radiation levels or expected nuclear fallout amounts and did not show elevated levels from LANL operations. However, the monitoring station was located west or north and most often upwind of LANL’s primary production areas (e.g., TA-3, TA-10, TA-21, TA-35) and would not have been expected to routinely collect and measure activity released from these LANL process operations.

In March of 1963, the H-8 monitoring group relocated their offices to TA-50 and moved the fallout air station to the roof of their new building which was located about 1.5 southeast of the TA-3 Administration Building (Aeby and Kennedy, 1964).

In 1964, LANL published results for long-lived fission products measured in rain water and air particulate samples continuously collected from 1958 through 1963. The purpose of the report was to describe isotopic analyses of composite samples and present concentration values for \(^{90}\text{Sr}\), \(^{137}\text{Cs}\), and radioactive rare earth elements (Graham 1964).

Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1960. LAMS-2499 (Kennedy 1961).

Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1st Quarter 1961. ER37183. Los Alamos, New Mexico. (Kennedy 1961a).

Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1961. LAMS-2702 (Kennedy 1962).


### Gamma Monitoring

Direct gamma exposure rates or integrated gamma measurements were used to further define changes in environmental conditions as a result of airborne and waterborne releases from LANL operations. As described in a 1948 monthly H Division report, film badges on South Mesa were planted for daily monitoring (see Fig. 14-5) (LASL 1948). No further details on when this monitoring began are provided in the report and a search for these monitoring data did not identify any additional records. These types of data could provide useful, supplemental information regarding impacts from early effluents during the 1940s and could be used to assess direct radiation exposures for periods when effluent amounts are difficult to ascertain due to a lack of effluent monitoring data.
Descriptions in another 1948 monthly H Division progress report indicate that the film badges where placed on top of South Mesa to monitor radioactive cloud dispersion associated with RaLa implosion test shots carried out in Bayo Canyon (LASL 1948).

Sometime during 1949, direct gamma and beta exposure rates were monitored Geiger-Mueller (G-M) instruments with continuous monitoring and telemetry to a central location (see Fig. 14-6). These instruments were deployed in the Los Alamos area at six separate locations to provide another method for monitoring changes in the outside environment from LANL operations (LASL 1950).

Sometime during the 1950s, the six stations were expanded to seven locations as described in a 1959 LANL report. Twenty-four hour continuous readings were transmitted through telephone lines to a central recording station located at the main Administration Building. The transmitted readings were documented on automatic chart recorders. Variations in radiation levels were identified and most often determined to be attributable to variations in natural background radiation (Kennedy 1960b). It appears that these monitors remained in service throughout the 1960s and perhaps longer. A directed search for a complete set of these measurement results was unsuccessful during the project.

During the 1950s, beta and gamma monitor were designed and built at the laboratory to assess impacts from releases from the Omega Water Boiler reactor. Locations of these monitors were not stated in the report (LASL 1950b).
Additional ambient gamma exposure levels were routinely measured with film badges mounted on stakes 1 m above the ground surface. These badges were exchanged on a monthly basis. The film had a reported sensitivity above ambient background levels that approached the Radiation Protection Guide value used during this period. Any measurable dose recorded was then attributable to LANL effluents or other man-made sources of radiation (e.g., nuclear weapon test fallout). For 1960, 2400 gamma measurements were reported, and with the exceptions for 2 locations, all results were less than the 0.5 rem, the public dose limit used at the time and recommended by the Federal Radiation Council (Federal Register; May 18, 1960) (Kennedy 1961b). Records that contain detailed results of these measurements were not identified during the project.

By 1965, LANL used thermoluminescent dosimeters (TLDs) at 100 locations throughout the Los Alamos residential areas and surrounding areas on LANL property. The dosimeters were used to assess ambient gamma radiation levels and detect potential impacts from radionuclide emissions from the laboratory, particularly larger releases associated with accidents or other uncontrolled events (Kennedy 1965). The dosimeters were collected and analyzed on a monthly basis. A directed search for pre-1970 measurement results was unsuccessful during the project. By 1970, LANL reduced the number of TLD stations to 60 locations based on prior measurement experience (e.g., redundancy of adjacent monitoring locations) and the recognition that for future monitoring one location provided adequate spatial coverage in some areas that had used two to three TLDs during prior monitoring periods. However, LANL increased the number of TLD locations again in 1981 and has maintained more than 150 since that time.

**Summary of Annual Environmental Surveillance Reports (1970 – 2007)**

Beginning in 1970, as environmental monitoring increased, LASL began to publish annual reports for environmental monitoring results based on sampling and analyses conducted by laboratory staff and the USGS. These reports contain monitoring results for a variety of environmental sample types, including:

- direct radiation readings for alpha, beta, and gamma radiation,
- outdoor/external thermoluminescent dosimeters (TLDs),
- surface water including drainage ditches, creeks, ponds, rivers, and lakes,
- ground water,
- particulate and gaseous air sampling,
- soil and sediment sampling,
- food sources,
- assorted biota and wildlife, and
- special environmental sampling and research studies.
In the early 1970s, environmental samples were collected and analyzed by the Laboratory’s Environmental Services Group. Table 14-2 identifies the annual reports that have been published and Table 14-3 presents a summary of chemical and radionuclide monitoring data that are available in the annual environmental surveillance reports.

Data contained in the annual reports represent samples routinely collected in air, surface water, ground water, soils, sediments, a variety of biota, and some food sources. The laboratory did not perform any measurements of food sources until the later part of the 1970s. The annual reports also contain information about special studies conducted to provide better coverage of areas of particular interest or to study in detail individual sources of contamination. For example, a study of radionuclide uptake in garden plants grown in the Mortandad Canyon was initiated in 1976 and reported in the Environmental Surveillance at Los Alamos During 1977 report (LASL 1978). Additional descriptions of the types of monitoring data contained in the annual reports are presented below.

**Examples of Early Environmental Studies of Interest**

This section presents various environmental monitoring and research data that describe the historical presence and behavior of contaminants in off-site areas around LANL. Media addressed include surface water, sediment, ambient air, aquatic and terrestrial foodstuffs, soil, drinking water, and groundwater. Hydrologic and meteorological data are also presented below. Descriptions of additional studies will be added to this section as more information becomes available to the project team.

**Historical Surface Water and Sediment Data**

Sample of available surface water and sediment monitoring data collected in areas of concern described in the above section are presented below. Due to large volumes of data, not all of the available data have been summarized for this report.

**Study #1: Radioactivity in Los Alamos and Pueblo Creek (1945-1947)**— Some of the earliest measurement results for samples collected from wastewaters released from the Technical Area into Pueblo and Los Alamos Canyons are reported. Samples were collected at various points along the creeks and terminated at the Rio Grande River about 0.25 miles downstream of Otowi Bridge (Tribby 1945; Tribby 1947). The samples were analyzed for plutonium and polonium. A detection limit of 20 disintegrations per minute per liter of creek water was reported at that time. One-liter samples were collected at each location and submitted to counting laboratory for analyses.
Table 14-2. Annual Environmental Monitoring and Surveillance Reports

Starting in 1970, LASL began publishing annual reports that describe annual environmental monitoring results of media sampled both on-site and off-site at the laboratory. The data contained in these reports represent a wide range of sample types and sampling frequencies and to a more or lesser extent vary according to priorities and emphasis placed on monitoring and surveillance during a given year. Annual reports available for review during this and any future health studies are listed below.

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Page 14-23
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Table 14-3. Data Availability - LANL Annual Environmental Surveillance Reports (1971 - 1999)
Study #2: Radioactivity in Los Alamos and Pueblo Creek (1947-1949)-- Samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap et al. 1948a; Schnap 1950).

Four liquid discharge pipes that serviced Technical area 2 (TA-2) and two liquid discharge pipes that serviced Technical Area 3 (TA-3) all discharged liquid wastes to separate two seepage pits systems. These pits were designed to hold the liquids for seepage to underlying soils and evaporation, but are reported to have clogged on occasion and resulted in release of waste liquids to Pueblo Canyon.

Monitoring of radioactive contamination within surrounding canyons was performed to determine the impact from these early waterborne releases. Documented in reports as early as 1945, direct alpha, beta, and gamma radiation surveys were conducted by LASL personnel along the discharge drainage areas immediately down-gradient of the discharge pipes (i.e., canyon walls) and throughout drainage areas of the canyons. Water samples from each discharge pipe were collected and analyzed for plutonium, uranium, mixed fission products, fluorine, and toxic metals. Plutonium was measured in effluent waters released from TA-1 and TA-2 operations and ranged up to 1% by weight (Tribby 1947). During these early years, TA-3 did not handle plutonium compounds and concentrations usually averaged around 0.01 dpm L$^{-1}$. Seepage pits were also surveyed for radioactive contamination and found to be highly radioactive.

Results for selected soil samples collected around TA-1 and TA-2 seepage pits in 1947 revealed levels of plutonium up to 50 dpm g$^{-1}$. Polonium levels around TA-3 seepage pits were measured up to 3,000 dpm g$^{-1}$. In 1947, Tribby reported that plutonium levels on canyon walls and canyon beds near discharge points were quite high and that concentration levels drop-off rapidly 100 ft and beyond release points.

Waterborne radioactive waste was released without treatment to Acid Canyon from 1944 to 1951, when a treatment plant at TA-45 became operational. From 1951 to mid-1953, the TA-45 waste treatment facility only treated liquid waste from the Original Technical Area (TA-1). Beginning in the second half of 1953, wastes from TA-1 and TA-3 were treated at TA-45.

From 1953 through the 1960s, wastes from TA-1 and TA-3 were treated at the TA-45 Waste Treatment Facility and discharged to Pueblo Canyon. Ferric sulfate and lime were added to incoming wastes to form a precipitate of ferric hydroxide which contained most of the plutonium which would in turn settle to the bottom of the waste storage tanks. Also during this period, liquid wastes from DP West production area were treated at the DPW Area Waste treatment Plant and released to Los Alamos Canyon.
Study #3: Radioactivity in Los Alamos, Pueblo, and Bayo Canyons (1957–1958) – During 1957 and 1958, the U.S. geological Survey collected water samples from streams located in Los Alamos and Pueblo Canyons. These locations include: 1) Pueblo Canyon at Otowi Ruins, 2) Los Alamos canyon at bridge, 3) Los Alamos Canyon at Totavi, and 4) Bayo Canyon (Abrahams, 1958a; Abrahams, 1958b).

Study #4: Radioactivity in Rio Grande (1957–1958) – During 1957, the U.S. Geological Survey collected water samples from the Rio Grande. Monthly samples were analyzed for gross alpha, plutonium, and uranium, and gross beta. Samples were collected at stations Embudo, Chama, Otowi, and Cochiti (Abrahams 1958a; Abrahams 1958b).

Study #5: Radioactivity, Chromate, and Zinc in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons (1969-1970) – During 1969 and 1970, LASL (H-8 Group) reported measured radioactivity levels for surface water samples collected from streams located in DP, Los Alamos, Pueblo, Mortandad, and Sandia Canyons. Monthly and quarterly samples were analyzed for gross alpha, gross beta, plutonium-238, plutonium-239, americium, strontium, cesium, tritium, and uranium (Kennedy, 1971). A limited number of samples were also analyzed for hexavalent chromium and zinc.

Study #6: Plutonium in Pueblo and Acid Canyons (1970) – Sediment samples collected along Pueblo Canyon drainage basin show a decreasing trend in plutonium levels as a function of distance from LANL discharge points (Hanson, 1973). Based on a limited number of samples the following plutonium concentrations in sediment are reported:

- 27 pCi g⁻¹ in lower Acid Canyon
- 4.6 pCi g⁻¹ in Pueblo Canyon 1 mi below Acid Canyon
- 1.1 pCi g⁻¹ in Pueblo Canyon 2 mi below Acid Canyon
- 1. pCi g⁻¹ in Pueblo Canyon 0.1 mi above the junction with Los Alamos Canyon

Detailed survey results are reported in document LA-4561, and will be reviewed by the project team for the next version of this report. The reported estimate of plutonium releases from TA-1 and TA-45 to Pueblo Canyon from 1944 to 1964 is 170 mCi (Hanson 1973). Plutonium measured in surface water samples collected in Acid and Pueblo Canyons averaged 20 pCi L⁻¹ during this period, compared to 1.5 and 0.22 pCi L⁻¹ in Mortandad and Los Alamos Canyons, respectively.

Study #7: Radioactivity in Bayo Canyon (1977) – During 1977, LASL collected surface water samples from Bayo Canyon. Radiochemical analysis of samples showed that residual ⁹⁰Sr concentrations in soil averaged for the time period was 1.4 pCi g⁻¹ (LASL 1978b).
Historical Soil Monitoring Data

Samples of available soil monitoring data collected in areas of concern described in the above section are presented below.

**Study #1**: Radioactivity in Los Alamos Canyon (1947) – Soil samples were collected along the canyon walls and at various locations along the canyon floor and analyzed for plutonium, polonium, uranium, other unspecified radionuclides, fluorine, and unspecified toxic metals (Tribby 1947). The available copy of this memo report reviewed by the project team appears to contain limited data for these surveys and/or is missing some of the sample results and warrants further research for data of this time period.

**Study #2**: Radioactivity in Los Alamos and Pueblo Creek (1947) – Soil samples were collected at various points along streams inside Los Alamos and Pueblo Canyons and analyzed for plutonium, uranium, polonium, and gross beta/gamma (Schnap et al. 1948a).

**Study #3**: Radioactivity in Bayo Canyon (1973-1977) – During 1977, LASL collected soil samples from Bayo Canyon and analyzed them for radioactivity. Study results showed that residual ⁹⁰Sr concentrations in soil averaged 1.4 pCi g⁻¹ (LASL 1978b). Previously reported surveys cited in this report include measured soil concentration results for gross alpha, gross beta, cesium, plutonium, and uranium.

Historical External Radiation Monitoring Data

Samples of available external radiation monitoring data collected in areas of concern described in the above section are presented below.

**Study #1**: Direct Radiation Readings in Los Alamos Canyon (1947) – Direct radiation measurements with a Geiger Mueller survey meter were collected throughout Los Alamos Canyon as some of the first reported measurements of this type. The discharge line, canyon walls directly below the wastewater discharge point, and the canyon floor exhibited the highest readings up to 20,000 counts per minute of alpha radioactivity (Tribby 1947).

**Study #2**: Radiation Levels in Mortandad Canyon (1952) – In 1952, LASL scientists conducted a series of radiation surveys throughout Mortandad Canyon following an accidental release of 2000 to 3000 gallons of “hot water” from waste storage tanks located at the TA-35 Liquid Waste Treatment Plant. Survey results indicated that migration of measurable radioactive contamination had occurred several miles downstream in the canyon. Reported radiation dose rate readings ranged from 0.5 milliroentgens (mR) per hour at a distance of three miles to 300 mR h⁻¹ at the TA-35 perimeter fence (Aeby 1952).
report also discusses a planned release to the canyon of 50,000 gallons of radioactive liquid waste with a concentration of 1.5 mCi L$^{-1}$, significantly above the tolerance limit. Specific isotopes are not stated in the memo report. Based on other information obtained about operations at the TA-35 for this time period, it is assumed the released waste contained $^{140}$Ba, $^{140}$La, trace amounts of $^{89}$Sr $^{90}$Sr, and other radionuclides (LASL 1957);

Study #3: Radioactivity in Bayo Canyon (1973-1977) – Direct radiation measurements throughout Bayo canyon were taken with ion chambers and germanium detectors (LASL 1978b).

Historical Ambient Air Monitoring Data

Samples of available ambient air monitoring data (including meteorological) collected in areas of concern described in the above section are presented below.

Study #1: LANL Meteorological Data (1956 to 1971) – Measured wind, temperature, pressure, humidity, and precipitation collected at various locations throughout the Los Alamos and surrounding areas are presented (LANL 1976).

Study #2: Beta/Gamma Concentrations at LANL (1961) – Airborne radioactive particulate samples collected on filter paper are reported for an air sampler located on the roof of the Administration Building SM-43. Air samples were collected every 24 h and 72 h over weekends (LASL, 1961). Report contains sampling results for the first quarter, 1961.

Historical Groundwater/Water Supplies Monitoring Data

Samples of available groundwater monitoring data collected in areas of concern described in the above section are presented below.

Study #1: Radioactivity in Los Alamos, Pueblo, and Guaje Canyons (1957-1958) – During 1958, groundwater, water supplies, and springs located in the Los Alamos area and in Los Alamos, Pueblo, and Guaje Canyons were sampled by the U.S. Geological Survey. The samples were analyzed for pH, gross alpha, plutonium, uranium, gross beta, total hardness, potassium, sulfur, calcium, magnesium, sodium, chloride, fluoride, total solids, NO$_3$, and conductivity (Abrahams 1958a; Abrahams 1958b).

Study #2: Radioactivity and Other Constituents in U.S. Geological Water Samples (1960) – During 1960, groundwater and water supplies were sampled by the U.S. Geological Survey. The samples were
analyzed for pH, gross alpha, plutonium, uranium, gross beta, total hardness, calcium, magnesium, sodium, chloride, fluoride, total solids, and conductivity (USGS, 1961).

**Study #3:** Chromate and Zinc in Sandia Canyon (1969-1970) – During 1969 and 1970, LASL (H-8 Group) reported hexavalent chromium and zinc levels in groundwater samples collected from monitoring wells located in Sandia Canyon (Kennedy 1971).

**References for Environmental Data**


